British Society of Animal Science

The British Society of Animal Science aims to provide the opportunity for those with an interest in animals and animal production to exchange views, ideas and information. It is an energetic and active society with about 800 members from over 50 countries throughout the world. Today, as ever, the Society is the natural meeting point for all of those with an interest in animal science. Its membership is drawn from research, education, advisory work, commerce and the practical livestock industry.

The Society's Journal is Animal Science which publishes fundamental and applied research and is a major scientific title of international repute. Papers reporting findings from basic and applied research relevant to all aspects of animal science can be found in it.

The Society organises a major scientific meeting once a year and occasional specialist meetings on key issues facing animal production.

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The effect of slaughter weight on production characteristics of Holstein-Friesian male cattle

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Introduction Holstein-Friesian bull calves, although bred for dairy traits, are available at low cost as a potential resource for the beef industry. Finishing of these cattle on intensive feeding regimes has become more attractive in recent years reflecting, *inter alia*, the reduction in cereal prices and availability of subsidy payments. However, in the future, market-driven economy, production systems must become more efficient if they are to remain viable. The objective of the present study was to evaluate the effect of slaughter weight on production characteristics of Holstein-Friesian bulls offered cereal-based diets, whilst also evaluating the effects of sexual status on performance attributes.

Material and methods A total of 180 Holstein-Friesian bulls, mean initial age 112 (SD 26.0) days and live weight 134 (SD 37.6) kg were used in the study. Animals were blocked according to live weight and age, and allocated at random to treatments. The seven treatments in the study comprised six different slaughter live weights with bulls, namely 300, 350, 400, 450, 500 and 550 kg, and a further treatment with steers slaughtered at 450 kg. Calves allocated to the steer group were castrated at 6 months of age. Animals were housed in slatted pens accommodating 4 animals within each slaughter weight group and offered a diet consisting of *ad libitum* concentrates and a restricted quantity of straw (nominally 5% of DM intake). The composition of the concentrates was changed when animals reached 350 kg live weight and contained the following ingredients (g/kg) : barley 500 and 535, soya bean meal 175 and 140, sugar beet pulp 200 and 200, maize meal 100 and 100, vitamin/mineral premix 25 and 25 for concentrates offered pre- and post-350 kg live weight respectively. Concentrate and total dry matter (DM) intakes for each pen group were recorded daily throughout the trial. All animals were weighed on two consecutive days initially and again prior to slaughter, and at regular intervals throughout the study. A range of carcass measurements was recorded for all animals. Data on feed intakes and carcass parameters were analysed using the REML technique in Genstat 5 (release 4.1 Rothamsted, England). Live weight and age at the start of the study, and deviation of actual weight from target slaughter weight, were used as covariates. All variates were tested for the presence of linear and asymptotic trends between the range of slaughter weights evaluated (bulls only).

Results The mean chemical composition of the concentrate offered pre- and post-350 kg live weight was : DM 846 and 851 g/kg, crude protein 190.9 and 154.4 g/kg DM, acid detergent fibre 80.9 and 78.8 g/kg DM, neutral detergent fibre 194.3 and 182.7 g/kg DM and ash 73.7 and 67.2 g/kg DM respectively. Data on food intake and animal performance are presented in Table 1. Feed intakes increased linearly ($P<0.001$) with increasing live weight at slaughter, resulting in total intakes of 624 and 2131 kg concentrate DM for bulls slaughtered at 300 and 550 kg respectively. Age at slaughter, carcass weight, food conversion ratio (FCR), kill out and conformation score increased linearly ($P<0.001$) with increasing live weight at slaughter, whilst carcass fat classification increased in an asymptotic manner ($P<0.001$), tending to plateau at the heavier slaughter weights. However, there were no significant relationships ($P>0.05$) between live weight of bulls at slaughter and daily liveweight or carcass gains, with overall mean values for bulls of 1.31 and 0.70 kg/d respectively. Steers required significantly ($P<0.001$) more concentrate, and had poorer ($P<0.001$) FCR and rates of liveweight and carcass gains than bulls slaughtered at the same live weight. However kill out, conformation and fat scores were similar ($P>0.05$) between steers and bulls.

Table 1 Data on food intake, animal performance and carcass parameters of Holstein bulls and steers

	Bulls						Steers	SED	Significance		Bulls v
Slaughter wt (kg)	300	350	400	450	500	550	450		Linear	Asymp	Steers[1]
Feed intake (kg DM/d)											
Straw	0.21	0.26	0.27	0.31	0.33	0.36	0.34	0.025	***	NS	NS
Concentrate	4.36	4.79	5.66	5.96	6.20	6.57	6.24	0.201	***	NS	NS
Total conc (kg DM)	624	876	1111	1429	1779	2131	1670	54.1	***	NS	***
Animal performance and carcass data											
Slaughter age (days)	247	289	309	351	397	434	383	7.6	***	NS	***
LWG (kg/d)	1.32	1.27	1.39	1.36	1.31	1.33	1.19	0.043	NS	NS	***
Carcass wt (kg)	155	179	211	237	265	294	233	2.1	***	NS	NS
Carcass gain (kg/d)	0.70	0.65	0.75	0.73	0.71	0.72	0.62	0.024	NS	NS	***
FCR carcass[2]	6.41	7.49	7.62	8.31	8.86	9.23	10.15	0.405	***	NS	***
Kill out (g/kg)	509	506	522	521	526	530	514	5.2	***	NS	NS
Conformation[3]	1.16	1.28	1.71	1.47	1.64	1.79	1.50	0.120	***	NS	NS
Fat class[4]	1.90	2.27	2.38	2.86	2.76	2.94	3.05	0.119		***	NS

[1] Both slaughtered at 450 kg live weight; [2] feed conversion ratio (kg concentrate DM/kg carcass gain); [3] 5 point scale: 1 = worst; 5 = best; [4] 5 point scale: 1 = leanest; 5 = fattest

Conclusions Increasing slaughter weight from 300 to 550 kg live weight increased age at slaughter from 8.2 to 14.5 months and resulted in major increases in concentrate requirements and FCR. However, carcass weights and grading characteristics were superior with animals slaughtered at heavier weights. Finishing animals as steers resulted in lower levels of performance when compared to bulls.

Acknowledgements This work was funded by DARD and AgriSearch

Preliminary effects of altering plane of nutrition during different stages of the life cycle, and gender, on beef cattle performance

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Introduction Post Mid Term Review of the Common Agricultural Policy, beef production must survive in a subsidy-free, market led environment. It is essential that producers increase final carcass value by achieving cost effective performance from birth to slaughter. The aim of the present study was to evaluate the effects of plane of nutrition during the growing and finishing indoor feeding periods, and stocking rate and concentrate supplementation at pasture on the performance of steers and heifers from weaning to finishing.

Materials and Methods A total of 128 weaned, spring-born continental suckled calves, 64 steers and 64 heifers (mean initial live weight of 321 (s.d. 37.1) and 288 (s.d. 45.5)) were purchased post-weaning in late autumn and allocated to a total of 32 treatments. During the first winter indoor feeding period (W1) the cattle were offered grass silage supplemented with either 0.4 or 2.4 kg concentrates/head/day. On turnout to pasture the cattle were allocated to either a high (2750 kg live weight/ha) or low (1925 kg live weight/ha) stocking rate (SR) treatment. From 1 August during the grazing season the cattle were supplemented (S) with either 0 or 2.5 kg concentrates/head/day. During the final indoor finishing period (W2) the cattle received either grass silage *ad libitum* supplemented with 4 kg concentrate/day or *ad libitum* concentrate supplemented with 5 kg fresh silage daily. During W1 and W2 all animals received 50 and 100 g/day respectively of a mineral and vitamin mixture. The heifers and steers were slaughtered in blocks after being offered the final indoor period treatments for a mean of 70 and 101 days respectively. Data were analysed as 2 (gender) x 2 (planes of nutrition during W1) x 2 (SR at pasture) x 2 (concentrate supplementation at pasture from 1 August) x 2 (planes of nutrition during W2) experiment using Genstat ANOVA.

Results The pH and concentrations of dry matter and ammonia nitrogen of the silages offered during the first and second indoor feeding periods were 3.9 and 4.0; 184 and 173 g/kg; and 93 and 98 g/kg nitrogen respectively. Experimental liveweight and carcass gains, and carcass weight varied from 0.52 to 0.93 kg/day, 0.29 to 0.55 kg/day and 265 to 395 kg between treatments respectively. The main effects of altering the plane of nutrition at different stages of the life cycle, and gender, on animal performance are presented in Table 1. Gender, plane of nutrition during W1 and W2, and stocking rate and concentrate supplementation at pasture significantly (P<0.01 or greater) altered animal performance. There were significant (P<0.05) W1 plane of nutrition x SR at pasture x concentrate S at pasture interactions for final carcass weight and experimental carcass gain and these are presented in Table 2. There was a significant interaction between stocking rate and concentrate supplementation at pasture on experimental liveweight gain. At the high and low stocking rates receiving 0 and 2.5 kg concentrate, lifetime liveweight gains were 0.66, 0.75, 0.76 and 0.78 kg/day respectively.

Table 1 The effects of altering the plane of nutrition at different stages of the life cycle and gender on animal performance

	Gender (G)		Winter 1 (W1)		Stocking rate (SR)		Supplement (S)		Winter 2 (W2)			Significance†	
	Heifer	Steer	Low	High	Low	High	None	Conc	Low	High	Sem	W1	S
Live weight (kg)													
Turnout	344	384	338	390							2.11	***	
Housing	466	519	482	503	509	476	477	508			3.57	***	***
Final	564	642	594	612	614	591	591	615	581	624	3.95	***	***
LWG (kg/day)‡	0.71	0.77	0.72	0.76	0.71	0.77	0.71	0.77	0.69	0.79	0.010	**	***
Carcass weight (kg)	301	354	323	333	320	335	323	333	312	344	2.37	***	**
Carcass gain (kg/day)	0.38	0.46	0.41	0.43	0.40	0.44	0.41	0.43	0.38	0.45	0.005	**	**

† Gender, Winter 2 and stocking rate at pasture significantly altered performance (P<0.001)
‡ LWG = liveweight gain

Table 2 The effect of Winter 1 nutrition, and stocking rate and concentrate supplementation at pasture on experimental carcass gain and carcass weight

	Winter 1 liveweight gain (kg/day)					
	0.31		0.77			
Stocking rate	High	Low	High	Low	Sem	Sig
Carcass gain (g/day)						
Concentrate - none	355[a]	427[b]	403[b]	442[c]	10.6	*
- 2.5 kg/day	424[bc]	426[bc]	424[bc]	451[c]		
Carcass weight (kg)						
Concentrate - none	300[a]	331[b]	320[b]	338[c]	4.6	*
- 2.5 kg/day	330[bc]	331[bc]	330[bc]	342[c]		

Conclusions It is concluded that there are significant interactions between planes of nutrition offered at different stages in the production cycle of beef cattle on animal performance.

The effect of slaughter weight on boning out characteristics of Holstein-Friesian male cattle

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Introduction The continuing trend for increased use of Holstein genetics in dairy herds has resulted in a large number of Holstein-Friesian bull calves becoming available, at low cost, as a potential resource for the beef industry. However, whilst these calves have been bred for dairy traits, which are negatively correlated to many important beef traits (e.g. carcass conformation), it is important to determine the potential yield of boned out joints from these animals, in order to facilitate an assessment of commercial carcass value. The objective of the present study was to evaluate the effect of slaughter weight on yield of boned out joints from Holstein-Friesian bulls and steers offered a cereal-based diet.

Material and methods A total of 82 Holstein-Friesian bulls, mean initial age 123 (SD 24.5) days and live weight 147 (SD 36.4) kg were used in the study. Animals were blocked according to live weight and age, and allocated at random to treatments. The seven treatments in the study comprised six different slaughter live weights with bulls, namely 300, 350, 400, 450, 500 and 550 kg, and a further treatment with steers slaughtered at 450 kg. Calves allocated to the steer group were castrated at 6 months of age. Animals were housed in slatted pens accommodating 4 animals within each slaughter weight group and offered a diet consisting of *ad libitum* concentrates and a restricted quantity of straw (nominally 5% of DM intake). The composition of the concentrates was changed when animals reached 350 kg live weight and contained the following ingredients (g/kg) : barley 500 and 535, soya bean meal 175 and 140, sugar beet pulp 200 and 200, maize meal 100 and 100, vitamin/mineral premix 25 and 25 for concentrates offered pre- and post-350 kg live weight respectively. Hind- and fore-quarters of each carcass were boned out into 10 and 9 individual primal joints respectively, while carcass trim was also recorded. The sum of the primal joints and trim was taken as the red meat yield from each carcass, while high price joints included topside, silverside, knuckle, rump, sirloin, fillet and fore-rib joints. Primal joints and trim were weighed and subjectively assessed for suitability for particular market specifications by abattoir staff i.e. supermarket (highest quality), commercial, or manufacturing (lowest quality). Data were analysed using the REML technique in Genstat 5 (release 4.1 Rothamsted, England). Live weight and age at the start of the study, and deviation of actual weight from target slaughter weight, were used as covariates. All variates were tested for the presence of linear and asymptotic trends between the range of slaughter weights evaluated (bulls only).

Results The mean chemical composition of the concentrate offered pre- and post-350 kg live weight was : DM 846 and 851 g/kg, crude protein 190.9 and 154.4 g/kg DM, acid detergent fibre 80.9 and 78.8 g/kg DM, neutral detergent fibre 194.3 and 182.7 g/kg DM and ash 73.7 and 67.2 g/kg DM respectively. Data on boning out are presented in Table 1. Weight of red meat increased linearly ($P<0.001$) with slaughter weight. Similarly, weight of high price joints exhibited a significant ($P<0.001$) positive linear relationship with increase in live weight of bulls at slaughter, but decreased linearly ($P<0.001$) when expressed as a proportion of red meat or total carcass. In contrast, no significant relationships ($P>0.05$) were identified between percentage of the total carcass recorded as primal joints, trim or total red meat and increasing slaughter weight of bulls. However, when expressed as a percentage of total carcass, weight of the hind quarter declined linearly ($P<0.001$), while weight of the fore quarter displayed a positive increase ($P<0.001$) with increasing bull slaughter weight. Bulls had to be slaughtered at 500 kg or above if any joints comprising the red meat component were to achieve the premium supermarket specification. Furthermore, increasing weight at slaughter from 500 to 550 kg resulted in a significant ($P<0.001$) increase in the percentage of red meat reaching supermarket grade. Linear trends ($P<0.05$ or greater) were identified between bull slaughter weight group and percentage red meat achieving manufacturing grade specification. In the comparison of steers and bulls slaughtered at a similar live weight, steers had similar ($P>0.05$) weights and proportions of the carcass joint groupings and a similar ($p>0.05$) percentage of red meat assessed as achieving supermarket, commercial or manufacturing grade specifications.

Table 1 The effect of weight at slaughter and sexual status on boning out characteristics of Holstein bulls and steers

		Bulls						Steers	SED	Significance		Bulls v Steers[1]
Slaughter wt (kg)		300	350	400	450	500	550	450		Linear	Asymp	
Carcass weight (kg)		150.4	175.0	205.2	231.8	260.1	292.0	228.8	2.91	***	NS	NS
Red meat (kg)		105.2	122.1	146.0	163.8	185.1	207.4	160.5	2.53	***	NS	NS
High price joints	kg	42.2	49.2	57.9	63.1	68.4	78.4	60.6	1.57	***	NS	NS
	g/kg red meat	400.7	403.3	396.2	386.8	369.0	378.7	377.2	9.06	***	NS	NS
	g/kg carcass	280.3	281.2	282.0	273.1	262.8	268.8	264.8	6.03	***	NS	NS
Percentage carcass as :												
Primal joints		57.3	57.4	58.6	57.2	55.6	57.9	55.8	0.90	NS	NS	NS
Trim		12.7	12.4	12.7	13.5	15.6	13.1	14.4	1.09	NS	NS	NS
Hind quarter		52.3	52.3	51.8	50.9	50.5	50.9	51.0	0.57	***	NS	NS
Fore quarter		47.7	47.7	48.2	49.1	49.5	49.1	49.0	0.57	***	NS	NS
Red meat		70.0	69.8	71.2	70.7	71.2	71.0	70.2	0.81	NS	NS	NS
Red meat grade (%) [2]	S	0.0	0.0	0.0	0.0	5.7	34.0	2.8	3.29		***	NS
	C	46.9	46.9	48.5	47.1	39.2	11.7	42.4	3.49		***	NS
	M	52.5	52.3	52.6	53.9	55.1	54.3	54.8	0.94	**	NS	NS

[1] Both slaughtered at 450 kg live weight; [2] S = supermarket, C = Commercial, M = Manufacturing grade

Conclusions Increasing live weight at slaughter increased weights of primal joints and red meat, but decreased yields as a proportion of the carcass. However, carcass value increased at heavier weights, reflecting the shift from commercial to supermarket (high price) grade specifications with several joints.

Acknowledgements This work was funded by DARD and AgriSearch

Comparison of a pulp-based diet and a cereal-based diet in the fattening of young bulls from Belgian Blue, Limousin and Aberdeen Angus breeds

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Introduction Performances traits like live weight gain, feed conversion ratio or carcass quality were in the past the main objectives in beef meat production. Nowadays consumers attach an increasingly large importance to technological and nutritional qualities. In terms of dietetic, a low fat content associated with a high polyunsaturated fatty acids content and a low n-6/n-3 ratio is required. In this context, the present work was undertaken to compare performances and meat characteristics in young fattening bulls of 3 beef breeds offered 2 different diets.

Materials and methods A total of 36 young bulls from 3 different breeds were used : 12 double-muscled Belgian Blue (BB), 12 Limousin (LIM) and 12 Aberdeen Angus (AA). The animals were fattened in a free station barn. At the age of 14-15 months, the animals of each breed were randomly allocated in 2 groups of 6 animals. They received respectively a concentrate diet based on barley and maize or on sugar beet pulp. Animals were weighed every month and their total weight gain and average daily gain were calculated. Bulls were slaughtered at 18-20 months of age and samples of *Rectus abdominis* (RA), *Longissimus thoracis* (LT) and *Semitendinosus* (ST) were taken for analysis. Carcass composition was assessed by dissection of 7 to 9th ribs. Data were analysed using the GLM procedure of SAS. Fixed effects of diet and breed were studied for all parameters. Muscle effect was also studied for fat and fatty acid content. Animal effect was nested within diet and breed and interactions diet/breed and breed/muscle studied. Diet and breed effects were tested against animal within diet and breed. Muscle effect was tested using the residual error of the model.

Results The nature of the diet dit not influence any of the measured parameters. By contrast, large and significant effects were observed between breeds on the carcass characteristics and on meat quality and composition but not on animal performances (Table 1). Breed and muscle location influenced to a large extent both the fat content and the fatty acid composition of meat (Table 2). BB bulls were characterized by leaner carcasses and meat and by a higher proportion of PUFA and a lower proportion of SFA + MUFA when expressed in g/100 g fatty acids as compared with the 2 other breeds. But when expressed in mg/100 g fresh meat, the PUFA content within the 3 breeds was not significantly different. Meat from BB bulls was also characterized by a lower total n-3 fatty acid content and higher total n-6 fatty acid content when expressed in mg/100 g fresh meat as compared with the AA animals, intermediate values being observed with LIM.

Table 1 Performance and characteristics of carcass and meat (LT) in the 3 breeds

		Breed			P<F	RSD
		BB	LIM	AA		
Performance	Average daily gain (kg/d)	1.59	1.62	1.66	NS	0.03
	Feed conversion ratio (kg/kg)	5.74	6.00	6.11	NS	0.14
Carcass	Killing out (%)	65.19	60.65	55.01	***	0.75
	Muscle (%)	77.45	67.55	62.16	***	1.13
	Connective and adipose tissue (%)	10.21	18.67	23.56	***	0.99
Meat	Brightness L* day 8 (%)	44.17	41.75	39.10	***	0.54
	a* day 8	17.68	16.83	15.48	*	0.35
	Crude protein (% DM)	89.82	85.57	81.72	***	0.85
	Ether extract (% DM)	2.69	6.51	9.30	***	0.63

Table 2 Fat and fatty acid content of muscle expressed in g/100 g fatty acids (FA) and in mg/100 g fresh meat (FM) as influenced by the breed and the muscle location

	Breed			Muscle			P<F		RSD
	BB	LIM	AA	LT	RA	ST	B	M	
Fat (% DM)	2.19	4.50	6.00	6.19	4.10	2.40	***	***	1.22
SFA+MUFA (g/100 g FA)	60.11	78.71	83.28	82.07	74.77	65.26	***	***	6.55
SFA+MUFA (mg/100 g FM)	301.01	874.17	1222.08	1250.22	726.65	420.37	***	***	303.39
PUFA (g/100 g FA)	39.89	21.29	16.72	17.93	25.23	34.74	***	***	6.55
PUFA (mg/100 g FM)	180.1	176.91	174.99	191.36	170.35	170.29	NS	***	17.00
n-3 (mg/100 g FM)	26.88	30.60	37.33	32.56	26.98	35.26	***	***	3.27
n-6 (mg/100 g FM)	153.22	146.31	137.66	158.79	143.37	135.03	**	***	14.61
n-6/n-3	5.91	4.89	3.70	5.12	5.50	3.88	***	***	0.41

Conclusions The carcass and meat characteristics of BB bulls are more interesting than in the 2 other breeds owing to more valuable carcasses and leaner meat. Although the n-6/n-3 ratio is higher in BB when compared to LIM or AA, the SFA + MUFA levels are by far the lowest on the basis of 100 g fresh meat intake.

The effects of grain storage and processing method and level of feeding on the performance of finishing beef cattle offered two contrasting grass silages

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Introduction Traditionally cereals have been dried or treated with propionic acid and processed prior to feeding to finishing beef cattle. However this process is labour intensive, particularly as it involves rolling or milling the grain prior to feeding. Currently labour is an expensive and scarce resource on many beef units. Recently new techniques have been developed for storing and feeding grain to beef cattle which reduce the need to process grain immediately prior to feeding. The objective of the current study was to evaluate the effects of grain storage and processing method, and grain feed level on performance of beef cattle offered two contrasting feed value grass silages.

Materials and Methods Two grass silages, which were harvested from the primary growth of perennial ryegrass swards on 15 May and 2 June respectively, were offered supplemented with either 3.5 or 5.9 kg concentrate dry matter/head/day. Wheat was harvested and ensiled either crimped and treated with 4.5 litres/t fresh weight of a proprietary acid-based additive, ensiled whole mixed with 20 kg urea and 30 litres of water/t fresh weight or harvested conventionally and treated with propionic acid. The 12 treatments were offered to 132 continental cross beef cattle (mean initial live weight 510 kg (s.d. 50.8)) in a continuous design, randomised block experiment for a mean feeding period of 111 days. The concentrate consisted of 850 g/kg DM wheat and 150 g/kg DM citrus pulp. The silages were offered *ad libitum* once daily whilst the concentrate was offered in two equal feeds daily. Each animal received 100 g mineral and vitamin mixture per day with the concentrates. Cattle were slaughtered after constant intervals on experiment. Data were analysed as 3 (grain storage/processing methods) x 2 (grain feed levels) x 2 (grass silage feed values) experiment using Genstat ANOVA.

Results The high and low feed value silages were well preserved with pH and concentrations of dry matter and ammonia nitrogen of 3.76 and 3.83, 240 and 192 g/kg and 64 and 86 g/kg total nitrogen respectively. The dry matter of the urea and crimped grain at harvest was 663 g/kg. The effects of grain processing/storage method, grain feed level and grass silage feed value on animal performance are presented in Table 1. Urea treatment increased silage and total DM intake and tended to decrease (P=0.09) carcass gain. Increasing silage feed value increased (P<0.05 or greater) feed intake, final live weight, carcass weight, liveweight gain, carcass gain, fat classification and kill out proportion. Increasing grain feed level decreased (P<0.001) silage intake and increased (P<0.05 or greater) total DM intake, final live weight, carcass weight, liveweight gain, carcass gain and conformation. There were significant grass silage feed value by grain processing method interactions (P<0.05) for final live weight and liveweight gain. For the high and low feed value grass silages supplemented with the high and low concentrate feed levels, liveweight gains were 1.13, 1.10, 1.03 and 0.83 (sem = 0.037) kg/day respectively.

Table 1 Effect of grain storage and processing method, and feed level and silage feed value on feed intake and animal performance

	Processing method (PM)				Silage feed value (SIL)		Grain feed level (GFL)			Significance[†]		
	Convent-ional	Urea	Crimped	Sem	Low	High	Low	High	Sem	PM	SIL	GFL
SDMI (kg/day)[‡]	4.16[a]	4.74[b]	4.35[a]	0.129	3.84[a]	4.99[b]	5.22[b]	3.61[a]	0.092	**	***	***
TDMI (kg/day)[§]	8.85[a]	9.43[b]	9.04[a]	0.129	8.70[a]	9.51[b]	8.72[a]	9.49[b]	0.092	**	***	***
Final LW (kg)[#]	625	618	625	4.74	613[a]	633[b]	616[a]	630[b]	3.4	NS	***	**
LWG (kg/day)[¶]	1.04	0.98	1.04	0.036	0.93[a]	1.11[b]	0.96[a]	1.08[b]	0.026	NS	***	**
Carcass wt (kg)	338	333	341	2.66	330[a]	346[b]	334[a]	341[b]	1.9	NS	***	*
Carcass gain (kg/day)	0.60	0.55	0.61	0.020	0.52[a]	0.66[b]	0.56[a]	0.61[b]	0.014	0.09	***	*
Kill out (%)	54.2	54.0	54.5	0.358	53.8[a]	54.7[b]	54.4	54.1	0.026	NS	*	NS
Conformation[¢]	3.07	3.07	2.93	0.635	2.98	3.07	2.94[a]	3.11[b]	0.045	NS	NS	*
Fat class[¤]	3.47	3.38	3.33	0.115	3.21[a]	3.59[b]	3.29	3.51	0.082	NS	**	0.07

[†] There was a PM x GFL interaction (P<0.05) for SDMI and TDMI; SIL x GFL interaction (P<0.05) for final LW and LWG. There were no PM x SIL or PM x SIL x GFL interactions
[‡] SDMI = Silage dry matter intake; [§] TDMI = Total dry matter intake; [#] LW – Live weight; [¶] LWG = Liveweight gain; [¢] = EUROP scale: 5, 4, 3, 2, 1 respectively; [¤] EU fat classification, where 5 = fat, 1 = lean

Conclusions It is concluded that crimping grain resulted in the same level of animal performance as conventionally processed and stored grain. However, urea treatment tended (P=0.09) to decrease carcass gain by 9%. Increasing silage feed value had a greater effect on animal performance than increasing grain intake by 2.4 kg DM/head/day. For the low and high feed value grass silages, an additional 33 and 89 kg DM of supplement would be required for each additional kg of carcass gain if the supplement feed level was increased above 3.5 kg DM.

Effects of stage of maturity and protein supplementation on growth and nitrogen utilisation by cattle fed oat silage

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Introduction Cereal silages are used extensively in the diets of feedlot cattle all over western Canada. Plants are generally harvested at dough stage as this stage is believed to represent the best compromise between feeding value and dry matter yield. However, under the growing conditions of eastern Canada, where cereals are grown as cover crops, it has been argued that harvesting at the boot stage would be beneficial to the establishment of the under sown crop and could improve yields of digestible dry matter. Previous experiments have suggested that cereal silages harvested at boot stage vs soft dough stage (Acosta *et al.,* 1991), although the former were more digestible, resulted in no benefit in terms of animal performance. Our work with grass silages (Berthiaume *et al,* 1996) showed that this could be due to the highly degradable nature of protein in immature silages, and that protein supplements would be beneficial. This study evaluated the effect of harvesting oats for silage at boot vs milk stage with or without the addition of a protein supplement on nitrogen utilisation and growth of calves.

Materials and methods Two fields were planted with oats (*cv Rigodon*), divided in two, and harvested as silage in June at boot stage (E) or August at milk stage (L) and stored in two bunker silos. Thirty two crossbred beef calves, mean initial live weight 229 (sem 3.4) kg, were blocked by live weight and allocated to one of four dietary treatments in a randomised complete block design. The study was divided in two 56-d phases. In phase 1, treatments consisted of two oat silages (Early vs Late) as the sole forage with or without canola meal (600 g/d). In phase 2, the same basal diets were fed with rolled barley (60 : 40 forage to barley ratio, DM basis). Diets were fed once daily through individual Calan gates. Animals were weighed on day 0, 56 and 112 after an overnight fast. Diet digestibility and nitrogen balance were determined in a 4-period latin square design experiment with 4 additional animals. Data were analysed using the GLM procedure of SAS with maturity, protein supplement and their interaction as the main factors.

Results The N, NDF and starch contents (g / kg DM) of silages E and L were 19.7, 555 and 3 and 15.0, 503 and 59, respectively. Silage DM and pH were respectively, 213, and 4.3 and 300 and 4.0, indicating that E silage was not well preserved. Intake, growth and N partitioning results are presented in Table 1.

Table 1 Effects of oats maturity and protein supplements on DM intake, live weight gain and N partitioning during phase 1

	E		L			Significance (*P*=)		
	Control	+ Protein	Control	+ Protein	s.e.m.	Maturity	Protein	Mat * Prot
DM intake (kg /d)	4.88	5.48	5.13	6.17	0.19	0.02	0.0004	0.26
Final live weight (kg)	241	258	254	272	3.62	0.0001	0.0001	0.97
Liveweight gain (kg/d)	0.24	0.56	0.36	0.79	0.04	0.0001	0.0001	0.17
DMI / LWG (kg/kg	24.31	16.52	36.59	13.53	7.35	0.43	0.03	0.20
DM digestibility	66.6	68.3	58.2	58.7	1.1	0.0002	0.37	0.62
DE (MJ/kg DM)	11.56	12.06	10.68	10.76	0.33	0.02	0.45	0.56
N intake (g/d)	87.0	115.7	66.0	97.3	2.1	< 0.0001	< 0.0001	0.57
Faecal N (g/d)	32.3	37.0	31.3	37.5	1.5	0.88	0.01	0.65
Urine N (g/d)	43.3	52.0	26.8	34.5	0.7	0.0001	0.0001	0.49
N retained (g/d)	11.5	26.8	8.0	25.3	1.0	0.05	< 0.0001	0.37

There were significant effects of oats maturity stage and protein supplements on animal performance, diet digestibility and N partitioning. Live weight gains were higher for L than E oat silage, despite the fact that DMD was lower on the former, confirming observations made by Acosta et al (1991). Moreover, protein supplementation had the same effect on both silages which is contrary to our previous observations with grass silages where fishmeal exerted a stronger effect when added to early cut grass silages.

Conclusions These results suggest that harvesting oats at an earlier stage of maturity would be detrimental to animal performance and increase significantly the proportion of N wasted in urine. The addition of a protein supplement did not alleviate this problem.

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Genetic associations between maturity rate and functional traits in Swiss Holsteins

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Introduction Adulthood of a dairy cow is reached when she is about 60 months old, but cows first calve at a much younger age. Therefore, most heifers are still growing during their first lactation and part of the energy and protein intake will be assigned to this purpose. As the cow grows closer to mature body weight and is able to use more energy and protein for the milk production, milk production will increase from 1st to 2nd to 3rd lactation, but the amount of increase differs among cows. A gradual production increase is believed to be found in trouble-free cows (i.e. cows with good fertility and high disease resistance), and is a measure of the maturity rate (MR), where maturity is defined as reaching mature body weight. Genetic variance for this production increase exists (Krogmeier *et al.*, 2003). The aim of this study was to define MR in a way that enables selection, and to estimate genetic correlations with functional traits.

Materials and methods Records since 1991 were available from the Holstein Association of Switzerland. Milk production data was used in the formula for maturity rate, which was adapted from Schleppi and Bigler (2002): $((2*M_2 + 3*M_3)/5)-M_1$, where M_x is the 305d milk yield in lactation x, x=1, 2 or 3. The dataset contained 42,807 cows with a value for the production increase. Analysed functional traits were udder health, fertility and conformation. Conformation data included 21 linear traits, 5 composites and the final score. The fertility trait was days to first service (DFS), and somatic cell score (SCS) was considered as an indirect trait for clinical mastitis (CM). Variance components were estimated with a sire model. The model used was: Y = μ + fixed effect + sire + error. The fixed effects included were herd, year-season of calving, age at calving, days in milk per lactation, classifier, and days in milk at classification.

Results and Discussion Heritability for MR was low (0.08) (Table 1), but genetic variation among sires existed. Additive genetic correlations of MR were moderately favourable with SCS (about -0.30) and chest width (0.30); that is, with traits often found in long-lasting cows. High milk production in the first lactation reduces the action of the immune system in the udder, and cows are more susceptible for CM. A case of CM in the first lactation leads to damage of the udder that hinders a high production increase in the following lactations. A moderate first lactation production allows the udder time to develop into a full producing mammary system. Of all linear conformation traits, angularity was strongest negatively correlated with MR. Angularity often characterizes "milky" cows. However, cows showing lots of angularity have difficulties in keeping enough energy to grow. They have high first lactation productions, which makes it harder to increase in following lactations. From the composites, unfavourable trends were found for rump and dairy character (Table 1). Correlations with DFS were highly variable and had high standard errors.

Table 1 Estimated heritabilities for maturity rate and functional traits for udder health, fertility and conformation[#] and genetic and phenotypic correlations of maturity rate with these functional traits, with their respective standard errors

	h^2	se	r_g	se	r_p	se
Maturity Rate	0.08	0.01				
SCS1	0.18	0.02	-0.30	0.09	0.01	0.01
SCS2	0.19	0.02	-0.30	0.09	-0.12	0.01
SCS3	0.17	0.02	-0.29	0.09	-0.16	0.01
DFS1	0.03	0.01	-0.08	0.14	-0.03	0.01
DFS2	0.03	0.01	0.12	0.12	0.03	0.01
DFS3	0.03	0.01	0.02	0.12	0.00	0.01
Angularity	0.28	0.03	-0.24	0.08	-0.09	0.01
Chest Width	0.25	0.03	0.30	0.09	-0.01	0.01
Final Score	0.36	0.03	0.06	0.09	-0.04	0.01
Frame/Capacity	0.41	0.04	0.09	0.09	-0.03	0.01
Rump	0.32	0.03	-0.09	0.08	-0.04	0.01
Dairy Character	0.32	0.03	-0.17	0.09	-0.09	0.01
Feet & Legs	0.14	0.02	0.06	0.10	-0.01	0.01
Mammary System	0.24	0.03	0.08	0.09	0.00	0.01

[#] SCS*x*: Somatic cell score in lactation *x*. DFS*x*: Days to first service in lactation *x*. Conformation traits: Final score and the 5 composites.

Conclusions Production increase, as an indicator of maturity rate, is a potential trait to be included in a breeding goal. Results show that animals can be selected for production increase as there is a good genetic variation between bulls and this trait has favourable genetic relationships with economically important functional traits that are currently (or will be in a near future) in the dairy cattle breeding goals of many countries (e.g., health, fertility, conformation).

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Genetic heterogeneity of residual variance within families for body weight in poultry

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Introduction In classical quantitative genetic models, phenotypic value depends on genotype, but phenotypic variation among individuals of the same genotype is assumed to be the same for all genotypes. ANOVA and other statistical tests are underpinned by the assumption of a multivariate normal distribution with homogenous variances and independent normally distributed deviations. Heterogeneity of phenotypic or environmental variance has been estimated in dairy cattle (Brotherstone and Hill, 1986). Models and analyses developed by SanChristobal *et al*. (1998) and Sorenson and Waagepeterson (2003) provide strong evidence for litter size in pigs of heterogeneity of residual variance under genetic control. Environmental sensitivity dependent upon genotype has implications for livestock production, and may explain phenomena such as plasticity and canalisation. The aim was to calculate variability in within family variance among large half sib broiler families, in order to test for the presence of and quantify heterogeneity in residual variation amongst genotypes.

Materials and Methods Records of 35-day body weights (BWT) of 196000 broilers from pedigree breeding stock reared in a constant environment were supplied by Aviagen. Sires with >100 records on offspring of one sex and >50 in the other were included, resulting in 51805 female and 47730 male BWT records from 377 sires. Data were classified by 50 mating groups (MG), which comprised contemporary sires, dams and offspring, with an average of 7.5 sires mated to 9 dams for 12 hatch weeks. Average sire family sizes were 126 and 137 and dam family sizes were 14 and 15, for males and females respectively. The method used (Hill, 2004) is based on that of Brotherstone and Hill (1984), to quantify variation *amongst* sire families in *within* family variance. All analyses were carried out within sex, within MG. Restricted maximum likelihood (Asreml program) was used to fit a sire model including hatch within MG (i.e. contemporary groups), sires and dams/sires. Within dam family variances (S^2) were estimated separately for each sire. Variance amongst S^2 within a mating group (S_{BV}^2) was calculated. Under the assumption of homogenous variance, each S^2 estimates V_w; thus variation amongst them should be attributable to sampling. Sampling variances were estimated assuming a chi-squared distribution as $2S^4/d$, where d is the harmonic mean of degrees of freedom within sire families. Sampling variance was subtracted from S_{BV}^2 to estimate V_{BV}, the part of var(S^2) attributable to sires. To check for scaling effects the entire analysis was repeated using log transformed bodyweights. The deviation of sire progeny mean from its respective mating group mean was used to assess sire effect on mean.

Results Table 1 shows weighted mean values over mating groups. There was variation above estimated sampling variance in both sexes. Despite higher variation in the males the coefficient of variation or $\sqrt{V_{BV}}/ S^2$ was 0.15 in males and in females. Analysis of log transformed body weights gave similar values for this quantity. Table 1 also shows population parameters for the additive genetic variance of sire effects upon the mean (V_{AM}), the equivalent in variance terms (V_{AV}) (obtained as $4V_{BV}$ for half-sibs) and cov_{AMV}, their covariance.

Table 1 Mean parameter values for mating groups. Weights are in decagrams (1dg=10g). SE in brackets.

	Males	Min	Max	SD	Females	Min	Max	SD
BWT	229.1	202.9	271.3	20.7	205.1	182.8	237.8	17.5
S^2	312.8	210.8	473.8	56.2	239.3	181.8	307.5	29.9
S_{BV}^2 (× 100)	43.1	< 0.1	238.1	46.8	23.6	0.85	98.8	17.6
V_{BV} (× 100)	25.5 (3.42)	-20.5	211.3	43.0	14.2 (1.80)	-13.2	86.0	17.1
V_{AM}	55.1 (7.00)				49.5 (5.52)			
cov_{AMV}	-116.4				-57.1			
V_{AV} (× 100)	102.0				56.6			

Conclusions Evidence was found for heterogeneity of residual variation amounting to ~15% of residual variance attributable to sire. Conflicting evidence for a genetic explanation was, however, a low correlation (0.1) of sire effect on variance of male and female offspring. Sire effects upon mean and variance were negatively correlated (-0.1, from cov_{AMV}), implying that sires increasing the variance and likelihood of selection can have a negative effect upon the mean and vice versa. Genetic environmental sensitivity has implications for homogeneity of product, rearing environment and breeding values in the commercial environment and could play an important role in adaptation of homeostatic mechanisms controlling trait expression.

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Genetic parameters for a heavy female turkey line

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Introduction The major selection criterion in the turkey breeding industry is increased breast muscle and body weight in order to adapt to market demands. In female lines a dual selection for both body weight and egg production is performed. However, most published estimates indicate a variable correlation between growth and egg number (Nestor et al., 1996) and so the challenge posed is how to best to select for those opposing goals. The objective of this study was to investigate the effects of simultaneous selection for body weight and egg number by estimating the genetic parameters for a research population held by a commercial company in two different locations.

Materials and methods Data included records with full pedigree for four generations from two populations derived from the same line in two locations and selected for body weight and egg number (Site A & Site B 20784 and 16231 birds respectively). The traits studied were body weight at 14 (BW14), 19 (BW19) and 24 (BW24) weeks of age on males and females as well as the total egg number in 139 days (EGG). Sequential selection and culling were practised on these traits. Egg production data were skewed; therefore a Box-Cox transformation was applied to approximate the normal distribution. Various maternal models were tested and the optimum for the dataset was selected based on a likelihood ratio test. The final genetic model included cohorts and sex (or pen for EGG) as fixed effects and the additive genetic and the permanent maternal environment (full-sib resemblance) as random effects. Multivariate REML was used to estimate genetic parameters.

Results Box-Cox transformation had a significant effect on the approximation to the normal distribution for egg number data (the optimum was to take the cube of the data). Maternal effects were significant for body weight traits, but accounted for only 4% of the total phenotypic variance. Genetic parameter estimates are given in the table. Two trends were observed: firstly that heritability estimates were lower for Site A population; and secondly, that the magnitude of the negative genetic correlations between body weight traits and total egg number were higher for the population in Site A. Moreover, heritability of BW tended to decrease with age, despite the use of multivariate REML.

Table 1 Genetic parameter estimates

	BW14	**BW19**	**BW24**	**EGG**
• SITE A				
BW14	**0.37 ± 0.03**	0.96 ± 0.01	0.89 ± 0.02	-0.74±0.07
BW19	*0.65*	**0.34 ± 0.03**	0.96 ± 0.01	-0.75±0.08
BW24	*0.53*	*0.79*	**0.28 ± 0.03**	-0.75±0.08
EGG	*-0.14*	*-0.22*	*-0.26*	**0.22 ± 0.04**
• SITE B				
BW14	**0.48 ± 0.03**	0.97 ± 0.01	0.89 ± 0.01	-0.48±0.09
BW19	*0.72*	**0.43 ± 0.03**	0.97 ± 0.01	-0.51±0.08
BW24	*0.69*	*0.77*	**0.43 ±0.03**	-0.55±0.09
EGG	*-0.15*	*-0.15*	*-0.14*	**0.34 ± 0.06**

Heritability estimates are given on the diagonal (in bold), genetic correlations above diagonal and phenotypic below

Conclusions The differences in the environment (e.g. climate) between Sites A and B may explain partially the observed variability in our parameter estimates, as a result of a genotype-environment interaction. However, differences in selection strategy also apply: in Site A more emphasis is put on increasing body weight. Moreover, in Site A, where hens qualifying as parents reach a higher body weight, the genetic correlation estimates are stronger. Hence, it is possible that the size of the genetic correlation is affected by the current selection for body weight. A plausible scenario could be that alleles with pleiotropic or linked but antagonistic effects on growth and reproduction have been selected in these lines. This strongly negative genetic correlation between body weight and total egg number provides evidence that progress within the line from simultaneous selection on both traits may be slow. These results may also warrant an investigation into alternative selection strategies for heavy turkey lines, including a greater role for body composition in the selection criteria.

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Developing a method to predict body composition in mice using computerised tomography

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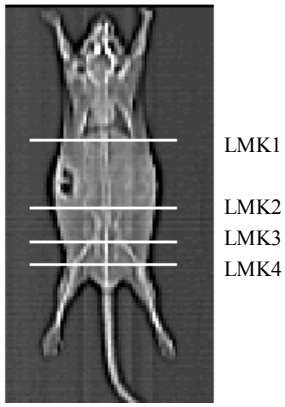
Introduction The mouse is a widely used model in experimental genetics especially for the genetic dissection of fat and lean tissue deposition in farm animals and humans (Bünger & Hill 2005). The body composition of mice has been recently measured *in vivo* and using carcasses with newly developed technologies and special equipment such as Dual-Energy X-ray Absorptiometry topographic scanners, like the PIXImus series, or micro computed axial tomography scanners (Medlin 1999). These methods, although accurate, are still relatively expensive. The aim of this study was to assess whether a computerised tomography (CT) scanner designed for scanning of humans, was capable of providing sufficiently accurate estimate of the body composition of mice of different lines, to prepare the ground for studies in mice as model animals to fast-track experiments in farm animals in a cost-effective way.

Methods Frozen adult mice from different selection lines were scanned using a Siemens Somatom Esprit Computer Tomography (CT) Scanner held by the SAC in Edinburgh. The lines used were a F(fat) and a L (lean) line, divergently selected for fatness and two closely related lines of the growth selected Dummerstorf strain (DUI). After CT scanning the mice, they were freeze dried prior to chemical analysis, allowing a prediction of fat percentage based on the dry matter (DM) content as suggested earlier (Hastings & Hill 1989). Cross-sectional CT scans at 4 anatomical landmarks (LMK) were taken - end of sternum (LMK1), iliac crests (LMK 2), hip joints (LMK 3) and ischial tuberosities (LMK 4) - (Figure 1). LMK1 images were analysed twice, *without* and *with* manually cutting out irrelevant tissues from the image, here referred to as 'LMK1 gutted'. The relative areas of fat and muscle at each landmark were calculated for each CT image using STAR (Sheep Tomogram Analysis Routines) software and then compared to the DM-based estimates for the fat content (fat%) and the fat free mass (FFM) in % using simple linear regression (Table 1).

Table 1 Correlation coefficients (r) *(significant values in bold)*

Mice lines		DUI	Fat	Lean	Fat+Lean
N		100	63	67	130
$Fat\%_{DM}$	Mean ± SD	13.0±3.84	18.5±3.42	5.61±1.95	11.8±7.02
Age at Slaughter	Mean ± SD	70.0±0.9	106±7	106±8	106±7
Body weight at Slaughter	Mean ± SD	71.9±12.5	37.7±4.26	29.1±1.94	33.2±5.41
$Fat\%_{CT}$ vs. $Fat\%_{DM}$	LMK1	**0.44**	**0.40**	**- 0.29**	**0.78**
(gutted)	LMK1	**0.52**	**0.76**	- 0.13	**0.93**
	LMK2	**0.80**	**0.75**	**0.41**	**0.96**
	LMK3	**0.68**	**0.66**	**0.47**	**0.94**
	LMK4	**0.63**	**0.46**	**0.18**	**0.91**
$Muscle\%_{CT}$ vs. $FFM\%_{DM}$	LMK1	**0.34**	0.04	**- 0.33**	**0.35**
(gutted)	LMK1	**0.37**	- 0.01	**- 0.27**	**- 0.68**
	LMK2	**0.77**	**0.72**	**0.10**	**0.93**
	LMK3	**0.68**	**0.33**	**0.38**	**0.86**
	LMK4	**0.41**	0.17	0.13	**0.73**

Fig 1 *CT reference scans*



Results The chemical analysis results are still pending, but lines differ substantially in their fat content predicted from DM content, with the F line three- fold fatter than the L line (18.5% vs. 5.6%) and the DUI with intermediate values. The accuracy of the prediction of fat% from CT depends very much on the line, with higher values in DUI and F or when F and L were combined, and on the LMK, with highest values at LMK2. 'Gutting' at LMK1 generally increased the r-values. The prediction of fat% in very lean mice is insufficient. The prediction of the FFM% from the muscle area in the CT images when compared to the fat prediction slightly less accurate and depends also on the line and LMK. Best values are found at LMK2 particularly when F and L lines were combined, but unacceptable values were obtained in very lean mice.

Conclusions Measurements at LMK 2 provide the highest accuracies in the prediction of fat% and FFM%. The accuracy of prediction increases when there is a wider range of fat% in the experimental animals but very low accuracies were achieved when animals are very lean. Further investigation into LMK using also the results from the chemical analysis and with further adjustment of the CT interpretation settings may prove this site to be a quick, efficient location for estimation of body composition in frozen mouse bodies. These studies raise expectations that *in vivo* CT measurements could become a very useful tool in future studies on model animals.

Acknowledgements Thanks to SEERAD for funding this project.

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Nutritional control of gastrointestinal parasitism in lactating rats

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Introduction Small ruminant studies have shown that a reduction in protein scarcity, through either an increase in protein supply or reduction in protein demand, results in reduced nematode egg excretion and worm burdens during the periparturient period (Houdijk and Athanasiadou, 2003). Whilst this reduced degree of parasitism indirectly suggests that such nutritional effects are mediated through changes in host immune responses, there is only limited direct evidence for this. A rodent model may be used for directly assessing immune responses that underlie nutritional control of nematode parasites. There is indirect evidence that lactating rats undergo a breakdown of immunity to the intestinal nematode *Nippostrongylus brasiliensis* (Houdijk *et al.*, 2003). Provided that this breakdown is sensitive to protein nutrition, this model may be used for elucidating interactions between nutrition and immunity to parasites. Therefore, we assessed whether breakdown of immunity to *N. brasiliensis* in the lactating rat is sensitive to host protein nutrition.

Materials and Methods Eighteen second-parity rats were infected with a single dose of 1,600 infective larvae, and were mated 14 days later. During the last 10 days of pregnancy, rats were *ad libitum* fed a low protein food (60 g crude protein per kg dry matter) in order to reduce their body protein reserves. Following parturition (day_0), three groups of six rats were offered *ad libitum* one of three foods, formulated to supply 100 (L), 200 (M) or 300 (H) g crude protein per kg dry matter. Litter size was standardized at 10 pups by day_2, when rats were re-infected with the same dose of infective larvae. Food intake, dam and litter body weight was measured daily until day_{12}, when rats were humanely killed by CO_2 asphyxiation for the assessment of nematode eggs in the colon contents and worm burdens in the small intestine. Worm and egg counts were log- transformed prior to analysis of variance and are reported as backtransformed means with their 95% confidence intervals.

Results Dam weight, litter weight and litter size on day_0 averaged 311±7 g, 69±9 g and 12.8±0.8 pups, respectively. Feeding treatment did not affect final litter size, which averaged 9.8±0.1 pups on day_{12}. Final dam weight and mean dry matter intake during lactation for the L, M and H rats averaged 267, 334 and 317 g (s.e.d. 11 g; $P<0.001$) and 20, 31 and 30 g/day (s.e.d. 2 g/day; $P<0.001$), respectively. Figure 1 shows the litter weight (±s.e.), number of nematode eggs in the colon and worm burden in the small intestine on day_{12}. The M- and H-rats had heavier litters ($P<0.001$), less eggs in their colon contents ($P<0.001$) and less worms ($P<0.01$) than L-rats.

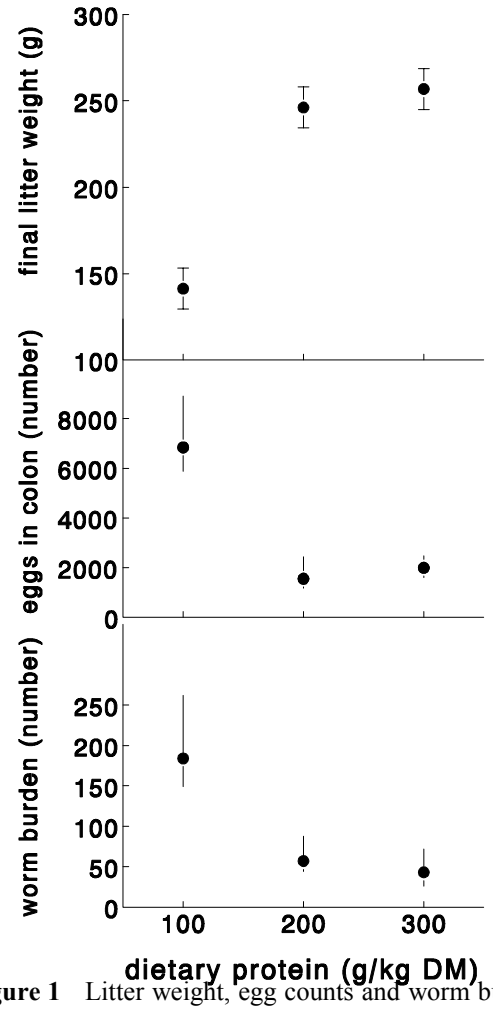

Figure 1 Litter weight, egg counts and worm burden of lactating rats, secondarily infected with *Nippostrongylus brasiliensis*, and offered foods with different levels of crude protein.

Conclusion The performance data of this experiment indicate that achieved protein supply ranged from scarce to more than adequate. However, the increased protein supply was confounded with increased food intake *per se*. Therefore, some of the effects observed on parasitism may be associated with increased supply of non-nitrogenous food components. Feeding the M and H foods reduced the level of parasitism, which supports the view that expression of immunity to *N. brasiliensis* was improved. Whilst these results suggest that this model may be used for assessment of underlying immune responses, more work is needed to exclude the possibility that the effects observed are related to changes in nutrient intake *per se*. In addition, it would also need to be excluded that the observed increase in food intake *per se* may have resulted in non-immunological changes within the gastrointestinal tract that are detrimental to nematode survival.

Acknowledgements This work was supported by SEERAD.

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The effect of changes in nutrient demand on gastrointestinal parasitism in lactating rats

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Introduction A recent study carried out by Houdijk *et al* (2005), used a rodent model to assess whether a reduction in protein scarcity during lactation resulted in a reduced degree of parasitism. Feeding high protein foods resulted in a reduced worm burden, but was confounded with increased food intake *per se*. Therefore, effects observed on parasitism may not necessarily have been associated with an increased protein supply, but with changes in the gut environment due to the increased food intake. Before this model can be used to assess the underlying immune responses, further work is needed to verify that the effects observed are indeed related to changes in nutrient supply. This experiment aimed to provide further evidence on the nutritional control of parasitism during lactation by manipulating nutrient demand. It was expected that the latter would not be associated with changes in food intake *per se* and results could therefore be used to exclude the influence of non-immunological changes in the gut environment as a contributing factor of reduced parasitism.

Materials & method 27 second parity female Sprague-Dawley rats were given a single dose of 1600 third-stage infective *Nippostrongylus brasiliensis* larvae after arrival in the animal house. Post primary infection, females were mated and during pregnancy, rats were subjected to a feeding protocol known to reduce body protein reserves. Parturition was considered as day 0, and from then onwards received either a low protein diet (LPL, 10 % CP) or a high protein diet (HPL, 30% CP). Litter sizes for the LPL groups were standardised to 9, 6 or 3 pups by day 2, while HPL groups had only 9 pups. The rats were re-infected with a single dose of 1600 *N.brasiliensis* on day 2. Rats were slaughtered on day 12 to assess worm burdens. Sections of small intestine were removed for analysis of mucosal mast cells and globule leukocytes. Worm numbers were log-transformed, and reported as backtransformed means with 95% confidence intervals. ANOVA was used to assess the treatment effects on worm burden and immunological cell analysis. It was assumed that LPL-3 and HPL-9 would place the same nutrient demand on the dam, as would LPL-6 and LPL-9, therefore, contrast statements were used to make comparisons between the combination of these two groups.

Results During lactation, HPL-9 dam weight change averaged at +34g, LPL-9 –18g , LPL-6 –16g and LPL-3 +39g (s.e.d. 8.6g). Mean final litter weight reached 157.4g, 61.5g, 60.9g and 38.0g respectively (s.e.d.12.2g; P= <0.001). Figure 2 shows the number of worms in the small intestine. LPL-3 rats had significantly lower worm burdens (P=0.03) compared to LPL-6 and LPL-9 rats. HPL-9 + LPL-3 combined had a highly significant reduction in worm burden compared to LPL-6 + LPL-9 (P=0.008). There was no significant difference between feed intakes for rats receiving the low protein treatments, displayed in Fig.1. Feeding treatments had no significant effect (P=0.85) on mucosal mast cell numbers (mean 27 cells/0.45mm^2, 18-34 95% CI). Globule leukocytes were absent in all tested sections.

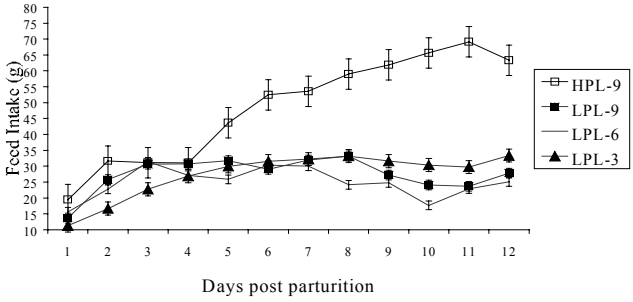

Figure 1 Feed intake of lactating rats nursing 3, 6, or 9 pups receiving high (HPL) or low (LPL) protein

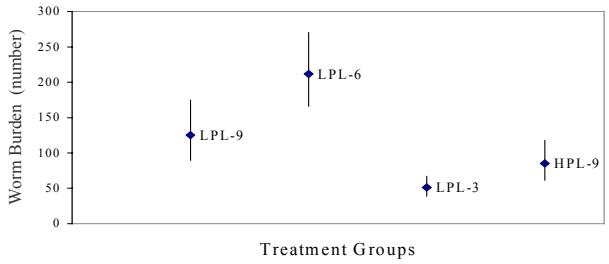

Figure 2 Worm burden of lactating rats on day 12, receiving high (HPL) or low (LPL) protein

Conclusion The results support the view that the periparturient breakdown of immunity to *N. brasiliensis* (measured by a reduced worm burden) is sensitive to changes in nutrient demand and that these effects are independent of changes in feed intake *per se.* Hence, further analysis is required to understand the underlying immunological basis of relaxation in immunity during the periparturient period.

Acknowledgements This work was supported by SEERAD.

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Growth trajectories of Holstein dairy cows

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Introduction All genetic selection in dairy cattle is applied to traits that are measured during the animal's productive life, mostly those recorded during early productive life because genetic evaluations are best calculated from unbiased early data. Since body lipid is normally accumulated partly as a function of body protein accretion and in part as a function of degree of maturity (which is also related to protein content), it follows that selection for yield in relatively mature life, and concomitant alteration of body lipid profiles, may have altered early life growth profiles as well. If this is the case, parameters of early life growth may be used to predict later life events such as production and functional traits associated with the degree of maturity when these events occur. The objectives of this study were: 1) to model the growth of dairy cows of average and high genetic merit from birth to the end of third lactation and identify any differences in their growth curves.

Materials and Methods Data were extracted for all select (S) and control (C) line cows up to lactation 3 from the database of Langhill Research Farm records collected from 1990 until 2002. The approximately equal number of S and control C line animals were reared from birth up to first calving as one management group. After first calving, half of each genetic group were assigned to a high concentrate feed group or a low concentrate feed group as part of a long-term genotype by environment interaction trial. Prior to first calving, animals were weighed at specific calendar times that approximated to major management events. These weights were recorded at birth, weaning, first winter, spring turnout, mid summer and subsequent housing then second winter, turnout and summer. Variance components for liveweight were estimated using a random regression model in the ASREML statistical package.

Figure 1 Pregnancy adjusted liveweight (kg) for each day of life from birth to day 1825 for select (▲) and control (□) cows.

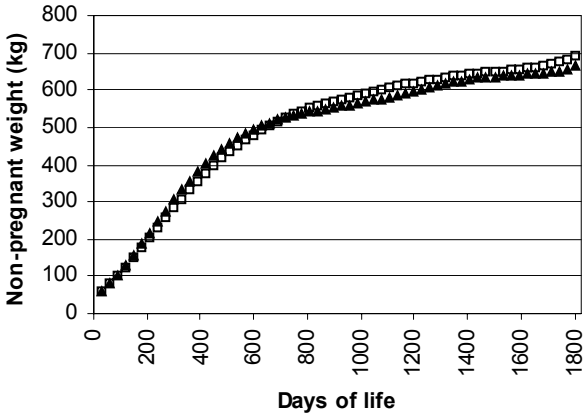
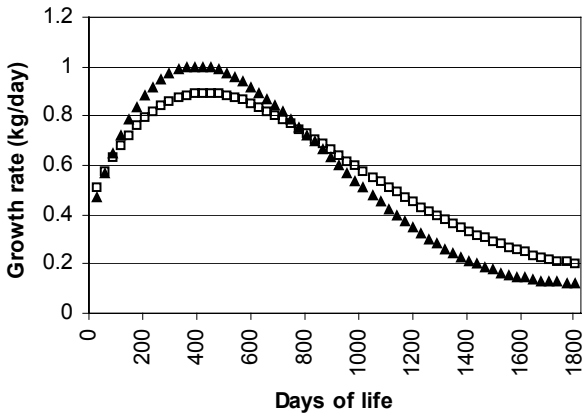


Figure 2 Growth rate for pregnancy adjusted liveweight (kg/day) for each day of life from birth to day 1825 for select (▲) and control (□) cows.



Results No significant difference in birth weight between select and control cows was found. Select cows are heavier at first calving but remain lighter throughout the trajectory thereafter (Figure 1). Select cows grow at a faster rate from soon after birth until around day 825 of life. At this point control cows continue to grow at a higher rate than select cows. Daily rate of gain was highest for S animals and reached a maximum of 1.00 kg/day at days 387 to 421 (Figure 2). Control animals grew fastest between days 417 and 440 and during this period grew at 0.894 kg/day. Day of life at which peak growth occurs differed between select and control cows by around 20 days, with select cows maturing earlier. This may imply that select cows reach maturity earlier or that they are willing to lose weight after calving to a greater extent than control cows. This liveweight loss will include body lipid since condition score loss is pronounced in select animals in this herd (Coffey et al., 2002).

Conclusions Results presented here demonstrate that selection for milk production in first lactation Holsteins has led to dairy cattle with significantly different growth curves prior to first calving and significantly different weights at first calving. This may have implications for the management of animals selected for production in order to optimise lifetime performance. Likewise, growth prior to first lactation could be included in future selection policies in order to optimise the expression of lifetime utility (including fitness) of dairy cattle in modern management systems.

Acknowledgements We thank Ross McGinn for storing and extracting the Langhill data. SAC receives funding from SEERAD.

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Profiles of genetic changes of linear type in Holstein Friesians

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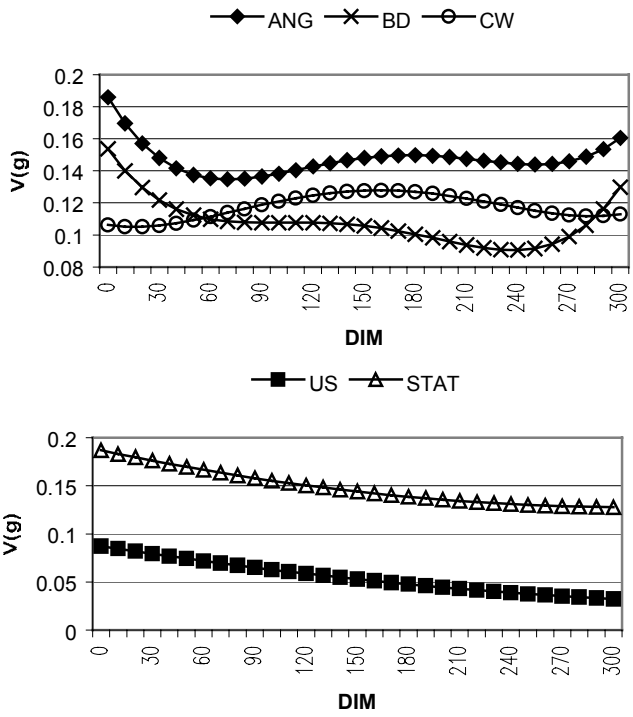
Introduction Changes in body condition score and other linear type traits can be indicative of changes in body energy balance in dairy cattle (Coffey *et al.,* 2003). As an animal proceeds through her lactation it is expected that body shape and fatness levels will change both with peaks and troughs of lactation as well as changes as the animal grows and matures. Wall *et al.* (2005) showed that udder support (US) was correlated to fertility; cows with weaker udders had poorer fertility. If there are differences between animals in terms of how their udders grow and mature across the first lactation, this could be indicative of health and fertility problems later in life. The aim of this study was to examine how type traits recorded in the national dairy population change over the first lactation and if there is a difference between sires in the type profiles of their daughters.

Materials and methods This study focuses on the most appropriate model and description of change across first lactation for the linear type traits of udder support (US), stature (STAT), angularity (ANG), body depth (BD) and chest width (CW). All traits are adjusted for differences in scoring range by scaling records so that individual field officer standard deviations were equal to the mean standard deviation of all field officers. The data were validated, resulting in a dataset of 28,680 daughter records for 954 sires. Genetic and environmental variance components were estimated using a random regression sire model using ASREML (Gilmour *et al.,* 2003). Legendre polynomials were employed to model both the fixed population curve and sire deviations from this curve, and additive genetic random regression coefficients for sires were predicted.

Results The heritability of ANG changed throughout the lactation with the genetic variance being lowest around peak lactation (day 60 to 80) (Figure 1). Although the genetic variance for US was low and decreased across lactation the heritability ranged from 0.25 to 0.1. STAT tended to rise throughout the first lactation, indicating that the animal is continuing to grow, in height, across first lactation (0.8 of a unit). The genetic variance of STAT falls slowly across the first lactation with the heritability also dropping from 0.45 to 0.35. The genetic variance of BD was higher at the start and end of the lactation and the heritability is higher at these points (Figure 1). The genetic variance of CW is highest around day 160 (Figure 1). However, the heritability of CW was relatively stable across the lactation and varied between 0.25 and 0.3. The phenotypic profiles of type trait change differed between traits and between sires (not shown). For example, the daughters of one sire were shown to have an US profile that is increasing (getting stronger) whilst another sires were decreasing across lactation (udders getting weaker). The results also showed that some traits (e.g. ANG) could be lowest in the middle of lactation (approximately peak milk yield) and higher at either end.

Figure 1 Genetic variance (Vg) of US, STAT, ANG, BD and **CW** across the 1st lactation



Conclusions Genetic variances and heritabilities for the type traits agree with estimates from other studies. Linear type traits associated with body volume and size (BD, CW, STAT) were shown to vary across lactation. There are differences in the profiles of change in type traits across lactation for daughters of sires. These changes could be indicative of animals utilising body reserves to maintain lactation and/or differences in the rates of maturity.

Acknowledgements We thank DEFRA, BOCM Pauls, CIS, Cogent, Dartington Trust, Genus, HUK, NMR and RSPCA for their support

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Predicting the voluntary food intake of growing animals during exposure to pathogens of different kinds and doses

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Introduction Pathogens (parasites, bacteria and viruses), when causing sub-clinical disease, affect the voluntary food intake, VFI kg/d, of animals, with subsequent reductions in rates of growth. However, no general quantitative framework for predicting the effects of different kinds and doses of pathogen on the VFI of animals has been proposed that could be integrated with existing models of growth. The aim here was to develop a general quantitative framework of VFI during exposure to sub-clinical doses of pathogens and to integrate such a framework with a general model of growth (Wellock *et al*. 2003).

Materials and Methods The model predicts the VFI over time of an animal challenged by a pathogen. The model deals only with sub-clinical challenge doses and it is assumed that a reduction in VFI occurs only in animals that are naïve to a particular pathogen. The model assumes that there is a lower threshold dose, below which there are no reductions in VFI. An upper threshold dose defines a clinical reduction in VFI, which is beyond the scope of this model. The actual intake of the challenged animal, relative to that of the healthy animal at the same protein weight, is the relative food intake, RFI. It is further assumed that an animal has recovered from a pathogen challenge once it has regained the VFI of a health animal at the same protein weight i.e. there is no compensatory intake.

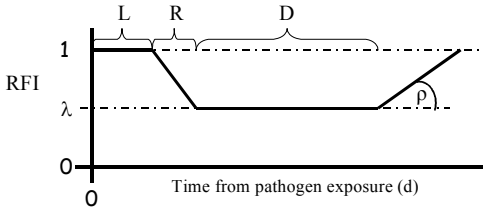

Figure 1 The parameters of the model

The parameters of the model, shown in Figure 1 are: lag time, L d; reduction time, R d; the lowest value of RFI, λ; the duration of λ, D d; rate of recovery of RFI, ρ RFI/d. The values of the parameters L and λ were assumed to be specific to pathogen type and dose and were parameterised on biological grounds. The values of the parameters R, D and ρ were made pathogen specific, but dose independent. Experiments were simulated to assess the effect of challenges of different sub-clinical doses of model pathogens on VFI. The model parameters may reflect the different stages of an acquired immune response and genetic resistance may have an affect on their values. A genetically resistant animal may be more able to cope with a pathogen challenge of a certain dose, resulting in a greater value of L. Acquisition of immunity may develop at a faster rate, accompanied with lower values of R and D. λ may be affected to a greater extent for a resistant genotype. Values of ρ may be greater as it may be able to express immunity at a greater rate. Relevant experiments were simulated to assess the consequences of the above assumptions for a 'susceptible' and a 'resistant' genotype.

Results The effects of challenges of different doses of a parasitic model pathogen are shown in Figure 2, with a greater dose causing a larger reduction in VFI, with a faster onset. The possible effects of different doses of a model parasitic pathogen on two different genotypes, which were assumed to vary in their genetic resistance to the pathogen, are shown in Figure 3. It illustrates how a resistant genotype may have no effects on RFI, when challenged by the same dose as susceptible genotype. While for a dose that is greater than the minimum threshold, RFI may be reduced to a lower value, but for a shorter period of time for a resistant genotype.

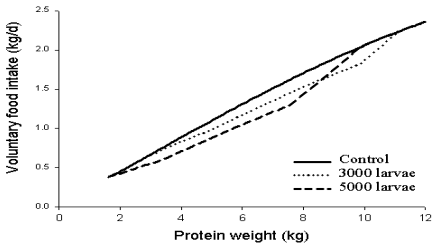

Figure 2 Predictions of effects of larval number on the VFI of an animal

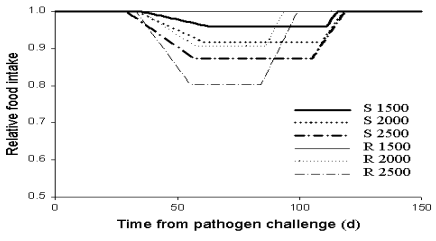

Figure 3 Predictions of larval number on RFI of a susceptible (S) and resistant (R) genotype

Conclusions The model attempts to quantify the effects of different doses of pathogens on VFI, and hence performance of animals. Predictions are in qualitative agreement with experimental findings. Improvements are needed in relation to the description of pathogen exposure and subsequent pathogen load in the host. Experiments that test the predictions of this model, especially in relation to state and genotype may improve our understanding the problem, which is the interaction between pathogen challenge, host resistance (immunological and genetic) and performance.

Acknowledgements This work was supported by BBSRC and Sygen Plc.

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Predicting the effects of body fatness on food intake and performance of sheep

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Introduction Food intake (FI) can be predicted on the basis of variables that describe food quality and the animal. Live weight (LW) is usually the only variable that is used to describe the animal. Animal fatness, as estimated by condition score (CS), can affect FI at a given LW. Body lipid produces signals (leptin) that affect energy intake and energy expenditure. If fatness acts on intake via its effect on energy expenditure, the effects of body lipid content on food intake can be incorporated into an existing intake model. Our objectives were to construct and test models that predict effects of fatness on intake and performance, using data obtained with ewe lambs to parameterise and test the models.

Materials and methods Two foods, H (hay) and P (concentrate pellets) were used in an experiment of 50 weeks on female Greyface*Texel lambs with a mean initial LW of 35 kg. Five treatments with 8 to 10 lambs each were investigated. Treatment H received hay throughout. Treatments P45H, P65H and P95H received P from week 1 but were switched to hay after reaching 45, 65 or 95 kg LW, respectively. Treatment H45P received hay from week 1 but was switched to P after reaching 45 kg LW. FI and LW were recorded weekly and CS every 2 weeks. Before fitting the model, CS was smoothed and values for missing weeks were interpolated. Ratios of lipid to lean in the body (LipLean) were estimated from LW and CS. An equation that predicts intake of net energy (NEI) from intake of metabolisable energy (MEI) plays a crucial role in the intake model of Tolkamp and Ketelaars (1992): NEI = B*(1-exp(-p*MEI)). Food quality affects parameters B and p and that is used to predict intake. Parameters B and p are highly correlated and parameter p was replaced with 0.89/B in our model. We hypothesised that for a given genotype consuming a given food the value of parameter B will be affected by animal fatness. The effect of LipLean on parameter B was estimated for sheep consuming H (from treatment P65H, last part) or P (from treatment P95H, first part). Estimated values for B were then used to predict intake of sheep in the remaining treatments. The same model was subsequently used, together with an additional module based on a Gompertz function that describes maximum protein retention, to simulate (time step: one day) changes in LW and CS in animals fed H or P. Finally, the same model was extrapolated to predict the effect of time on LW and lipid content (including the final values to be achieved) of ewe lambs fed H only or P only.

Results The intake model predicted food intake well (see example in Figure 1[a]). With one exception (LW for treatment P65H, latter part) changes in LW and CS were predicted quite accurately for all treatments by the simulation model (see Figures 1[b] and 1[c]). Final LW and lipid content in the empty body were predicted at 77 kg and 26% for animals fed H only and 119 kg and 57% for animals fed P only (see Figure 1[d] for predicted change in lipid content with time).

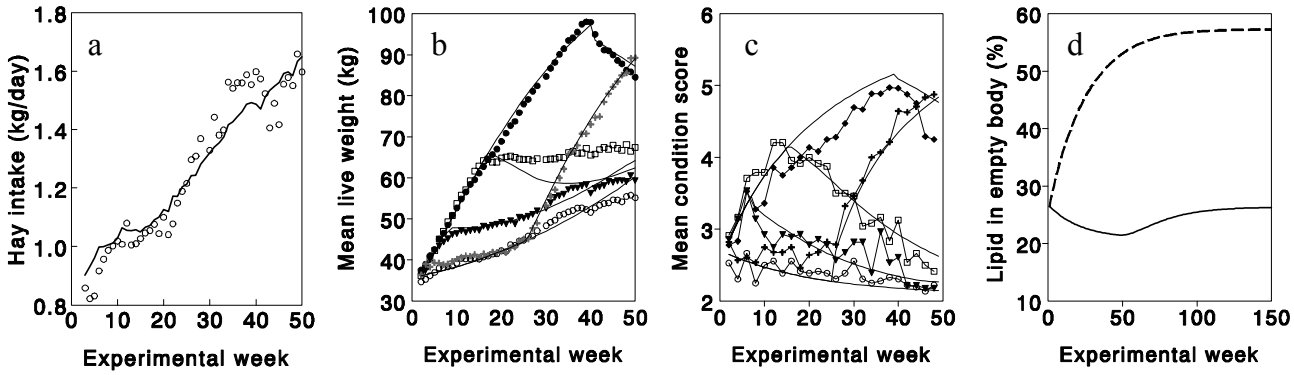

Figure 1 Observed (symbols) and predicted (solid lines) mean hay intake of treatment H (a), LW (b) and CS (c) of all treatment groups and the predicted lipid content in the empty body (d) of lambs fed hay only (solid line) or pellets only (broken line). In Figures (b) and (c) treatments were H (hay trough-out, o), P45H (pellets to 45 kg, then hay, ▼), P65H (pellets to 65 kg, then hay, □), P95H (pellets to 95 kg, then hay, ●), and H45P (hay to 45 kg, then pellets, 2)

Conclusions The hypothesis that lamb fatness affects energetic efficiency and, therefore, food intake survived the first test (predict food intake accurately). The results of the simulation study based on the model gave no reason to reject the hypothesis. Extrapolation of the model suggests that the final weight and fatness attained by sheep will depend on the quality of food offered. Although no data are available to test predictions of final LW and lipid content, the predictions are well within the range of expectations. The hypothesis seems, therefore, promising for the prediction of intake and performance in sheep but further experiments are required to test for effects of other food qualities, sex and genotype.

Acknowledgements We gratefully acknowledge the assistance of David Anderson and Terry McHale with collection of the data. The work was funded by SEERAD.

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Selection for improved lean growth in Large White pigs can affect levels of total white blood cell counts, CD11R1$^+$ leukocytes and alpha-1 acid glycoprotein

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Introduction Productivity in pigs can be improved by continued selection, however the impact of such selection on immune responses and resistance towards infectious challenges is not known. A risk is that this method may lead to a correlated reduction in the immune response and disease resistance. To estimate the effect of selection for performance traits upon immune responses, we compared levels of immune traits between divergent lines of Large White pigs selected for either lean growth under restricted feeding or feed intake.

Materials and methods A range of immune traits was measured in Large White pigs (62 male; 57 female) at ages 18- and 24-weeks, undergoing a standard performance test under *ad libitum* feeding conditions. These pigs were previously selected as described by Cameron (1994) for high (n=31) and low (n=38) lean growth under restricted feeding, and high (n=24) and low (n=26) feed intake. Each group consisted of approximately equal numbers of pigs from both sexes and from both of two consecutive generations. Daily weight gain was measured from ages 14- to 24-weeks. All pigs in the study were housed in the same environment and were apparently healthy. Immune traits measured included total white blood cell numbers (WBC) and mononuclear leukocyte subsets (i.e. neutrophils, monocytes, eosinophils, CD4$^+$ cells, CD8$^+$ cells, B cells, gamma delta T cells and CD11R1$^+$ cells) from peripheral blood samples. CD11R1$^+$ cells resemble natural killer cells (Haverson *et al.* 2001). Mononuclear sub-set proportions were calculated from the total mononuclear leukocyte population. Additionally, plasma levels of acute phase proteins, alpha-1 acid glycoprotein (AGP) and haptoglobin were measured. Data were analysed using Residual Maximum Likelihood, accounting for sex, selection line and generation, and day of sampling.

Results Significant high *vs.* low line differences were observed in pigs selected for lean growth under restricted feeding; immune traits altered by selection are shown in Table 1. Overall, components of the innate immune response, *viz.* total white blood cell counts, the proportions of CD11R1$^+$ cells and AGP levels were consistently elevated in high lean growth pigs compared to low lean growth pigs. Selection for feed intake did not have consistent effects upon total white blood cell counts, any particular leukocyte subset or acute phase protein levels. Daily weight gain was similar between 'high' and 'low' lines within each selection criteria.

Table 1 Immune traits altered by selection for lean growth under restricted feeding in Large White pigs: predicted means for, and differences between, high and low lines; * $p < 0.05$, ** $p < 0.01$; '-' = not tested.

			WBC x 10^6 cells/ml		CD11R1$^+$ proportion		AGP μg/ml	
Age		Generation:	1st	2nd	1st	2nd	1st	2nd
18 weeks	High line		-	31.8	-	0.213	-	630.9
	Low line		-	24.3	-	0.172	-	363.3
	Difference		-	7.5**	-	0.042*	-	267.6**
	SED		-	2.85	-	0.016	-	64.8
24 weeks	High line		40.2	39.2	-	0.201	318.8	314.7
	Low line		28.2	27.2	-	0.143	229.5	214.7
	Difference		12.0**	12.6**	-	0.058**	89.3*	100.0*
	SED		2.42	2.74	-	0.012	32.8	34.6

Conclusion Selection for lean growth under restricted feeding influenced levels of various immune traits whilst selection for feed intake did not consistently alter any of the immune traits tested. Thus selection for increased lean growth under restricted feeding (i.e. efficiency) has increased various innate immune measures in pigs that are apparently healthy, suggesting that higher levels of these measures may be predictive of improved performance in the environment in which these pigs performed.

Acknowledgements This work was funded through LINK SLP by Defra and the UK Pig Breeders' Consortium.

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Prediction of body weight and composition in lactating dairy cows: Prediction of empty body contents of lipid and crude protein

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Introduction The accurate prediction of body composition of dairy cows is important for developing appropriate nutritional and management regimes. The objective of the present study was to develop prediction equations for empty body (EB) composition of lactating dairy cows using body weight and other live animal data.

Material and methods Body composition data (n = 146) used were derived from Holstein Friesian lactating cows and animal and dietary information for these cows was reported by Yan *et al.* (2005). The foetus and associated fluid and membranes were removed for pregnant cows. The exsanguinated bodies of the animals were then divided into eight components, i.e., hide, feet, udder, head (including spinal cord and thymus), alimentary tract (excluding all contents except contents of omasum), urino-genital tract, pluck (trachea, lungs, heart, diaphragm, liver, kidneys and tail) and carcass. The weight of each component was recorded at the time of collection and all components were stored at –20 ºC. Each component was subsequently shredded and minced while in the frozen state and representative samples taken for determination of nitrogen and lipid concentrations. Linear and stepwise multiple regression techniques were used to examine relationships between body composition and body weight plus other live animal data.

Results There was a large range in lipid (16.6 – 133.7 kg) and CP (55.8 – 103.5) contents. Lipid and CP contents were positively related to live weight (LW), EB weight (EBW, Figure 1), condition score (CS), parity and stage of lactation (LS, 1 for lactation days of 1 to 100, 2 for 101 to 200 and 3 for over 200) ($P < 0.05$ or less). The relationship of milk yield (MY) with lipid content was negative ($P < 0.05$). Prediction equations for lipid and CP contents have been developed (Table 1). These relationships are all highly significant ($P < 0.001$) and each predictor has a significant effect on the relationship ($P < 0.001$). The R^2 values in linear relationships ('a' set Eq.) were lower than those in multiple equations ('b' set Eq.) (0.47 – 0.91 *vs*. 0.76 – 0.94). Prediction of CP (Eq. (2a), (2b), (4a) and (4b)) generated higher R^2 values than lipid (Eq. (1a), (1b), (3a) and (3b)) (0.88 – 0.94 vs. 0.47 – 0.82). Using EBW (Eq. (3a) – (4b)), rather than LW (Eq. (1a) – (2b)), as the primary predictor increased R^2 values (0.62 – 0.94 vs. 0.47 – 0.89).

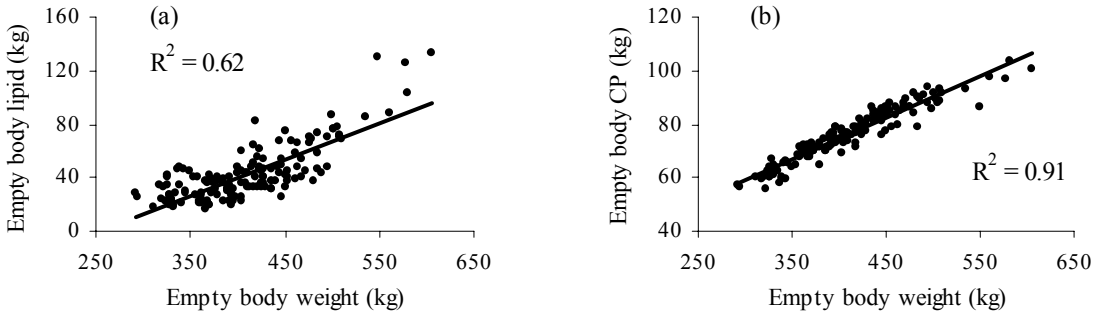

Figure 1 Relationships between empty body weight and EB contents of lipid (a) and CP (b) in lactating dairy cows

Table 1 Linear and multiple prediction equations (subscripted data in parentheses are s.e. values)

	Equations	R^2	Eq. No
Lipid (kg) =	$0.196_{(0.018)}$ LW – $69.1_{(10.1)}$	0.47	(1a)
	[$0.059_{(0.023)}$ + $0.038_{(0.004)}$ CS – $0.0012_{(0.0003)}$ MY] LW – $29.0_{(8.0)}$	0.76	(1b)
CP (kg) =	$0.126_{(0.004)}$ LW + $3.5_{(2.3)}$	0.88	(2a)
	[$0.119_{(0.004)}$ + $0.0027_{(0.0007)}$ LS] LW + $4.7_{(2.2)}$	0.89	(2b)
Lipid (kg) =	$0.273_{(0.018)}$ EBW – $69.0_{(7.4)}$	0.62	(3a)
	[$0.146_{(0.030)}$ + $0.045_{(0.005)}$ CS – $0.0020_{(0.0004)}$ MY – $0.0117_{(0.0028)}$ LS] EBW – $34.3_{(6.7)}$	0.82	(3b)
CP (kg) =	$0.155_{(0.004)}$ EBW + $12.2_{(1.7)}$	0.91	(4a)
	[$0.178_{(0.009)}$ – $0.0079_{(0.0013)}$ CS + $0.0003_{(0.0001)}$ MY + $0.0020_{(0.0008)}$ LS] EBW + $6.1_{(1.9)}$	0.94	(4b)

Conclusion The R^2 values in relationships between CP and lipid contents and live animal measurements are relatively high (up to 0.94), indicating these two variables can be accurately predicted in lactating dairy cows.

Acknowledgement Authors thank DARD for funding this work and their colleagues for assistance with this project.

Reference

Yan, T., Agnew, R. E. and Patterson, D. C. 2005. Prediction of body weight and composition in lactating dairy cows: Prediction of empty body weight and carcass weight. In: *The Proceedings of BSAS Annual meeting*, p180, York, UK.

Prediction of body weight and composition in lactating dairy cows: Relationship between body condition score and body composition

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Introduction Body condition of lactating dairy cows varies at different stages of lactation. Cows usually mobilise their body reserves to provide energy and protein for milk production in early lactation, and gain weight to deposit energy and protein for pregnancy at a later stage. The objective of the present study was to examine relationships between body condition score (CS) and body concentration of lipid, CP and energy.

Material and methods Empty body (EB) composition data (n = 146) used in the present study were derived from Holstein Friesian lactating cows. The information on animals and diets for these cows was reported by Yan *et al.* (2005). Twenty nine cows were in first lactation, 32 in second lactation and remaining cows in third lactation or over. The foetus and associated fluid and membranes were removed for pregnant cows before measurements of lipid, CP and energy contents in whole body. The EB weight (EBW) was determined as live weight minus weights of gut contents and foetus and associated fluid and membranes. Body CS was determined using 1 to 5 scales (1 for very thin and 5 for very fat). Linear and stepwise multiple regression techniques were used to examine relationships between CS and EB concentrations of lipid, CP and energy.

Results There was a large range in EBW (293 – 606 kg), CS (1.1 – 4.0) and EB concentrations of lipid (198 – 1146 g/kg$^{0.75}$) and energy (27 – 67 MJ/kg$^{0.75}$), while the range of EB CP concentration (733 – 902 g/kg$^{0.75}$) was much smaller than that of lipid. Relationships between CS and EB concentrations of lipid, CP and energy are presented either in Figure 1(a) or Table 1 or both. There was no significant relationship between EB CP concentration and CS (Figure 1(a)) or EB energy concentration (Figure 1(b)), indicating that with increasing CS (accordingly EB energy concentration), the increase in EB CP mass is proportional to the increase in EBW. However, increasing CS significantly ($P < 0.001$) increased EB concentrations of lipid (Eq. (1), $R^2 = 0.57$) and energy (Eq. (2), $R^2 = 0.58$) when the effect of stage of lactation (1 for lactation days of 1 to 100, 2 for 101 to 200 and 3 for over 200) was removed. There is a highly significant relationship between EB concentrations of lipid and energy (Figure 1(b) and Eq (3), $R^2 = 0.98$) when the effect of parity range (1 for lactation 1, 2 for lactation 2 and 3 for lactation 3 or over) was removed.

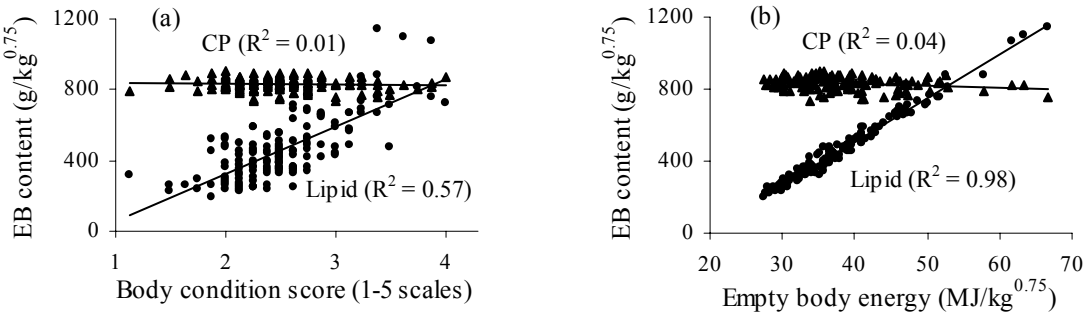

Figure 1 Relationships between empty body composition and CS (a) and empty body energy concentration (b) in lactating dairy cows

Table 1 Linear prediction equations (subscripted data in parentheses are s.e. values)

	Equations	Effect removed	R^2	Eq. No
Lipid (g/kg$^{0.75}$) =	271.7 $_{(20.9)}$ CS – 233.7 $_{(51.8)}$	Lactation stage	0.57	(1)
Energy (MJ/kg$^{0.75}$) =	10.06 $_{(0.85)}$ CS + 9.9 $_{(2.1)}$	Lactation stage	0.58	(2)
	0.040 $_{(0.0005)}$ Lipid (g/kg$^{0.75}$) + 19.6 $_{(0.3)}$	Parity range	0.98	(3)

Conclusion Increasing CS had no significant effect on EB concentration of CP (g/kg$^{0.75}$), but significantly increased EB concentrations of lipid (g/kg$^{0.75}$) and energy (MJ/kg$^{0.75}$) in lactating dairy cows.

Acknowledgement Authors thank DARD for funding this work and their colleagues for assistance with this project.

Reference

Yan, T., Agnew, R. E. and Patterson, D. C. 2005. Prediction of body weight and composition in lactating dairy cows: Prediction of empty body weight and carcass weight. In: *The Proceedings of BSAS Annual Meeting*, p180, York, U.K.

Colour stability and lipid oxidation in M. *longissimus dorsi* from lambs fed oils or oilseeds rich in polyunsaturated fatty acids

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Introduction Due to ruminal biohydrogenation, the increase in muscle polyunsaturated fatty acids (P) in ruminant tissue is small relative to dietary supply. Some biohydrogenation is desirable since conjugated linoleic acid (CLA), considered to have human health promoting properties, results from incomplete ruminal biohydrogenation of linoleic acid and by tissue desaturation of ruminally derived trans-vaccenic acid (TVA). Noci *et al*., (2004) reported that controlling the rate of oil release from linseed and camelina to the rumen increased the efficiency of transfer of dietary P to tissue while allowing the production of CLA. Increasing the P concentration, in particular the longer carbon chain P, predispose lipids to oxidation which is believed to be linked to muscle pigment oxidation and consequently to colour instability. The objective of this study was to compare the effects of the strategies used by Noci *et al*., (2004) to protect dietary lipids from ruminal biohydrogenation, on the colour and lipid stability of muscle.

Materials and methods Sixty-six wether lambs (40kg, s.d 4.69 kg) were offered, for 100 days prior to slaughter, one of six barley/beet pulp-based rations which contained 500 IU vitamin E/kg and which differed in fat source: i.e. Megalac (ML), Camelina (C) oil (C18:2:C18:3 = 0.68, CO), Linseed (L) oil (C18:2:C18:3 = 0.47, LO), C seed treated with 10gNaOH/kg (CS), L treated with 5gNaOH/kg (LS) and CO treated with ethanolamine (CA). Feed allowances were adjusted periodically to achieve similar carcass weights. Following slaughter, intramuscular fat was extracted from M. *longissimus dorsi* (LD), methylated and fatty acid methyl esters (FAME) analysed by gas-chromatography. Samples of thawed LD were placed in retail display trays and stored under an atmosphere of 80% O_2 : 20% CO_2. Colour (redness) and lipid oxidation (2-thiobarbituric acid reactive substances; TBARS) were measured at 3-day intervals during retail display. Data were analysed according to a randomised block design using Genstat 6.0. "A priori" contrasts were also used to compare oils and NaOH treatment *per se.*

Results Data are summarised in Table 1. LS was most effective in increasing the C18:3 and CLA concentration and decreasing the n-6:n-3 P ratio in muscle. Within C treatments, CA resulted in the highest C18:3 and lowest CLA concentration in muscle. On average, oil resulted in lower C18:3 concentration and n-6:n-3 ratio and higher TVA concentration and than seeds. There was no difference in colour stability during retail display (data not shown). Vitamin E concentration was lower for all treatments compared to ML. TBARS were highest for LS and lowest for ML in the early part of display. The trend was for seeds to result in higher TBARS than oil and for L to result in higher TBARS than C.

Table 1 Concentration of fatty acids (mg/100g muscle), TBARS (mg malondialdehyde/kg muscle) and vitamin E (mg/g) in *M. longissimus dorsi*

Treatment	ML	CO	LO	CS	LS	CA	s.e.d.	Sig	Oil	Seed	Sig	C	L	P
Fatty acids														
C 18:2	123.4	139.8	130.9	126.0	123.5	144.3	11.63	NS	135.4	124.8	NS	132.9	127.2	NS
C 18:3	18.4^{a}	60.9^{b}	76.5^{bc}	68.4^{bc}	103.1^{d}	81.1^{c}	8.47	***	68.7	85.8	*	64.7	89.8	**
CLAc9t11	29.3^{a}	44.2^{bc}	42.2^{abc}	49.6^{cd}	58.5^{d}	33.5^{ab}	7.36	**	43.2	54.1	*	46.9	50.4	NS
TVA	99.1^{a}	217.1^{c}	223.8^{c}	164.9^{b}	155.1^{b}	137.3^{ab}	25.74	***	200.5	160.0	**	191.0	189.5	NS
P:S Ratio	0.15^{a}	0.17^{b}	0.18^{b}	0.19^{b}	0.22^{c}	0.18^{b}	0.010	***	0.18	0.2	**	0.18	0.20	**
n-6:n-3 Ratio	5.28^{c}	2.14^{b}	1.75^{b}	1.83^{b}	1.15^{a}	1.72^{ab}	0.248	***	1.95	1.49	*	1.99	1.45	**
Total FA	3524	4659	4177	4056	3980	4171	376.0	NS	4418	4018	NS	4358	4079	NS
TBARS														
- Day 3	0.23^{a}	0.66^{ab}	1.33^{bc}	1.04^{ac}	2.89^{d}	0.24^{a}	0.605	**	1.00	1.97	NS	0.85	2.11	*
- Day 6	0.60^{a}	1.47^{ac}	2.99^{bcd}	2.05^{ac}	4.56^{d}	2.15^{ac}	1.230	*	2.23	3.31	NS	1.76	3.77	*
- Day 9	1.92	2.65	4.87	3.05	6.89	4.06	2.375	NS	3.76	4.97	NS	2.85	5.88	NS
- Day 12	3.81	5.99	7.41	5.48	11.05	7.16	3.250	NS	6.70	8.27	NS	5.74	9.23	NS
Vitamin E	4.71^{c}	2.27^{a}	$2.99^{a,b}$	$2.71^{a,b}$	2.05^{a}	3.41^{b}	0.467	**	2.63	2.38	NS	2.49	2.52	NS

ML, CO, LO, CS, LS, CA, C and L = megalac, camelina oil, linseed oil, camelina seed + NaOH, linseed + NaOH, camelina amide, camelina and linseed, respectively. Means with similar superscripts do not differ significantly.

Conclusions Caustic treatment of oilseeds *per se* and chemical protection of C increased the concentration of C18:3 in muscle compared to oil. Higher muscle C18:3 concentration was associated with higher oxidation during retail display despite high and similar vitamin E consumption, but this was not reflected in a loss of colour stability.

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The fatty acid composition of muscle fat and relationships to meat quality in Charolais steers: influence of level of fish oil in the diet

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Introduction Previous studies have demonstrated that including fish oil (FO) in the diet of beef cattle resulted in increased long chain C20*n*-3 PUFA (20:5*n*-3 and 22:6*n*-3) in muscle resulting in a lower *n*-6:*n*-3 ratio (Scollan *et al*., 2001). However, it may result in negative effects on colour shelf life and organoleptic properties (Vatansever *et al*., 2000). Fish oil is also a good inhibitor of biohydrogenation in the rumen, resulting in increased production of 18:1*trans* (TVA), the precursor for conjugated linoleic acid (CLA *cis*-9, *trans*-11) in muscle. This study investigated the effects of incremental levels of fish oil in the diet on the fatty acid composition of the *m. longissimus dorsi* and meat quality.

Materials and methods Thirty two Charolais steers (initial live weight 569 kg (s.e.d. 7.2) were randomly allocated to one of four dietary treatments, each consisting of eight animals. The treatments were based on *ad libitum* grass silage plus one of four concentrates in which the level of fish oil (salmon oil) was 0, 20, 40 or 60 g/kg fresh, referred to as control, FO1, FO2 and FO3, respectively. Megalac was used to balance oil across all four concentrates. Diets were formulated so that total oil intake was approximately 0.06 of DM intake of which proportionally 0, 0.15, 0.30 and 0.45 was provided by fish oil across the 4 treatments. Vitamin E content of the concentrates was approximately 500 IU/kg. Total-N and AHEE averaged 24.5 and 71.2 g/kg DM across all 4 concentrates. Feed levels were adjusted weekly to maintain a forage:concentrate ratio of 60:40 and animals were slaughtered after 90 days on treatment, samples of *m. longissimus thoracis et lumborum* (LTL) were taken at 48h post-mortem for fatty acid analysis. Colour (L*a*b*) and lipid oxidative shelf life were determined on meat conditioned for 10 days at 1^{o}C and then packed in a modified atmosphere for simulated retail display shelf-life at 4^{o}C. Eating quality was determined on meat conditioned for 10 days by a 10-member trained sensory panel. An ANOVA with diet as the main factor was used to analyse the data.

Results Half carcass weights were similar across treatments and averaged 194 kg (s.e.d. 5.9). Total muscle fatty acids and the content of the main saturated FA (16:0, 18:0), 18:1*n*-9, 18:2*n*-6 and 18:3*n*-3 were not different (Table 1). The content of 20:5 *n*-3 (EPA) and 22:6*n*-3 (DHA) increased and the *n*-6:*n*-3 ratio reduced with increasing FO. The P:S ratio was not affected. Content of 18:1 *trans* increased accompanied by a trend for increased content of CLA. As a proportion (x 100) of total FA, CLA increased from 0.47 to 0.62 from control to FO3 (p=0.04), respectively. Lipid oxidation in displayed steaks increased at the highest level of FO and fishy flavour paralleled this. These changes were relatively small and did not affect abnormal flavour or overall liking scores.

Table 1 Fatty acid content (mg/100g muscle) of *longissimus dorsi* and meat quality attributes of LTL.

	Control	FO1	FO2	FO3	s.e.d.	P
Total fatty acids	4050	4708	3921	4920	1449	NS
16:0 palmitic	1061	1278	1044	1353	420	NS
18:0 stearic	576	621	495	642	187	NS
18:1 *trans*	87.4	115.1	133.7	179.5	46.4	0.003
18:1*n*-9 oleic	1364	1564	1236	1427	520	NS
18:2 *n*-6 linoleic	102.1	99,3	83.1	94.6	21.1	NS
18:3 *n*-3 α-linolenic	34.0	36.4	30.3	37.7	7.96	NS
CLA cis-9, trans-11	19.0	23.1	24.0	30.3	10.24	NS
20:5 *n*-3 eicosapentaenoic (EPA)	19.9	20.8	23.1	36.0	5.75	0.001
22:5 *n*-3 docosapentaenoic (DPA)	30.2	32.0	29.0	37.1	7.44	NS
22:6 *n*-3 docosahexaenoic (DHA)	5.07	7.20	9.44	12.90	2.60	0.001
n-6:*n*-3 ratio	1.56	1.43	1.24	1.04	0.09	0.001
Colour saturation (day 7)	19.6	19.6	19.5	19.6	0.72	ns
Lipid oxidation (mg MDA/kg meat) day 10	0.5	0.6	0.7	1.3	0.19	0.002
Fishy (0-100)	0.5	0.6	0.9	3.2	1.00	0.05
Abnormal flavour (0-100)	13.8	15.1	15.0	13.6	2.27	ns
Overall liking - hedonic (0-100)	27.5	28.2	28.5	29.1	2.43	ns

Conclusions Feeding increasing amounts of FO resulted in beneficial increases in long chain C20*n*-3 PUFA and 18:1 *trans*. The latter was associated with a significance increase in proportion of CLA in muscle tissue. FO at these levels had only minor effects on colour shelf life and sensory attributes.

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The effect of rate of inclusion of processed, urea-treated whole-crop wheat on the intake and milk production and apparent digestibility in dairy cows

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Introduction The development of a forage processor that grinds the grains in whole-crop wheat (WCW) prior to ensiling has been shown to improve whole tract digestibility of the starch component and improve the efficiency of forage utilisation (Jackson *et al.* 2004). This allows wheat to be harvested over a much wider harvest window than was previously possible. Further work (Bond *et al.*, 2004) demonstrated that animals fed processed, urea-treated WCW harvested at 700 g dry matter (DM) per kg had a significantly higher milk yield than those fed fermented WCW harvested at approximately 450 g DM/kg, or urea-treated WCW harvested at approximately 850 g DM/kg. Previously, processed, urea-treated WCW for dairy cows has been included at 0.67 of the forage DM intake, although, the optimal inclusion rate of processed WCW is unclear. The objective of the current experiment was to investigate the effect of rate of inclusion of processed, urea-treated WCW on the performance and apparent digestibility in dairy cows.

Materials and Methods A conventionally managed crop of winter wheat (*c.v.* Equinox) was harvested when the grain was at the hard dough stage and preserved using a urea and urease product (Home n'Dry, Volac Limited, Royston, UK) to supply 20 kg urea/t forage DM. Grass silage was mixed with WCW in the following proportions (DM basis) to provide four dietary treatments; grass silage alone (U-0); 0.75 grass silage: 0.25 WCW (U-25); 0.5 grass silage: 0.5 WCW (U-50) and 0.25 grass silage: 0.75 WCW (U-75). Forty-four Holstein-Friesian dairy cows that were on average 29 days (s.d. +/- 5.5 days) into lactation were allocated to one of the four treatments. Forages were offered at a rate of 1.05 of *ad libitum* intake. All cows were supplemented with 2 kg/day of rapeseed meal, 1.5 kg/day of molassed sugarbeet pulp and 0.5 kg/day of lactose mixed with the forage component, and 7 kg/d of a standard dairy concentrate (DM 893 g/kg, ME 13.7 MJ/kg DM, crude protein 239 g/kg DM) fed through out-of-parlour feeders. Milk yield and intake were recorded daily and milk composition weekly. Animals were blood sampled at 11:00 h at the start of the experiment and during weeks 3, 8 and 13 of the experimental period. Apparent digestibilities of the neutral detergent fibre (NDF; Van Soest *et al.,* 1991) and starch (MAFF, 1982) fractions were measured during week 10 of the experiment for 5 cows per treatment using acid insoluble ash as an indigestible marker. Results were analysed using Genstat version 5 (VSN Int. Ltd, Oxford, UK) as a randomised block design. Linear and quadratic effects of the rate of inclusion of WCW were also examined, but only linear relationships were significant and are presented.

Results The WCW had a high DM and crude protein content at 836 g DM/kg and 163 g/kg DM respectively, with a starch concentration of 340 g/kg DM. The grass silage had a DM of 323 g/kg, crude protein content of 141 g/kg DM and ME value of 10.9 MJ/kg DM. Forage DM intake increased linearly from 9.90 kg DM/d in cows fed grass silage alone (U-0) to 14.63 kg DM/d in animals fed U-75 ($P<0.001$). Milk yield was higher ($P<0.05$) in animals fed 0.25 WCW (U-25) compared with those fed grass silage alone (U-0). There was no significant difference between treatments in milk fat or protein concentration (g/kg) or milk fat yield (kg/d). Milk protein yield was, however, 0.11 kg/d higher ($P<0.05$) in cows fed U-25 compared with those fed U-0. Blood urea concentrations increased ($P<0.001$) with level of inclusion of WCW whilst both NDF and starch digestibility decreased with WCW inclusion rate.

Table 1 Effect of inclusion rate of processed, urea-treated WCW on animal performance and diet digestibility.

	U-0	U-25	U-50	U-75	s.e.d	Sign.	Linear
Forage DM intake (kg/d)	9.90	12.25	13.58	14.63	0.78	<0.001	<0.001
Milk yield (kg/d)	34.2[a]	37.8[b]	35.2[ab]	35.8[ab]	1.22	0.043	0.569
Fat (g/kg)	39.2	38.0	39.9	35.6	2.48	0.342	0.253
Protein (g/kg)	30.6	30.9	32.1	31.7	0.88	0.293	0.103
Fat yield (kg/d)	1.37	1.41	1.37	1.26	0.09	0.429	0.218
Protein yield (kg/d)	1.06[a]	1.17[b]	1.11[ab]	1.12[ab]	0.04	0.048	0.135
Mean plasma urea (mmol/l)	4.46	5.31	5.59	6.04	0.39	0.008	<0.001
Digestibility (kg/kg)							
NDF	0.72	0.69	0.63	0.58	0.03	<0.001	<0.001
Starch	0.97	0.97	0.96	0.95	0.009	0.101	0.02

[a] within a row, means without a common superscript letter differ ($P<0.05$)

Conclusions Inclusion of processed, urea-treated WCW at 0.25 of the forage DM will result in a higher DM intake along with a higher milk yield (kg/d) and milk protein yield (kg/d) than feeding grass silage alone. Inclusion of WCW at higher levels than 0.25 of the forage DM provides little benefit on milk yield compared with grass silage alone, whilst NDF and starch digestibility decrease with increasing WCW inclusion.

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Effects of mixtures of red clover and maize silages on milk production and Nitrogen utilisation by dairy cows

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Introduction Legumes are important to sustainable agriculture because of their N fixing ability and consequent reduced reliance on increasingly scarce oil resources. Our previous studies showed consistently higher intakes and milk yields when red clover silage replaced grass silage in dairy cow diets (Dewhurst *et al*., 2003). However, the increased intakes of a forage which contains higher levels of N led to a reduction in the efficiency of conversion of feed N into milk N (g/g) from around 0.25 to 0.20 or less. Maize silage has similar high intake characteristics, but its low N content and considerable starch content suggest that it would be highly complementary to red clover silage in terms of N-use efficiency. This study evaluated production and efficiency responses to mixtures of red clover and maize silages in comparison with perennial ryegrass silage.

Materials and methods Eight Holstein-Friesian dairy cows in early- to mid-lactation were used in a changeover-design experiment with three 4-week periods. All cows received 4 kg/day of a standard concentrate (N, NDF, starch and acid hydrolysis oil contents of 3.66, 206, 243 and 63 g/kg DM, respectively) and one of three forage treatments *ad libitum*: perennial ryegrass silage (GS), 0.4 red clover silage/0.6 maize silage (DM basis; 40RC) and 0.25 red clover silage/0.75 maize silage (DM basis; 25RC). A fourth treatment used 40RC, with intake restricted to the level obtained for GS (40RCr) in order to eliminate effects of intake on N-use efficiency (Dewhurst *et al*., 2003). The perennial ryegrass and red clover silages were first cuts prepared in clamps and as round bales respectively. Feed intake, milk production, milk composition and Nitrogen partitioning (6-day total collections of faeces and urine) were recorded in the final week of each period. Results were analysed using REML (Genstat 7; Lawes Agricultural Trust, 2003) with a random model of 'period' + 'cow' and a fixed model of 'forage treatment'.

Results The N and NDF contents (g/kg DM) of GS, 40RC and 25RC forages were 2.25 and 575, 2.25 and 526, and 1.88 and 506 respectively. The pH values for the original silages (grass, red clover and maize) were 4.22, 4.59 and 3.68 respectively. Results for silage intake, milk production and N partitioning are given in Table 1. There were no significant effects on milk fat, protein and lactose concentrations, which averaged 45.6, 31.0 and 46.3 g/kg respectively.

Table 1 Effects of forage mixtures on silage DM intake, milk production and N partitioning

	GS	40RC	40RCr	25RC	s.e.d.	Sig.
Silage DM intake (kg/day)	11.8	18.1	13.1	17.2	0.46	***
Milk yield (kg/day)	20.2	25.7	24.6	27.7	1.05	***
N intake (g/day)	392	533	424	450	7.9	***
Milk N (g/day)	98	129	117	129	5.1	***
Urine N (g/day)	155	161	124	120	16.9	*
Faecal N (g/day)	139	180	143	163	9.8	***
Milk-N/Feed-N (g/g)	0.251	0.242	0.277	0.287	0.0011	***

Unaccounted N was within the expected range for body N accretion (-0.4 g/day) for GS, but increased with N intake (legume inclusion) to 37.7 and 68.8 g/day for 25RC and 40RC respectively (s.e.d. = 19.3; $P<0.01$). Whilst these values for unaccounted N are consistent with the literature, they seem too large to be explained as accreted N (see review by Spanghero and Kowalski, 1997). The effects of diets GS and 40RC on intake and milk production were confirmed in a 3-month period of continuous feeding in a linked study with 16 cows.

Conclusions Large (5 kg/day) increases in milk production were achieved by replacing ryegrass silage with mixtures of red clover and maize silages, even when forage intake was restricted. N-use efficiency was similar for GS and 40RC, despite the 0.36 (proportionally) higher N intakes for 40RC. N-use efficiency of the red clover containing diets was increased significantly by reducing N intake, either by restricting forage intake (40RCr) or using a lower inclusion of red clover silage (25RC). Milk N production per unit of urinary N output (g/g) was increased from 0.67 to 1.15 by using 25RC in place of GS. Further studies are underway to determine whether the large unaccounted N fraction is an error or some other loss associated with high N intakes.

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Pastoralist parliamentary groups: a comparative study

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Introduction Pastoralists (broadly speaking, people dependent on extensively grazed livestock for their livelihoods), are a vulnerable group of people who have been marginalised in developmental and political terms, and whose problems are very different from those of people in mainstream agricultural areas. Pastoralist Parliamentary Groups (PPGs), groupings of MPs concerned with the issue of pastoralism, have been formed since 1997 in the national parliaments of Ethiopia, Kenya and Uganda (Mohammed Mussa 2004, Livingstone forthcoming a and b). A research project investigated the context, successes and failures of the three PPGs, using interviews with their members and other stakeholders and document review.

Context In the countries concerned democratisation has taken very different forms: in Ethiopia a very-thorough going ethnically-based federalism combined with the heavy dominance of a ruling party across the regions; in Uganda, a significant experiment in "no-party" democracy following the conflicts of the 1970s and early 80s, only recently giving way to a party system; and in Kenya elections in 2003 replacing the formally democratic, but *de facto* despotic, régime of President Moi. In all three countries pastoralists are found around the national frontiers, which means any politics that involves them is closely bound up with real and perceived national security needs.

The evolution and functioning of the PPGs The three PPGs emerged between 1997 and 2003, influenced by NGOs, donor projects, researchers and each other. Both the Kenyan and Ugandan PPGs have suffered periods of dormancy, in Kenya caused by repression, in Uganda caused by individual electoral defeats of the leaders. They operate in different ways; in Uganda and Kenya as voluntary groupings of MPs, open in principle to MPs from pastoralist and non-pastoralist areas. In Kenya the PPG is dominated by MPs from the former ruling party and almost entirely made up of pastoral MPs. In Uganda it spans supporters of the President and of the opposition, and includes an important group of MPs from an agro-pastoral region subject to raiding by pastoralists. In contrast, the Ethiopian Pastoral Affairs Standing Committee (PASC) is a select committee appointed by parliament and includes MPs representing both pastoral and non-pastoral areas. This appears to limit the degree to which it "represents" pastoralism, but adds to its effectiveness in legislation and oversight.

Successes and failures The PPGs have so far had a mixed record of achievement. In Uganda PPG members played an important role in bringing an end to evictions of pastoralist "squatters" from ranches, in pursuing corruption in the valley dam scandal of 1998, and in negotiating exceptional access to a National Park in the drought of 1999. The group has also contributed to alleviating, though not stopping, armed conflict between pastoralists and agro-pastoralists. In Ethiopia, the PASC has influenced the establishment of pastoralist departments and units within various ministries and exercised effective parliamentary oversight. In all three counties, the PPGs have had a diffuse, but important, role in raising awareness of pastoral issues, but had little success in influencing major policy processes such as the Ugandan Plan for the Modernization of Agriculture. Much of the success or failure of the PPGs has been determined by specific national political circumstances, and the agendas and hidden agendas of party politics. But also important are the extent to which the PPGs have also been able to ensure their own continuity and "institutional memory", and the extent to which their members have access to information, both on conditions in the pastoral areas and on international ideas on pastoral development and appropriate policy towards pastoralism. The quality of linkages between the PPGs, civil society organizations and researchers are crucial in both these respects. Lastly, much depends on the role of individuals, particularly "policy entrepreneurs" (Keeley and Scoones 2003) who can network across these different worlds.

Lessons for donors and NGOs The PPGs are worth supporting as one strand in the development of pastoralism, but they can only ever be part of the picture. Donors and NGOs need to: be pragmatic about the "representativeness" of these groups; understand them in a real-world context of history, ethnicity, real and perceived national security needs, and party politics; understand formal and informal processes of parliaments, and the relation between MPs and local tiers of governments; understand the role of individuals as leaders and bridge-builders between politics, NGOs and academia. Donors can help the PPGs with: their information and training needs; their needs for continuity, "institutional memory" and external linkages; their needs for transport and physical capacity; and their need to work across national boundaries.

Project impact The project has already had some policy impact, as there has been a declaration of intent from Tanzanian Pastoralist MPs to establish a formal group, and as the EC are discussing assistance to the Ethiopian Pastoral Affairs Standing Committee. As democratisation takes further root in Africa, the roles of MPs as decision-makers and agents of development, and the ways they can coalesce around specific issues, have importance well beyond pastoralism or livestock.

Mohammed Mussa 2004 "Case Study on the Pastoral Affairs Standing Committee of Ethiopia" unpublished report By Mohammed Mussa Associates available at: http://www.nri.org/projects/pastoralism/ethiopiafinal.pdf
Keeley, J. and I. Scoones (2003) *Understanding Environmental Policy Processes*, London, Earthscan
Livingstone, J, K. (forthcoming) (a) "Kenya Case Study" and (b) "Uganda Case Study", PENHA, Kampala

Ceiling to milk yield on Kenya smallholdings requires rethink of dairy development policy

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Introduction The UN millennium goal of halving the percent of people in poverty in Sub-Saharan Africa by 2015, will not be achieved. Where animal scientists have contributed to this failure, they have assumed that small farms are inefficient and will be improved by adopting scaled-down versions of the large commercial systems in which their science has evolved. Kenya illustrates the problem, with its rural poverty and a project to increase the standard of living of smallholders through milk production. Despite the socio-economic difference from the large dairy farm, the cow of choice for these small zero-grazing units remains the Friesian (F), but her productivity is so low as to threaten the sustention of the system (Bebe, 2003). We need to understand why the breed is popular, what shapes the lactation curve and extends the calving interval (CI), and what are sustainable levels of milk and calf production.

Materials and methods In the hot season of February 2003, the thermal responses of six pure or crossbred Fs in separate zero-grazing units, at a mean lactation of 54 days (s.d. 21.6), were quantified, and the effect of raising current levels of feed intake and daily milk yield (DMY) predicted. It was done using new models of animal energetics and nutrition, (Parsons *et al.,* 2001), modified for the tropics. The 24 h model runs were related to the subsequent lactation, CI and profitability of the cows (Table 1). Data input for each cow included: energy requirements (weigh band, DMY and butterfat), energy intake (dry matter intake (DMI) of fine feed and forages, with metabolisable energy (ME) values from Kenya Agricultural Research Institute), and shed microclimate (hourly readings of dry bulb, relative humidity, air speed, global solar radiation, and mean radiant temperature). The model output of stress levels was compared with cow rectal temperatures at milking. Further validation was obtained by comparing the hourly mean coat temperature with that predicted by the models, which was within 1 s.d. or 1 ºC in the highlands, and 2 s.d. or 2 ºC at the coast. Curves were fitted to records of DMY at the start, middle and end of the lactation, and annual milk yield (AMY) calculated from lactation yield and CI. Budget analysis of milk production was backed by data on herd demography (Bebe, 2003).

Results Thermal load caused moderate stress for all cows during the day. In the highlands, stress was severe for one cow in the sun, but the air temperature drop to 13 ºC at night dissipated body heat gained. At the coast, there was no remission of heat stress for cows with DMY >11 l, because the nights were warm (>24 ºC), still and humid (RH 86 %). In all cows, DMY declined from an initial peak to a low stable profile of 5 l/d. Cows in each region with high initial DMY (>20 l/d) had the steepest decline and longest CI, but largest lactation yield and lowest direct milk cost/l. However, their poor breeding performance, reduced cull sales and high cow replacement cost raised the total cost/l. By contrast, the cow with the lowest DMY and lactation yield had lowest total milk cost, because she calved twice in the year. The average annual milk price of KSh/l 19.6 (excluding niche markets ≥25 KSh/l, including Jersey milk) was only 5 % above direct cost of KSh 18.7/l. Seasonally, the price dropped as low as 16 KSh/l. Ceilings to DMY, from feed intake from which the heat could be dissipated, were predicted at 22 l/d giving 5000 l AMY in the highlands, and 14 l/d giving 3000 l AMY at the coast, assuming a 365 d CI would be achieved.

Table 1 Model runs of energy balance and heat stress in early lactation, with subsequent AMY and milk cost-price

Location	Kenya Coast			Highlands		
Cow breed	FxBoran		FxZ‡	Friesian		
DMY l	11.4	17.0	7.3	18.0	18.3	13.0
DMI kg /d	12.9	15.9	7.8	17.6	17.3	12.5
ME MJ/kg	8.1	8.7	8.2	8.5	8.6	8.2
ME available†	0.96	0.83	0.66	0.96	0.97	0.82
Moderate stress h	24	24	10	24	10	7
Severe stress h	0	0	0	0	0	4
Lactation l	2945	3060	1365	4635	5355	3575
CI d	343§	370	317	457‼	663	468
AMY l	3100	3020	1570	3700	2950	2790
Milk cost KSh/l¶	17.6	18.2	22.7	16.3	16.4	19.8
Total herd cost/l	17.9	17.2	14.5	17.3	18.0	19.5
Milk sale price/l	20.2	18.1	18.5	40.0	21.5	25.0

† ME need from diet. ‡ ⅞Friesian x East African Zebu.
§ Aborted 246d. ‼ Died 4 d post-partum. ¶ Ksh76: US$

Conclusions The thermal load, which is predicted to increase, puts a ceiling to DMY from feed intake at half to one third of the potential of the modern F. The energy deficit of this genotype will exceed that normally associated with the start of lactation, and decrease cow fertility, fitness and longevity. The F is popular, because of the extra milk for the family and cash for the housewife, who can take a wage. The low profit margin is not apparent until the price of milk drops, there is a lack of revenue from cull sales, and provision for a cow replacement rate of <1 (in the budget) is not made. It is difficult to accumulate small amounts of cash to buy, as opposed to breed, a replacement, if one can be found. So the F becomes a drain on wealth, an insecurity against contingencies, and an extra to be financed, not a means of financing. Development policy should adjust to the reality of poverty and sustain levels of herd and milk production.

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Novel adaptive research process for Africa's livestock producers

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There is general agreement on the need to develop appropriate technologies that respond to farmers' needs and opportunities. However, much research output is dominated by technical considerations, and often does not include key information that farmers need in order to make informed decisions on uptake. Such information includes: economic viability, risks, resources required, local availability of inputs, mechanisms for realising the benefits of technologies at a group level, and the availability and characteristics of markets. Some of the information needed by farmers is tacit and highly contextual, such as managing social organisation. In that case users require advice on how to generate the relevant knowledge for themselves, e.g. through experimentation or interaction (such as contacting potential buyers for their produce, or experimenting with different ways of sharing assets).

The DFID-supported[1] research project *"Linking demand for and supply of agricultural information in Uganda"* is piloting a novel adaptive research process in collaboration with Ugandan stakeholders, including farmers and private extension service providers, which identifies and addresses the gaps in the information that farmers need.

The adaptive research process being piloted has nine steps: 1. Collect information relevant to the technologies; 2. Evaluate information to identify gaps in knowledge; 3. Meet with farmers and service providers to identify information needed by them to assess and use the technology; 4. Design activities to provide the missing information (surveys, studies, on-station/on-farm trials etc); 5 Conduct the activities, with the participation of relevant stakeholders; 6. Provide feedback to farmer groups and confirm results; 7. Draft extension materials in formats useful to service providers and different types of farmers; 8. Test extension materials with farmers and service providers, and modify as necessary; 9. Finalise, print and disseminate extension materials.

The process is being piloted with 4 contrasting enterprise topics that have been identified as priorities by farmer groups: Draught animal power; goat de-worming; legume crop protection, and sweet potato production and marketing.

This paper presents results of experience from the draught animal power (DAP) adaptive research pilot. The DAP team comprises researchers from the National Agricultural Research Organisation (NARO), NGO staff, private service providers and 4 farmers groups. The farmer groups were followed through the processes of training of oxen and operators, the growing of test crops, the organisation of groups and the commercial exploitation of the DAP assets. Lessons learned were documented and form part of the extension materials.

It was found that although a considerable amount of research-station testing of prototype DAP equipment has been done, little careful on-farm testing of commercially-available tools had been conducted. Several major, basic faults were identified with commercially-available equipment that rendered them almost un-useable in real field conditions. There were no guidelines on how draught animals could be cared for by farmers in a group situation, how the group could go about making the best of the income-generating opportunities that owning draught animals and DAP equipment presented, how risks (animal disease, equipment breakdowns etc) can be minimised and overcome, and how DAP can be accessed by the poor, women and the aged.

[1] The project *"Linking demand for and supply of agricultural information in Uganda"* (Project Code R8281) is supported by the DFID Crop Protection and Livestock Production Research Programmes. The views expressed here are those of the authors, and not necessarily those of DFID.

Participatory production of a new animal science text book `Livestock and wealth creation: improving the husbandry of animals kept by resource-poor people in developing countries'

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Introduction This text book was conceived in January 2002, in Tanzania, during a DFID Livestock Production Programme (LPP) workshop. Perceived justifications for such a book were: (1) to improve the preparation of animal science students to address livestock issues faced by resource-poor subsistence farmers in developing countries; the majority of livestock text-books are either a) authored in the 'north' and based on temperate, large-scale, commercial systems or b) based on a single species and technology 'fix' approach, with insufficient focus on the systems under which livestock are kept by the resource-poor, or on improving livestock survival and productivity and understanding the contribution they make to livelihoods; (2) to address the UN Millennium Development Goal of halving the number of people living in absolute poverty by 2015 through `training teachers' using appropriate information. Three quarters of poor people live in rural areas and keep livestock; (3) to respond to the large demand for meat and milk over the next 20 years foreseen by the burgeoning 'Livestock Revolution' and the consequent opportunities for resource-poor livestock keepers to move from subsistence to a market-oriented economy. The LPP agreed to commission the book provided that consultation with stakeholders confirmed a demand for it and that a broad electorate of stakeholders participated in the book's design and production. Two editors (E. Owen and T Smith) were appointed to undertake the consultations and subsequent production of the book in collaboration with the Manager of LPP (J.I. Richards).

Method i) Participatory consultation with stakeholders Stakeholders (university lecturers, researchers, specialist consultants, policy makers and NGOs) concerned with livestock in developing countries met at brainstorming meetings in Reading, UK (June, 2002), Merida, Mexico (November, 2002) and Embu, Kenya (February, 2003) to discuss the structure and authorship of the book; other consultations were undertaken by e-mail and through individual meetings during the period October 2002 to March 2003. All stakeholder consultations confirmed the need for an affordable new textbook to focus on small-scale livestock systems and improvement in production and livelihoods. In the first two brainstorming meetings there was much discussion on how to structure the book (one driven by livestock production systems or one based on animal science and species?). As the book was aimed at animal science/husbandry lecturers and undergraduates, it was agreed that a science/species structure would have more utility. A two-part structure was planned. Part One would discuss cross-cutting issues (including livestock systems) and Part Two would consider individual species. The book would have a concluding chapter to discuss lessons learned and the way ahead. To provide students with perspective, it was also agreed that brief cameos be written at the beginning of chapters describing the benefits of improved livestock husbandry to the social and economic well-being of livestock keepers.
Method ii) Participatory production process – principal authors, co-authors, consulting authors During April 2003 stakeholders were sent a draft synopsis and invited to express interest in contributing. There was a good response, with several stakeholders willing to be involved in more than one chapter. At a meeting of editors, LPP and a publisher in June 2003, it was agreed to appoint two additional editors - A. J. Kitalyi, representing an African perspective, and M.C.N. Jayasuriya, representing an Asian perspective. A further, innovative, decision was to have `consulting authors' for each chapter, to help widen the participation. Consulting authors would be specialists who would vet the draft manuscript for factual integrity and relevance of the facts to poor communities. Principal authors were appointed during July 2003; they were encouraged to appoint co-authors and consulting authors from different developing countries. First drafts were requested by December 2003. Editors met to review drafts in January 2004. During February to June 2004 drafts were revised in response to comments from consulting authors and editors. In June 2004 Nottingham University Press (NUP) was appointed publishers. Editors, LPP and NUP met in July 2004 to review progress and agree layout etc. Editors and LPP consulted stakeholders in Masaka, Uganda, in November 2004, during an LPP workshop.

Results Published in Spring 2005, the 500-page book involved collaboration between 90 contributors from 25 countries. Part 1 considers cross-cutting issues to be understood before embarking on improving livestock output. Issues include considering why the poor keep livestock (social, livelihood, gender etc.); livestock systems; poverty assessment methods; livestock development and poverty; knowledge - key to empowerment; livestock-poverty-environment; livestock products; marketing to promote development; processes to give nutritional responses; feeds and feeding to improve productivity; breeding strategies for sustainable development; improving livestock health. In Part 2 individual species are considered, with emphasis on how to improve productivity to achieve sustainable livelihoods for livestock keepers. There are chapters on bees, giant snails, poultry, small mammals (grasscutters, guinea pigs and rabbits), pigs, goats, sheep, camels, cattle, buffalo, yak, equines and wildlife. The final chapter concludes that providing appropriate information and an enabling environment are key elements in facilitating resource-poor livestock keepers to move from poverty to relative prosperity. Further reading and a reference list are provided, and the book is fully indexed.

Conclusion LPP will buy-back 2000 copies of the book and CDs from the publishers for distribution (free) to key lecturers and institutions in developing countries. In autumn 2005, an evaluation of the book from the perspective of teachers and students will be conducted by LPP and the need for a possible CD revision considered.

Using a decision support tool to screen for pro-poor policies: Application of EXTRAPOLATE to smallholder dairy systems in East Africa

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EXTRAPOLATE (EX-ante Tool for RAnking POLicy AlTErnatives) is a decision support tool to assess the impact of policy measures on different target groups. It is designed to serve as a "filter" that, given the broad characteristics of the population, allows the user to sift through different policy measures to assess *ex ante* the broad potential impacts of these before deciding to look at particular policy options in more detail. EXTRAPOLATE models, in a very simple way, the impact of changes on constraints facing potential beneficiary groups, and how these may affect outcomes and their livelihood status. EXTRAPOLATE now makes use of mapping facilities from another decision-support tool, PRIMAS (Poverty Reduction Intervention Mapping in Agricultural Systems), that allows the user to match characteristics of particular technological options and constraints with the spatial characteristics of particular target groups in the landscape.

Initial testing of EXTRAPOLATE in Senegal and Kenya has indicated that the tool provides a simple but useful framework for assisting people to think clearly about the likely impacts of particular policies on different groups of beneficiaries, and hence to identify policies that are pro-poor. Assembling a scenario in EXTRAPOLATE will usually involve the collation of appropriate spatial data layers that describe agro-ecology, livestock systems, etc. A short workshop is then held, that brings together counterparts from national and local planning and decision-making bodies, to outline the tool and the steps required to set up a policy model. If field work is required, this can be carried out to help define the various elements of an EXTRAPOLATE scenario, such as stakeholders, constraints, the outcomes that may result and their concomitant impacts on the livelihoods of the different stakeholder groups, and the policies that may affect the constraints in both negative and positive ways. The information gathered is then reviewed and subjective scores assigned in the model, and the results documented and disseminated. To illustrate the use of the tool, we describe a simple example application of EXTRAPOLATE to smallholder dairy systems in Kenya. Lessons from the use of EXTRAPOLATE to date are presented and discussed. Finally, we discuss plans to refine EXTRAPOLATE, and to apply it to livestock policy issues in the five FAO PPLPI (Pro-Poor Livestock Policy Initiative) hub countries over the next 18 months.

Dissemination of outputs from a cluster of livestock production programme projects in Zimbabwe

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Background During the mid to late 1990's a cluster of Livestock Production Programme (LPP) projects, funded by the Department for International Development (DFID) was established in Zimbabwe, as a representative country of southern sub-Saharan Africa, to develop outputs to increase the livestock contribution to the alleviation of poverty. All stakeholders were involved with the projects from the planning stage and participatory on-farm research was a key feature. Several of the projects addressed one of the major constraints to livestock production in arid and semi-arid areas, dry season feeding, the animal species considered being poultry, donkeys (draught power), goats and milking cows. The benefits of these projects can only be realised through effective dissemination to relevant target groups (farmers, extension staff, which because of failing government extension services in several African countries, must include NGOs, churches and local organizations, and policy makers) and development of relevant training materials.

Outputs Printed material for dissemination has included scientific and proceedings reports, higher degree theses, popular articles, both in newspapers and farmers magazines, and extension leaflets, each containing a message for farmers. The leaflets are being produced electronically so that local language versions can be produced when required. Other forms of media presentation have been used, including radio and television. Outputs have now been included in materials form use in Farmers Field Schools and teaching curricula. To extend the technologies developed to neighbouring states, a regional tour to Mozambique, Namibia, South Africa and Zambia was undertaken in 2004, the impact of which is now being assessed through a questionnaire to all participants. Current indications are that practical demonstrations (training, Field days, visits etc.) supported by leaflets are found most useful by farmers. At the research level, there was demand for cross-country linkages between research institutions. Similar dissemination tours will be conducted at several locations within Zimbabwe, in May 2005.

The future Knowledge banks (CDs) containing the outputs of research projects funded by the LPP, DFID Animal Heatlh Programme (AHP) and Danida, and aimed predominantly at a research audience, are being prepared by the LPP. The Knoweldge Banks will be available in different themes including; smallstock, draught animal power, nutrition and feeding, dry season interventions, tsetse and smallholder dairy. The outputs will also be used in the preparation of four thematic toolboxes (again, CD-based), currently being developed by LPP, and covering smallholder dairying, small stock, draught animal power and coping strategies for feed allocation. The brief for this fourth toolbox goes beyond dry season feeding, in that solutions to the feeding problem will be based on manipulating resources throughout the full growing/feeding cycle. The toolboxes are being developed as aids to those advising and training farmers. They will contain technologies developed both through LPP projects and other sources. The LPP commissioned book, 'Livestock and Wealth Creation' (Owen *et al*., 2005) is aimed at Universities and students. These activities and outputs will be discussed and, where appropriate, their impact assessed.

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Tannins: an environmentally friendly method of controlling intestinal parasites in ruminants in the tropics and subtropics?

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Introduction Infections caused by the infestation of the gastrointestinal tract with parasitic nematodes are among important factors responsible for poor productivity of livestock including small ruminants. These infections cause significant losses in terms of poor growth, reduced reproductive performance and mortality. Nematode control is routinely by the use of synthetic chemical anthelmintics. However, over-dependency and even misuse of these anthelmintics has resulted in the emergence and spread of nematode populations that are resistant to these pharmaceutical agents. This has led to increases in the cost of control through higher dosages and frequency of treatments. Moreover, anthelmintics are expensive and so not affordable to many resource-poor farmers in the developing countries. There is, therefore, a need to search for cheap and sustainable nematode control alternatives. One such alternative could be the use of plants and plant products with anthelmintic activities. The use of naturally ocouring tannins is one such approach.

Experimental observations Some field studies in the temperate region have shown that forages rich in condensed tannins can improve general performance of sheep with nematode infestations. These promising results have stimulated considerable research interest on the effect of tannins on different nematodes particularly those of small ruminants. For instance, dietary inclusion of the condensed tannins in quebracho extract (a source of tannin used in the leather industry) was found to significantly reduce faecal egg counts and worm burden of sheep reared in the United Kingdom infected with *Trichostrongylus colubriformis* (Butter et al. 2000, Anthanasasiadou et al. 2001). In our previous studies (Max *et al.,* 2002), it was shown that when condensed tannin was orally administered as drench it was effective in reducing worm burdens of temperate sheep infected with *Haemonchus contortus* and *T. colubriformis*. However, similar studies with tropical goats obtained from local farmers in the Morogoro region of Tanzania using wattle tannin, which is produced for the local leather industry and readily available in Tanzania, (Max *et al*., 2003) revealed no significant reduction in faecal egg counts or worm burdens. It was argued that the apparent differences between sheep and goats could either be a species difference or an adaptation of the animals to tannins. This was tested in Tanzania using growing Black Head Persian rams obtained from local farmers. The wattle tannin was again administered by an oral drench. The drench significantly reduced intestinal mixed worm burdens including *Heamonchus* sp by 87%. This suggests an existence of species difference between sheep and goats as far as the effect of tannins on gastrointestinal nematodes are concerned.

Tannins are found in high quantities in many browse plants. The quantity varies with the session. A survey of local plants was undertaken in Tanzania and *Acacia polyacantha* was found to contain significant quantities of condensed tannin. In another study (Max *et al*., 2003) supplementation of worm-infected Small East African goats with 130g of tanniniferous browse (*Acacia polyacantha*) meal/day gave 27% and 13% reduction in faecal egg counts and worm burdens, respectively. Further work on this approach is required, including the use of sheep raised in the tropics.

Conclusions Dietary application of tannins is potentially an environmentally friendly technique for controlling intestinal parasites in ruminants. Its effectiveness should be increased when combined with other husbandry techniques designed to reduce the impact of intestinal parasites, e.g. controlled grazing.

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Less is more: restricted application of pyrethroids for controlling tsetse

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Introduction In Africa, the animal trypanosomiases kill about 3 million cattle each year with related annual losses in animal productivity of ~£3 billion. 32 of the 36 affected countries have *per capita* incomes of less than US$1 per day. The most effective method of combating the trypanosomiases is to eradicate their vectors, the tsetse. Up to the early 1980s, responsibility for vector control in Africa was largely taken by government agencies, using techniques such as large-scale aerial and ground spraying. Following economic crises, structural adjustment and decline or privatisation of veterinary services, much of the onus for controlling tsetse has fallen on livestock keepers themselves (Eisler *et al.* 2003), but partly as a consequence of trypanosomiasis, many are too poor to afford the cost. Treating cattle with synthetic pyrethroids may provide a way of breaking this cycle of poverty and disease.

Reducing costs through restricted application Synthetic pyrethroids were originally used to protect cattle from tick-borne diseases but it was soon realised that these insecticides were very effective against tsetse. Subsequently, many government- and donor-supported projects used insecticide-treated cattle to control tsetse in countries such as Ethiopia, Tanzania and Zimbabwe, this technique being only 10-25% as expensive as other insecticidal techniques, and offered year-round protection against tsetse invasion. But sustaining this success without donor or government support is difficult. This relates to a number of factors including problems of communicating the benefits of the new technology, in managing collective action by livestock keepers, and in facilitating livestock-keepers regular budgeting. However, the recurrent costs of the insecticide itself is probably the biggest single factor. Recent research, however, has shown that most tsetse feed on the legs and belly of a few 'attractive' animals within a herd. By selectively applying the insecticide to these sites, and adjusting treatment intervals to match the recently refined measurements of the persistence of the deposits (fig. 1), the costs of insecticide requirement can be reduced by 90% while also improving the efficacy. This means that effective control and anti-invasion measures can be achieved by treating about three large animals per square kilometre, at a *per capita* cost of around £1 per year. The new regime can form part of an integrated vector management package which can control a range of vector-borne diseases with minimal impact on the environment.

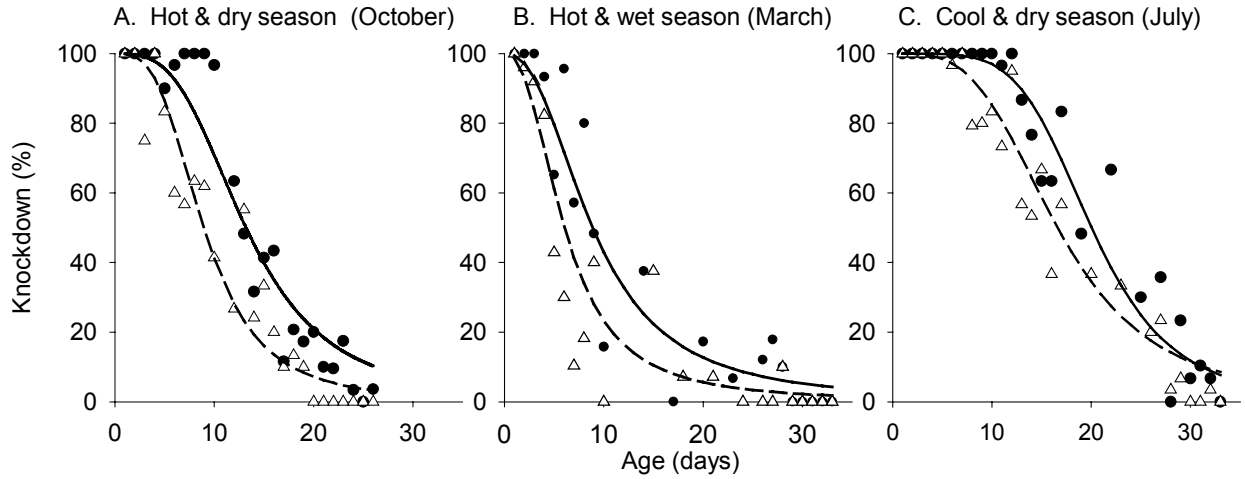

Figure 1 Knock-down of wild, female *G. pallidipes* exposed to insecticide-treated cattle during different seasons in Zimbabwe. Cattle were treated with deltamethrin (0.005% Decatix spray) applied either to the whole body (solid cicles) or with 20% of the standard dose applied to the legs and belly only (triangles). Knock-down was assessed for up to 35 days post-treatment, with each percentage knock-down being based on the observation of 30 tsetse. Curves fitted by logistic regression. Knockdown of tsetse exposed to untreated (control) cattle was <1% (data not shown).

Electronic and interactive dissemination Developing an improved method of controlling tsetse is only half the solution. Pushing the technology to these extreme levels of cost-effectiveness demands careful planning and understanding of the scientific principles involved. The institutions, often NGOs or area-based projects, that advise livestock keepers need to be told how to use this technology effectively in their particular circumstances. In the past, specialist entomologists from government or donors would have provided this advice but in Africa today there are too few advisers. However, access to the internet or to computers with CD-ROM drives is gradually increasing among NGOs and field-level government staff. DFID has therefore supported the development of an interactive programme which allows users to specify the local tsetse problem – www.tsetse.org. The programme then produces a customised plan, shopping list, budget and implementation notes. These developments provide an opportunity to remove a major obstacle in the path out of poverty for many of Africa's livestock keepers.

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Alleviating dry season forage shortages by improved crop protection in the Central Kenyan Highlands.

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Introduction In the Central Kenyan Highlands, dairy cattle ownership is a crucial element in poverty alleviation. For example, in Kiambu district just north of Nairobi, out of the population of 744010, 48% of 189709 households stall feed dairy cattle. Farm sizes average 1.1 to 2.0 ha per household. Producing sufficient forage for dairy cattle is difficult and low dry matter intake constrains dairy production and there is a positive correlation between stover intake and milk yield.. Napier grass comprised 40% of the total dry matter fed to cattle and maize forage 24% according to the project's Rapid Rural Appraisal, maize thinnings and stover being routinely fed to livestock. In another survey, dry maize stover accounted for nearly 65% of dry matter intake of dairy cattle during October.

In spite of this use of maize forage and especially of stover, forage is in short supply in the dry seasons – especially January to March and to a lesser extent in August and September. Practices which increase the health of maize are expected to increase forage and hence milk production. The purpose of this project was to alleviate dry season shortages by increasing yields of forage and grain through integrated control of pests, diseases and weeds. Increased forage offtake in terms of thinnings due to crop protection actually occurs at times when there is no forage shortage. The project therefore also linked with the NGO Land O'Lakes to combine their small-scale silage making technology with improved crop protection, conserving the excess forage produced during the wet seasons for use in the dry seasons.

Maize streak virus disease (MSVD) is the most destructive disease in the Central Kenyan Highlands although not necessarily the most prevalent. The project's RRA found MSVD was the problem the farmers found most difficult to control – resistant cultivars were not generally available in Kenya when the project commenced in 2001 even though they were in neighbouring Uganda. A milestone of this project was to address this issue with policy makers and seed suppliers and MSVD resistant cultivars are now becoming available to farmers. The influence of this project on this policy issue is considered to be significant and very positive. While the project did not breed locally-adapted cultivars which are resistant to the disease, the project did an excellent job of raising awareness of the two cultivars, KH521 and PAN67 confirming that control of MSVD was possible using these cultivars and that these not only increased grain (as was already well-established) but also forage production and achieved much better economic returns even when the crop was infected with MSVD only 14 days post-emergence (Fig.1).

Weeding regimes involving herbicides substantially reduced labour inputs, but their economics was fairly neutral relative to the traditional method of handweeding on-farm once the value of the forage offtake was included.

Insect pests: Participatory research with two farmer groups into the control of maize stemborers using the Push-Pull Habitat Management system pioneered by ICIPE, proved very popular with the farmers due to the increased production of high quality forage more than the control of stemborers. The start-up costs for the push-pull system were high in these case studies, due to the cost of establishing *Desmodium* seedlings but the economics become much more favourable when forage conservation and silage use in the dry season was evaluated.

The scope for increasing forage was therefore clear – an important conclusion for resource poor farmers as almost all maize research in Africa has focussed on grain to the exclusion of forage. Economically, the value of this forage can be increased perhaps as much as fourfold by conserving as silage for use in the dry season.

The outputs of the project were (and still are being) promoted to farmers, extension agents, the Kenya Institute of Organic Farming and seed companies in field days and training workshops.

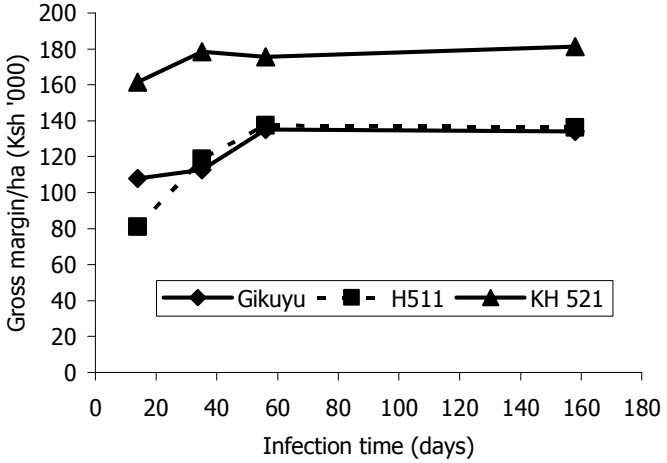

Fig.1 Gross margins (GM) (including maize thinnings, stover and grain and intercropped beans) of a local maize landrace (Gikuyu), the commonly grown hybrid (H511) and the new MSVD resistant cultivar (KH521) as a function of the period post crop emergence when the crop was artificially infected with MSV by placing infective leafhoppers on the leaves. The uninfected control is plotted as though it were infected on the date of harvest (158 days after emergence). The LSD (P=0.05) was 28000 KSh. The most important comparison is between uninfected control and the infected treatments. Early infection did not significantly reduce the GM of KH521 but did of the commonly grown hybrid, H511.

Increasing the productivity of smallholder owned goats through supplementation with tree fruits

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Background Production from smallholder owned goats in the semi-arid tropics is constrained by dry season feed shortages. Kid mortality is high and low growth rate of kids weaned at the onset of the dry season delays slaughtering of males and breeding in females. Supplementation with purchased feed is unaffordable so only locally available, probably non-conventional feeds can be considered. In Southern Zimbabwe, the typical natural vegetation in communal grazing areas consists of annual and perennial grasses and trees and shrubs, many of which are *Acacia* species. In this project tree fruits, from *Acacia* and other available species were evaluated as dry season protein supplements for goats.

Activities Research included a participatory rural appraisal (PRA) and on-farm observation, laboratory and *in vivo* assessments of selected species of tree fruits, on-station and on-farm measurements of animal responses and dissemination activities. Simple, safe methods of mitigating the anti-nutritional affects of tannins in tree fruits were sought.

PRA This revealed that some farmers collect and store fruits to use as dry season feed, although they have no technical support. In some years fruits are also marketed. Preferred species reflected local availability. From the findings of the PRA, stakeholder meetings and discussions the following species were selected for evaluation: *Acacia erioloba*; *A. erubescens*; *A. nilotica*; *A. tortilis*; *Dichrostachys cinerea*; *Piliostigma thonningii*. *Acacia karroo*, probably the most widespread *Acacia* species in Southern Africa, is dehiscent and unsuitable for collection and storage. Studies elsewhere indicated that removal of moderate amounts of fruits is unlikely to inhibit bush regeneration. However, collection and grinding of *D. cinerea* fruits could also be a management tool to control bush encroachment.

Laboratory analysis All fruits contained over 100 g CP/kg DM, and except *A. nilotica,* were high in fibre. Of the two species most available on-farm during the project, *A. nilotica* contained more total carbohydrates and total phenolics than *D. cinerea.* The addition of polyethylene glycol (PEG) increased cumulative gas production *in vitro*, up to 95 h, and organic matter degradability in *D. cinerea*, *A. erioloba* and *A. nilotica.* On- farm treatment to break the tannin/protein complex requires a safe, cheap and available agent. Wood ash proved effective in the laboratory, especially without PEG (unaffordable on-farm) and is currently being tested in trials with goats.

In vivo studies Dry matter intake, digestibility and N retention from hay plus supplement were suppressed when *A. nilotica* was fed but increased with *D. cinerea,* compared to the other fruits offered In controlled feeding trials, supplements of *D. cinerea* increased growth rates and reduced kid mortality, especially in twin-born kids. Milk available to the household was also increased. On-farm, a collegiate approach to evaluation was taken, with goats being offered available fruits. Farmers expressed satisfaction with the technology. Many were also persuaded to keep a notebook of major events affecting their goats.

Dissemination has been through published papers (scientific, proceedings and popular articles), the media (radio and television), contributions to farmer field schools, farmer meetings and station visits. Increased productivity from smallholder owned goats will improve livelihoods of resource-poor livestock keepers in semi-arid conditions.

Conclusion Tree fruits can be stored for strategic use late in the dry season, for both pregnant and lactating does, and recently weaned kids. More work is needed on the upgrading of pods and on the use of *A. nilotica*. Dissemination activities should be continued.

Managing the working donkey in Ethiopia to assist poor people make the most of their resources

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Introduction

The donkey is essential to the livelihoods of many families, providing relief from drudgery and diversification of household income in both rural and urban areas, particularly in their role in transport. Ethiopia possesses the largest donkey population in Africa. The donkey is preferred over other equines because of its affordability, survivability and ease of handling.

Intake and digestibility of forages

The ability of donkeys to survive on poor quality feed with little supplementation has been investigated. Comparative studies of the nutrition of horses, cattle, sheep and donkeys on different quality forage diets have been undertaken. Donkeys had lower voluntary intakes and apparent DM digestibilities of feed components compared to those of the horses and the two ruminant species on good quality forages. On poor quality forages the intakes were lower in all species, but similar for the cattle, horses and donkeys. The advantage of the donkey over the horse was seen in its ability to digest the poor quality forages. On poor quality diets the feed apparent digestibilities of DM, OM, ADF and NDF by donkeys were close to those seen in the ruminants, and significantly greater than those seen in the horses. This strategy by the donkey enables it to exploit the nutrients more effectively than the horse can when forage is of poor quality or limited in supply. Despite this intakes of nutrients by donkeys even on forages of moderate quality were not sufficient to meet estimated requirements for other than maintenance and 1-2 hours work. Not surprisingly many donkeys in Ethiopia are undernourished, particularly those with high nutrient demands such as lactating females.

Anthelmintics and feed supplementation

Mortality and poor growth are a common problem in donkey foals. The effect of providing feed supplements and antihelminthics to donkeys during late pregnancy and lactation on live weight and survival of dams and their foals was therefore also studied on-farms in three sites in Ethiopia. When applied singly anthelmintic treatment (A) or feed supplementation (F) had no significant effect on live weight gain or foal survival. However, when combined, anthelmintic and feed supplementation (A+F) did significantly improve both live weight gain in adults and foals and foal survival. Work output was not affected by any of the treatments. Treatments A and A+F resulted in a significant reduction in faecal worm egg counts in all three localities during the course of study and for at least six months after the last dose of anthelmintic in one of the study areas (Holetta). Despite the nutritional advantages donkeys have over horses in consuming poor quality forage diets, donkey owners in Ethiopia should be encouraged to adopt both anthelmintic treatment and feed supplementation if they wish to maintain their animals in good condition and expect tangible benefits in animal performance.

Enhancing the contribution of draught animals to poor people's livelihoods in Uganda

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This presentation describes a process of Participatory Technology Development that took place in the Teso Farming System (TFS), northeast Uganda between 1998 and 2004. The main objective of the research/extension was to alleviate labour constraints and drudgery associated with weeding annual crops (in an area where the presence of HIV is reducing the numbers of economically active people available for agricultural labour) and to reduce costs and improve returns to these enterprises. There has been a shortage of draught animals in the TFS following civil disruption during the 1980s and 1990s. This constraint has been addressed by a number of 'restocking' projects and many households are now able to open up land (plough) with oxen. The benefits of using draught animal power (DAP) however, are not fully realised until animals are used for weeding and other tasks (planting, groundnut lifting and potato ridging). Although only 50% of households own oxen, 90% use them for ploughing, including some of the poorest households as it is cheaper to hire oxen than to employ manual labour. Hand weeding is mainly undertaken by women and children resulting in drudgery, withdrawal of children from school during the weeding seasons, high costs if labour is hired to undertake the task, reduced yields (in poorly weeded fields) and poor returns (gross margins).

On-farm evaluation of draught animal weeders

Weeder evaluation (4 designs) by farmers on their own farms took place during 2000 and 2001 in sorghum and groundnut crops. For sorghum DAP weeding made little impact on yield but reduced the time needed for hand weeding from 157 hours to 34 hours per hectare. Hand weeding costs were reduced from 47,000/- to 10,000/- per hectare. For groundnuts DAP weeding gave higher yields (not significant) and reduced the time needed for hand weeding from 73 hours to 31 hours per hectare. Hand weeding costs were reduced from 30,700 Ush to 13,700 Ush per hectare. Following field testing farmers identified their preferred weeding tool.

Farmer-to-farmer extension

Following weeder evaluation a farmer-to-farmer extension system was established to promote DAP weeding technology and more than 2500 farmers have been trained in this way. Links have been developed between farmers and manufacturers of agricultural implements (weeders) to ensure that these tools match their requirements and to ensure future sustainable supplies of appropriate equipment. Staff of NGOs working in Teso are being trained to ensure that DAP weeding extension continues post project. Recent training has not been restricted to weeding only, with the addition of ridging (using a plough), planting (marking lined with a weeder) and groundnut lifting using a plough (minus mouldboard) as an important part of the labour reducing DAP package. Ridging of sweet potatoes and groundnut lifting has been particularly well received by farmers and widely adopted in those communities receiving training. The mechanisation of potato ridging reduces labour costs from 123,000/- to 24,000/- per hectare (and drudgery) of this operation. In some communities this has allowed area expansion (as labour availability and costs formerly restricted the area cultivated), improved food security and incomes.

Impact on livelihoods

The introduction of DAP weeding has made women feel less oppressed and men have become involved is this task as it is mechanised and a great reduction in drudgery is reported along with improved food security and higher incomes. Women are now able to pursue more rewarding activities and are experiencing a better quality of life. Children are no longer withdrawn from school during the weeding seasons (April-May and October-November). Farmer-to-farmer extension may be one of the more effective means of effecting rapid adoption of technology; as most farmers in rural Africa have little contact with formal extension services. Their main source of information and knowledge – which they trust – and the results of which they can easily observe, are the activities of neighbouring farmers. It is anticipated that in the longer-term even the poorest of economically active households will benefit from mechanisation as hire markets develop for DAP services (weeding, groundnut lifting and potato ridging) – they already exist for ploughing and to a limited extent weeding.

Key factors contributing to success

These include:

- Allow rural communities to prioritise their problems before embarking on research and/or extension (undertake a Needs Assessment)
- Provide a range of options and allow farmers to determine which technology best meets their needs
- Develop links with the private sector for sustainability (post-project) (technology production and promotion)
- Encourage exchange of information between farmers (farmer-to-farmer extension)
- Develop partnerships and train trainers (those organisations that are likely to continue to be active for the foreseeable future)

The molecular mechanisms of inhibitory effect of androstenone on hepatic skatole metabolism in relation to boar taint

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Introduction Boar taint is off-odours in cooked pork from uncastrated male pigs. It is caused by an excessive accumulation of skatole and androstenone in backfat. Accumulation of skatole is due to a low expression and activity of hepatic enzyme CYP2E1. The mechanism of androstenone accumulation is not clear. It could be due to low activity and expression of 3β-hydroxysteroid dehydrogenase (HSD), an enzyme metabolising androstenone in liver. On the basis of our previous *in vivo* experiments with castrated animals we suggest that accumulation of skatole is regulated by androstenone. Castrated pigs manifest lower levels of skatole and androstenone and higher CYP2E1 expression. We hypothesise that high levels of androstenone inhibits CYP2E1 expression and hence, reduces the rate of hepatic skatole metabolism. The aims of the present study were (i) to investigate the expression of androstenone-metabolising enzyme HSD in liver of pigs with high and low skatole and androstenone deposition; (ii) to investigate the effect of androstenone on expression of the skatole-metabolising enzyme CYP2E1 *in vitro* (in cell culture).

Materials and methods Uncastrated Large White x Landrace (LW) and Meishan x Landrace (M) male pigs, which are known as low and high skatole depositors respectively, were used in the study (five animals per each experimental group). The pigs were fed a standard pelleted diet and slaughtered at the carcass weight 60-70 kg. Skatole and androstenone levels in backfat were measured by high resolution gas chromatography. The rate of androstenone metabolism was estimated by measuring the formation of β-androstenol (using HRGC) after incubation of isolated microsomes with 1mM androstenone and 1mM NADH. CYP2E1 protein expression was analysed by Western Blotting with commercial antibodies. HSD cDNA level was measured by competitive PCR. Effect of androstenone on CYP2E1 expression was studied using cultured pig hepatocytes. The significance of differences was assessed by Student's *t*-test.

Results The rates of androstenone metabolism (Fig 1) and the amount of HSD cDNA (which reflects the HSD expression) (Fig 2) ,were higher in LW pigs when compared to M . The level of androstenone in backfat followed an opposite pattern: it was higher in M pigs and lower in LW (Fig.3). This indicates that high androstenone deposition is due to low expression of the androstenone metabolising enzyme. In cultured pig hepatocytes, skatole activated CYP2E1 expression and this activition was inhibited by androstenone (Fig.4). The results confirm our hypothesis that skatole accumulation is a result of repression of CYP2E1 expression by high levels of androstenone.

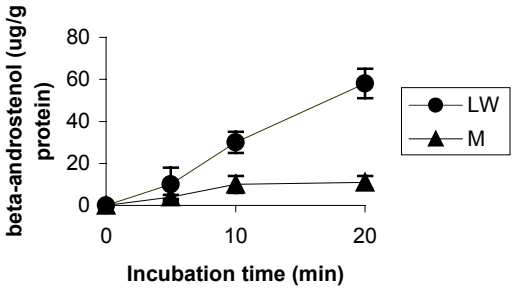

Figure 1 Rate of androstenone metabolism

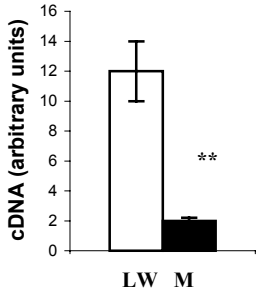

Figure 2 HSD cDNA in liver, **P<0.01

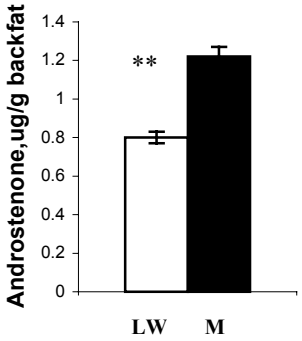

Figure 3 Androstenone level in backfat **P<0.01

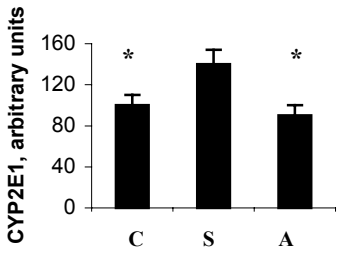

Figure 4 Effect of androstenone on CYP2E1 protein expression: C=control, S= plus 0.5 mM skatole**,** A=plus 1mM androstenone *P<0.05 when compared to S

Conclusions Excessive accumulation of backfat skatole might be secondary to the accumulation of androstenone: a high level of androstenone inhibits expression of the skatole metabolising enzyme CYP2E1. An excessive accumulation of androstenone in backfat is due to low activity and expression of hepatic HSD. HSD can be considered as a possible physiological candidate gene for boar taint.

Prenatal undernutrition increases fat deposition and collagen content within skeletal muscle in the porcine fetus

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Introduction Connective tissue content of skeletal muscle plays a key role in meat quality. Previous pilot studies carried out in our lab have indicated that the smallest littermate may have a higher proportion of connective tissue in skeletal muscle (Clelland A., 2001). Connective tissue provides a structure to the muscle belly and is composed of ground substance, fibres and connective tissue cells. A proportion of these three elements of the connective tissue comprise of collagen I and fat deposits. This is an important concept to the meat industry as an increased amount of these components can increase meat toughness and intramuscular fat respectively, both having an impact on the resultant meat quality. The primary objective of this study is to investigate the relationship between undernutrition, collagen and fat content using a naturally occurring model. In the pig, it can be argued that differing levels of nutrition received, *in utero*, are a major cause of intra-litter variation. Therefore the smallest and largest littermates were chosen and content of collagen I and fat deposition were analysed in the *M. semitendinosus* of both.

Materials and methods Twenty-eight pairs of porcine fetuses from a Large White-Landrace origin were used in this study. Muscle samples (*M. semitendinosus*) were obtained from the largest and smallest littermates ranging in age from 37 to 86 days gestation. Frozen transverse sections were cut and histochemistry and immunocytochemistry employed. The extent of fat deposition in the smallest and largest littermates was determined using the Oil Red O stain. An antibody to Collagen I was used to identify collagen fibres within the connective tissue matrix. Both stains were conducted on the littermates across all ages. Results of both techniques were analysed to assess the collagen I and fat deposition within a unit area (mm^2) of muscle using the Kontron image analysis system. Paired t-Tests were performed.

Results The analysed values of the Oil Red O stain for detection of lipids (fat) deposition is shown in Figure 1. The smallest littermate showed significantly more fat per mm^2 present than the largest littermate (P=0.009). Values obtained for the antibody staining technique against Collagen I antibody are illustrated in Figure 2. Similarly to the fat deposition results, the smallest littermate had significantly more expression of Collagen I area per mm^2 than the largest littermate (P=0.01).

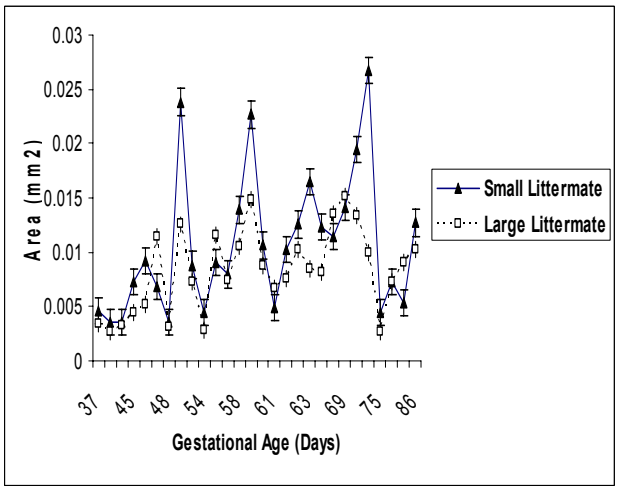

Figure 1 Fat Area per mm^2 of Muscle

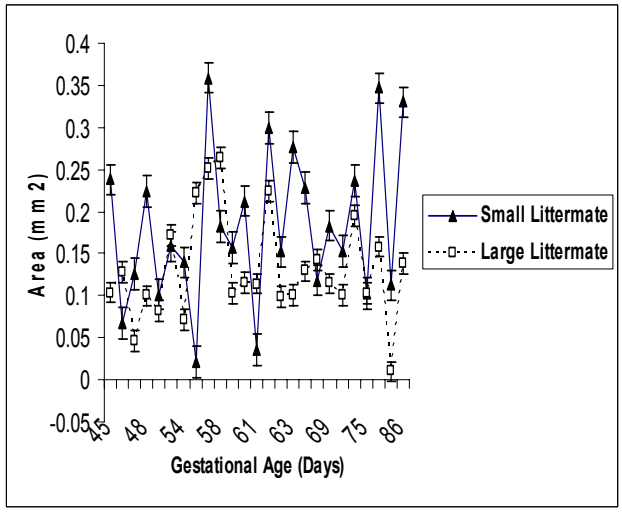

Figure 2 Collagen I Area per mm^2 of Muscle

Conclusions The results of the present study demonstrate that an increased amount of fat and collagen I content was present in the smallest littermate compared with the largest littermate. More intra-muscular fat can enhance meat tenderness; however with the ever prevailing risks of Cardiovascular diseases meat purchasing may be affected. High levels of collagen within meat increases toughness resulting in poor quality meat. Previous studies have shown undernutrition reduces muscle fibre number (Dwyer *et al., 1994)*. It can be deduced from this concept together with results gathered here that the ratio of fat and collagen to muscle fibre number is increased in the smaller fetus. This suggests that there is increased partitioning of cells committing to fat and collagen (components of the connective tissue) compared to nuclei committing to muscle fibre number in the fetus experiencing undernutrition, *in utero*. We are currently investigating the mechanisms underlying these findings.

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The role of supra basal progesterone concentrations in the aetiology of follicular cysts in cows

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Introduction While cystic follicles remain a significant problem in dairy cows, their aetiology still remains unclear. Recent studies have shown that treatment with low levels of progesterone can interfere with the induction of an LH surge and induce cystic follicles leading to the theory that supra basal concentrations of progesterone may act as a trigger for the formation of cystic follicles (Silvia et al., 2002).

In a recent study monitoring the endocrinology of the ovulatory period, a number of the cows under investigation failed to ovulate and developed cystic follicles. In this study, the endocrinology of these animals is compared to normal cows in order to test the hypothesis that the development of follicular cysts are preceded by supra basal circulating progesterone concentrations.

Materials and methods All procedures were carried out under the Animals (Scientific Procedures) Act 1986. In 24 non-lactating multiparous Holstein Friesian, oestrous cycles were initially synchronised by inserting a CIDR device (Pfizer Animal Health, Sandwich, UK) for 10 days and injecting the PGF2α analogue, cloprostenol (Estrumate, Schering-Plough Animal Health, Welwyn Garden City, UK) on the day of CIDR withdrawal. During the ensuing cycle luteolysis was induced in the mid luteal phase by a further cloprostenol injection and ovaries scanned daily by transrectal ultrasonography to determine the occurrence/timing of ovulation. Prior to induction of luteolysis, a jugular vein catheter was inserted and plasma samples collected at 8h intervals for progesterone and oestradiol analysis and 4h intervals for LH analysis. The study was carried out over 5 identical replicates between January and October.

In 3 cows, ovulation failed to occur with animals developing follicular cysts ("cystic anovulatory group"; n=3). In all cases these animals were included in the subsequent replicate of the study and in this replicate all cows ovulated normally ("cystic ovulatory group"; n=3). For comparison, in each replicate of the study additional, normally ovulating cows were randomly selected for comparison to the cystic cows during their anovulatory cycle (n=4 normal cows selected) and their subsequent ovulatory cycle (a further n=4 normal cows selected). In the cystic anovulatory group and the associated normal cows an 8h LH pulse bleed was undertaken 72h following luteolysis. The normal cows from the 2 replicates showed no differences in any of the parameters analysed and were combined for analysis ("normal group"; n=8). All data were analysed by analysis of variance.

Results In the normal group all parameters were within typical ranges (Table 1). In the cystic ovulatory group these parameters were not different from the normal group. However, in the cystic anovulatory group, while progesterone concentration prior to luteolysis was similar, the follicular phase concentration was two fold higher than the normal and cystic ovulatory groups. While size of follicle and peak follicular phase oestradiol concentrations were similar between the 3 groups, no LH surge was detected in the cystic anovulatory cows. Compared to the normal group, while LH pulse amplitude was similar in the cystic anovulatory group, LH pulse frequency was significantly attenuated.

Table 1 Comparison of reproductive characteristics of ovulatory and anovulatory cows.

	Normal (n=8)	Cystic ovulatory (n=3)	Cystic anovulatory (n=3)
Progesterone at luteolysis (ng/ml)	6.9 ± 0.7^{a}	5.6 ± 1.5^{a}	4.4 ± 0.7^{a}
Follicular phase progesterone (ng/ml)	0.35 ± 0.04^{a}	0.22 ± 0.06^{a}	0.69 ± 0.16^{c}
Peak follicular phase oestradiol (pg/ml)	2.9 ± 0.4^{a}	3.9 ± 0.2^{a}	3.1 ± 0.5^{a}
Amplitude of LH surge (ng/ml)	6.9 ± 1.1^{a}	6.8 ± 2.9^{a}	* 1.1 ± 0.2^{c}
Luteolysis to ovulation interval (days)	4.4 ± 0.4^{a}	3.8 ± 0.6^{a}	-
Follicle size at ovulation/predicted ovulation (mm)	15.6 ± 0.8^{a}	15.5 ± 1.9^{a}	** 16.2 ± 0.2^{a}
Progesterone on day 4 post ovulation (ng/ml)	2.1 ± 0.1^{a}	2.2 ± 0.3^{a}	-
LH pulse frequency (number per 8h; n=3 per group)	7.0 ± 0.4^{a}	not determined	4.3 ± 0.9^{b}
LH pulse amplitude (ng/ml; n=3 per group)	1.7 ± 0.2^{a}	not determined	1.7 ± 0.4^{a}

* mean LH at anticipated time of surge (2.5 - 3.5 days following luteolysis)
** mean diameter at anticipated time of ovulation (4 days)
different subscripts differ significantly
a b $P<0.05$; a c $P<0.01$

Conclusions The results of the present study clearly demonstrate that elevated plasma progesterone concentrations are associated with reduced LH pulse frequency and the absence of a LH surge in cows failing to ovulate and developing follicular cysts. These data support the hypothesis that elevated plasma progesterone during the pre-ovulatory period is a causal factor in the development of follicular cysts.

Acknowledgements This work was supported by a grant from the BBSRC.

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Mammary specific function of a bovine mammary epithelial cell (ABERMEC) clone cultured on collagen I coated inserts in the presence and absence of foetal bovine serum

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Background
The aim was to establish a representative model of the bovine mammary gland in order to underpin applied research in mammary gland development and lactation. Cell culture insert methodology is currently being utilized in place of a three dimensional culture system, the shortcomings of which have been discussed elsewhere (McConochie *et al.,* 2004). Cell culture insert methodology offers a promising alternative, with the potential to recreate *in vitro* a polarised epithelial layer. Previously it has been shown that on collagen I coated inserts, ABERMEC are able to synthesise and secrete mammary specific proteins in the apparent absence of the key mediators laminin and prolactin. It was hypothesised that undefined factors in serum were a possible cause for this phenomenon.

Materials and methods A bovine mammary epithelial cell clone (ABERMEC) was cultured at 1.9 x 10^5 cells per cm^2 on collagen I coated inserts for 18 days, using techniques reported previously (McConochie *et al.,* 2004). Treatments included cells cultured in the presence of 1% foetal bovine serum (F) (n=4), with the addition of lactogenic hormones (FPDI) (n=3), or with lactogenic hormones alone (PDI) (n=3). Trans-epithelial resistance (TER) was measured, visual assessments of the cultures on a daily basis were made, the expression of the alpha S1 casein and occludin genes were compared, an additional insert of each treatment was probed with a polyclonal anti-laminin antibody, and alpha-casein concentration was measured using a sandwich ELISA. Data was analysed using the REML linear mixed model procedure of Genstat (VCN International) to account for the unbalanced distribution of treatments. Differences between treatments were analysed using the Student's-t test.

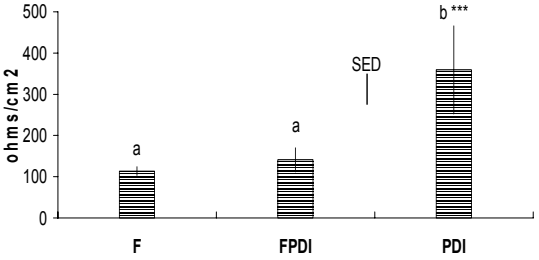

Figure 1. TER on the day of RNA isolation. (* = P<0.001), values are the means of 3 replicates (treatments FPDI and PDI) and 4 replicates (treatment F).**

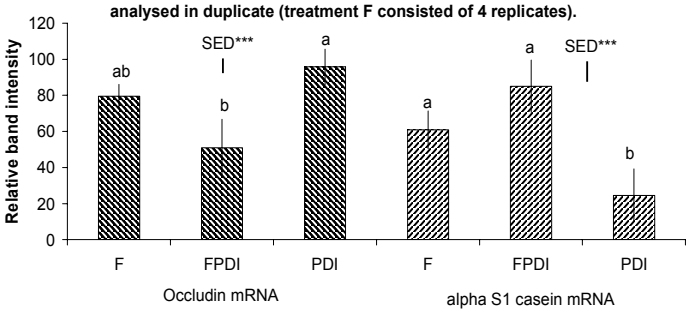

Figure 2. Occludin and alpha S1 casein mRNA expression on the day of RNA isolation (* = P<0.001), Values are the means of 3 replicates analysed in duplicate (treatment F consisted of 4 replicates).**

Results and discussion In the presence of serum alone, cells tended to aggregate extensively to form duct like structures, or areas of high cell density in the presence of FPDI. However, in the absence of serum, cells established a homogenous monolayer with a significantly higher (P<0.001) TER (Figure 1). Trans-epithelial resistance has been shown to be associated with the presence of inter-cellular tight junctions (Martin *et al.,* 2004) a major component of which, is the protein occludin. Despite having a superior TER, treatment PDI did not show a higher level of occludin mRNA expression (Figure 2) compared to treatment F. Alpha-casein gene expression (Figure 2) was significantly higher (P<0.001) in those cultures where the cells had aggregated. The pattern of alpha-casein protein synthesis reflected mRNA expression; although differences between treatments were not significant (data not shown). The presence of laminin in the cultures was also demonstrated.

Conclusion
In line with previous experiments, the lactogenic properties of foetal bovine serum were demonstrated. In addition, it was shown that by the deposition of the basement membrane protein laminin, mammary epithelial cells have the potential to establish a micro-environment capable of supporting mammary specific function. In order for cell culture insert methodology to provide a representative model of mammary development and lactation, it is essential that cells establish and maintain an epithelial monolayer with distinct apical and basal regions. Although an epithelial layer capable of mammary specific function was established in the absence of serum, enhanced morphological and functional differentiation occurred in the presence of serum where the cells had aggregated. Due to this undesirable effect of cell aggregation in the presence of serum, future work will concentrate on enhancing mammary specific function in a serum free model.

References
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Prediction of the reproductive status of cattle on the basis of milk progesterone measures

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Introduction The trend of increasing cow numbers per husbandry person makes it difficult to achieve good reproductive management by traditional means. A system to predict the reproductive status of cows would be of great value. There exist time-series models for detecting oestrus from milk traits other than progesterone and decision strategies for interpreting progesterone measures have been suggested but a system combining these aspects to predict not just oestrus but reproductive status throughout the reproductive cycle is lacking. The objective of this study was to develop such a model on the basis of automated milk progesterone sampling.

Model description The main input to the model is milk progesterone concentration. A number of additional inputs are incorporated, where available, to make use of other known effectors of reproductive performance. These are: days from calving, breed, parity, signs of behavioural oestrus, insemination date, pregnancy determinations, energy status, body fatness, milk urea content and reproductive disorders associated with calving. Additional inputs are defined on recording system independent scales to provide generality e.g., 0 to 1 for signs of behavioural oestrus where 0 is no sign and 1 is 100% certain oestrus, thus a cow visually detected to be "possibly" in oestrus could be assigned 0.5. However, the model is designed to be able to function in the absence of all these additional inputs. In cases of contradictory inputs e.g., a positive pregnancy determination and low progesterone, it is assumed that progesterone is the definitive measure of reproductive status. The model is dynamic and deterministic, designed to run each time a new trigger input (progesterone, behavioural oestrus, inseminations, pregnancy determinations) occurs using both the current and previous values. The progesterone values are smoothed using an extended Kalman filter before being processed in the biological component of the model. The model predicts the reproductive status of the cow, which can be one of 3 mutually exclusive states: postpartum anoestrus (0), oestrus cycling (1), and potentially pregnant (2). The other model outputs are: risk of prolonged postpartum anoestrus, risk and type of ovarian cyst, onset of oestrus, likelihood of a potential insemination succeeding, and likelihood of being pregnant (following oestrus), these are all reproductive status specific. Days to next sample is calculated in each model run regardless of reproductive status, it is designed to feedback to the sampling system so that the frequency of milk sampling (i.e. progesterone measurement) can be varied according to the predicted likelihood of a future reproductive event, such as onset of oestrus cycling, occurring.

Model Evaluation Simulated data were used to check the model logic and ability to detect onset of oestrus cycling, oestrus and pregnancy. Robustness was tested by adding random noise to the progesterone values and by reducing the sampling frequency.

Results The model was found to readily be able to identify and distinguish reproductive states, e.g. Figure 1. It was robust to reductions in sampling frequency and to a doubling in the random variation in the raw progesterone values.

Conclusions Reproductive status can be predicted from milk progesterone values using a biological model. Such a model has the potential to provide the basis for a useful reproductive management tool.

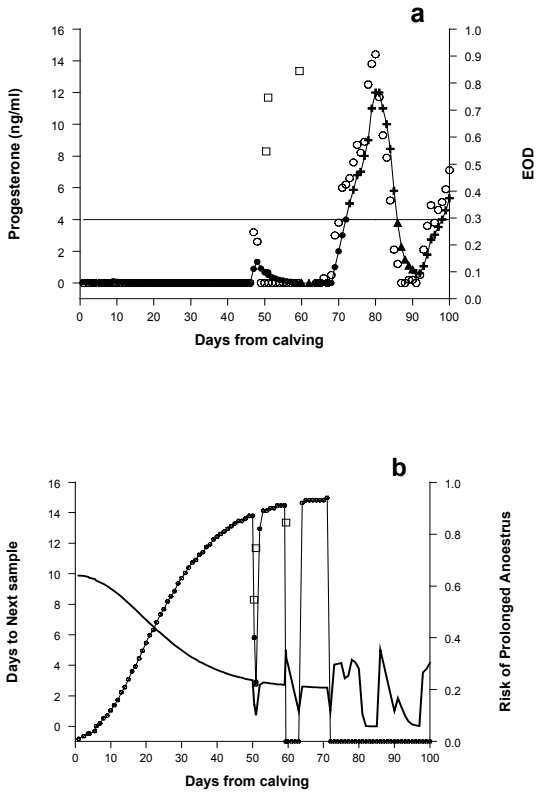

Figure 1 Results of model evaluation with focus on postpartum anoestrus using simulated data. a) Input progesterone values (open circles), input external behavioural oestrus detections (EOD; open squares), smoothed progesterone values (line with symbols) and reproductive status (0 = solid circles, 1 = crosses, 2 = solid triangles) generated by the model are shown. The threshold progesterone value of 4 ng/ml is also shown. b) The days to next sample (solid line with no symbols) and risk of prolonged postpartum anoestrus (line with circles) generated by the model are shown. Input EOD values (open squares) are shown for reference.

Effect of crossing Blackface ewes with five sire genotypes on performance of F1 and F2 offspring

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Introduction Relative to purebreeding, crossbreeding in the hill flock has been shown to increase lamb growth rates from birth to weaning by up to 12% and weight of lamb weaned by up to 24%, depending on ewe and ram breeds concerned (Carson *et al* 2001). Traditionally crossbred females produced in the hill are sold to the lowland as replacement females, so that potential hybrid vigour effects associated with crossbreeds are not fully exploited in the hill environment. A research programme has been established in Northern Ireland to investigate the potential for retaining crossbred females in the hill environment, as replacement breeding females, to improve the genetic potential of the hill flock. This paper presents the results from the first phase of the study which involved the production of the crossbred lambs from Scottish Blackface ewes (over 3-years) and the first year of the second phase, an evaluation of the performance of crossbred ewes as breeding females in the hill sector.

Material and methods Six hill farms, located in the main hill regions of Northern Ireland were involved in the study. In October 2001 – 2003, on each of the farms, 200 purebred Blackface ewes were allocated to five mating groups, balanced for ewe live weight, condition score and age. The mating groups comprised Blackface, Swaledale, Cheviot, Lleyn and Texel rams. In the first year of the study, single sire mating groups were used separately on each farm, whilst in the second and third year a team of rams were used across all the farms using artificial insemination. In October 2003, crossbred females produced from the October 2001 mating were naturally mated with Texel (6 farms) and Dorset rams (3 farms). Rams were selected, when possible, on the basis of their selection indices to represent the top 10% of recorded animals. A total of 15 Blackface, Swaledale, Cheviot, Lleyn and Texel rams were used to produce the crossbred progeny. Blackface and crossbred ewes were weighed and condition scored prior to mating and lambing, post-lambing and at weaning. Lambs from each of the crosses were weighed at birth, at six weeks of age and at weaning. The degree of intervention required at lambing was assessed on a five point scale where 1 = no assistance required and 5 = caesarian section required. The data were analysed using the Genstat REML (Residual Maximum Likelihood) procedure. This fitted fixed effects for farm, year and mating group or crossbred ewe genotype.

Results When mated with Blackface ewes, Texel and Swaledale sires produced a greater number of lambs ($P<0.01$) compared with the Blackface sires. A lower proportion of Cheviot and Texel cross lambs were born without assistance relative to purebred Blackface ($P<0.001$) and Swaledale ($P<0.01$) cross lambs probably due to the greater birth weights of Cheviot and Texel cross lambs. Output of weaned lamb, in terms of total weight of lambs weaned per ewe lambed, was greater for Texel and Lleyn cross lambs relative to purebred Blackface or Cheviot cross lambs ($P<0.01$). Lleyn X Blackface ewes were the most prolific of the four crosses ($P<0.05$), had the greater number of lambs weaned ($P<0.05$) and greatest weight of lamb weaned per ewe ($P<0.01$). Cheviot X Blackface ewes had the lowest output at weaning.

Table 1 The effect of sire breed on the performance of F1 progeny

	Sire breed mated with Blackface ewes						
	Blackface	*Swaledale*	*Cheviot*	*Lleyn*	*Texel*	*sem*	*significance*
No lambs born/ewe	1.45[a]	1.55[b]	1.49[ab]	1.52[ab]	1.56[b]	0.025	**
Lamb birth weight (kg)	3.9[a]	3.9[a]	4.3[b]	4.0[a]	4.2[b]	0.04	***
Proportion of lambs born without assistance	0.83[b]	0.81[b]	0.73[a]	0.76[ab]	0.70[a]	2.8	***
Lamb performance to weaning							
No lambs reared/ewe	1.18[a]	1.29[b]	1.19[a]	1.31[b]	1.28[b]	0.032	**
Weight of lambs weaned/ewe	35.1[a]	38.5[bc]	37.4[ab]	41.3[c]	41.3[c]	1.007	***
	Ewe genotype(Sire breed X Blackface)						
	Blackface	*Swaledale*	*Cheviot*	*Lleyn*	*Texel*	*sem*	*significance*
No lambs born/ewe	1.41[a]	1.57[bc]	1.44[ab]	1.70[c]	1.57[bc]	0.062	*
Lamb birth weight (kg)	4.0[a]	3.9[a]	4.4[b]	3.9[a]	3.9[a]	0.11	*
Proportion of lambs born without assistance	0.61[a]	0.78[b]	0.69[ab]	0.67[ab]	0.71[ab]	0.055	*
Lamb performance to weaning							
No lambs reared/ewe	1.15[ab]	1.30[bc]	1.02[a]	1.42[c]	1.28[bc]	0.086	*
Weight of lambs weaned/ewe	36.7[ab]	44.0[bc]	32.3[a]	45.6[c]	42.7[bc]	2.83	**

Conclusions Crossbreeding in Scottish Blackface ewe flocks leads to significant increases (up to 18%) in lamb output at weaning compared to purebreeding. Retaining crossbred females as replacement hill ewes has the potential for further improvements in output from the hill sector. In the first year of breeding, crossbred ewes produced up to 25% more lamb output compared with Scottish Blackface ewes, although lifetime performance needs to be evaluated.

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Two methods of using X-ray Computed Tomography to predict carcass composition in sheep

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Introduction X-ray computed tomography (CT) can be used to accurately assess carcass composition in sheep (Sehested, 1984; Young *et al*., 2001) both in research and commercially, as part of a breed selection programme. Two different CT scanning methods have been used: a) the reference scan method where tissue weights are predicted from tissue areas in a small set of cross-sectional scans at 'anatomical landmarks', and b) the Cavalieri method where a larger number of scans are taken along the body. It is of interest to examine the accuracy of evaluations made using these two methods and the individual merits of the two methods depending on their application.

Methods Lambs of 3 terminal sire breeds at 14 (n32), 18 (n32), 22 (n32) and 26 (n64) weeks of age were CT scanned using both the Cavalieri and reference scan methods to evaluate lean, fat and bone weights. For the Cavalieri method, lambs were scanned at 15-20 positions along the body between the base of the skull and the proximal tibia with a constant distance between the scans for each lamb and the first scan positioned at random along the scanning axis. Each tissue weight was then estimated from the product of its average density and its volume, which was calculated by multiplying the total tissue area across all scans by the interscan distance. For the reference scan method, each lamb was scanned at 3 positions: ischium, 5th lumbar vertebra and 8th thoracic vertebra. Tissue weights were predicted from tissue areas in these scans using prediction equations previously developed in this data set, either without or with live weight. Lambs were slaughtered and the left carcass sides dissected to determine lean, fat and bone weights (kg) shortly after CT scanning. Dissected tissue weights were regressed (Genstat 7, 2003) on those obtained from each method and the accuracy of the methods appraised.

Results Intercepts and slopes of the regression equations generated are shown in Table 1 along with R^2 statistics and r.s.d. Tissue weights were accurately predicted. For all tissues, the reference scan method including live weight was slightly more accurate than the Cavalieri. Since the prediction equations were derived from these same data this might be anticipated, particularly when including a proxy for size similar to the Cavalieri method. The Cavalieri method over-predicted lean weight by 1.34 (s.e. 0.006) times, which was not the case with the reference scan method (slope of regression close to 1) as shown in Figure 1. For the reference scan approaches, tissue weights were predicted with lower accuracy when live weight was excluded in the prediction equation. However, even when live weight was excluded, predictions were not biased.

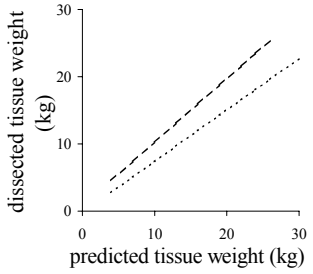

Figure 1 Regression lines for RS (- - -) and Cavalieri (· · ·) prediction of lean

Table 1 Intercepts and slopes of regression equations for tissue weights (kg)

Tissue	Prediction method†	Intercept	s.e.	Slope	s.e.	R^2	r.s.d.
Lean	Cavalieri	-0.317	0.247	0.766	0.0129	95.7	0.706
	RS	0.740	0.330	0.947	0.0230	91.4	0.993
	RS+LW	0.399	0.213	0.972	0.0148	96.4	0.641
Fat	Cavalieri	0.682	0.079	0.947	0.0096	98.4	0.487
	RS	-0.040	0.108	1.009	0.0131	97.4	0.616
	RS+LW	0.009	0.081	1.001	0.0098	98.5	0.468
Bone	Cavalieri	0.361	0.112	0.988	0.0302	87.1	0.341
	RS	0.213	0.147	0.950	0.0369	80.6	0.417
	RS+LW	0.058	0.094	0.987	0.0235	91.7	0.272

†RS - reference scan without live weight; RS+LW - reference scan with live weight

Conclusions The Cavalieri method and prediction equations both gave highly accurate predictions of carcass composition. The Cavalieri method over-estimated dissected lean weight in part because of blood loss at slaughter, moisture loss from the carcass post-slaughter and because it measures lean both in muscle and non-muscle depots (e.g. inside bones; within adipose tissue). With a reduced scanning method (reference scans), which is less costly, tissue weights were still accurately predicted. Commercial CT scanning in the UK sheep industry uses the reference scan method. Cavalieri scanning may be useful to estimate tissue weight as an alternative to dissection where prediction equations are unavailable for a given breed-type. Where live weight was *versus* was not included in the prediction equations, prediction accuracies were slightly higher. Still, in genetic evaluations, where both live and tissue weights may be of interest, excluding live weight from prediction may be preferred to avoid colinearity among weight measures with little affect on prediction accuracy.

Acknowledgements Thanks to Defra, MLC and SEERAD for funding through the LINK SLP Scheme and to SAC staff for their technical input.

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Effect of growth rate to finishing on *in vivo* composition and muscularity traits in lambs

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Introduction The amount and distribution of different body tissues changes as lambs grow and mature. Ratios of muscle to bone and of fat to muscle increase with growth post-weaning, as does muscularity (Jones *et al*., 2002), with the rate of change differing between breeds. Growth patterns have also been found to affect carcass composition (e.g. Thatcher and Gaunt, 1992). This preliminary study investigated the effects of growth rate on *in vivo* body composition and shape measurements and their relationships, in two contrasting breeds of lambs.

Methods Scottish Blackface (BF; n=91) and Texel (T; n=125) lambs were grazed in single-sex (female/entire male), mixed-breed flocks from weaning to 'finishing' (defined as commercial slaughter point, based on condition score and live weight). Lambs reached finishing point in five batches, of mixed breed and sex, over a 12-week period, and were CT scanned at this time. One half of each batch (balanced for breed and sex) was slaughtered after CT scanning. The other half was slaughtered 30 days later, after the sedative withdrawal period (to allow taste panel analysis as part of a larger study). Using CT image analysis, the following measurements were taken for each lamb: predicted weights (kg) of carcass fat (FW), muscle (MW) and bone (BW), based on earlier derived breed-specific prediction equations; hind leg shape (HLS), a ratio of leg muscle depth to width; eye muscle area (LDA, $mm^2/1000$); eye muscle shape (LDS), a ratio of eye muscle depth to width. Least-squares (LS) means were estimated in each breed for each trait using REML analysis (Genstat v.4.1). The model included hot carcass weight (HCW, predicted from live weight and average batch dressing percentage for those lambs slaughtered after 30 days), condition score, line (high or low muscularity sire), sex, litter size, line/sex/litter size interactions, sire (random), age class (age at finishing, 1=<115d, 2= 115-130d, 3=130-145d, 4=145-160d, 5=>160d) and date of birth within age class. Average daily live weight gains (birth to finishing) in age classes 1 to 5 respectively were: 360g, 333g, 276g, 238g, 183g for T lambs, and 337g, 314g, 267g, 235g, 175g for BF. Differences between means for age classes were tested for significance, to estimate effects of growth rate to finishing on CT composition and body shape traits. Residual correlations were estimated between traits, for each age class separately and over all lambs within breed, and approximate standard errors calculated.

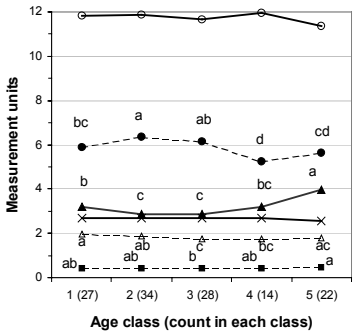

Figure 1 Texel LS means

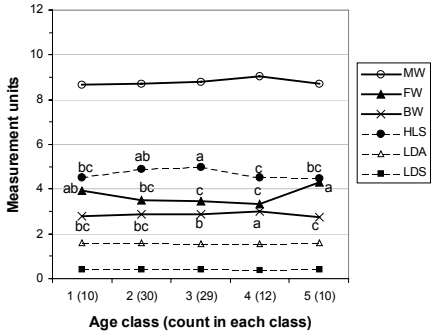

Figure 2 Scottish Blackface LS means

Table 1 Residual correlations between traits (bold= sig. different from zero, $P<0.05$)

	T	BF
FW:MW	-0.14	-0.06
MW:BW	**0.32**	**0.57**
FW: BW	-0.11	-0.04
MW:HLS	0.10	0.16
FW:HLS	-0.17	**-0.30**
LDA:HLS	0.11	**0.38**
LDS:HLS	**0.24**	**0.34**
LDS:LDA	**0.53**	**0.47**
s.e. range	0.08-0.09	0.09-0.11

Results Figures 1 and 2 show LS means for age class (means sharing a common character in their superscript, or means of traits with no superscripts, are not significantly different ($P>0.05$)). MW did not differ significantly between age classes in either breed. In both breeds, lambs in the youngest and oldest age classes (1 and 5) at finishing had higher FW than those in age classes 2, 3 and 4. BW showed no clear trend with age at finishing in either breed, although in BF lambs, BW was higher in age class 4 than in other classes. HLS was higher in age classes 2 and 3. LDA and LDS were lowest in age class 3 in T lambs, but showed no significant differences between age classes in BF lambs. Overall correlations are shown in Table 1. Considering correlations within age class, no clear trends with growth rate were observed and few correlations differed significantly from overall values.

Conclusions These preliminary results suggest that in both breeds growth rate (as predicted by age at finishing) did not affect total weights of muscle and bone at finishing, in lambs of constant HCW and condition score. Carcass fat was higher in lambs finished at weaning (age class 1) and in lambs with the lowest growth rates (age class 5), compared to lambs with intermediate finishing rates. Muscularity of the leg **(**HLS**)** was greatest in lambs of intermediate growth rate (classes 2 and 3). However, in BF lambs, measures of muscularity in the loin **(**LDA; LDS**)** did not change with growth rate, and in T lambs, these measures tended to be lowest in lambs finished in age class 3. Several of the traits studied appear to have non-linear relationships with growth rate. Relationships among conformation and muscularity traits did not change significantly with growth rate. Following further data collection, more sophisticated models of growth rate (e.g. random regression) will be used to investigate similar relationships with CT traits.

Acknowledgements Thanks to Defra and SEERAD for funding this project.

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Association among objective *in vivo* and post-slaughter assessments of muscularity in lambs

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Introduction Muscularity of lamb carcasses, which is defined as the depth of muscle relative to dimensions of the skeleton (De Boer *et al.*, 1974), is a commercially important trait in many countries. An objective index of muscularity was defined by Purchas *et al.* (1991) based on the weights of the muscles around a bone and the bone length. Jones *et al.* (2002) proposed an objective index to assess *in vivo* the shape of the muscle in the hind leg using X-ray Computed Tomography (CT), which had a phenotypic correlation of 0.63 with dissection measures of muscularity, as described by Purchas *et al.* (1991).
The potential of new CT imaging technology, called Spiral CT scanning, to measure body composition and real dimensions of skeletal structures and muscularity is investigated here. Preliminary studies suggest that it is possible to calculate the muscle mass in the hind leg with high accuracy using spiral CT scans (SCTS) (Glasbey *et al.*, 2004). In this paper, the associations between *in vivo* measurements of muscularity, using CT data, and muscularity indices based on post-slaughter measurements are reported.

Methods SCTSs were taken on 34 Scottish Blackface and 44 Texel lambs before slaughter. These scans were automatically segmented and the volumes of muscle in the hind leg were calculated as explained earlier (Glasbey *et al.,* 2004) and divided by 2 to obtained the muscle volume of one leg (MV_{CT}, cm^3). Using 3-dimensional reconstruction of the SCTS, the lengths of the femur bones in each leg were measured and averaged (FEM_{CT}, cm). The hind leg shape (HLS) was calculated as the ratio of leg muscle depth to width (Jones *et al*., 2002). Muscles from the hind leg were dissected and weighed (MW_{Dis}, gr) and the lengths of the femur (FEM_{Dis}, cm) were measured. The weights of the three main muscles attached to the femur (*semitendinosus*, *semimenbranosus* and *biceps femoris*; $3MW_{Dis}$, gr) were also recorded. Based on these traits, and using the approach of Purchas *et al* (1991), muscularity indices for the hind leg were derived: $Mindex_{CT} = (\sqrt{(MV_{CT} \times FEM_{CT}^{-3})}) \times 10$; $Mindex_{Dis} = (\sqrt{(MW_{Dis} \times FEM_{Dis}^{-3})}) \times 10$, and $3Mindex_{Dis} = (\sqrt{(3MW_{Dis} \times FEM_{Dis}^{-3})}) \times 10$. The associations among the different traits were investigated by regression analysis (Genstat v.4.1; Lane and Payne, 1996).

Results The associations between the muscularity indices obtained from SCTS and dissection were high (Table 1). $Mindex_{CT}$ was better correlated than HLS with dissection measures. The association between $Mindex_{Dis}$ and $Mindex_{CT}$ (R^2=79.9%) is explained by the strong relationship between MV_{CT} and MW_{Dis} (β=1.0058 ± 0.004 gr/cm^3; R^2=97.0%) which is in agreement with previous findings (Glasbey *et al.*, 2004). On the other hand, the R^2 between the FEM_{CT} and FEM_{Dis} in this study was about 50%. Jones *et al.* (2002) analysed the association between FEM_{CT} measured in the CT topograms (a 2D longitudinal scan of the animal) and FEM_{Dis} and reported R^2 values lower than 5%. This poor relationship was explained by the authors as due to a variable orientation of the femur bone relative to the plane of the topogram.

Table 1 Intercept (α), slope coefficient (β) and coefficient of determination (R^2) for the regression between muscularity indices

Y	X	$\alpha \pm se$	$\beta \pm se$	R^2%
$Mindex_{Dis}$	$3Mindex_{Dis}$	NS	1.693 ± 0.003	97.1
$Mindex_{Dis}$	HLS	4.78 ± 0.27	0.539 ± 0.05	60.9
$Mindex_{Dis}$	$Mindex_{CT}$	NS	1.035 ± 0.005	79.9

NS = non significant.

Conclusion The approach proposed by Purchas *et al.* (1991) provides an objective measurement of muscularity but one that could not be applied in live animals in the past. The $Mindex_{CT,}$ which was calculated based on this approach, was closely related to $Mindex_{Dis}$. In terms of the components that define the $Mindex_{CT}$ the association between the MV_{CT} and the MW_{Dis} was very high. However, there is scope to improve the accuracy of the estimation of the length of the femur. This needs to be explored to further improve the value of $Mindex_{CT}$ as an objective *in vivo* predictor of the muscularity of lamb carcasses.

Acknowledgements We are grateful to Defra and SEERAD for supporting this work.

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Identifying QTL for meat quality and carcass composition traits in Blackface sheep

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Introduction The development of genetic markers and their application to farm animals has progressed rapidly, opening new prospects for identifying chromosomal regions that control quantitative traits (quantitative trait loci or QTL). However, there is less activity in QTL identification in sheep than in other livestock species. Surprisingly few QTL have been published for traits of direct relevance to sheep meat production, apart from studies of individual major genes such as the callipyge locus (Freking *et al.*, 2002). This suggests there may be more QTL effects still to be found in sheep. Hence, this study aims to identify QTL for carcass composition and meat quality traits. This will provide a basis for targeting genomic regions to verify QTL in independent sheep populations.

Materials and Methods The population studied comprised lambs derived from LEAN and FAT lines of Blackface sheep, previously divergently selected for predicted carcass composition. A double backcross design created 9 half-sib families for QTL detection, ranging from 23 to 141 individuals. Phenotypic measurements included cross-sectional scans at the ischium (ISC), the 5th lumbar vertebrae (LV5) and the 8th thoracic vertebrae (TV8), obtained by computerised tomography (CT), on 600 5-month old lambs. From each scan image the areas and image densities were obtained for the fat, muscle and bone components of the carcass. Additionally, meat quality measurements were made on 300 8-month old male lambs that had previously been scanned, including initial and final pH of the meat, colour and chemical composition. DNA was extracted from blood samples and all animals were genotyped at candidate regions on chromosomes 1, 2, 3, 5, 14, 18, 20 and 21, chosen on the basis of current knowledge. The probability of inheriting a particular sire chromosome at a particular position was calculated for each offspring at 1 cM intervals (Knott *et al.,* 1996). Phenotypes were then regressed upon the conditional probability that a particular haplotype is inherited from the sire, fitting fixed effects of year, line, sex, litter size, dam age and, where appropriate, slaughter day as a covariate. CT traits that had high genetic correlations, calculated using *ASREML,* were averaged and treated as one trait in the QTL analysis. For each regression an F-ratio of the full model including the inheritance probability versus the same model without the inheritance probability was calculated across families. The location with the largest F-ratio signified the QTL location. Stringent significance thresholds were set, declaring QTL results to be significant only if they met chromosome-wide or genome-wide criteria. Finally, QTL confidence intervals were constructed by taking the region of the chromosome covered when reducing the largest F-ratio by the equivalent of a LOD score of either 1 or 2 to get the 95% and 99% confidence intervals.

Table 1 QTL significant at the 5% genome-wide threshold

Chromo-some	Trait	Position (cM)	F	5% Gen-ome-wide Threshold	95% Confidence Interval
1	Bone Density ISC	261	3.15	2.97	246-279
1	Slaughter LW	229	3.23	3.08	218-239
2	Mus. Dens LV5-TV8	28	3.45	2.97	17-40
3	Muscle Density ISC	172	3.16	2.97	158-195
3	Colour a*	113	3.31	3.02	106-117
5	Hot Carcass	0	3.07	3.02	0-15

Results Significant QTL were detected at the 5% genome-wide level in 4 chromosomal regions (Table 1). A highly significant QTL affecting muscle density (LV5-TV8) was identified on chromosome 2 (LOD=6.60), and a QTL affecting bone density (ISC) was located on chromosome 1 (LOD=6.03) close to the transferrin gene. The remaining QTL for muscle density (ISC), colour a*, hot carcass weight and slaughter live weight all showed a good profile definition with reasonably tight confidence intervals. A further 12 QTL achieved significance at the 5% chromosome-wide level (results not shown). These were for slaughter live weight (chromosome (chr.) 2), hot carcass weight (chr. 1), colour L* (chr. 20), bone area (TV8) (chr. 20), colour L* (chr. 18), hot carcass weight (chr. 21), colour b* (chr. 1), bone density (ISC) (chr. 20), bone area (LV5) (chr. 20), muscle area (chr. 5), live weight at CT scanning (chr. 21) and bone area (LV5) (chr. 18). Of these QTL, four are located in the major histocompatibility complex region on chromosome 20.

Conclusions The study has been successful in detecting QTL, that meet highly stringent significance thresholds, for a range of meat quality and carcass traits including carcass and live weight, meat colour attributes, muscle density, muscle area, bone area and bone density. Bone density is possibly of lesser relevance to meat production, but it may be of particular importance as an animal model for osteoporosis. Future work aims to evaluate and refine possible alternative breeding goals and selection strategies for meat quality traits.

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Effects of the strategic supplementation of does' diets on goat performance and smallstock keeper livelihood in the Gangetic plains of Nepal

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Introduction Keeping goats can make an important contribution to the livelihoods of small and landless farmers in Nepal, one of the world's poorest countries. Work with four communities in the Dhanusha district of southern Nepal identified that a key constraint to goatkeeping in this area was doe infertility. Of 114 does over 10 months old that were monitored for a 12 month period, 33 did not kid and a further six were sold because of infertility. The objective of this experiment was to determine the effect of strategic supplementation of does' diets on doe and kid performance, and on the contribution that the goat flock made to the livelihoods of the goatkeepers.

Materials and methods Twenty households from each community were involved. Each household kept between three and eight goats, which are taken out to browse during the day and at night are tethered and offered cut forage. Does are fed kitchen leftovers or some boiled cereal (maize or rice) for between one week and one month after kidding. Treatments (7 households per treatment in each community) were given to does two weeks before and six weeks after kidding. The treatments were 100 g/d ground maize (DMZ); 500 mg selenium and 50 mg Vitamin E (DSE). The remaining six households in each community were the control group (CON) whose does were offered no additional supplement beyond that normally fed (described above). Goat liveweight was measured each month and household income was recorded fortnightly. The effects of treatment, community and interaction between treatment and community on kid and doe liveweight gain, income from goat sales and changes to the asset value of the goat flock were estimated by analysis of variance.

Results Data relating to the economics of the participating households is summarised in Table 1. Mean household size was six. The effect of treatment on goat performance and on the potential income from goats is summarised in Table 2. Does and their kids in the DMZ treatment gained more weight in the first month after kidding than those in the other groups, and this was reflected in an almost (P=0.053) significant increase in the potential income made from the goat flock. No interactions between village and treatment were observed. The farmers' evaluation of DMZ was that it increased doe fertility and the value of the kids produced.

Table 1 Summary of the economic status of participating households in the study

	Minimum	Maximum	Mean
Total mean monthly income (GB £)	4.98	76.19	19.93
Total mean monthly income from goats (NRs)	0	37.32	2.79
Proportion of income coming from goats	0	0.56	0.11
Household debt (NRs)	0	252.38	70.57
Size of landholding (ha)	0	2.8	0.29
Number of months household can grow their own food	0	12	5.1

Table 2 Effect of treatments on kid and doe liveweight gain and on the potential income from goats

	Treatment				
	DMZ	DSE	CON	sem	Sig.
Liveweight gain in the first month after kidding (kg)					
Does	2.15	1.35	1.29	0.1[illegible]	***
Kids	1.52	1.15	1.08	0.0[illegible]	***
Potential income from goats[1] (GB £)	37	20	22	6.2	0.053

[1]Calculated as the sum of income from goat sales and the change in the calculated asset value of the flock between the start and end of the experiment

Conclusions Farmers were fully aware of which treatment group they belonged to, and this may have affected how they managed their goats, as well as their perception of the values of the different treatments. However, from the objective data reported here, it is clear that there was no evidence that selenium was a limiting nutrient in this experiment, but energy clearly was. The strategic supplementation of does' diets with ground maize cost £0.15 per household per annum, but resulted in a net benefit (compared with CON) of £13.75 per annum. This is equivalent to 19% of mean household debt, and 69% of mean household monthly income.

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The effect of exercise on microbial activity in the hindgut of horses

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Introduction Most studies on digestion in the equine have been carried out with animals confined to stables with little or no exercise. An increased rate of digesta passage has been reported in exercised versus non exercise horses with an associated decrease in digestibility (Pagan *et al*., 1998). Microbial degradation makes an important contribution to diet digestibility in the equine. It is not clear however, if exercise has any effect on the composition and activity of the microbial population within hindgut which may impact on the digestion. The aim of this experiment was to assess the impact of exercise on microbial fermentation within the hindgut of the horse.

Materials and method Five geldings and one mare average age 8.5 ± 1.5 years, average weight 413 ±25.8 kg were used in a two period switch over design. Horses were given a 14 day adaptation period prior to the commencement of the experiment to allow them to adjust to the diet and regime. Experimental periods were 14 days long and samples were taken on the last day of each period. All animals received 500g of a mix (Dodson and Horrell Leisure Mix) and 250 g of molassed chaff (Youngs Animal Feed Ltd) twice daily (am and pm). Hay (4.5 kg) was fed at night and all animals had access to rough grazing for 7 h each day. Exercised animals were ridden for 8.9 km each day, the route chosen was the same each day and was made up of 1.3 km of cantering or galloping, 2.5 km of trotting and the remainder taken at a walk. Non-exercised animals were turned out but not ridden. There was a cross over rest period of 5 days between exercise and non-exercise periods. Faecal samples were collected at first light (circa 4.30 am) prior to morning feeding and immediately stored in thermos flasks for transport to the laboratory. Total and cellulolytic bacteria were estimated by the most-probable-numbers method (Dehority, *et al*. 1989), protozoal numbers were estimated by direct microscopic count (Dehority 2003). Gas production by a faecal slurry incubated with hay or barley was determined as described by Lowman, *et al*. (1999). Rates of gas production (ml) were fitted to the model $p = a + b (1 - e^{-ct})$, where p = volume of gas after time t; a = the intercept of gas volume curve at t = 0; b = volume of gas produced at asymptote; c= rate constant of gas production (h^{-1}) (Orskov and McDonald 1979). Data were analysed by analysis of variance using Genstat 5.

Table 1 Gas production (ml) from barley incubated with a faecal slurry form exercised v non-exercised horses

Incubation Time (h)	Exercise GP (ml) n=6	Non –Exercised GP (ml) n=6	SED
0	0	0	
3	15.1	17.7	3.67
6	33.7	37.3	3.78
9	50.4	53.7	2.51
12	62.7	65.3	2.16
15	70.1	73.5	2.07
18	75.42	77.3	2.63
24	80.4	81.2	3.60
30	85.2	80.6	2.69
36	87.7	80.9	2.35*
48	91.1	82.3	2.10*
60	92.1	84.9	2.49*
72	93.2	87.1	2.38
a + b	93.1	85.7	2.83
c	0.090	0.115	0.0042*

* P<0.05

Results There was no significant effect of the exercise regime applied here on bacterial numbers in the faeces although there was a trend towards a higher count of both total and cellulolytic bacteria in exercised animals (1.84 versus 1.12 total bacteria ($x10^7$/g) SED1.01 for exercised and non exercised animals respectively, 3.5 versus 1.8 cellulolytic bacteria ($x10^6$/g) SED 2.7 respectively). Nor was there an effect on protozoal numbers (7.92 versus 8.95 ($x10^5$/g) SED 1.20). The rate of gas production (c) from barley was significantly lower in exercised versus non exercised animals (Table 1). No effect on rate gas production (c) from hay was observed (0.036 versus 0.0370 SED 0.0082).

Conclusion Despite an apparently enhanced bacterial population in exercised animals rates of barley digestion were decreased. These results suggest that the decreased digestibility reported in exercised horses (Pagan *et al*., 1998) may also represent a reduction in the degradative capacity of microbial populations and not solely a result of increased rates of passage.

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Algebraic methods to determine total tract mean retention time of digesta in ponies given *ad libitum* access to pelleted diets containing different levels of unmolassed sugar beet pulp

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Introduction Digesta passage rate may have influenced previously reported work on the intakes, apparent digestibilities and nutritive values of complete pelleted diets containing unmolassed sugar beet pulp (USBP) at levels ranging from 0-800 g/kg dry matter (DM) when offered to ponies (Hyslop, 2002). This study's objective was to compare total tract mean retention time (TMRT) of digesta using two algebraic calculation methods in the same ponies.

Materials and methods 6 mature Welsh-cross pony geldings (mean LW 296 kg) were individually housed and offered one of 6 pelleted complete diets *ad libitum* as the sole ration. Diets were formulated from dried grass (DG), USBP, minerals and molasses such that USBP inclusion levels were 0, 160, 320, 480, 640 and 800 g/kg DM respectively in the 6 diets (U0, U160, U320, U480, U640, U800). The experiment was a 6 x 6 latin square changeover design lasting for 6 periods of 21 days (16 day adaptation and a 5 day recording phase). 50 g subsamples of each respective Ytterbium (Yb) labelled complete diet were administered orally on day 16 of each period as a single pulse dose. Faecal samples were collected at regular interval for 112 hours and Yb concentrations determined by atomic emission spectroscopy. Total faecal collections were also made over days 16-21. TMRT (hours) was calculated using 2 algebraic methods as follows:- (1) TMRT = ΣtiMi where ti = time post dose (mid-point between faecal samples) and Mi = amount of marker excreted as a proportion of total marker excreted (Faichney, 1975): (2) TMRT = ΣtiCiΔti / ΣCiΔti where ti is as above, Δti is the difference in time between collection of successive samples and Ci = Yb concentration in each sample (Theilmans *et al*, 1978). Differences in TMRT for the diet x calculation method interaction were determined by ANOVA. Regression analysis was used to estimate relationships across diets and between calculation methods.

Results No significant difference exited between TMRT calculated using the two methods within each of the six diets but TMRT was significantly ($P<0.05$) higher at USBP inclusion rates of 480 g/kg DM and above compared with the lower inclusion levels (Table 1 - uncommon superscripts differ significantly ($P<0.05$). The quadratic relationship between USBP inclusion levels and individual pony TMRT (Faichney) illustrates that increase in USBP inclusion progressively increased TMRT in ponies (Figure 1). The linear relationship between TMRT (Faichney) and TMRT (Theilmans) illustrates the negligible difference in TMRT estimation between these two calculation methods (Figure 2).

Table 1. TMRT in ponies offered USBP based pelleted diets *ad libitum*, calculated using two algebraic methods.

	Complete pelleted diet (USBP inculsion level g/kg DM)							
Algebraic method	U0	U160	U320	U480	U640	U800	sed	Sig
(1) Faichney	35.7^{a}	35.8^{a}	35.8^{a}	41.6^{bc}	47.5^{cd}	50.2^{d}		
(2) Theilmans	36.8^{ab}	37.1^{ab}	37.6^{ab}	43.2^{c}	48.6^{cd}	51.6^{d}	2.70	*

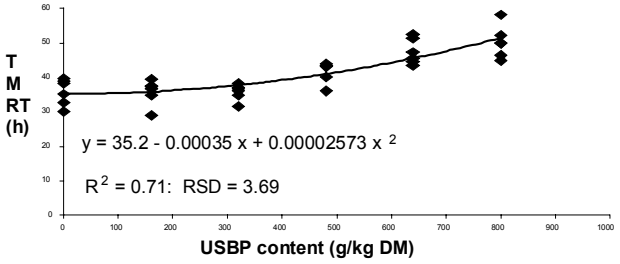

Figure 1. TMRT in relation to USBP inclusion.

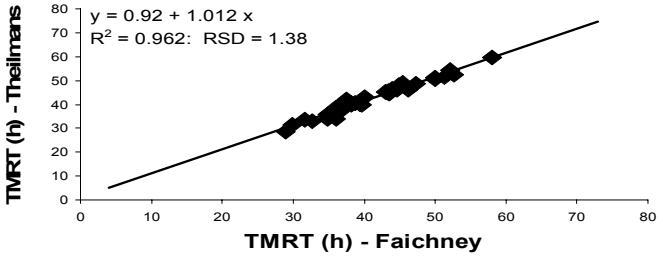

Figure 2. TMRT comparison using 2 algebraic methods.

Conclusions Increasing USBP inclusion level above 320 g/kg DM progressively increased digesta TMRT in ponies by up to 40%. Both algebraic calculation methods resulted in similar estimates of TMRT in ponies. However, since only the concentration of marker in spot faecal samples and not total faecal collections are required using the Theilmans equation, this method offers the most cost and time efficient method of determining TMRT in equine nutrition studies.

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Opportunities for breeding for disease resistance in British sheep

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Introduction Recently, the costs of eight sheep diseases were calculated by Bennett and IJpelaar (2003). The highest annual costs were estimated for enzootic abortions in ewes (EAE) £20 M and toxoplasmosis £12M. In a survey among its members, the Moredun Foundation (1997) identified internal parasites (GI parasites), sheep scab and footrot as the most important sheep diseases, but these three diseases were not analysed by Bennett and IJpelaar (2003). The aim of this study is to estimate the benefits of reductions in the incidence or severity of these diseases, using the methodology of Bennett *et al*. (1999), and the benefits of reductions in disease incidence or severity. From this, marginal economic values for resistance are calculated and applied in selection index scenarios that mimic current sheep breeding schemes.

Materials and Methods The costs of diseases were calculated from actual probabilities of an animal contracting a disease and associated costs of prevention, treatment and reduced performance, using literature values and expert opinion for disease incidence and incurred costs, assuming a national flock size of 16.4 million ewes. For calculation of marginal values of decreasing the impact of the disease it was assumed that lost production and treatment costs depend linearly on disease severity or incidence, while preventive costs (e.g. vaccination) were considered fixed. Faecal egg count (FEC), the indicator trait for GI parasites, are exponentially distributed and the marginal costs are therefore equal to the average costs (per ln(FEC)). For other traits the incidence was assumed to indicate thresholds of an underlying normally distributed trait, and the marginal values were calculated from the average costs per animals and the incidence. Genetic progress was calculated for a terminal sire (TS) breed selecting for weight and for a maternal breed selecting for weight and litter size. Genetic progress from one round of selection was predicted using standard selection index theory, following inclusion of resistance to one disease in the goal, and through measurements on ewes and/or lambs (depending on the disease). It is assumed that h^2 for resistance is 0.3 for each disease, based on literature for GI parasites and footrot, with standardised selection intensities of 1.0 in females and 2.0 in males. Benefits of disease reduction at national level were calculated assuming 100% uptake, taking into account the proportion of lambs and ewes in TS and maternal breeds. For GI parasites genetic progress was multiplied by the current unit costs. For other diseases, the genetic progress was expressed as reduction in annual incidence and multiplied by the average costs per affected animal. For all diseases discounting was used to take into account time of expression and repeated expression.

Results Total annual costs for each disease, along with each category of cost, at the National level, are shown in Table 1. The most costly disease, of those studied, is infestation with GI parasites (which under normal conditions can be controlled, but not prevented); for EAE and sheep scab variable costs are low. Costs for scab are imprecise, due to lack of data. For the three diseases with large variable costs, marginal values are £7.50/unit for GI parasites, £1.77/unit for Toxoplasmosis and £ 2.06/unit for footrot. Rounded values of £8 (GI parasites) and £2 were then included in the index calculations, and responses to selection are shown in Table 2. Selection for GI resistance will reduce FEC proportionately by 0.16 in the first round of selection, footrot by 0.005 to 0.007 in lambs (original prevalence of 0.03) and about double in ewes (from 0.0625). Reductions in the prevalence of Toxoplasmosis are small. Assuming 100% uptake, total financial returns from one round of selection for the GB sheep industry are £21M for GI parasites, £2.7M for footrot and £1.0 for Toxoplasmosis. For lower uptake levels, these benefits will be reduced proportionately.

Table 1 *Annual costs (£ M) for sheep diseases in Great Britain*

Disease	GI par	Footrot	Scab	EAE	Toxopl
Prevention	0	13	8	19	3
Treatment/control	19	4	0	0	0
Lost performance	64	8	1	1	9
Total costs	83	24	8	20	18

Table 2 *Relative responses to one round of selection*

Disease:	GI par†	Footrot‡		Toxopl‡
Group:	Lambs	lambs	ewes	ewes
TS	-0.17	-0.007	-0.014	-
Maternal	-0.15	-0.005	-0.009	-0.002

† change in average ln(FEC); ‡ change in prevalence

Conclusions Total disease costs and benefits from breeding for resistance depend on whether the disease costs are incurred through prevention measures or treatment and lost performance. Of the diseases investigated, infestation with GI parasites is the most costly disease and also the one with the greatest potential benefits from breeding. Footrot also incurs substantial costs and offers considerable benefits from breeding for increased resistance. For both diseases, most benefits are realised through maternal breeds. Costs for scab and EAE are mainly preventative, and therefore offer little scope for benefits arising from breeding. Toxoplasmosis has a low incidence and measures are only available on ewes, making it unlikely that genetic improvement of resistance will make a substantial contribution to disease control.

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Quantitative trait loci associated with parasitic infection in sheep

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Introduction Gastrointestinal nematodes cause major losses to the UK sheep industry. As anthelmintic resistance is becoming a widespread problem alternative control methods are now sought. Breeding for improved parasite resistance is a possible control method (Woolaston and Windon, 2001). As genetic markers are now widely available there is considerable potential for application to livestock breeding through quantitative trait loci (QTL) detection and subsequent marker-assisted selection schemes. Although much work is underway, there are few published studies that identify QTL associated with parasite resistance. Therefore this study aims to identify QTL associated with parasitic nematode infection in a population of Scottish Blackface lambs using faecal egg count and Immunoglobulin A activity.

Methods The study population comprised 816 straight bred Scottish Blackface lambs, which formed 9 half-sib families ranging from 23 to 141 individuals, bred over a 3-year period. The lambs were born outside and were continually exposed to mixed nematode infection by grazing. Pasture larval counts were performed prior to faecal sampling; all pastures were heavily contaminated. Faecal samples were collected in August, September and October. Faecal egg counts (FEC) were performed and recorded for both *Nematodirus* and *Strongyles* egg counts. Blood samples were collected in October from which Immunoglobulin A (IgA) activity was measured and DNA was extracted for genotyping. All animals were genotyped on chromosomes 1, 2, 3, 5, 14, 18, 20 and 21, and the probability of inheriting a particular sire chromosome at a particular position was calculated for each offspring at 1 cM intervals (Knott *et al.,* 1996). FEC traits analysed were either the individual measurement or the average animal effect across the three months. Phenotypes were then regressed upon the conditional probability that a particular haplotype is inherited from the sire along each chromosome, fitting fixed effects of year, sex, litter size, management group and day of birth as a covariate. For each regression an F-ratio of the full model including the inheritance probability versus the same model without the inheritance probability was calculated across families, the location of the QTL was indicated by the largest F value. Significance thresholds were set at both chromosome-wide (5% and 1%, using permutation testing) and genome-wide (5%, using false positive discovery rates) levels. Finally, QTL confidence intervals were constructed by taking the region of the chromosome covered when reducing the largest F-ratio by the equivalent of a LOD score of either 1 or 2 to get the 95% and 99% confidence intervals.

Results Mean FEC was 256 eggs/g. QTL significant at the 5% chromosome-wide level are shown in Table 1.

Table 1 QTL significant at 5% chromosome-wide level

Trait	Chromosome	Position (cM)	F	5% Chromosome-wide Threshold	5% Genome-wide Threshold	95% Confidence Interval
IgA Activity	20	40	2.90	2.45	2.96	25-53
IgA Activity	3	118	2.48	2.48	2.96	113-126
Nematodirus Average Effect	14	103	5.26	2.42	2.96	91-117
Nematodirus August	3	174	3.43	3.41	2.96	162-197
Nematodirus August	14	100	3.54	3.17	2.96	85-122
Nematodirus September	2	134	3.06	2.88	2.96	123-159
Nematodirus October	14	104	3.74	2.61	2.96	90-117
Strongyles Average Effect	20	10	2.64	2.44	2.96	0-27
Strongyles October	3	150	2.59	2.44	2.96	131-168

Two QTL associated with IgA activity on chromosomes 3 and 20 were significant at the 5% chromosome-wide threshold. Both QTL mapped to regions where previous knowledge suggests a link to immune function. The QTL on chromosome 3 mapped to a 13 cM interval containing IFNG and on chromosome 20 to a tight interval contained within the major histocompatibilty complex (MHC) region. A highly significant QTL linked to Nematodirus infection was identified on chromosome 14, for the average animal effect and FEC in August and October, with LOD scores of 10.0, 6.79 and 7.17 respectively. For all three phenotypes the QTL mapped to a tight region at approximately 100 cM, close to the Halothane gene. QTL associated with Nematodirus infection, significant at 5% genome–wide level, were also found on chromosomes 2, a region including the myostatin gene, and 3. Strongyle FEC analyses identified two QTL, although these were less significant than the Nematodirus QTL. These QTL were on chromosomes 3 and 20, again the mapping interval on chromosome 20 is within the MHC region and the interval on chromosome 3 contains IGF1.

Conclusion In conclusion this study identified several QTL associated with parasitic infection across 4 chromosomes. These QTL appear to be linked with locations associated with immune function and cell growth and specialization. Further work will involve a quantitative genetic analysis of this data and QTL analyses involving other parasite species.

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Bayesian segregation analysis of osteochondral diseases in pigs to determine major gene role

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Introduction Osteochondrosis (OC) in pigs is an abnormal condition in the bone development which has high economic and welfare implications. Select for OC resistance would be difficult to achieve due to low polygenic heritability (~0.06 – 0.15; Kadarmideen *et al.,* 2004), unless a major gene exists. Segregation analysis provides evidence for major gene using only phenotypic data. Bayesian Segregation Analysis (BSA) method via Gibbs sampling is suitable for pedigreed animal population as shown in the application of this methodology to milk flow in dairy cattle (Ilahi and Kadarmideen, 2004). The main objective of this study was to conduct a BSA to determine whether osteochondral disease in pigs has mixed inheritance (major + polygenes).

Materials and methods Data on OC were obtained from the company, SUISAG, which conducts a national pig breeding program in Switzerland. Kadarmideen *et al.,* (2004) provided detailed explanations of the breeding programs, station-tested traits, including osteochondral lesion observations. OC lesions were recorded with a score of: 1='Normal' and 4 or 5 or 6= 'severely affected', depending on the lesion. OC lesions considered here were from 5 parts of the front and hind leg bones (see Table 1 for names). Data (from 2002 and 2003) consisted of OC lesions on 1163 station-tested pigs and were characterized by 194 boars and 697 dams, 23 year-month of testing, 59 stable periods, 4 breeds and 2 sexes. Pedigrees were traced as far back as possible which included 2891 animals. Models for all lesions fitted fixed effects together with major gene, polygenes and residual component. BSA of OC lesions were implemented using MaGGic software package (Janss *et al.,* 1995). Three replicates of Gibbs chains of 50000 cycles each were run, using a spacing of 50 cycles, obtaining 1000 Gibbs samples per chain for a total of 3000 samples. Posterior means and standard deviations were based on 3000 samples.

Results and discussion Posterior means (PM) and standard deviations (PSD) of parameter estimates of OC lesions from BSA are presented in Table 1. Results showed a presence of major gene with significant additive effect (a) for CLH, CMH, RUP, CMF and DEU (range 0.466-0.587) and high additive genetic variances, σ_a^2, (0.011 to 0.048) compared to the polygenic variances (σ_u^2). Therefore, the heritabilities at the major gene (h_m^2) were much higher than the heritabilities from the polygenes (h^2) for all lesions. The dominance variances at the major gene (σ_d^2) for all diseases ranged from 0.022 to 0.058. The frequencies of unfavorable allele that increases the incidence of the disease (f_A) were mostly lower than the frequencies of favorable alleles (f_B) and ranged from 0.28 to 0.58. The estimated dominance effects at the major gene (d) ranged from -0.587 to -0.468. The total major gene variances, σ_m^2 ($=\sigma_a^2+\sigma_d^2$), ranged from 0.105 to 0.231.

Table 1 Bayesian inference of major genes for osteochondral lesions: [1]Condylus medialis humeri (CMH); condylus lateralis humeri (CLH); radius and ulna proximal (RUP); distal epiphyseal cartilage of ulna (DEU); and condylus medialis femoris (CMF) in 1163 station-tested pigs

	CLH[1]		CMH[1]		RUP[1]		CMF[1]		DEU[1]	
	PM	PSD	PM	PSD	PM	PSD	PM	PSD	PM	PSD
σ_u^2	0.002	0.001	0.002	0.001	0.007	0.002	0.002	0.002	0.001	0.001
σ_a^2	0.048	0.013	0.048	0.013	0.011	0.004	0.163	0.017	0.048	0.013
σ_d^2	0.058	0.007	0.058	0.007	0.022	0.004	0.068	0.003	0.058	0.007
σ_m^2	0.105	0.020	0.105	0.020	0.033	0.008	0.231	0.016	0.105	0.020
h^2	0.065	0.052	0.065	0.052	0.948	0.047	0.066	0.067	0.065	0.052
h_m^2	0.402	0.041	0.402	0.041	0.441	0.019	0.644	0.029	0.402	0.041
f_A	0.712	0.030	0.713	0.030	0.802	0.026	0.459	0.031	0.713	0.021
f_B	0.288	0.030	0.288	0.030	0.198	0.026	0.541	0.030	0.288	0.021
a	0.587	0.007	0.587	0.007	0.466	0.006	0.530	0.008	0.587	0.007
d	-0.587	0.008	-0.587	0.008	-0.468	0.007	-0.527	0.011	-0.587	0.008

Conclusion BSA of osteochondral diseases in station-tested pigs showed presence of major genes with significant additive and dominance effects as well as additive genetic variance compared to the polygenic variance. This indicates that this disease could be under the control of very few loci. This is the first study to report evidence of major genes for osteochondral lesions in pigs.

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Estimation of genetic variation in Δ9-desaturase enzyme activity in dairy cows

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Introduction The Δ9-desaturase enzyme adds a *cis*-9 double bond to fatty acids in adipose and mammary tissue. In the mammary gland, this reaction converts $C_{14:0}$ to $C_{14:1}$, $C_{16:0}$ to $C_{16:1}$, $C_{18:0}$ to *cis*-9 $C_{18:1}$ (oleic acid), and *trans*-11 $C_{18:1}$ (vaccenic acid) to *cis*-9, *trans*-11 conjugated linoleic acid (CLA). Oleic acid is of interest in human nutrition as a component of the "Mediterranean diet" and CLA has been shown to have numerous health benefits. Conversion of vaccenic acid to CLA in the mammary gland accounts for 75-80% of CLA found in milk (Lock and Garnsworthy, 2002), but activity of the Δ9-desaturase enzyme varies among individual cows irrespective of dietary manipulations (Lock and Garnsworthy, 2003), suggesting that it may have a genetic component. The objective of this study was to estimate the genetic variation in Δ9-desaturase activity in dairy cows using milk fatty acid profiles.

Materials and Methods A database consisting of 499 paternal half-sib families varying between 1 and 29 daughters/sire was used. Cows (Holstein-Friesian; n=1520) were selected from 281 commercial farms and milk samples (one per cow) were collected by NMR field technicians. Proportions of individual fatty acids (FA; g/100 g total FA) in these samples were determined by gas chromatography using the extraction and analysis procedures of Feng et al. (2004). Indices of Δ9-desaturase activity (DI) were calculated for each pair of fatty acids by expressing each product as a proportion of the product plus precursor, i.e. $DI_{14} = C_{14:1}/(C_{14:0} + C_{14:1})$, $DI_{16} = C_{16:1}/(C_{16:0} + C_{16:1})$, DI_{18} = *cis*-9 $C_{18:1}/(C_{18:0}$ + *cis*-9 $C_{18:1})$ and DI_{CLA} = *cis*-9, *trans*-11 CLA/(*trans*-11 $C_{18:1}$ + *cis*-9, *trans*-11 CLA), and the sum of products as a proportion of the sum of precursors and products (DI_{TOTAL}). A mixed linear model was fitted to the data using the restricted maximum likelihood method (REML; Genstat 6, Lawes Agricultural Trust) and variance components and mean values for the fixed effects were estimated for each index. Functions of the variance components of particular interest were phenotypic variance, additive genetic variance and heritability. Wald statistics were used to test the significance of fixed effects (farm, season, parity and days postpartum, pp) and a likelihood ratio statistic was used to test the random effect of sire.

Results Mean indices of desaturase activity (±s.e.) were: DI_{14} 8.0 (0.05); DI_{16} 6.7 (0.05); DI_{18} 73.8 (0.09); DI_{CLA} 25.2 (0.11); and DI_{TOTAL} 41.0 (0.13). DI_{14}, DI_{18} and DI_{CLA} had moderate, significant estimates for heritability (Table 1). Season had a significant (P< 0.001) effect on all indices and specific contrasts show that desaturase activity was lower during spring than any other season. Lower parity was associated with reduced (P<0.001) desaturase activity, with the exception of DI_{CLA}. DI_{14} and DI_{CLA} increased with days pp; the other indices decreased (P<0.001). Farm had a significant (P<0.001) effect on all indices; for example, the farm average for DI_{CLA} ranged from 19.0g/100g to 43.15g/100g (s.e.d. 2.77).

Table 1 Estimate of variance components and heritability estimates after fitting fixed effects into the model

Index	σ^2_S (s.e.)	σ^2_e (s.e.)	σ^2_A	σ^2_P	h^2
DI_{14}	0.24 (0.10)	2.91 (0.14)	0.96	3.15	0.30***
DI_{16}	0.01 (0.06)	2.84 (0.13)	0.04	2.84	0.01
DI_{18}	0.51 (0.29)	10.24 (0.48)	2.04	10.75	0.19*
DI_{CLA}	0.94 (0.41)	12.25 (0.58)	3.76	13.19	0.29**
DI_{TOTAL}	0.09 (0.35)	16.29 (0.74)	0.36	16.28	0.02

σ^2_S, sire variance; σ^2_e, residual variance; σ^2_A, additive genetic variance; σ^2_P, phenotypic variance; P<0.05,*; P<0.01,**; P<0.005,***

Conclusions This analysis provides evidence that additive genetic variance is responsible for a substantial proportion of the phenotypic variation in Δ9-desaturase activity in dairy cows. Desaturase activity could, therefore, be used in future breeding programmes to increase the CLA and mono-unsaturated fatty acid contents of milk. The low heritability of the DI_{16} and DI_{TOTAL} indices, however, reflects the high degree of variation in $C_{16:0}$ supply from dietary and body fat sources. Effects of season, parity, days postpartum and farm probably also reflect changes in diet and body fat mobilisation.

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The relationship between fertility, rump and other type traits in Holstein Friesian cows

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Introduction Cattle breeders, farmers and vets believe that the decline in fertility seen in recent years can be partially attributed to changes in rump angle with selection being for more angular cows. This suggests that animals with pin bones that sit above the hip bones (high rump angle) will have poorer fertility. Few studies have shown a significant relationship between fertility and rump traits. This study investigates the popular belief that high rump angle equates to poor fertility by examining the genetic and phenotypic correlation between rump angle and fertility traits. The relationship between rump angle and fertility was also examined to see if there was an intermediate optimum or threshold of rump angle for good/bad fertility. The correlation of other type traits (udder and composite traits) with fertility was also examined to see if they had potential to add information to the estimation of fertility breeding values.

Material and methods Direct fertility traits were defined using information on inseminations and calvings from national milk recording databases, including: (i) calving interval, **CI**, (ii) number of days to first insemination, **DFS**, and, (iii) a binary trait measuring a return to service within 56 days of first insemination, **NR56**. Based on a preliminary analysis of the correlations between fertility PTAs and type PTAs, six linear type and composite traits were chosen for further investigation; namely rump angle (**RA**), rump width (**RW**), rear udder height (**RUH**), udder support (**US**), and the composite traits of mammary system (**MAM**) and legs and feet (**L&F**). After edits the dataset contained 29,212 cow records with 57,530 animals in the pedigree file. (Co)variance components were estimated by residual maximum likelihood (REML), using VCE4 (Neumaier & Groeneveld, 1998). In order to ascertain whether there is an intermediate optimum or if **RA** is only related to fertility after a threshold value has been reached, the relationship between rump angle and fertility was examined further by fitting adjusted **RA** as a linear and quadratic effect in the model for each of the fertility traits and analysing with an animal model in PEST (Groeneveld et al., 1990). The significance of the solutions for the linear and quadratic **RA** covariate was tested using a two-sample t-test.

Results The majority of the genetic correlations between the type traits and fertility were not significantly different from zero (Table 1). However, **CI** was genetically correlated with **RA** suggesting animals with high pins have a longer calving interval. However the correlation between **RA** and the components of **CI** (**DFS** and **NR56**) was not significant. **CI** was correlated with **MAM** (0.14) and **US** (0.25) was genetically correlated with **CI** with a better mammary system resulting in a longer calving interval. This may be considered counter-intuitive as animals with good udders are generally in good health and therefore expected to have less fertility problems. However, a good mammary system is favourably correlated with higher 305 day milk yields (0.14, Brotherstone unpublished). Many studies have shown that higher milk yields result in longer calving intervals (e.g. Veerkamp et al., 2001). Therefore, it could be the relationship between yield and **CI** that is mediating the unfavourable relationship between udder traits and **CI**. **L&F** was favourably correlated to **NR56**, suggesting that animals with good **L&F** score would be less likely to return to service.

Table 1 Estimates of genetic correlations for CI, DFS, NR56 with RA, RW, RUH, US, L&F and MAM

	RA	**RW**	**RUH**	**US**	**L&F**	**MAM**
CI	-0.1556 ±0.0684	-0.0109 ±0.0744	0.0945 ±0.0761	0.2458 ±0.0779	-0.0101 ±0.0504	0.1421 ±0.0530
DFS	0.0925 ±0.0635	-0.0482 ±0.0637	0.0456 ±0.0591	0.1295 ±0.0691	-0.1229 ±0.1735	0.0751 ±0.1344
NR56	-0.0069 ±0.1190	-0.0624 ±0.1380	-0.0913 ±0.1270	-0.0922 ±0.1210	-0.2048 ±0.0940	-0.1341 ±0.1040

There was no significant linear or quadratic relationship between change in **RA** and fertility. The lack of evidence of such a relationship between **CI** and **RA** was surprising given the significant genetic correlation between the two traits, suggesting that the genetic correlation is being mediated through some other biological mechanism that is not included in this analysis.

Conclusions This study has shown that there is little relationship between some linear type traits and fertility in UK dairy cows. Analysis of a non-linear relationship between **RA** and **CI** showed that change in **RA** did not have a significant effect on **CI.** This challenges the anecdotal evidence from the farming sector that cows with poor fertility (both cyclicity and conception) will have higher pins and poor legs and feet. **MAM** was correlated with fertility but this was not adjusted for production. **L&F** was significantly correlated with fertility and could be a useful addition to the evaluation of fertility in the UK.

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An investigation into the genetic relationship of reproduction traits of sows under different mating method (artificial insemination versus natural service)

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Introduction Falconer and MacKay (1996) note that the measurement of a trait in two different environments may be considered as two traits rather than one. In this way it is possible, through the calculation of genetic correlations, to estimate to what extent the two measurements under different conditions are in fact the same characteristic and are determined by the same genes. The widespread use of AI in pig production has faltered due to problems with dilution and cryopreservation of semen and yet an industry split, where breeders and nucleus herds use AI extensively but multipliers and commercial producers do not, is becoming apparent. Reproductive traits are increasingly seen as an important component of overall pig production and while the genetic correlation between reproductive and production traits has been explored, little work has focused on the genotype by environment interaction of such fertility traits. The present study reports the genetic relationship of number born alive (NBA) in litters conceived naturally and by AI, and in rate of weaning to first service ($WTFS^{-1}$).

Materials and methods Data consisted of 28,550 Landrace and 42,361 Large White farrowing records of litters 1-4 from the Cotswold Pig Development Company (currently JSR Genetics) nucleus herds between 1979 and 2001. Y variables were NBA and weaning to first service interval (WTFS) and the variance components of the linear models were estimated using ASReml. No significant deviation from one was found in the correlation of NBA over litters 1 and 2-4 allowing the first four litters to be analysed together. The distribution of WTFS was highly skewed and a Box Cox analysis of the family of power transformations was undertaken. Finally, multivariate analysis of NBA under AI and natural service, a random mate type factor assignment to NBA, univariate analysis of transformed WTFS, and multivariate analysis of transformed WTFS were performed. Fixed effects were litter, number of inseminations in a service event and unit/year/week; farrowing to weaning interval was a covariable and service boar was added as a random effect.

Results NBA from both mating methods increased steadily and in tandem over the time spanned by the data, the lack of a sudden jump in mean or 'overtaking point' indicating an absence of 'watershed' improvements in AI with regard to NBA. The Box Cox analysis revealed that $WTFS^{-1}$, pertaining to the rate of return, gave the highest likelihood of the biologically justifiable transformations. Heritability estimates are given in table 1 and are in broad concurrence with literature estimates for these traits. The genetic correlation of NBA under AI and natural service was 0.752 (P=0.048) for Large White and 0.627 (P=0.053) for Landrace (P value denotes significance of difference from one). Pooling the estimates gave a weighted mean correlation of 0.71 (s.e. = 0.103) for both breeds. When the model was re-run with the r_G fixed to 0.71, the significance from $r_G = 0.999$ calculated by twice the difference in log-likelihoods elicited a P value of 0.007 indicating that the genetic correlation is significantly less than one with no evidence of a difference between breeds. Substituting the mating method for a randomly allocated factor in the same proportion resulted in the genetic correlation being bound to 0.999 in both breeds. Univariate analysis of $WTFS^{-1}$ yielded heritability estimates of 0.071 and 0.053 in the Large White and Landrace respectively. The genetic correlation of $WTFS^{-1}$ over the two mating methods were 0.499 and 0.851 in the Large White and Landrace respectively, but were not significantly different from one in either instance.

Table 1 Heritabilities, common environmental effects, repeatabilities and boar variances for NBA and $WTFS^{-1}$ under AI and natural service (NS) in Large White and Landrace breeds[#]

	Large White		Landrace		Large White		Landrace	
	NS NBA	AI NBA	NS NBA	AI NBA	NS $WTFS^{-1}$	AI $WTFS^{-1}$	NS $WTFS^{-1}$	AI $WTFS^{-1}$
h^2	0.125*	0.098*	0.054*	0.056*	0.107^{ns}	0.063*	0.108^{ns}	0.057*
c^2	0.028^{ns}	0.076*	0.106*	0.090*	0.061^{ns}	0.042*	0.029^{ns}	0.091*
Repeatability	0.125*	0.174*	0.159*	0.114*	0.168*	0.106*	0.138*	0.148*
Boar effect	0.005^{ns}	0.040*	0.006^{ns}	0.014*	-	-	-	-

[#] *or ^{ns} denotes the significance of the estimate from zero (P<0.05 and P>0.05 respectively)

Conclusions A genetic correlation significantly less than one for NBA across mating method indicates that NBA is affected by a different array of genes in the female pig under natural and artificial insemination. Although probably not sizeable enough to warrant alteration of policy, breeders should nevertheless be aware of the re-ranking of sows for NBA under mating method. The genetic correlation of $WTFS^{-1}$ showed no significant deviation from one as would be expected from any variable prior to the mating method.

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Inverdale fecundity gene ($FecX^I$) influences twin ovulation incidence in pubertal ewe lambs from Texel sires and Cheviot or Scottish Blackface dams

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Introduction A key to long-term sustainable enhancement of viable livestock production is the introduction of genetic traits that ensure that fertility and meat quality characteristics are compatible with farming environments and market needs. For example, the sheep industry could benefit if daughters of hill-breed ewes were of a crossbred genotype that enhances both carcass characteristics and fertility traits. Use of sires that confer better conformation is an option but does not significantly boost prolificacy. Introduction of the 'Inverdale' fecundity gene could change this. On a flock basis in the Romney breed, mean ovulation is increased by 1.0 and litter size by 0.6 in adult ewes carrying a single copy of this gene (designated as $FecX^I$ because it is on the X chromosome; Davis *et al*. 1992). Carrier males transmit it to all of their female offspring, these being heterozygous carriers of the gene unless it also is maternally inherited. In the latter instance, young would be infertile the homozygous genotype confers an undesirable 'streak ovary' phenotype. Although a number of sheep breeds world-wide exhibit significant 'single gene' effects on ovulation and litter size (Montgomery *et al*. 2001), Scottish hill sheep breeds show no evidence of this. Consequently, all ewe lambs generated by crossing these hill ewes with a ram carrying the Inverdale gene should be heterozygous. To ascertain whether such animals exhibit enhanced fecundity, an on-farm study investigated ovulation incidence in cyclic ewe lambs born to Cheviot or Scottish Blackface ewes that had been bred to Texel rams carrying a single copy of the 'Inverdale' gene.

Materials and methods In late Spring - early Summer 2003, two Scottish flocks of hill ewes, one Cheviot and the other Scottish Blackface, gave birth to lambs sired by Texel rams that were either carriers or non-carriers of the Inverdale gene and these lambs were reared commercially. When the lambs were about 7 months old, ovarian activity in the females was recorded via laparoscopy on one or two occasions. Animals with a detectable corpus luteum (CL) at first examination were not re-examined; those without a CL at that time were re-examined 9 or 10 days later. All observations were by a single experienced operator. Live-weight data and body condition scores were recorded at the time of the first examination. Live-weight data were compared using ANOVA, body condition scores (5-point scale) via Kruskal-Wallis test and ovulation data (expressed as proportions) by Chi-square analysis.

Results Data presented are mean ± s.e.m. values or proportions, as appropriate. None of the lambs in the study had more than 2 corpora lutea. In the Cheviot flock, of 44 Inverdale- carrier females that had ovulated recently, 16 (proportionately 0.36) had 2 corpora lutea. Corresponding data for non-carrier flockmates were 16 and 1 (proportionately 0.063 with 2 corpora lutea; $P<0.05$). In the Scottish Blackface flock, none of the 13 non-carriers that ovulated bore two corpora lutea, compared to 17 of 40 Inverdale-carrier flockmates ($P<0.05$). Liveweight and body condition score data are presented in Table 1. In the Scottish Blackface flock, Inverdale carriers that had just one CL were significantly lighter than their twin-ovulating counterparts; this was not the case in the Cheviot flock.

Table 1 Live weight and body condition data for cyclic 'Control' and 'Inverdale' ewe lambs from hill sheep flocks

		Cheviot			Scottish Blackface		
Genotype	CL No.	n	Wt (kg)	BCS	n	Wt (kg)	BCS
Control	1	15	37.6 ± 0.62^{a}	2.40 ± 0.08^{c}	13	36.7 ± 1.55^{ab}	2.40 ± 0.13^{ab}
Control	2	1	43	3	0		
Inverdale	1	28	36.0 ± 0.85^{a}	1.91 ± 0.07^{d}	23	35.7 ± 0.92^{a}	2.40 ± 0.09^{a}
Inverdale	2	16	36.7 ± 0.56^{a}	1.98 ± 0.08^{d}	17	39.7 ± 1.03^{b}	2.71 ± 0.10^{b}

Within columns, data with different superscripts differ pairwise as follows: $^{ab}P<0.05$; $^{cd}P<0.01$

Conclusions Among ewe lambs that were cyclic at laparoscopy, those carrying the Inverdale gene had a higher incidence of twin ovulations than observed among non-carrier flockmates. The fact that none of the lambs in the study had more than 2 corpora lutea is encouraging as the release of, for example, 4 or 5 ova would be undesirable. Investigation of ovulation and litter size in the subsequent breeding season will provide additional information on the likely impact of this gene on the prolificacy of crossbred females from hill ewe flocks in Britain.

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The eating quality of Scottish beef – a whole chain approach

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Introduction There are many studies that show that breed, gender, age and feeding regime influence animal growth rate, meat yield and composition. These factors, together with slaughter and post-slaughter conditions, are thought to influence tenderness and flavour attributes of meat (Thompson, 2002)). Low variability is highly desirable and processes such as 'A blueprint for improved consistent quality beef' (MLC, 1999) in the UK has attempted to improve the level and consistency of beef eating quality. This project was designed to test a package of best-practice techniques, both on-farm and in-abattoir, on the eating quality of Scottish beef as assessed by a trained sensory panel and a recruited take-home panel.

Materials and methods Thirty two farms in Scotland produced cattle to the enhanced on-farm protocol. They were steers or heifers only, with a minimum 75% beef genome which had been suckled for least 5 months. They were finished on grass, or mainly preserved grass-forage with concentrates in the winter and grew at greater than 0.8 kg d^{-1} in the finishing period. Farmers were given written guidance for on-farm protocols and were inspected at least once during the growth period. Licenced hauliers, who were part of a QA scheme giving particular regard to good welfare practices, transported animals to the abattoir. Cattle from two farms were slaughtered through each of two commercial abattoirs on eight occasions between March and December 2003. Cattle with no prior known history were randomly selected from two farms submitted on those days to act as a basal group. In the abattoir, the groups of cattle were divided between an enhanced abattoir treatment and a standard abattoir treatment. In one abattoir the advanced treatment was high voltage electrical stimulation (HVES) (which could be applied to one carcass side after carcass splitting and not to the other which formed the basal treatment side) and in the other low voltage electrical stimulation (LVES) and hip suspension. Carcasses were monitored through the abattoir for weight, grade and pH at two and 48 hours post-slaughter. Loins (*m. longissimus thoracis et lumborum*) from two sides from each farm and abattoir treatment were selected for submission to the taste panel. Enhanced-processed samples had to be from carcasses weighing 260-400kg, with a minimum of fat class 3 and conformation of E, U or R having a pH greater than 6.00 at 2h and less than pH 5.80 at 48h postmortem. Basal samples were taken at random from the specified groups. Samples were frozen after 7 (basal) or 21 (enhanced) days post-slaughter, stored until balanced sets had accumulated then thawed overnight cut into 20mm thick steaks and grilled to a centre temperature of 74ºC. Two samples from one enhanced farm with both basal and enhanced abattoir treatment and two from a basal farm were tested in the same session. They were scored on an 8-point scale for texture, juiciness, beef flavour intensity and abnormal flavour intensity. The take home panel were given these same samples, one a week over four weeks, and were asked to cook samples as normal and to score samples on an 8-point category scale for the acceptability of the same attributes as the taste panel with the addition of overall acceptability. The trained taste panel results were analysed, adjusted for assessor and order of testing, using Genstat and a model with several random (error) terms and fixed terms fitted with Residual Maximum Likelihood (REML).

Results Cattle were sourced within specification and the experimental design was effective in detecting statistically significant differences within attributes of 0.1-0.2 units on the 1-8 scale. Pre-slaughter enhanced protocols had little effect on overall mean eating quality scores as assessed by either the trained taste panel or the take-home panel. It is probable that the basal farms sourced by these abattoirs were rearing cattle to a reasonable specification within a registered scheme. There was a clear and highly significant effect of abattoir processing treatment on the eating quality of the meat, the enhanced treatment producing an increase in rating for texture of over one unit, which is very large in sensory terms. The effect on flavour was an increase of 0.2 units, which is still highly significantly different. Carcasses from both basal and enhanced farms and both plants responded in a similar manner.

Sensory characteristics of beef, assessed by a trained taste panel, according to processing category and abattoir

			Sed	Sig.	Plant 1		Plant 2		Sed	Sig	
abattoir	Basal	Enhanced			Basal	Enhanced	Basal	Enhanced		Plant	Interac
n	128	128			64	64	64	64			
Texture	4.06	5.09	0.077	***	3.95[a]	5.25[b]	4.18[a]	4.92[b]	0.178	ns	***
Juiciness	4.75	4.68	0.057	ns	4.62[a]	4.42[a]	4.88[b]	4.93[b]	0.100	***	*
Beef flavour	3.59	3.78	0.036	***	3.55	3.76	3.64	3.80	0.077	ns	ns
Abnormal flavour	2.79	2.76	0.043	ns	2.72	2.74	2.85	2.79	0.111	ns	ns

Conclusions A combination of HVES, or LVES and hip suspension, with two weeks longer conditioning time, produced a highly significant improvement in beef loin steak eating quality, both methods resulting in meat of similar eating quality and reduced variability.

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The eating quality of Scottish lamb – a whole chain approach

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Introduction There are many studies that show that breed, gender, age and feeding regime influence animal growth rate, meat yield and composition. These factors, together with slaughter and post-slaughter conditions, are thought to influence tenderness and flavour attributes of meat (Thompson, 2002)). Low variability is highly desirable and processes such as 'A blueprint for improved consistent quality lamb' (MLC, 1999) in the UK have attempted to improve the level and consistency of lamb eating quality. The purpose of this trial was to test whether the adoption of several key enhanced on–farm and in-abattoir practices led to improved eating quality throughout the lamb production season, especially for heavier, lean carcasses.

Materials and methods Twenty two participating farms selected wether lambs at weaning that were above average in terms of weight and leanness. These lambs were finished on a planned system that avoided growth and dietary checks with slaughter from Sept-March. At slaughter, at each of three participating abattoirs, enhanced lambs were selected that were in a target carcass weight range of 16-21 kg for Blackfaces and 21-26 kg for crossbreds, and were at a target fat class of 3L. Carcasses from other flocks sent to the abattoir on the same day, which were generally lighter, were chosen as basal samples. At the abattoir, the carcasses from both enhanced and basal groups were subjected to either an enhanced or a basal abattoir procedure. Basal samples were allowed to progress straight to the chiller without any post-slaughter interventions. Enhanced processed samples were electrically stimulated (either low or high voltage depending upon abattoir). At boning, left carcass side loins were cut, vacuum packed and conditioned for five days, right side loins were cut, vacuum packed and conditioned for ten days. Samples were frozen, stored until balanced sets had accumulated then thawed overnight and cut into ten, 2cm thick steaks and grilled to a centre temperature of 75ºC. At each session, trained taste panellists received two samples from left and right sides of the same lamb. Hence, both samples had received the same processing procedure for both farm and abattoir. In the three panels immediately following, they received similar samples, but with either a different farm or different abattoir processing regime, until all four combinations of basal or enhanced farm or abattoir regimes had been tested. Samples were scored on an 8-point scale for texture, juiciness, lamb flavour intensity and abnormal flavour intensity. The results were analysed, adjusting for assessor and order of testing, using Genstat and a model with several random (error) terms and fixed terms fitted with Residual Maximum Likelihood (REML).

Results The experimental design was effective in detecting, as statistically significant, differences of 0.1-0.2 units in eating quality attributes on the 1-8 scale used by the trained taste panel. Pre-slaughter enhanced protocols had little effect on sensory attributes. Hence, lambs raised under standard conditions in an assurance scheme and delivered to an abattoir with due regard to welfare, will produce carcasses of good eating quality with texture and juiciness averaging around 5 on an 8-point scale. It is possible to select heavier carcasses (>16 kg for Blackface and >23 kg for crossbreds) with acceptable fatness (3L) without deleteriously affecting texture or flavour, the main components of eating quality. There was a suggestion that this meat may be less juicy and this needs further investigation. Seasonal effects were minor. Post-slaughter enhanced processing and conditioning had a major, positive impact on most attributes of lamb eating quality and reduced variability in tenderness. The improvement in eating quality due to post-slaughter enhancement occurred across all breeds, abattoirs and pre-slaughter treatments. Electrical stimulation had a much greater impact in improving meat texture than the length of time meat was conditioned (see Table 1).

Table 1 The sensory characteristics of lamb, assessed by a trained taste panel, according to Processing and Conditioning time (days)

Processing	Basal		Enhanced		Sed	Sig.
Conditioning time (days)	5	10	5	10		Interaction
N						
Texture	4.34	4.79	5.85	6.06	0.145	*
Juiciness	5.01	4.87	4.87	4.97	0.084	*
Lamb flavour	3.79	3.81	3.82	4.00	0.070	*
Abnormal flavour	2.77	2.85	2.84	2.70	0.086	*

Conclusions Post-slaughter enhanced processing and conditioning had a major, positive impact on most attributes of lamb eating quality and reduced variability in tenderness. This improvement occurred across all breeds, abattoirs and pre-slaughter treatments. Electrical stimulation had a much greater impact in improving meat texture than the length of time meat was conditioned.

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The eating quality of Scottish pigmeat - a whole chain approach

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Introduction Whilst many of the on-farm factors identified as enhancing pigmeat meat eating quality are already standard commercial practice, variability in quality is still a problem whose reasons are poorly understood. Particular uncertainty exists about the effect on eating quality of increasing slaughter weight, a current development which facilitates reduced cost of production by spreading carcass overhead costs between more kg of saleable meat. However, this strategy means that pigs will be older at slaughter, which carries uncertainties about the risk of increased toughness and boar taint. In targeting a market for branded pigmeat of high eating quality, there may also be beneficial strategies for adoption in carcass selection and post-slaughter management. These questions were addressed as part of a research project on the improvement of meat eating quality in the Scottish red meat sector.

Materials and methods A total of 16 farms, all conforming to current best practice defined by the Scottish Farm Assurance Scheme, produced contemporary pigs of either heavy (~90 kg deadweight) or conventional (~75 kg) weight at slaughter. From each farm, 8 pigs were selected at the abattoir to give full representation of a factorial design including slaughter weight, gender and carcass quality selection criteria (based on P2>12mm and muscle pH_{45} >6.0). Selected carcasses were split to provide a within-animal comparison of Enhanced processing (hip suspension and 10-day conditioning) against Basal processing (achilles suspension and 5-day conditioning). 256 meat samples from 128 pigs were subject to assessment by a trained sensory panel. 64 meat samples from 32 pigs, derived from a representative subset of 4 of the 16 farms, were also subject to assessment by a consumer panel in take home studies. The selected carcasses were cut into primals at 24h and a sample loin taken. After conditioning, loins were stored at –20ºC until sensory analysis, with frozen loins bandsawn to give 20mm loin steaks. Prior to assessment, samples were thawed overnight, then grilled to a centre temperature of 72.5ºC. Samples were scored on an 8-point scale for texture, juiciness, pork flavour intensity and abnormal flavour intensity. The take home panel were given samples, one a week over four weeks, and asked to cook samples as normal and to score them on an 8-point scale for the acceptability of the same attributes as the taste panel with the addition of overall acceptability. The trained taste panel results were analysed, adjusted for assessor and order of testing, using Genstat and a model with several random (error) terms and fixed terms fitted with Residual Maximum Likelihood (REML).

Results The trained panel detected no effect of slaughter weight on intensity of quality attributes, whilst the consumer panel scored eating quality of meat from heavy pigs more highly (Table 1). Selection of carcasses post-slaughter according to quality thresholds for fatness and muscle pH resulted in samples differentiated primarily by fatness, as a result of the consistently good pH results in the source population. The 4mm difference in fatness resulted in small but significant improvements in texture and flavour, as assessed by a trained sensory panel. In consumer panel assessments, significant benefits for eating quality were counterbalanced by higher levels of perceived fat, which were viewed as undesirable. Enhanced post-slaughter processing, a combination of hip suspension and prolonged ageing, gave conflicting outcomes for objective sensory attributes assessed by the trained sensory panel, with enhanced tenderness but reduced juiciness. However, the consumer panel scored positive benefits for all hedonic attributes of eating quality.

Table 1 The sensory characteristics of pigmeat, assessed by a trained taste panel or take home panel, according to slaughter weight and gender

	Light (75 kg dwt)		Heavy (90 kg dwt)		Sed	Sig.		
Eating Quality -Panel	Male	Female	Male	Female		W	G	G.W
Texture	4.44	4.21	4.31	4.13	0.116	ns	**	ns
Juiciness	4.66	4.27	4.54	4.32	0.115	ns	***	ns
Pork flavour	3.72	3.74	3.86	3.68	0.056	ns	ns	**
Abnormal flavour	3.10	2.86	3.10	3.03	0.110	ns	*	ns
Eating Quality -Family								
Tenderness	5.67	5.76	6.32	6.30	0.256	***	ns	ns
Juiciness	5.33	5.47	6.11	6.08	0.260	***	ns	ns
Flavour	5.76	5.93	6.30	6.35	0.242	*	ns	ns
Overall acceptability	5.57	5.86	6.30	6.30	0.253	**	ns	ns

Conclusions In pigs of an appropriate genotype, and with good nutrition and management, increasing slaughter weight to a mean of 90 kg deadweight had no detrimental effect on eating quality attributes and did not significantly increase risk of boar taint. Selection for a minimum threshold of carcass fat appeared to offer some possibilities for potential niche marketing of higher eating quality pigmeat, but only if combined with fat trimming of the product. In view of the very positive improvements obtained by post-slaughter treatments, the relative contributions of hip suspension and prolonged ageing justify further evaluation.

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The effect of genotype, carcass weight and fat classification, and pelvic hanging technique on meat quality

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Introduction Currently 53 and 47% of prime beef production in Northern Ireland originates from beef and dairy herds, respectively. The beef herd comprises of a diverse range of genotypes which result in major variability in carcass weights, conformation and fat classification. The present study was undertaken to investigate the effect of genotype, carcass weight and fat classification, and pelvic hanging technique on meat quality.

Materials and methods The experiment involved a total of 41 steers, consisting of two breeds, Holstein (Hol) (initial weight range 409-639 kg) (100% Holstein) and Charolais (CH) (initial weight range 440-669 kg) (>75% Charolais). All animals were offered grass silage *ad libitum* supplemented with 4.5 kg concentrate for 98 days prior to slaughter. At slaughter, one side of each carcass was randomly allocated to one of two pelvic hanging techniques, namely Achilles tendon (AT) or tenderstretch (TS) (Carcass suspended through the aitch bone from 0.75 to 48 hours post-mortem). Meat quality was assessed according to Lively *et al.* (2005). These data were analysed using Genstat regression procedures with a model including the factor breed and either carcass weight or fat class as independent variates and their interactions. Predicted values were calculated for genotype at a range of carcass weights or fat classifications.

Results Genotype had no effect (P>0.05) on liveweight gain. However, CH cattle had a higher kill-out proportion relative to Hol cattle. The effects of genotype and carcass weight on animal performance and meat quality are presented in Table 1. At specified carcass weights CH cattle had a lower final live weight (P<0.001), fat classification (P<0.01), kidney, channel and cod (KCC) fat (P<0.001), marbling score (P<0.001) and sarcomere length, but had higher cooking loss (P<0.001) and Warner Bratzler Shear Force (WBSF) (P<0.001). Increasing carcass weight at slaughter increased conformation (P<0.001) and decreased cooking loss (P<0.001) and WBSF (P<0.001). The effects of genotype and fat classification on animal performance and meat quality are presented in Table 2. Increasing fat classification increased final live weight (P<0.05), KCC fat (P<0.001) and cooking loss (P<0.001) but did not alter (P>0.05) WBSF or sarcomere length. Genotype, carcass weight, fat classification or hanging technique did not alter (P>0.05) ultimate pH or meat colour. Tenderstretch hanging produced meat with a lower (P<0.001) WBSF (3.45 and 2.60 (sem = 0.082) kg/cm^2) and a greater (P<0.01) sarcomere length (2.37 and 2.63 (sem = 0.063) μm).

Table 1 Effects of genotype and carcass weight on animal performance and meat quality (prediction[1])

	Carcass weight (kg) (C)									
	250		300		350			Significance		
Breed (B)	Hol	CH	Hol	CH	Hol	CH	sem	B	C	BxC
Final LW (kg)	519	469	613	550	708	632	11.11	***	***	NS
Conformation[†]	1.12	2.40	1.39	2.84	1.67	3.28	0.247	***	***	NS
Fat class[‡]	2.86	2.64	3.42	2.80	3.98	2.97	0.246	**	NS	NS
KCC fat (kg)	11.9	5.83	17.9	8.01	23.9	10.2	1.424	***	NS	**
Marbling score	2.44	0.94	3.16	1.22	3.88	1.51	0.356	***	NS	NS
Cook loss (%)[2]	29.0	32.5	28.3	32.2	27.6	31.9	0.704	***	***	NS
WBSF (kg/cm^2)[2]	2.78	3.80	2.60	3.68	2.43	3.56	0.266	***	**	NS
Sarcomere length (μm)[2]	2.52	2.26	2.58	2.33	2.65	2.40	0.118	*	NS	NS

Table 2 Effects of genotype and fat class on animal performance and meat quality (prediction[1])

	Fat classification (F)									
	2		3		4			Significance		
Breed (B)	Hol	CH	Hol	CH	Hol	CH	sem	B	F	BxF
Final LW (kg)	501	616	565	649	628	682	22.46	***	*	NS
Carcass wt (kg)	237	348	274	360	310	372	12.06	***	NS	NS
KCC fat (kg)	10.8	6.84	14.8	10.6	18.8	14.4	1.495	**	***	NS
Cook loss (%)[2]	30.1	33.0	28.8	31.8	27.6	30.7	0.541	***	***	NS
WBSF (kg/cm^2)[2]	2.79	3.71	2.69	3.53	2.59	3.35	0.225	***	NS	NS
Sarcomere length (μm)[2]	2.48	2.48	2.55	2.41	2.61	2.34	0.100	P=0.09	NS	NS

[1] Values predicted from regression analysis
[2] Values are for average of AT and TS hung sides
[†] EUROP scale: 5, 4, 3, 2, 1 respectively;
[‡] EU fat classification, where 5 = fat, 1 = lean

Conclusions It is concluded that the Charolais genotype produced leaner, heavier and better conformed carcasses relative to the Holstein genotype regardless of slaughter weight. Beef from Holstein was more tender and had a lower cooking loss percentage than beef from Charolais. Tenderstretch hanging improved meat tenderness compared to Achilles tendon hanging as assessed by sarcomere length and WBSF.

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The effect of sire genotype on the histochemical profile of the *M. longissimus dorsi* of pigs slaughtered at a heavy weight and its relationship with meat colour

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Introduction Over the last twenty years, pig breeding has been very successful in the selection for improved lean meat production and reduced fat level. In order to meet increasing pressure to reduce fatness and increase muscularity in fatteners different types of meat boars are used by pig producers instead of traditional sires (Landrace, Large White or Duroc). There is some concern that meat and eating quality have suffered as a result of this strong use of meat boars. According to Warriss (2000), specifically the presence of Pietrain genes in many meat-line boars could potentially make their offspring more prone to the production PSE meat. Colour is the major determinant of appearance of raw meat. It can be determined by two main factors – the first is the concentration of the haem pigments, myoglobin and haemoglobin - the second is the muscle microstructure. Heavier slaughter weights have become a feature of a number of markets. Therefore, the objective of this work was to study the effect of sire genotype on the histochemical profile of the *M. longissimus dorsi* from pigs slaughtered at a relatively heavy weight the 129.3 kg.

Materials and methods The research was carried out on one hundred and fifty finished pigs from three different crosses – 50 from each cross. Landrace (L) sows (mothers of tested fatteners) were from the same herd and were crossed with 3 different boars Duroc (D), Pietrain (P) and Yorkshire (Y). Complete feed was formulated according to Polish Feed Requirements. Daily feeds were given in two parts with free access to water. Muscle samples for histochemical analysis were taken from the *M. longissimus dorsi* on the right side of the carcass immediately after slaughter between the 13th and 14th ribs and deep within the muscle. Two different staining methods were used to determine muscle fibre types: The activity of diaphorase and myofibrillar ATPase activity. Colour was measured 24 h post-slaughter on a sample of *M. longissimus dorsi* collected between the 4th and 5th lumbar vertebrae by Minolta Chromameter CR 310 (Minolta, Japan). A slice of the *M. longisimuss dorsi* was taken and subjective colour assessments were made on the freshly cut surface using 5 point score scale (1=pale, 3=normal, 5=dark) by 8 trained panellists. All data are presented as means ± SD. The data were analysed by analysis of variance.

Results The results are shown in table 1. There were significant differences in both the percentage of fibre types, and their diameter, between the three genotypes. Muscles from LD pigs had a lower percentage of white fibres and a higher percentage of red fibres than muscles from LY, and LP animals while LY genotypes had a lower percentage of white fibres than LP genotypes. The muscle of LP pigs had red and white fibres with a significantly greater diameter than those of other pigs while LY pigs had muscles with a greater diameter of white and red fibres than in LD pigs. In LD pigs the L* value was lower and the a* value higher while the b* value did not differ between the three genotypes. LP pigs had the highest L* value and the lowest a* value than the rest of the pigs. LD genotypes had higher muscle colour scores determined by subjective assessment compare with LY and LP genotypes.

Table 1 The percentage distribution of fibres, fibre diameter and muscle colour in pigs of three genotypes

	Percentage content $\bar{x}$ ± SD		
	LD	LY	LP
White fibres	76 .8 ± 1.7[a]	80.1 ± 1.4[b]	83.4 ± 1.5[c]
Intermediate fibres	10.4 ± 2.1	12.1 ± 1.7	10.3 ± 2.2
Red fibres	13.8 ± 1.6[a]	7.8 ± 1.4[b]	6.3 ± 2.1[b]
	Fibre diameter [µm] $\bar{x}$ ± SD		
White fibres	86.1 ± 1.6[a]	92.4 ± 1.9[b]	98.1 ± 1.3[c]
Intermediate fibres	80.9 ± 1.4	79.6 ± 2.1	80.3 ± 1.2
Red fibres	72.1 ± 2.1[a]	83.1 ± 1.6[b]	90.8 ± 1.9[c]
	Muscle colour		
L*	51.3 ± 0.9[a]	54.9 ± 0.8[b]	58.4 ± 1.1[c]
a*	8.8 ± 0.11[a]	8.2 ± 0.16[b]	7.8 ± 0.12[c]
b*	7.4 ± 0.09	7.5 ± 0.1	7.5 ± 0.07
Subjective assessment	2.7 ± 0.03[a]	2.6 ± 0.06[a]	2.1 ± 0.04[b]

a, b, c - Means in rows with different letters are significantly different at $P \leq 0.05$

Conclusion The significantly larger diameter of both white and red fibres in the muscle of the LP genotypes suggests a negative effect on muscle physiology because of the increase in fibre hypertrophy in the muscle of pigs slaughtered at heavier weights with the stress susceptible breed. The higher L* and lower a* value in the muscles from LP genotypes could be caused by a higher percentage, and increased diameter, of white muscle fibres. Because muscle pigment is the major factor affecting the a* and b* coordinates, the observed differences were most likely related to a lower concentration of pigment in the stress susceptible pigs.

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Calpastatin gene promoter activity associated with growth promoter pathways in pigs

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Introduction β-agonists are known to enhance muscle growth in livestock species, although sometimes at the expense of increased meat toughness. In pigs, administration of porcine somatotropin (pST) produces muscle hypertrophy without detrimental effects on toughness. Calpastatin, a specific inhibitor that regulates the calpain proteinases responsible for cleavage of myofibrillar proteins, has a key role in growth and the rate at which meat tenderises post-mortem. In the porcine calpastatin gene there are at least three calpastatin promoters (upstream of exons 1xa, 1xb and 1u respectively), of which 1u is used predominantly in skeletal muscle. All three promoters contain transcription factor binding motifs suggesting sensitivity to β-agonist/cyclic AMP (cAMP)/protein kinase A (PKA) and IGF-1/Ca^{2+}/calcineurin–mediated signalling pathways (Parr *et al*., 2004). It was previously shown that expression of calpastatin mRNA from all three promoters can be increased in pigs treated with clenbuterol and suppressed in pST-treated animals (Sensky *et al*., 2004), suggesting differential regulation by the two pathways. In this study, the effect of manipulating these pathways is evaluated *in vitro* in order to determine if there is a specific element within the porcine 1u promoter that is responsive to both pathways, using rat muscle cells transfected with a series of 5'-deleted porcine 1u promoter constructs and treated with cAMP analogues and the calcium ionophore calcimycin.

Materials and methods Four 1u promoter constructs in the pGL3 Basic vector (Promega) were generated (termed A, B, C and D, in order of decreasing length), in which potential cAMP responsive elements (CRE) and other transcriptional motifs were systematically eliminated (Figure 1). pGL3 with a viral promoter (SV40) and the promoterless pGL3 Basic were used as a positive and negative controls, respectively. The constructs were transiently transfected into a rat muscle cell line (L6G8) using GeneJuice reagent (Novagen). Immediately after transfection, the cells were treated with either 2 mM dibutyryl cAMP (db cAMP) to simulate the cAMP/PKA pathway associated with β-receptor activation, or 1 μM calcimycin to increase intracellular Ca^{2+} to simulate the Ca^{2+}/calcineurin signalling pathway. Luciferase activities were measured 24 h after transfection using the Dual-Glo Luciferase Assay System (Promega). The data from 8 replicates per construct ± treatment were normalised to untreated pGL3 SV40 data and the relative expression of the different promoters resulting from the different treatments was calculated. The effect of treatment on each construct was analysed using Student's t-test for unpaired data.

Results The data imply that only three of the 1u constructs (A, B and C) are functional promoter sequences. Treatment of cells with db cAMP immediately following transfection significantly increased the expression of promoters A ($p < 0.05$), B ($p < 0.01$) and C ($p < 0.01$), but had no effect on D (Figure 2). The effect of calcimycin tended to be the opposite to that of db cAMP, with a reduction in A and significant decreases in B ($p < 0.01$) and C ($p < 0.01$).

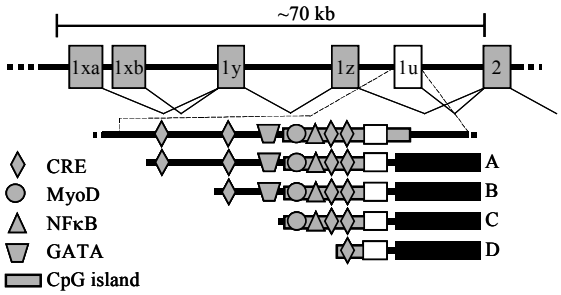

Figure 1 Calpastatin 1u promoter constructs and potential regulatory components

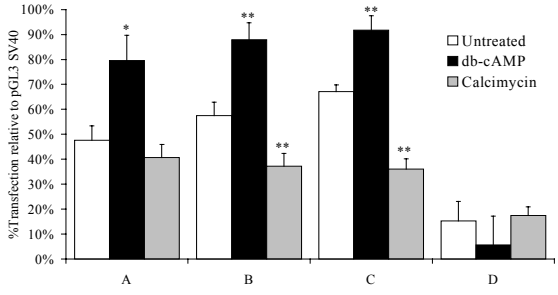

Figure 2 Effects of dibutyryl cAMP and calcimycin on the expression of different calpastatin gene promoter constructs in a rat skeletal muscle cell line. Levels of significance relative to untreated cells are indicated (* $p < 0.05$, ** $p < 0.01$)

Conclusions The effects of db cAMP and calcimycin on calpastatin 1u promoter efficiency were consistent with previous observations on the effects of β-agonists and pST on 1u calpastatin mRNA expression in muscle from whole animal studies, with increases seen with clenbuterol and cAMP and decreases with pST and calcimycin. This supports the hypothesis that β-agonists regulate calpastatin via the cAMP/PKA signalling pathway, whilst pST regulates calpastatin via a Ca^{2+}-mediated pathway. Furthermore, there appears to be a critical component required for calpastatin expression that is present in the calpastatin gene between promoters C and D. This implies that the 1u promoter region of the porcine calpastatin gene is susceptible to regulation by growth promoting factors.

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Grazing and plant biodiversity in upland acid grassland systems – why can we manipulate animal performance easily but not plant biodiversity?

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Introduction Upland livestock systems dominate land use on upland semi-natural habitats of high conservation value. The future is unclear. CAP reform is likely to highlight the poor financial performance of hill livestock, cross compliance may be very light and agri-environmental support for positive management is likely to be limited. There is much debate about management for different objectives. Trends of abandonment of livestock grazing may continue. This paper highlights alternative outcomes of management of semi-natural grasslands and the linked impacts on livestock production.

Materials and methods A series of large scale system studies integrating grazing ecology measurements with livestock data were carried out from 1991 to the present on acid grassland ecosystems in the Kirkton Glen area, below Ben Challum in the west Highlands of Scotland. These involved full hill systems, each with resident flocks of ewes and lambs in highly varied plant communities, typically >20 NVC types per grazing treatment. In study 1, there were 3 phases with different grazing management treatments; baseline with 1 ewe/ha in all three plots; treatment period 1 with three treatments – 1 ewe/ha, 0.5 ewe/ha and 0.5 ewe/ha plus summer grazing cattle providing the same overall LU/ha per year as the first treatment. Treatment period 2, continued at 1 ewe per hectare on an annual basis in the first system area and no winter grazing in the second flock area. Exclosure areas were established. Sample stands composed of thirty-two nested quadrats (8m x 4m grids) were established in each system on comparable *Nardus stricta*-dominated grassland (NVC U5c). Study 2, commencing 1999 involved a shift in management of c 660 ewes from a typical all year around grazing system to one with ewes removed to high quality grazing (on lowland) from November to March. Within this study, vegetation studies established baseline data within grazed areas and also studied grazing exclosures on species rich pastures. Logistic regression analysis was used in analysis of ewe performance and probability of reproductive success.

Results In study 1, the overarching result for treatment period 1 was of only very small changes in species composition and cover in these highly robust grazed systems. Sward heights varied between grazing systems and year (both $p<0.001$), but there were larger year effects than treatment effects. In terms of species composition none of the dominant species showing any significant variation in cover, though there were changes in cover and presence of less frequent species. Figure 1 for treatment period 2, shows that seasonal grazing, and removal of grazing both led to highly significant differences in sward structure ($p<0.001$). With grazing removal, in Study 2 (Table 1) annual species and low growing herbaceous species showed considerable declines, with perennial sedges and dwarf shrubs showing some of the greatest increases (all significant $p<0.01$), overall moving towards less species rich composition. Rarer montane species, such as Sibbaldia procumbens, Silene acaulis and Carex capillaris all declined in frequency. Results of animal performance in Study 2, demonstrates large improvements in reproductive performance with a highly significant increase ($p<0.001$) from baseline of 0.85 (+/- 0.05) to 1.25 (+/-0.06) lambs weaned per ewe. The probability of a ewe being barren dropped significantly between the pre-treatment phase and the treatment phase ($\chi 21,3611=13.33$, $P<0.001$), while the probability of having twins or triplets more than tripled ($\chi 21,3326=605.99$, $P<0.001$) under the off-wintering system. Improved welfare linked measures with improvements in survival from 0.90 (+/- 0.01) to 0.93 and 0.94 (both +/-0.01) for singles and twins respectively were significant ($p<0.01$). Nevertheless, variation in economic performance of these systems is relatively small, compared to the large impacts of headage based payments.

Table 1 Impact of removal of livestock grazing on species composition over 5 years (study 2) – data from 9 fixed 1x1 m quadrats, 100 cells per quadrat (maximum score 900).

	Number of species	Mean number of cells that species present (SE of Mean)	
		1999	2004
Major Reduction	10	52.5 (10.25)	6.5 (2.33)
Moderate Reduction	5	333 (111.2)	162(65.2)
Minor Reduction	3	325 (33.9)	201(25.7)
Increase	7	72 (19.2)	130 (32.3)
Large Increase	1	8	71

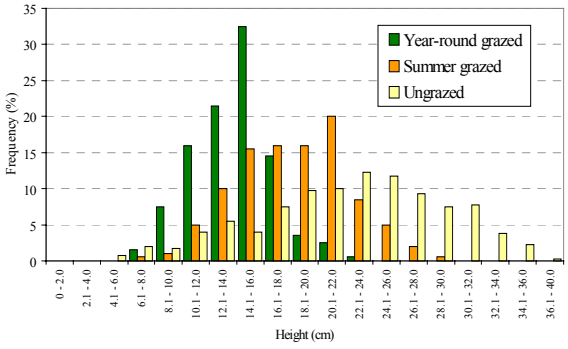

Figure 1 Study 1, period 2, sward structure impacts

Conclusions Within the mid-range of grazing intensities, upland systems are very robust to plant species change, though structure responds quickly to seasonal grazing. By contrast, animal performance can be modified quickly by inputs, or by off-wintering. Large reductions in grazing can lead to significant decreases in botanical diversity in species rich grasslands. Plant biodiversity maintenance is arguably a more sensible target than improvement and requires continued grazing.

Effects of social behaviour on patch utilization by sheep in a complex vegetation mosaic

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Introduction In heterogeneous environments, such as complex vegetation mosaics, there is likely to be a dynamic interaction between the spatial pattern of the vegetation and the distribution of the animals grazing there. Preferences for particular vegetation types will influence where animals choose to feed and, in turn, changes to the vegetation caused by damage from grazing and trampling will affect the dynamics of the mosaic. Social interactions, amongst highly social grazers such as sheep, can also affect the distribution of the animals, depending on the relationship between the dimensions of vegetation patches and the characteristic spacing of the animals. The aim of this study was to investigate the relationship between patch utilization and patch size for small groups of Scottish Blackface sheep foraging in a natural heather (*Calluna vulgaris*) and grass mosaic.

Materials and methods Six 1-ha plots were each stocked with a group of six female sheep. The plots consisted largely of heather-dominated vegetation (79% by area), with grass arranged in different-sized patches (range 1 m^2 to 690 m^2, mean 118$\pm$10.7 patches per plot) connected by a network of paths. Over a 10-day period, the location and behaviour of each of the animals were recorded on 25 occasions each day by scan sampling, carried out between 0730 and 2130 h. Scanned locations were marked on a vegetation map of the plots, which had been prepared from aerial photographs (Oom, 2003). The percentage of scans on each vegetation type and distances between the animals were subsequently obtained using a GIS. Statistical analyses were carried out using GENSTAT. The relationship between the percentage of scans and patch size was analysed using a generalised linear mixed model, which compared the number of scans on individual patches with expected values based on the area of each patch. In order to test whether or not sheep were sharing patches simply as a consequence of the number of times that they visited them, the observed frequencies with which different numbers of sheep (from 0 to 6 animals) grazed on particular patches were compared with the frequencies with which they would be expected to graze together, based on the total number of scans of sheep on those patches. This was done using a dispersion test, in which the sample variance was compared with the variance for a binomial distribution (Cochran, 1954).

Results There were more observations of sheep grazing on the largest patches in each plot than were expected (see Figure 1). For each plot, there was a positive linear relationship between the actual and expected percentages of scans of sheep grazing patches, as patch area increased, which was highly significant across all the plots ($P<0.001$). The sheep were more likely to graze together on large patches, and the majority (79%) of scans in which 4 or more sheep grazed the same patch were on one of the two largest patches in the plot. When observations of sheep on the most popular grass patch in each plot (mean area 311 $\pm$ 89 m^2) were analysed, there were many more occasions when 4, 5 or 6 sheep grazed there together, than would have been expected from the total number of sheep observations on those patches (272 actual vs 57 expected scans, $P<0.001$).

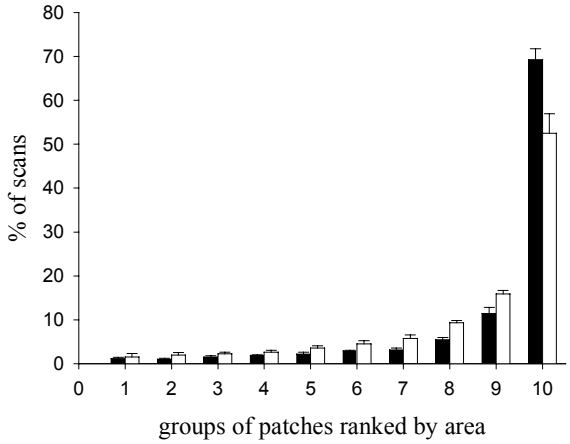

Figure 1 Actual (■) and expected (□) percentage of scans of sheep grazing, for groups of patches each containing 10% of the patches in each plot and ranked in ascending order by area.

Conclusions The sheep showed a preference for grazing on large patches and the results suggest that this was partly because they could graze there together. Although it is possible that the large patches were also attractive for non-social reasons, such as the provision of shelter by nearby fences, the sheep grazed there together more often that would have been expected by chance. The results demonstrate how the utilization of different vegetation types within vegetation mosaics may vary depending on the patch size distribution. This will have consequences for biodiversity, since the concentration of grazing in particular areas is likely to result in changes to the spatial pattern of the vegetation in these areas and to the heterogeneity of the vegetation mosaic as a whole. Since social behaviour affects the distribution of grazing animals, it is likely that different groups will have different impacts on biodiversity within a given vegetation mosaic, depending on the size of the group and the strength of the social bonds between the animals.

Acknowledgements This study was funded by the Scottish Executive Environment and Rural Affairs Department.

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Native breeds and conservation management: an analysis of strengths, weaknesses, opportunities and threats

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Developments in UK agriculture and nature conservation provide promising prospects for native breeds of farm livestock, and hence for the conservation of their genetic resource, but only if certain difficulties can be overcome. This analysis explores the opportunities provided by those developments, the strengths and weaknesses of the use of native breeds in conservation management, and threats posed to native breeds by extraneous factors.

Strengths The wide variety of breeds found in the British Isles, and their adaptation to a wide range of habitats and environmental conditions, allows selection of appropriate stock for most situations. Conservation of these breeds, and their inherent qualities, has been the aim of the Rare Breeds Survival Trust (RBST; Mansbridge, 2004) and their use in conservation grazing has been promoted by the Grazing Animals Project (GAP) e.g. through the publication of the Breed Profiles Handbook (Tolhurst and Oates, 2001).

Weaknesses Lack of scientific breed characterisation and inadequate knowledge of variations in grazing behaviour are further hampered by the difficulty of establishing well-designed, rigorous scientific studies on land of conservation value. The impacts of grazing on, and the response of, vegetation and invertebrates, are documented for some habitats, but are still poorly understood in the general terms that would allow clear prescriptions for conservation management. The scarcity of farmers and graziers with the requisite knowledge of native breeds and their use in management of demanding sites leads conservation organisations to manage their own stock with consequent demands on limited resources. The availability of appropriate stock in the required numbers at the right times, one of the drivers for the formation of the GAP, remains a problem particularly for rare breeds, which are often preferred by conservation managers, but which are, by definition, numerically scarce. Recent sales have seen high prices for some favoured breeds; this is likely to encourage breeders but puts additional demands on the budgets of conservation agencies.

Opportunities The higher level of the new agri-environment scheme, Environmental Stewardship Scheme (ESS), includes a secondary objective of 'conservation of genetic resources' that provides additional payments if farmers use 'indigenous, locally-adapted, hardy and rare breeds', but only where such use contributes to one of the primary objectives of ESS. The new agricultural support mechanism, Single Payment Scheme (SPS), also provides an opportunity in that it replaces production-related support with an area-based payment; this may encourage farmers to adopt native breeds that can be used in less intensive systems, especially if the Over Thirty Months Scheme ends, as is anticipated in 2005. These agricultural support changes are additional to the increasing use of grazing livestock in conservation management (Small *et al.,* 1999) and their possible use in 're-wilding' projects (Kirby, 2003).

Threats The dominance of continental beef breeds in the lowlands (Defra, 2002) and introgression in native breeds as breeders try to match the performance of continental breeds are likely to further reduce the availability of hardy breeds for conservation grazing. Outbreaks of disease such as foot and mouth and the continual presence of diseases such as bovine TB are further threats to native breeds. Arguably misplaced governmental programmes to eliminate diseases such as scrapie through the National Scrapie Plan pose particular threats to some rare breeds in which the incidence of 'resistant' genotypes is low (Small, 2004). Demographic and economic factors such as the ageing farmer population (mean age in 2003: 58yr) and the overall viability of farming (mean farm income in 2003: £11,100) may also be threats, particularly in the uplands where the SPS may deter beef and suckler herd farming. Importations of Konik ponies for use on conservation sites have led to a debate in conservation circles as to whether non-native breeds should be promoted where appropriate, or whether conservation of native breeds should be an aim of conservation agencies in itself. This debate is likely to intensify if proposals for landscape scale re-wilding projects come to fruition.

These issues are discussed to determine what the future may hold for the conservation of farm animal genetic biodiversity in the UK. The roles of organisations such as the RBST and GAP are evaluated. The research needed if native breeds are to overcome the problems and realise the potential offered by developments in agriculture and conservation is identified.

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The effects of grazing on spider assemblages in upland heather moorland

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Introduction Invertebrates are of particular interest on heather moorlands because of their rapid response to small scale habitat changes. Spiders constitute a variable proportion of the diet of heather moorland bird, mammal and reptile species. Furthermore, spiders may be an important indicator of habitat change resulting from management practices, especially those that exert a large- scale spatial impact, e.g. grazing. The component families and species of spider assemblages indicate, through their differing preference for web attachments and web structure, the vegetation density, height and structure (Marc et al., 1999). This effect may be especially pronounced where continued grazing at a particular stocking rate results in characteristic patterns in the vegetation structure. Species and family specific hunting strategies determine prey type and so the presence of some spider species may indicate the presence of a preferred prey species. This study aims to investigate the effect of grazing with sheep alone or in combination with cattle grazing on an upland heather moorland in the north of England.

Materials and methods The experiment investigates the additional effect of cattle to an area grazed by sheep. The two grazing treatments are 1.5 ewes/ hectare and 1.5 ewes/ha with 0.75 cattle/ ha. Fuzzy cluster analysis of the vegetation types at 164 permanent quadrats was used to show those quadrats with vegetation most representative of one of 4 types present on moorland*; Juncus, Nardus, Molinia* and *Calluna*. Subsequently, four quadrats were selected for each vegetation type in both treatment areas. These quadrats were used to sample spiders using 5 pitfall traps at each in June, July, August and September 2003 and were emptied monthly. A second study investigates the effect of grazing at each of the above grazing treatments. Three, 6 m by 10 m fenced areas constructed in 2002 were used as the non grazed controls and an adjacent area was used to sample the grazed treatment. Three pitfall traps were placed in the grazed part of each plot and 3 in the ungrazed. These pitfall traps were emptied every 2 days during July and August, 2004.

Results 96 species of spider were collected in 2003. There were no significant differences in the species richness or abundance of spiders on the sheep only treatment compared to the sheep and cattle treatment. However, multivariate ordination (detrended correspondence analysis - DCA) showed a separation of the treatments along the first DCA ordination axis. This was significant at $P < 0.001$, and appeared to be associated most strongly with changes in the abundance of Lycosidae. Changes in vegetation structure were significantly ($P < 0.05$) associated with this pattern.

Conclusions Spider communities in general, but particularly species belonging to the Lycosidae, would appear to provide very sensitive indicators of environmental change associated with changes in livestock management. Spiders have an important role in upland ecosystems as major predators of other invertebrates, and as prey for many vertebrate species. Therefore, their rapid response to management change suggests that more subtle impacts on other taxa may also be occurring.

Acknowledgement The authors are grateful to Defra, English Nature and CCW for funding this work.

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Novel field margin management to enhance invertebrate biodiversity in intensive livestock farms

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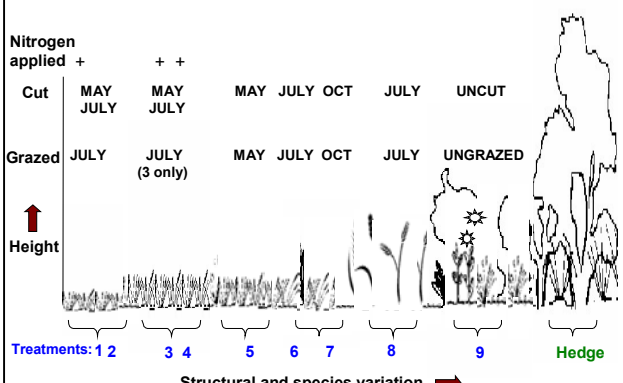
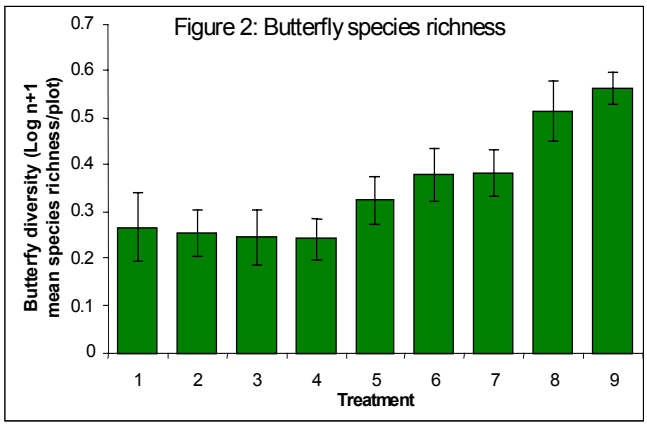
Introduction Most agricultural grassland in lowland UK is species-poor and structurally uniform. Management intensification has had a deleterious affect on the biodiversity of invertebrates and the suitability of grassland as feeding and breeding habitat for birds (Vickery et al. 20001). The PEBIL project (Defra BD 1444: Potential for Enhancing Biodiversity in Intensive Livestock Farms) is investigating the effects of structural and plant species manipulation on the invertebrate communities of field margins. The different treatments are designed to test the effects of increasing amounts of sward structural heterogeneity, in terms of canopy height, architectural complexity & botanical composition, on faunal abundance and diversity as well as improving food resources for birds.

Materials and methods In 2002, experimental plots were established on two intensively managed farms in Devon and two in Somerset, using a variety of grazing, cutting and sowing treatments (Figure 1). Each treatment (1-9) was applied to a separate 10 x 50 m field margin, with 3 replicated blocks of 9 treatments/farm. Treatments 1 to 4 provide a fully factorial design testing for effects/interaction between fertilizer nitrogen input, silage stubble height and/or aftermath grazing intensity. Treatments 5 to 7 explore the influence of temporal variation in cutting/grazing date, and treatments 8 (barley with a legume/grass undersow) and 9 (sown with kale and 'conservation mix') explore the influence of enhanced canopy architectural complexity. Key invertebrate groups were sampled four times between April and September 2003 using vortis suction sampler, transect walks, sweep nets and pitfall traps. Vegetation structure was measured using a 'drop disc'. Results for Orthoptera (grasshoppers and crickets) and pollinators (bumblebees and butterflies) only are presented here.

Figure 1 Graphical representation of plot treatments





Results (A) Butterfly species richness (Figure 2: r_p=0.882, n=7, p=0.009) and abundance (r_p=0.958, n=7, p=0.001) increased with vegetation complexity in treatments 1-7. Meadow brown (*Maniola jurtina*) was the commonest species, increasing in abundance (r_p=0.944 , n=7, p=0.001) with vegetation structure (1-7), but was less common in the sown treatments (8 & 9). **(B)** Bumblebee numbers were greater in the sown plots than the grass plots (p<0.016 in all cases). *Bombus terrestris* is associated with the 'conservation mix' (9) while *Bombus pascuorum* was associated with barley undersown with legumes (8), and to a lesser extent the conservation mix (9). **(C)** The effect of field margin manipulation on grasshoppers (Orthoptera) and their dispersal into fields was tested by a series of sweep transects at increasing distance from the hedge boundary into the field. The Field Grasshopper *Chorthippus parallelus* was the commonest species (92% of samples in 2003 and 2004) which also showed greatest migration into the field. Margin manipulations with greater structural heterogeneity (5-7) enhanced grasshopper movement into fields but only limited movement occurred beyond margin plots.

Conclusions Manipulation of field margin vegetation structure and composition can have a marked impact on invertebrate communities. The abundance and diversity of butterflies and bumblebees generally increased with increasing vegetation complexity. However, no single management treatment in this study provided 'optimum' conditions for all invertebrate groups. For instance, closely related species (e.g. *B. terrestris* and *B. pascuorum*) had different foraging preferences and were therefore associated with different Treatments. Orthoptera were favoured by taller grass treatments, suggesting that most traditional grazing/cutting regimes have a deleterious effect. Most grasshopper movement occurred along boundary features rather than into the field centre. Findings from this project will help develop agri-environment management agreements for intensive livestock farms to improve their value for wildlife, and have a strong relevance to the delivery of objectives in the Habitat Action Plans of the UK BAP.

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Grazing livestock interactions with upland and montane biodiversity

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Introduction Sheep and cattle interact with arthropods (e.g., insects and spiders) and small vertebrates (e.g., passerine birds and small mammals) directly and indirectly by the removal of vegetation during grazing, the trampling of vegetation and soil, and the deposition of excreta, associated with the redistribution of nutrients. The cold and wet upland and montane biotopes have low productivity, and grazing by free-ranging domestic livestock alters structure more than botanical composition of the vegetation in these biotopes over short periods (one to three years). In contrast to productive lowland or intensified upland pastures, upland and montane biotopes include patches of vegetation with a high proportion of leaf litter associated with plant species that are unpalatable or of poor nutritional value for grazers.

Habitat value of grazed upland and montane biotopes The intrinsic patchiness and litter content of grazed, upland and montane biotopes contributes to their value as habitat by providing resources for arthropod detritivores (Dennis *et al*. 1997), ground cover for short-tailed voles (Smit *et al*. 2001) and materials and cover for ground-nesting birds (Fondell and Ball 2004). Many arthropod species are dependent on taller herbage of a broader range of plant species than are present in intensively managed upland pastures; with requirements for physical structures (anchorage for spider webs; Cherrett 1964, Dennis *et al*. 2001), foliage of specific host plants, or particular feeding positions on a plant's architecture (plant bugs; Waloff 1980), many herbivorous insect species require a canopy of foliage above their feeding location to provide humidity and shelter to prevent desiccation and dislodgement (Waloff 1980). Insect herbivores are in direct competition with grazing livestock for the palatable foliage of certain plant species.

Trampling disturbance of vegetation and soil Trampling can mechanically damage plants and affect vegetation structure in a similar way to the biting and removal of foliage. Continuous activity of high densities of grazers or heavier livestock species alters the suitability of soil as a medium for larval stages of insects. Larger species of predatory ground beetles were observed as absent from experimental treatments that were grazed by cattle and sheep compared with sheep alone for two standardized levels of grazing intensity (Dennis *et al*. 2002). The effect is most likely caused by changes to the density and size of soil crevices available for the larvae of these beetles. Trampling disturbance can directly affect wildlife species, e.g., damage to spider webs and the eggs/ nests of ground-nesting birds. Small mammal runs are adversely affected by the compaction of patches of coarser vegetation and leaf litter, although sheep, if not cattle, tend to avoid these taller patches, such that they act to buffer effects of grazing (Cherrett 1964, Dennis 2003).

Dung and urine inputs The species and stocking density of grazers also affects the density and local mass of dung deposited in the biotope. This alters the species composition and abundance of dung beetles (direct effect) and likewise of other beetles that predate on the larvae of dung flies (indirect effect). The distribution of dung and urine redistributes nutrients in upland and montane biotopes, in turn altering soil fertility and changing vegetation composition and plant growth rates in the long term (five to ten and more years). It is difficult to be certain about the likely indirect consequences of these changes for arthropods because the timescale of change is greater than the scope and duration of standard research projects.

Summary The interactions between grazing livestock and the wildlife of indigenous biotopes of upland and montane ecosystems are complex and varied. Grazing experiments situated across Scotland and undertaken 1993-2004 identified detrimental effects at current commercial stocking densities of domestic grazing livestock on vegetation, the associated arthropod diversity, abundance and distribution, and small mammals and ground nesting bird species.

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Grazing animals as habitat engineers for ground-nesting birds – a review of the issues

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Introduction

Habitats associated with livestock production systems are important in terms of avian biodiversity in the UK and across Europe. Livestock play an integral role in structuring grassland habitats, which in turn affects their suitability for different ground-nesting bird species. Such habitat engineering is driven mainly by the effect of grazing on plant species composition and vegetation structure. However, ground-nesting birds are also negatively affected by the presence of grazing animals since livestock destroy nests mainly through trampling.

This paper reviews the main ecological issues relating to the use of grazing animals as habitat engineers for ground-nesting birds using a number of case studies involving wading birds from the UK and UK Overseas Territories. First, it shows that grazing management is capable of affecting large-scale population trends. Secondly, it discusses the type of ecological information used to examine the population level effect of grazing management on birds and how this reveals species-specific habitat requirements. Thirdly, it examines the impact of trampling on nesting success, and contrasts the vulnerability of different bird species to this risk. Finally, it synthesizes the available information with respect to concepts such as overgrazing and ecological traps.

Grazing and large-scale population trends

Grazing is not simply a localised process with implications for biodiversity on relatively small spatial-scales, but changes in grazing can have large-scale consequences. This is illustrated by changes in the abundance of redshank breeding on saline grasslands in Britain. Census data suggested a decline in redshank numbers during the 1990s. Statistical modelling of bird-habitat associations showed that breeding densities were lowest on areas of heavily grazed grassland, the intensity of grazing had significantly increased over time, and the rate of population decline was highest in areas that had experienced the greatest increase in grazing intensity. The precise cause of these changes is unclear, but observed habitat changes are consistent with an increase in sheep grazing.

Habitat requirements and grazing

The previous example illustrates the type of ecological information typically collected to investigate the impact of habitat engineering by grazing animals on bird populations. This kind of bird-habitat association modelling can be used to examine the response of specific bird populations to particular grazing systems. For example, redshank populations breeding on saline grasslands show a positive response to relatively heavy grazing in certain areas. This is similar to populations of St Helena wirebirds breeding on dry grassland sites. However, the grassland habitats 'engineered' by the grazing animals differ between these systems, and it is the effect of grazing on vegetation structure that drives bird population responses (e.g. Fig. 1).

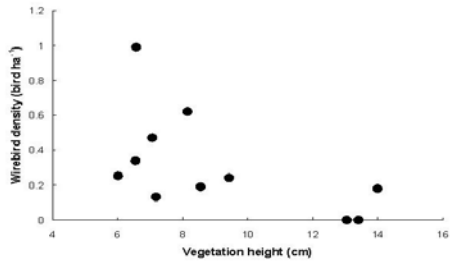

Figure 1 The relationship between vegetation height and the density of St Helena wirebirds at a number of pasture sites.

Trampling risks

Ground-nesting bird species vary considerably in the trampling risk they face – some species are susceptible and others relatively unaffected. Trampling risk also varies between livestock types, and is affected by the timing of grazing relative to the birds' nesting season. Individual-based models can be used to explore the consequences of these factors building a link between grazing management and demography.

Synthesis

In the context of ground-nesting bird species concepts such as 'heavy' or 'intensive' grazing are relatively meaningless. The important issue is how different livestock production systems influence grassland habitats (particularly in terms of vegetation structure) and the habitat requirements of individual species. 'Heavy' grazing to one species could be 'under-grazing' to another. We have good data on the habitat requirements of birds but less information on the details of the precise grazing management required to produce particular habitat features. If we wish to use grazing animals as targeted habitat engineers then we need more information on the relationship between grazing and habitat, and insights into the socio-economic drivers and consequences of specific forms of management. Linking bird demography and abundance in this context is also important in order to avoid ecological traps – management that creates suitable nesting habitat but at the cost of elevated trampling risks that reduce nesting success and the population birth rate.

Predicting the effects of grazing management on moorland bird abundance

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Introduction Field studies of grazing management have frequently concluded that the magnitude and direction of vegetation response is dependent on initial vegetation condition. On upland heath, this dependence reflects the importance of small-scale ecological processes (e.g. plant competition), and local neighbourhood effects (e.g. spatial distribution of plant species), in driving the vegetation dynamics. These small-scale effects, together with variation in grazing patterns, increase the difficulty of deriving general rules about the effect of grazing on vegetation change from field studies. However, we need to determine the impacts of such grazing-related vegetation change upon biodiversity, (e.g. birds). For many bird species it is impractical to use experimental approaches due to low breeding densities, and the influence of other site and management effects (e.g. predator control). To predict the effect of management changes on them requires an accurate assessment of the large-scale effects of grazing management on the ecological landscape using data from small-scale field studies. This paper sets out an approach that integrates field studies with theoretical models to investigate the large-scale effects of grazing management on plant and bird communities on upland heath.

Methods The approach combines outputs from separate models of vegetation dynamics and bird abundance. The vegetation model uses a grid-based modelling approach in which vegetation change is driven by plant competition, spatial distribution, growth and management (grazing, burning or cutting). The grid is constructed from a hierarchy of different sized units, to enable small-scale processes to be integrated with larger-scale drivers of vegetation change (Gardner 2002). Field data characterising the plant communities present on a site, their distribution, composition, growth phases and management, are used as input data. GLMs were used to identify the variables that significantly affect the abundance of bird species, and incorporated both site and management effects, and variables describing vegetation composition and structure (c.f. Pearce-Higgins & Grant 2002). The bird models used were derived from field data collected from 85 two square kilometre plots in southern Scotland, and were simplified to include outputs compatible with the vegetation model. Presently, the vegetation model focuses on how grazing regimes may affect vegetation composition rather than structure (which is important for some bird species), but work in progress aims to address this issue. To determine the effect of grazing on bird abundance, different regimes were simulated within the vegetation dynamics model, the outputs of which were used as inputs for the appropriate bird abundance models, illustrated here using the effects of 3 grazing regimes on red grouse and meadow pipit abundance. The vegetation input data were taken from a 100 ha wet heath mosaic of *Calluna, Molinia, Nardus,* sedges and rushes at ADAS Redesdale, Northumberland.. The regimes were: all-year high sheep grazing (4.5 ewes/ha), no grazing and all-year low sheep grazing (0.66 ewes/ha) with 0.75 cattle/ha during June-August. Vegetation simulations were run for 10 years.

Results Red grouse abundance was correlated with *Calluna* cover, whilst fine-leaved grass cover, sedge cover and *Calluna* cover were each correlates of meadow pipit abundance. Changes in the cover of these vegetation types under each of the three grazing regimes were entered into the models of bird abundance. *Calluna* cover was predicted to rise under each regime, with the greatest effect occurring under the mixed and no grazing regimes, driving the predicted increases in red grouse abundance (Figure 1). Fine-leaved grasses and sedges were predicted to decline under each grazing regime, with the smallest decline occurring under mixed grazing. Meadow pipit numbers were predicted to decline on each regime, but faired best under mixed-grazing, potentially reflecting changes in the balance of *Calluna*: fine-leaved grasses and the declines in sedge cover compared to the starting year.

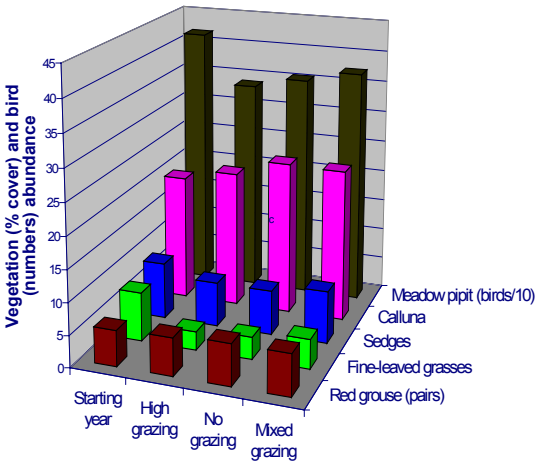

Figure 1 Predicted effect of grazing regime on specific plant and bird species (after 10 years)

Conclusions The study illustrates how, by linking field data to theoretical models, the effects of grazing management, recorded from small-scale measures of vegetation change can be modelled in relation to species groups that occur at larger spatial scale. Such models give an indication of the magnitude and direction of expected change, although predictions must be verified, and models refined, by field studies. This approach can therefore inform decisions about sustainable land management, help to set priorities and provide a sound rationale for action.

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Quantifying protozoal duodenal outflow in steers by real-time PCR

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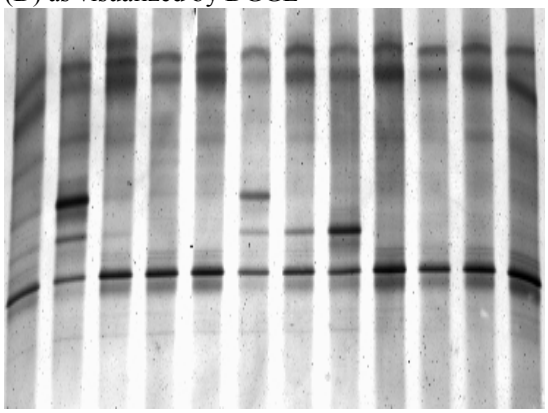
Introduction Microbial protein contributes about two-thirds of the amino acids absorbed by ruminants. Information on the proportion of bacterial and protozoal N passing to the duodenum would enhance our understanding of the effect of diet not only on microbial protein synthesis but also on the contribution of bacteria and protozoa to duodenal flow of others metabolites of interest. However, differentiation of the duodenal fractions has proven to be difficult because routine procedures cannot separate microbial protein at the duodenum into bacteria and protozoa (Punia et al., 1992). Molecular techniques that use group-specific rRNA-targeted probes may help overcome these problems. The objective of this experiment was to quantify the flow of protozoal N at the duodenum in steers, fed two silage diets differing in water soluble carbohydrates (WSC) content, by real-time PCR using protozoa specific primers.

Material and methods Six rumen cannulated Hereford x Friesian steers were fed diets of a control silage prepared from perennial ryegrass (*cv*. Fennema; CS, 5.81 g WSC/100 g DM) and a silage with higher residual sugar content prepared from a high WSC perennial ryegrass (*cv*. Ba11353; HS, 7.39 g WSC/100 g DM) in a two period changeover experimental design. Animals were adapted to the experimental diets for 15 days. Ytterbium and Chromium solutions were infused through the rumen cannula during five days prior to the collection of duodenal content on two consecutive days every four hours over a 24h period to estimate duodenal passage rate of digesta. Rumen and duodenal samples were also taken two hours after feeding. After DNA isolation, protozoal diversity in both samples was studied by polymerase chain reaction and denaturing gradient gel electrophoresis (PCR-DGGE) using 18S ribosomal DNA specific primers (Regensbogenova et al., 2004). Protozoal cells were isolated from rumen fluid, by gravitational separation followed by filtration on a 10 μm^2 nylon filter, for use as standard to determine DNA to N ratios. Protozoal DNA in duodenal samples was estimated by real-time PCR using specific primers targeting DNA encoding 18S rRNA (Sylvester et al., 2004). Differences in daily intakes and duodenal flows were investigated by analysis of variance.

Results The DGGE banding profiles were similar in rumen and duodenal samples from the same animal and were not affected by diet (Figure 1). Daily DM, OM and N intakes and duodenal flows are shown in table 1. Diet had no significant effect (P>0.005) on any of the studied parameters. The estimated protozoal outflow presented a high animal to animal variability, ranging from 87.8 to 2220 and from 90.5 to 1930 cells * 10^8/d for CS and HS diets, respectively. The protozoal contribution to the total duodenal N outflow was 11.8 and 13.0 % for CS and HS diets, respectively, which is within the range reported by Shabi et al. (2000) (6.9 to 18.3%) and Punia et al. (1992) (11 to 20%) using different approaches and experimental diets.

Figure 1 Ciliate diversity in rumen (R) and duodenal fluid (D) as visualized by DGGE



D_1 R_1 D_2 R_2 D_3 R_3 D_4 R_4 D_5 R_5 D_6 R_6

Table 1 Daily intakes and duodenal flows

	CS	HS	s.e.m
Intake, kg/d			
DM	3.54	3.53	0.02
N	0.10	0.10	0.00
Duodenal flow			
DM (kg/d)	2.68	2.75	0.02
N (g/d)	115.4	118.2	0.86
Protozoal Cells*	696.1	951.1	73.9
Protozoal N (g/d)	13.6	15.4	0.98

* x 10^8

Conclusions Despite the high variability reported in the present work, our results show the potential applicability of real-time PCR for quantification of the different microbial fractions in the duodenal outflow. More research is needed in order to accurately implement this approach in quantification of different microbial populations within digesta.

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Duodenal flow and biohydrogenation of C18 polyunsaturated fatty acids in beef steers fed isonitrogenous and isoenergetic diets with contrasting forage : concentrate ratios

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Introduction Data on ruminal metabolism of lipids from forages have shown extensive biohydrogenation of C18 polyunsaturated fatty acids (Lee *et al.* 2003). Recent studies have noted a reduction in biohydrogenation an increase in duodenal flow of C18:1 *trans*-11 and a shift in the ruminal production of CLA from *cis*-9 *trans*-11 CLA towards *trans*-10 *cis*-12 CLA with increasing amounts of concentrate in the diet (Kucuk *et al.* 2001, Loor *et al.* 2004). The study assessed the effect of feeding steers on isonitrogenous and isolipid diets differing in forage concentration and supplemented with linseed oil on ruminal lipid metabolism.

Materials and methods Eight Hereford × Friesian steers (*c.* 533 kg), prepared with rumen and duodenal cannulae were offered one of four forage : concentrate (grass silage F: barley, sugarbeet and soya C) ratios: F80C20; F60C40; F40C60 and F20C80 on a dry matter basis. All diets were fed at 1.3% body weight and designed to be isonitrogenous and isoenergetic with total lipid made up to 6% dry matter intake with linseed oil. The experimental design was a four by four incomplete Latin square consisting of 3-periods with two animals per treatment**.** On days 20 and 21 of each 24 d period duodenal digesta was collected every 3 h over a 24 h period and on day 23 rumen fluid was collected hourly over a 12 h period. Lipid extraction and GC analysis was as described by Lee *et al.* (2003). Statistical analysis was undertaken using ANOVA, blocking according to period + animal (Genstat 7 2004).

Results Increasing the concentrate component in the diet from 0.20 to 0.60 reduced rumen pH from 6.58 to 6.37 and caused a small but significant shift in volatile fatty acid molar proportions increasing the glucogenic (propionate) : lipogenic (acetate + butyrate) ratio. Rumen ammonia-N concentration was also significantly reduced with increasing concentrate, from 156.8 to 101.0 mgN/l on F80C20 and F20C80, respectively. Dry matter intake was lower (P=0.016) on F80C20 than the other diets resulting in a reduced duodenal flow of nutrients. Intake and duodenal flow of oleic and linoleic acids were significantly higher with increasing concentrate level in the diet whereas linolenic acid intake and flow was not different, averaging 143.6 and 6.37 g/d, respectively. There were no differences in the flows of total C18:1 *trans* or CLA (47.8 and 1.79 g/d, respectively) across the diets. Biohydrogenation of linoleic dropped from 0.91 to 0.84 when increasing concentrate in the diet from 0.20 to 0.40 but thereafter concentrate had no effect, as with oleic and linolenic acids.

Table 1 Effect of forage : concentrate ratio on intake and ruminal fatty acid metabolism.

	F80C20	F60C40	F40C60	F20C80	s.e.d	P value
DM Intake (kg/d)	6.1^{a}	6.7^{b}	6.7^{b}	6.7^{b}	0.18	*
Fatty acid intake (g/d)						
C18:0 stearic	8.03^{a}	9.11^{b}	9.76^{c}	10.4^{d}	0.094	***
C18:2*n-6* linoleic	54.7^{a}	77.5^{b}	98.0^{c}	110.0^{d}	0.52	***
C18:3*n-3* linolenic	144.0	146.8	141.3	142.4	2.45	NS
Total fatty acids	283.0^{a}	325.2^{b}	352.4^{c}	374.2^{d}	4.73	***
Duodenal flow (g/d)						
C18:0 stearic	162.4	159.4	192.5	191.6	15.86	NS
C18:2*n-6* linoleic	4.12^{a}	12.5^{b}	13.7^{b}	15.7^{b}	1.75	***
C18:3*n-3* linolenic	5.35	6.35	6.44	7.35	0.753	NS
Total fatty acids	298.9^{a}	316.0^{ab}	358.8^{b}	369.5^{b}	25.3	*
Biohydrogenation (%)						
C18:2*n-6* linoleic	91^{b}	84^{a}	86^{a}	86^{a}	2.3	*
C18:3*n-3* linolenic	96	96	95	95	0.5	NS

Values with different superscripts (^{abcd}) differ significantly ($p<0.05$).

Conclusion Increasing the proportion of concentrate in the diet when energy and nitrogen intakes were similar resulted in a drop in rumen ammonia and a small reduction pH with a consequent shift in VFA patterns towards propionate. The small drop in rumen pH on such contrasting F:C ratios was surprising. These results suggest that the F:C ratio had little effect on the flow of unsaturated fatty acids, C18:1 *trans* and CLA to the duodenum of beef steers, and that biohydrogenation of linoleic and linolenic acid is governed by other factors than forage : concentrate ratio.

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Tannins in animal nutrition and health – implications for temperate and tropical feeds

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Introduction This review surveys the nutritional and veterinary effects of tannins on ruminants and provides comparisons with non-ruminants. Tannins are a diverse group of naturally occurring compounds with useful biological effects. However, currently there are difficulties in predicting which tannins produce what effects.

Nutritional effects Tannins in fodder legumes and browses can produce useful benefits: better protein utilisation, growth rates, milk yields, fertility and animal health (Waghorn & McNabb 2003). However, the structural diversity of tannins has led to confusion in animal nutrition. The classification into condensed or hydrolysable tannins (CT, HT) has not proved useful. Procyanidins and prodelphinidins in *Lotus, Onobrychis* or *Calliandra* and ellagitannins in chestnut are beneficial, but profisetinidins in *Schinopsis*, procyanidins in sorghum and complex mixtures of CT and HT in *Quercus* and *Terminalia* sp. are harmful or even toxic to ruminants. Moreover, slight changes in tannin structures can produce measurable effects (Hagerman *et al*. 1992). The recommendation that <5% CT is safe applies to temperate legume forages but not to tropical browses.

Treatments to overcome negative effects Browse mixtures tend to be less deleterious than sole feeds (Dube & Ndlovu 1995) probably because mixed diets minimise the energetic costs of detoxification (Foley *et al*. 1999). High levels of sugars also appear to be beneficial (Ben Salem *et al*. 2003). Polyethylene glycol (PEG) binds strongly to tannins and can prevent negative effects (Silanikove *et al.*, 2001). However, as some tannins produce positive effects, PEG should not be promoted indiscriminately especially in developing countries (Mlambo *et al*. 2004). Alkaline treatments can be effective alternatives for deactivating toxic tannins (Murdiati *et al*. 1990).

Animal welfare and environmental effects Plants have traditionally been used for de-worming animals (Waller *et al*. 2001) and recent research showed that parasite numbers are lower in animals given tanniniferous forages (Athanasiadou *et al*. 2001; Butter *et al*. 2001). This is of practical importance as resistance is developing towards synthetic anthelmintic compounds. Tannins render plant proteins less susceptible to degradation in the rumen and are effective at preventing animal deaths from bloat. Furthermore, tannin-containing forages produce less urinary N and slightly higher faecal N, which is an environmentally safer form of N. Tannin-containing *Lotus* species also reduced methane emissions from ruminants by 16 to 20% (Waghorn & McNabb 2003). However, the active tannin molecules await identification.

Analysis The simplicity of colorimetry masks problems of extracting meaningful data for predicting nutritional responses to tannins (Lowry *et al*. 1996). The binding strengths between tannins and proteins vary over orders of magnitude and may account for the contradictory nutritional observations (Osborne & McNeill 2001). Hagerman *et al*. (1998) discovered that tannins bound via different mechanisms to proteins. As a result, a epicatechin polymer-BSA complex was much more stable than a pentagalloyl-BSA complex. Isothermal titration calorimetry (ITC) (Frazier *et al*. 2003) produced binding curves that exhibited highly specific binding for tara- and *Dichrostachys cinerea* tannins and non-specific binding for myrabolan and *Acacia nilotica* tannins to gelatin. ITC binding was also related to the octanol-water distribution coefficients, K_{ow}, of tannins (Mueller-Harvey *et al*. 2004). We hypothesise that toxic tannins have higher K_{ow}-values and bind non-specifically, whereas tannins with lower K_{ow}–values improve the efficiency of N-utilisation in ruminants and bind specifically to proteins.

Conclusions Current research focuses on their use as anthelmintics and on a more efficient use of nutrients by ruminants in order to reduce environmental N and CH_4 losses. New analytical techniques are being investigated currently to probe tannin structure-activity relationships (SARs). SARs present opportunities for future feeding strategies especially in developing countries, where many browses contain high levels of tannins.

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The effect of fatty acid oxidation products on lipid metabolism during *in vitro* batch culture

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Introduction. Milk fat conjugated linoleic acid (CLA) concentrations are higher for milk produced from cows grazing fresh pastures than for milk when conserved forages are fed (Jahreis *et al.,* 1997). This experiment investigated the hypothesis that this increased CLA production results from the action of volatile compounds (hydroperoxides, alcohols, aldehydes and ketones) released during the cutting of grass (De Gouw *et al.,* 1999).These compounds have antimicrobial activities (Kubo *et al.,* 1995) and may have an effect on rumen microbial populations.

Materials and Methods. Van Soest anaerobic incubation medium was made up and 10ml dispensed into 21 incubation bottles containing 1 g of freeze-dried and ground grass silage. Each fatty acid oxidation product was evaluated in triplicate: i) tert-Butyl hydroperoxide, ii) cis-2-Hexen-1-ol, iii) Methyl vinyl ketone, iv) Hexanal, v) trans-2-Hexenal, vi) trans-2-Decenal along with a water control. These were added to a final concentration of 50µM. Incubation bottles were inoculated with 10ml of rumen fluid, from grazing cows with rumen fistulae, under CO_2 then incubated at 39^{o}C in the dark. The incubation period was set at 6 h, as an optimal time to maximise capture of biohydrogenation intermediates. At the end of the incubation, the bottles were removed from the incubator and 20ml of isopropanol : chloroform (1:1 v/v) added along with 1ml of internal standard (2.5mg C19:0 / ml chloroform). The lipid was extracted as described by Lee *et al*. (2004) and bimethylated using 5N NaOH and 5% HCl in methanol. Fatty acid content of the vessels were analysed by ANOVA and compared against the water control. Biohydrogenation was determined as the proportional loss of C18 unsaturated fatty acids between time 0 h and 6 h.

Results. The results are reported as a mean percentage of total fatty acids in the vessels after 6 h incubation. Table 1 shows the major fatty acids and the biohydrogenation of C18:2 and C18:3. The addition of tert-Butyl hydroperoxide (TBH) and trans-2-Decenal (T2D) had the largest effect on the fatty acid proportions, with a significant reduction in C16:0, C18:1 *cis*, C18:2, C18:3 and BOC. They also produced a significant elevation in C18:0, C18:1 *trans* and in the case of TBH, total CLA proportions. The addition of cis-2-Hexen-1-ol reduced the proportions of C16:0 and C18:1 *cis*, and elevated both C18:0 and C18:1 *trans.* Methyl vinyl ketone addition resulted in a reduction in C16:0 and an increase in C18:1 *trans.* The addition of both TBH and T2D resulted in an elevation in the biohydrogenation of C18:2 and C18:3 compared to the control. Hexanal and trans-2-Hexenal appeared to have no effect on lipid metabolism in the incubations.

Table 1 Major fatty acids as a percentage of the total fatty acid content of the vessels after incubation.

	Cis-2-Hexen-1-ol	Hexanal	Methyl vinyl ketone	Tert-butyl hydro peroxide	Trans-2-Decenal	Trans-2-Hexenal	Water	S.e.d	Sig.
C16:0	14.7*	15.9	15.3*	13.3*	13.9*	16.2	17.1	0.62	***
C18:0	51.3*	46.7	49.5	54.5*	53.2*	47.0	45.6	2.06	**
C18:1 *trans*†	9.00*	8.51	9.01*	9.83*	9.04*	8.64	8.30	0.292	**
C18:1*trans* 11	6.16	6.03	6.16	6.75*	6.63*	6.12	5.83	0.181	**
C18:1 *cis*†	2.73*	3.23	3.02	2.45*	2.87*	3.29	3.41	0.162	***
C18:2*n-6*	3.30	4.21	3.53	2.74*	2.91*	4.05	4.25	0.446	*
C18:3*n-3*	6.91	9.07	7.35	5.68*	6.23*	8.66	9.00	1.065	*
CLA†	0.32	0.31	0.33	0.42*	0.35	0.32	0.35	0.021	**
BOC‡	4.14	4.49	4.34	3.50*	3.41*	4.30	4.51	0.302	**
Biohydrogenation									
C18:2*n-6*	0.65	0.59	0.65	0.72*	0.78*	0.64	0.58	0.053	*
C18:3*n-3*	0.70	0.65	0.71	0.77*	0.81*	0.69	0.64	0.045	*

Figures with * superscript are significantly different from the control (Water), † Sum of all isomers, ‡ Branched and odd chain.

Discussion. The increase in biohydrogenation of C18:2 and C18:3 and the associated increase in C18:1 *trans* and C18:0 may be attributable to the proliferation of biohydrogenating micro-organisms as a consequence of the toxic nature of TBH and T2D to competing micro-organisms reducing inter-specific competition. The results of this study show that fatty acid oxidation products affected rumen lipid metabolism. There is scope to investigate further the effect of long chain aldehydes and peroxides produced from freshly cut grass on the biohydrogenation of C18:2 and C18:3 in the rumen as a partial explanation for the increased flow of *trans* 11 C18:1 from the rumen of ruminants grazing fresh pasture and the consequential rise in milk fat CLA.

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Effects of washing procedure and dilution ratio on the size of non-washout, insoluble washout, and soluble washout fractions in concentrate ingredients

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Introduction A widely adopted procedure to characterize degradation in the rumen is the *in situ* incubation technique (IS), that assumes the washout fraction of feeds (W) to be equal to the soluble (S) fraction and that both are rapidly and completely degraded which may not be the case. Because IS technique is unable to measure the rate at which the W fraction is actually degraded; therefore, alternative washing procedures need to be developed to recover and fractionate the W fraction. Recently, simple washing procedure have been developed at Lelystad (method M) (Melin *et al*, unpublished results) and at Wageningen (method AA, SM and Y) (Azarfar *et al*., 2004; Yang *et al*., unpublished results), by which the feeds can be fractionated in a non-washout (NWF), an insoluble washout (ISWF) and a soluble washout fraction (SWF). The aims of this study were: 1-To study the effect of different washing procedures on the size of NWF, ISWF and SWF in some concentrate ingredients. 2- To study the effect of different dilution ratios[1] (5, 10, 20, 30 and 40) on the size of SWF, and soluble true protein (STP) in some concentrates ingredients.

Material and Methods This study was carried out in two stages. **Experiment 1:** In a 7×6 factorial arrangement of treatments with 3 replicates, the effects of 7 different washing procedures (methods AA_{10}, AA_{20}, AA_{30}[2] , IS, M, SM and Y) on the size of NWF, ISWF and SWF in 6 concentrate ingredients (maize, barley, milo, peas, lupins and faba beans) were studied. Methods M and Y were described in detail by Azarfar *et al*. (2004). Method SM was almost similar to Method M except that in method M the dilution ratio was 25 whereas in method SM this ratio was 12.5. In method AA, amounts of 5.5g of feed sample were weighed into a pre-weighed nylon bag. The bags were put into a polypropylene centrifuge tube and an amount of distilled water was added to the centrifuge tubes to reach dilution ratios of 10, 20 and 30. The tubes were then shaken in a waterbath at 150 rpm for an hour. After that, the nylon bags were removed and their outside was rinsed with a small quantity of distilled water. The centrifuge tubes were then centrifuged at 8000 rpm for 30 minutes. The supernatant was filtrated through a fast filter paper and the resulting filtrate, assumed to be SWF, was decanted into pre-weighed aluminum containers and freeze-dried to determine the size of SWF. The pellets in the tubes were collected, brought into aluminum containers with a small amount of distilled water, and freeze-dried. **Experiment 2:** In a 5×6 factorial arrangement of treatments with 3 replicates the effect of 5 different dilution ratios (5, 10, 20, 30 and 40) on the size of SWF and STP in the 6 concentrate ingredients was studied. To determine the quantity of STP, 1 g of each sample was weighed into a propylene centrifuge tube and an amount of distilled water added to each tube to reach the dilution ratio of 5, 10, 20, 30 and 40. The contents of the centrifuge tubes were left to soak for an hour while shaking at 160 rpm. After that the tubes were centrifuged at 12500 rpm for 30 min. The supernatant was filtrated through a paper filter to separate solid particles. After filtration, to precipitate STP, an amount of 30% TCA was added to the centrifuge tube to reach a final concentration of 50 g/l. After 2 hours the tubes were centrifuged at 12500 rpm for 20 minutes. The pellet, assumed to contain all STP, was freeze-dried and the size of STP was determined.

Results Experiment 1: The effects on NWF, ISWF and SWF of grain type, washing procedure (method AA_{10}, AA_{20}, AA_{30}, IS, M, SM and Y) and the interactions between grain and washing procedure were significant ($P < 0.001$). NWF in method AA_{30} was more similar to method IS (63.5, 67.5, 65.0, 62.9, 60.6, 59.9 and 56.8% in method IS, AA_{10}, AA_{20}, AA_{30}, M, SM and Y, respectively). Increasing the dilution ratio increased SWF in the legume seeds whereas its effect on SWF in grains was not significant (Figure 1a). **Experiment 2:** The size of STP in the legume seeds was higher than in the grains (0.19, 0.58, 0.25, 11.8, 3.7 and 13.4 % in maize, barley, milo, peas, lupins and faba beans, respectively). By increasing the dilution level, STP was increased in legume seeds, but no remarkable response to increasing the dilution ratio was seen in grains (Figure 1b).

Conclusion The results show that method AA_{30} was a promising method to mimic the washing procedure. Our data show that many factors can affect the size of NWF and SWF of which washing method, dilution ratio and grain type are the most important.

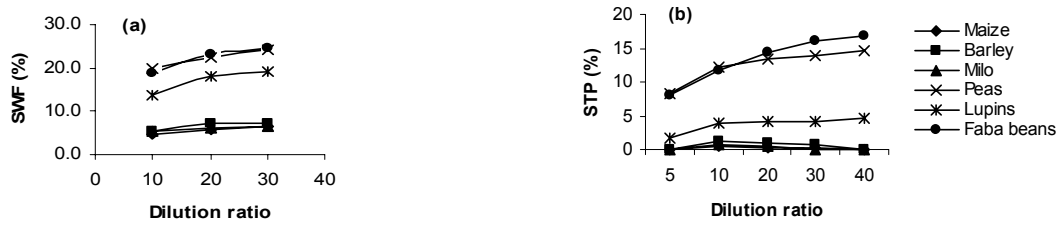

Figure 1 Effect of different dilution ratios in method AA on SWF (a) and the size of STP (b) in different grains.

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[1] Defined as the proportion of consumed water (ml) to sample weight (g).
[2] AA_{10}, AA_{20} and AA_{30} are AA method with dilution ratio of 10, 20 and 30, respectively.

The effect of reducing alfalfa hay cut length on TMR particle size distribution, rumen pH and chewing activity of cows in early lactation using Penn State Particles Separator(PSPS)

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Introduction The ability of a ration to meet the nutritional needs of a high yielding dairy cow requires understanding of both the chemical and physical characteristics of the ration (NRC, 2001). Having the proper particle size distribution (2 to 8 percent of the particles on the upper sieve, 30 to 50 percent on the middle and lower sieves, and no more than 20 percent on the bottom pan**)** of feeds is an important part of ration formulation. Chopping the crop at the proper length produces forages that can be combined to achieve the desired particle length in a TMR. The dairy cow's need for increasingly higher levels of energy have led to diets relatively high in concentrates. However, cows still require adequate fibre in the ration to function properly (Allen, 2000). Adequate forage particle length is necessary for proper rumen function and reduced forage particle size has been shown to decrease the time spent chewing and cause a trend toward decreased rumen pH. When cows spend less time chewing, they produce less saliva, which is needed to buffer the rumen. The objective of this study was to evaluate the effects of reducing alfalfa hay length of cut on TMR particle size distribution, rumen pH and chewing activity using penn state particles separator.

Materials and methods Twelve lactating multiparous Holstein cows averaging 18± 3 DIM and weighting 600± 52 kg, 4 total mixed rations (20, 40, 60 and 100 mm length cut of alfalfa hay) over 3 periods of 28 days which organized into 3 blocks, were employed. Mid bloom alfalfa hay (Alfa. H) was chopped with a chopper containing screens with apertures of 20, 40, 60 and 100 mm. The rations were chemically identical but different in Alfa. H particle size and were fed as a TMR with a ratio of concentrate to forage 60:40 (dry matter basis).Nutrient compositions of the rations were as following:NEL Mcal/kg DM 1.65, DM 72%, CP 17.2% ,NDF 32.85%,ADF 24.1%.Rumen pH and chewing activity (visually for a 24-h every 5 min)were recorded in the last day of each period. Alfa. H amd TMR particle size distribution were measured using PSPS (ASAE 2001). Data were analyzed using the mixed model procedure of SAS version 8.1 as a balanced change over design with the following model. $Yijklm=\mu+Ti+Pj+Bk+Al+Rm+Eijklm$. (where T: treatment (Alfalfa hay cut lengths), P: period, B: block, A: animal, R: residual, E: error)

Results Alfalfa hay and TMR particle size distribution, Geometric mean values are given in Table 1 and 2. Rechopping Alfa. H resulted in less material being retained on the 19.0 mm screen but increased the amount of particles being retained on both the 8.0 and 1.18 mm screens of the PSPS ($p< 0.05$). The amount of particles < 1.18 mm increased significantly with decreasing particle size ($p < 0.05$). Geometric mean decreased as the amount of rechopped forage in the TMR Increased ($p< 0.05$).Rumen pH and chewing activity decreased significantly as Alfa. H size reduced (Table 1).

Table1 TMR particle size distribution ,Rumen pH, TCA

Rations	1	2	3	4	p-value	s.e.m.
DM retained %						
19.0 mm	1.71c	3.50 c	13.97 b	30.28 a	<0.01	0.07
9.0-8.0 mm	24.68c	30.17a	28.46 b	20.66 d	<0.01	1.00
8.0-1.18 mm	52.63a	51.02a	46.74b	41.14 c	0.01	1.70
< 1.18 mm	21.61a	15.31b	10.83c	7.92 d	<0.01	0.50
Xgm (mm)[1]	3.94 c	4.42c	6.45 b	10.14 a	0.01	0.31
Sgm (mm)[2]	2.31d	2.46c	3.06 b	3.33 a	<0.01	0.05
Rumen pH	5.96a	6.13b	6.29c	6.40d	<0.01	0.09
TCA,Min/day	700b	746ab	767a	787 a	<0.01	27.00

TCA: total chewing activity

Table 2 Alfalfa hay particle size distribution

Rations	1	2	3	4	s.e.m
DM retained %					
19.0 mm	1.4	4.73	24.33	49.26	0.11
19.0-8.0mm	21.8	23.47	17.6	8.5	1.4
8.0- 1.18mm	62.0	58.6	47.33	34.11	2.2
<1.18 mm	14.8	13.2	10.74	8.13	0.8
Xgm (mm)[1]	3.94	4.42	6.45	10.14	1.0
Sgm (mm)[2]	2.31	2.46	3.06	3.33	0.2

1: geometric mean $= \frac{\sum \log\text{-}1 \ (mi \log xi)}{\sum Mi}$

2: standard geometric mean

[a,b,c] means within row with different superscript differ significantly at ($p<0.05$)

Conclusions Results of this study indicate that chopping Alfa. H at 60 mm length produces a desired particle size distribution in TMR which can affect animal performance. In this study, reducing Alfa. H cut length resulted in decreased chewing activity and rumen pH. Our data suggest that increasing the proportion of particles >19.0mm may be a primary factor affecting chewing activity and rumen pH in dairy cattle fed diets containing Alfa. H as a part of the forage source.

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Effect of enzyme addition on the availability for poultry of amino acids in rapeseed meal

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Introduction Rapeseed meal (RSM) is the richest source of commercially available home grown protein in the UK, but its inclusion in livestock diets is approximately half that of soyabean meal (SBM, DEFRA, 2004). RSM has a lower protein and available lysine content than SBM but increased nutrient digestibility was observed when pigs were fed RSM supplemented with non-starch polysaccharide degrading enzymes (Hoare et al., 2003). The objective of this experiment was to determine the effect of adding different amounts of a cell wall degrading enzyme on the available amino acid content of RSM as estimated in poultry.

Materials and methods A sample of UK rapeseed meal was divided into three subsamples, one of which was left untreated to act as the control (UT). The other subsamples (ENZ4 and ENZ6) were treated with cell wall degrading enzyme (Depol 740L, Biocatalysts Ltd, Pontypridd, Mid Glamorgan, UK) at the rate of 0.4 and 0.6 g enzyme/kg feed dry matter respectively. A sample of SBM was also used, to act as a positive control. The samples were analysed for amino acid availability using caecectomised cockerels, with three replicates (four birds per pen) of each sample. The cockerels were fed a basal diet based on maize and soyabean meal, and were then fasted for 24 h before being offered a glucose solution. The test feeds (RSM or SBM and maize starch mixture in proportions to make a mixture of 180 g/kg crude protein) were then administered by gavage 24 h later. Excreta were then collected for 48 h. Feeds and excreta were analysed for amino acid content. The effect of the different supplements on amino acid availability and available amino acid contents were estimated by analysis of variance using the General Linear Model of Minitab Inc.

Results The true availability of amino acids was lower in RSM compared with SBM, and the addition of exogenous enzyme did not increase amino acid availability in RSM (Table 1). RSM had a lower crude protein (CP) content than SBM (373, 366, 361 and 533 g CP/kg DM for UT, ENZ4, ENZ6 and SBM respectively). The concentration of available essential amino acids was lower in the RSM samples compared with SBM, except for cysteine and methionine (Table 2). Treating RSM with exogenous enzyme did not increase its available amino acid content.

Table 1 The true availability (%) of some essential amino acids in treated and untreated RSM and SBM

	Feed				sem	Significance
	UT	ENZ4	ENZ6	SBM		
Lysine	79.2	71.5	74.5	90.9	4.45	***
Methionine	89.8	84.0	86.7	90.6	1.35	**
Cysteine	79.2	63.4	69.7	88.1	10.89	**
Threonine	78.5	67.4	73.4	86.5	7.33	**
Leucine	87.6	80.4	84.1	90.7	3.23	**

** P<0.01; *** P<0.001

Table 2 Truly available amino acid content (g/kg DM) of treated and untreated RSM and SBM

	Feed				sem	Significance
	UT	ENZ4	ENZ6	SBM		
Lysine	16.3	15.1	15.5	29.8	0.23	***
Methionine	6.3	5.8	6.1	5.9	0.01	**
Cysteine	6.6	5.7	6.3	6.2	0.08	ns
Threonine	12.6	11.3	12.2	17.6	0.21	***
Leucine	23.6	23.2	23.8	38.5	0.29	***

ns:not significant; ** P<0.01; *** P<0.001

Conclusion RSM is at least as good as SBM as a source of available sulphur amino acids (methionine and cysteine), but is otherwise inferior to SBM. This is mostly because of the lower protein content of RSM compared with SBM, but also because of the lower availability of its amino acids in, which was not ameliorated by the addition of cell wall degrading enzyme. To ensure increased utilisation of RSM, a cost effective means of dehulling RSM and reducing heat damage during processing will need to be developed.

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The effect of oil supplementation and method of application on the overall digestibility of diets for finishing pigs

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Introduction By-product-based diets generally contain lower levels of energy than cereal-based diets due to higher levels of fibre (Bakker *et al.,* 1995). Supplementation with oil is a common method of improving the digestible energy content of by-product-based diets and it has been reported that this practice may also improve energy digestibility. However, the results of McCann *et al.,* (2004) suggested that the method of oil application to finishing pig diets may affect the digestibility of dietary nutrients. The aim of this experiment was to compare apparent digestibility coefficients determined in finishing pigs offered either by-product based diets or cereal-based diets, with and without vegetable oil blend supplementation applied using two different methods (either directly incorporated into the pellet (IN) or sprayed (SP) on after pelleting).

Materials and methods Seven diets were formulated; A (by-product-based), B (diet A + 40 g/kg oil IN), C (diet A + 10 g/kg oil IN + 30 g/kg oil SP), D (barley based), E (diet D + 40 g/kg oil IN), F (diet D + 10 g/kg oil IN + 30 g/kg oil SP), G (wheat, barley, maize based). The by-product-based diet (A) included (g/kg) 245 barley, 175 wheat, 35 maize, 50 maize gluten, 50 maize gluten feed and 150 pollard. Diet D included (g/kg) 451 barley and 250 wheat and Diet G included (g/kg) 250 barley, 313 wheat and 150 maize. The formulated DE contents were (MJ/kg) 12.5, 13.4, 13.4, 13.0, 13.9, 13.9, 13.5 respectively. The diets were offered to a total of 56 male crossbred (Large White x Landrace) pigs (50kg) housed in metabolism crates for a period of 14 days (7 day prefeed + 7 day balance collection period). Each of the seven treatments was replicated eight times and feed was offered at 1500 g/d. Samples of the diets, faeces and urine were collected and analysed to determine digestibility of dry matter (DM), crude protein (CP), oil, neutral detergent fibre (NDF), and energy. The results were analyzed by ANOVA using Genstat 5 (1993).

Results Higher DM, CP, NDF and energy digestibility coefficients were determined for cereal-based diets in comparison to by-product-based diets. There was no consistent effect of the method of oil application on DM, CP or NDF digestibility of either cereal- or by-product-based diets (Table 1). Spraying the oil onto the pellet improved oil digestibility for the by-product-based diets. The addition of oil to by-product-based diets increased oil digestibility to levels above cereal-based diets and improved dietary DE content. Energy digestibility was not affected by oil addition.

Table 1 The effect of energy source and method of oil application on the digestibility of the diet

	A	B	C	D	E	F	G	SEM	P
DM digestibility	0.790^{a}	0.785^{a}	0.784^{a}	0.827^{b}	0.842^{c}	0.838^{bc}	0.864^{d}	0.004	<0.001
CP digestibility	0.803^{ab}	0.792^{a}	0.790^{a}	0.822^{bc}	0.849^{d}	0.840^{cd}	0.856^{d}	0.007	<0.001
Oil digestibility	0.589^{b}	0.705^{c}	0.755^{d}	0.517^{a}	0.683^{c}	0.698^{c}	0.614^{b}	0.010	<0.01
NDF digestibility	0.552^{b}	0.524^{ab}	0.503^{a}	0.594^{c}	0.615^{cd}	0.590^{c}	0.628^{d}	0.011	<0.05
Energy digestibility	0.784^{a}	0.777^{a}	0.782^{a}	0.825^{b}	0.837^{b}	0.834^{b}	0.859^{c}	0.005	<0.001
DE (MJ/kg DM)	14.2^{a}	14.8^{b}	15.0^{b}	14.7^{b}	15.5^{c}	15.7^{c}	15.7^{c}	0.116	<0.001

Means with different superscripts are significantly different (P<0.05)

Conclusions Method of oil application did not affect the digestibility of DM, CP or energy, indicating that oil can either be incorporated directly into or sprayed onto the pellet. The increase in oil digestibility as a result of oil supplementation is an artifact of the higher level of oil in the diets. CP and energy digestibility was not increased with oil addition which is in contrast to the results of Jorgensen and Fernandez (2000) but in keeping with those of McCann *et al* (2004). DE content was increased with oil addition but the determined values were lower than the formulated values which is in line with the results of McCann *et al.,* (2004).

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The effect of method of dietary oil application on growth performance and carcass characteristics of finishing pigs

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Introduction Oil supplementation of by-product based diets is a common method of increasing the energy content of pig diets to levels equivalent to those of cereal-based diets (Overland *et al* 1999). However, by-product based diets supplemented with oil have been reported to reduce feed intake and digestible energy intake when compared with cereal-based diets (Magowan *et al* 2004). It is not known whether this effect occurs as a result of the higher levels of fibre in by-product-based diets or as a result of a reduction in palatability arising from the inclusion of oil in the pellet. The aim of this experiment was to investigate the effect of method of vegetable oil blend application (either incorporated directly into the pellet (IN), or sprayed on after pelleting (SP)) on the performance and carcass characteristics of commercially housed finishing pigs.

Materials and methods Seven diets were formulated; A (by-product-based), B (diet A + 40 g/kg oil IN), C (diet A + 10 g/kg oil IN + 30 g/kg oil SP), D (barley-based), E (diet D + 40 g/kg oil IN), F (diet D + 10 g/kg oil IN + 30 g/kg oil SP), G (wheat, barley, maize-based). The by-product-based diet (A) included (g/kg) 245 barley, 175 wheat, 35 maize, 50 maize gluten, 50 maize gluten feed and 150 pollard. Diet D included (g/kg) 451 barley and 250 wheat and Diet G included (g/kg) 250 barley, 313 wheat and 150 maize. Actual DE (MJ/kg DM) contents were determined in a parallel study and were 14.2, 14.8, 15.0, 14.7, 15.5, 15.7 and 15.7 respectively. The diets were offered to a total of 1140 thirteen-week old crossbred (Large White x Landrace) pigs until slaughter (100kg). Pigs were blocked for weight and sex in pens of 20, over eight replicates. Average daily gain (ADG), daily feed intake (DFI), feed conversion ratio (FCR) and digestible energy intake (DEI) were recorded. The level of backfat (mm) at the P_2 position and the kill out percentage (KO%) were also determined. Results were analysed by ANOVA using Genstat 5 (1993).

Results Supplementation of oil to both by-product and cereal-based diets improved FCR but had no consistent effect on ADG or DEI (Table 1). There was no difference in FCR due to method of oil application. When oil was included in the cereal-based diets (E and F), FCR was improved compared with oil included in the by-product diets (B and C) but DE/gain was not affected. DEI was higher for cereal-based diets (F and G). Oil supplementation of both by-product and cereal-based diets increased the backfat depth of pigs but again the method of oil supplementation had no effect.

Table 1 The effect of energy source and method of oil application on the performance of pigs

	By-product based			Barley based			Wheat, barley, maize based	SEM	P
Oil (g/kg)	0	40 IN	10 IN+30 SP	0	40 IN	10 IN+30 SP			
ADG (g/d)	743^{a}	789^{ab}	742^{a}	795^{bc}	813^{bc}	839^{c}	822^{bc}	16.7	<0.001
DFI (kg/d)	2.22	2.20	2.11	2.21	2.12	2.17	2.25	0.050	NS
FCR	2.99^{c}	2.79^{b}	2.84^{b}	2.79^{b}	2.61^{a}	2.59^{a}	2.75^{b}	0.049	<0.001
DEI (MJ/d actual)	28.2^{a}	28.8^{ab}	28.1^{a}	28.7^{ab}	29.3^{a}	30.4^{bc}	31.3^{c}	0.63	<0.01
DE/gain	38.0	36.5	37.9	36.3	36.1	36.2	38.2	0.65	NS
P_2 (mm)	11.1^{a}	12.0^{b}	12.2^{b}	11.0^{a}	12.5^{b}	12.0^{b}	11.7^{b}	0.28	<0.05
KO%	73.9	74.5	73.8	74.5	74.7	74.9	75.3	0.48	NS

Means with different superscripts are significantly different (P<0.05)

Conclusions Method of oil application had no significant effect on performance or carcass parameters indicating that palatability was not affected either by incorporating the oil directly into the pellet or by spraying on after pelleting. While there was no significant difference in DFI, DEI was reduced in pigs offered by-product-based diets compared with those offered cereal-based diets suggesting that the higher levels of fibre reduced energy intake in the by-product-based diet. Oil supplementation was effective in improving FCR of by-product-based diets to levels equivalent to the barley-based diets, which is in keeping with the results of previous research (Magowan *et al* 2004). The increase in backfat depth with oil supplementation could be of economic importance depending on the grading scheme in place.

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Effect of dietary concentrations of n-3 polyunsaturated fatty acids on the n-3 polyunsaturated fatty acid content of edible poultry tissues: a review and meta analysis

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Introduction The nutritional benefits of consuming long chain n-3 polyunsaturated fatty acids (PUFA), which are predominantly found in oily fish, are well known but consumption of oily fish is declining. Poultry consumption, on the other hand, is increasing, but poultry meat is generally a poor source of long chain n-3 PUFA. The concentrations of the n-3 PUFA α-linolenic acid (LNA), EPA and DHA in poultry meat may be increased by feeding birds diets that are themselves rich in these acids. The objective of this study was to review the literature to determine what relationship if any there was between n-3 PUFA content in the diet and edible tissues of poultry.

Materials and methods Data published by Ratnayake *et al.* (1989), Ajuyah *et al.* (1991, 1992), Chanmugam *et al.* (1992), Sheehy *et al.* (1993), Nam *et al.* (1997), Monney *et al.* (1998), Nitsan *et al.* (1999), Gonzalez-Esquerra and Leeson (2000), Kraasicka *et al.* (2000), López-Ferrer *et al.* (2001a,b), Howe *et al.* (2002), Özpinar *et al.* (2003) and Komprda *et al.* (2003) were collated. The relationships between n-3 PUFA contents of the diet and the edible tissues (skinless white meat, SWM and skinless dark meat, SDM) were investigated by regression.

Results Relationships between tissue and dietary n-3 PUFA contents are summarised in Table 1.

Table 1 Relationship between n-3 PUFA contents (g/kg fresh weight) of poultry diets and the edible tissues of poultry fed those diets

Response (y)	Predictor (x)	Equation	R^2 (%)	s	P
[LNA] SWM	Diet [LNA]	y = 0.015x + 0.189	30.9	0.267	0.000
[LNA] SDM	Diet [LNA]	y = 104x + 0.079	77.2	0.000	0.000
[EPA] SWM	Diet [EPA]	y = 0.311x + 0.219	67.1	0.284	0.000
[EPA] SDM	Diet [EPA]	y = 0.408x + 0.231	44.8	0.497	0.000
[DHA] SWM	Diet [DHA]	y = 0.173x + 0.420	15.8	0.656	0.179
[DHA] SDM	Diet [DHA]	y = 0.109x + 0.442	34.4	0.288	0.017

Conclusion LNA contents of dark poultry meat may be increased by supplementing the diet with LNA, but this will have little effect on the LNA content of white poultry meat. Conversely, supplementing the diet with EPA enhances the EPA content of white poultry meat, but this measure will have limited effect on the EPA content of dark meat. Although the DHA content of poultry meat is enhanced to some extent by supplementing the diet with DHA, the response is much weaker than with EPA and LNA, and more DHA needs to be added to the diet before noticeable increases in DHA content are observed in the edible tissues of poultry.

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The relationship between body dimensions of living pigs and their carcass composition

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Introduction Recent analysis pointed towards visual imaging analysis (VIA), which yields pig body size measures and shape indices from two-dimensional visual images of living pigs, as a potential technique for estimating fat and lean content in pig carcasses (Doeschl et al., 2004). The present analysis further explored the potential of using VIA body size and shape indices as indicators of the proportion of lean and fat in various carcass joints, either alone or in combination with ultrasonic backfat depth of the live animal. Due to increasing interest in the shape of retail cuts in the meat industry, the association between VIA size measures and the dimensions of the *longissimus dorsi* and *gluteobiceps* muscles is also assessed.

Materials and methods Ultrasonic backfat depth measurements at the P2 site (BF) and 9 VIA indices representing the shapes of various body regions were obtained for 48 pigs (24 boars and 24 gilts) prior to slaughter. Variations in shape and composition were achieved by differences in crude protein contents of the diets ranging between 0.14 kg/kg and 0.19 kg/kg. The body weights of the pigs prior to slaughter ranged from 52 to 120kg. Partial carcass dissection together with full pelvic limb dissection was carried out for all 48 pigs; a full carcass dissection was performed on a randomly selected subset consisting of 22 of these 48 pigs. The relationship between *in vivo* measures and carcass composition was assessed using multiple linear regression analysis.

Results The association between the carcass muscle areas and VIA size measures was statistically significant ($P<0.05$). Adjusted R^2 values were 0.52 (boars) and 0.18 (gilts) for the *longissimus dorsi* and 0.35 (boars) and 0.19 (gilts) for the *gluteobiceps* muscle. The relationship between carcass muscle dimensions and VIA size measures was stronger for boars than for gilts. A statistically significant relationship ($P<0.05$) between *in vivo* VIA body shape and carcass composition was found for most body regions (Table 1, model A). Adjusted R^2 statistics ranged between 0.13 and 0.50 for relative fat weights and between 0.14 and 0.51 for relative lean weights. The association between *in vivo* measures and carcass composition strengthened if VIA indices were combined with other *in vivo* measurements (Table 1, model B).

Table 1 Adjusted R^2 statistics for the proportion of fat and lean in the whole carcass or individual joints as dependent variables and the VIA shape indices and ultrasonic backfat depth (BF) as independent variables. Two types of models are presented for each carcass component: model A used only VIA shape indices as predictors, whereas model B combined shape indices BF measurements as predictors. With exception of those models denoted by NS (not significant) in the predictors, all of the shown relationships were statistically significant ($P<0.05$).

		Relative fat tissue weight		**Relative lean tissue weight**	
Carcass component	**Sex**	**Model A (VIA only)**	**Model B (VIA and BF)**	**Model A (VIA only)**	**Model B (VIA and BF)**
Shoulder	Pooled	0.13	0.49*	0.19	0.48*
Foreloin	Pooled	0.42	0.84	0.21	0.21**
Belly	Pooled	0.14	0.58*	0.15	0.47
Hindloin	Pooled	0.28	0.67*	0.38	0.39*
Flank	Pooled	0.14	0.47*	NS	0.13*
Pelvic Limb	Boar	0.42	0.62	0.14	0.19
	Gilt	0.50	0.56	0.29	0.32*
Entire Carcass	Boar	NS	0.54*	0.24	0.28
	Gilt	0.36	0.66	0.51	0.37*

*The final regression model contained only BF as predictors
** The final regression model contained only VIA shape indices as predictors

Conclusion These results show *in vivo* VIA measurements to be useful in the estimation of muscle size, carcass conformation and composition, all of which are measures of market importance.

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Influence of regrouping strategy on performance, behaviour and carcass parameters in pigs

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Introduction Large variations in weight within groups of pigs at slaughter lead to either (1) inefficient use of resources as some pigs have to be retained for longer periods in finishing accommodation than others, or (2) large variation in carcass weights, which creates problems for processors. The aim of this study was to assess the effect of creating uniform weight groups at weaning at 4 weeks of age, or at the start of the finishing period at 10 weeks of age, on coefficient of variation in slaughter and carcass weight. The effect of these regrouping strategies on mean production performance during the growing and/or finishing periods was also assessed. In addition, the effect of regrouping pigs at the start of the finishing period on aggressive behaviour was assessed.

Material and methods One thousand, two hundred pigs were assigned in a randomised block experiment to one of five treatments: (1) Uniform weight groups formed at weaning and retained until slaughter, (2) Mixed weight groups formed at weaning and retained until slaughter, (3) Uniform weight groups formed at weaning, and regrouped at the start of the finishing period to form mixed weight groups which were retained until slaughter, (4) Mixed weight groups formed at weaning, and regrouped at the start of the finishing period to form uniform weight groups that were retained until slaughter, (5) Mixed weight groups formed at weaning, and regrouped at the start of the finishing period to form mixed weight groups which were retained until slaughter (to assess the effect of regrouping at the start of the finishing period when compared with treatment 2). Three mixed-gender groups of ten pigs were assigned to each treatment, and this experimental set-up was replicated eight times. Uniform weight groups consisted of one group of small pigs, one group of medium-weight pigs and one group of large pigs. Mixed weight groups consisted of three groups of pigs, each containing small, medium and large pigs. Pigs were weaned at 4 weeks of age, moved to finishing accommodation at 10 weeks of age and slaughtered at 21 weeks of age. They were housed in combined stage 1/stage 2 accommodation between 4 and 10 weeks of age, and in separate finishing accommodation between 10 and 21 weeks of age. All accommodation was slatted, and pigs were housed at recommended space allowances. Individual live weights were recorded at 4, 10 and 21 weeks of age, and carcass weights were also recorded. Within-group coefficient of variation was calculated for all weight parameters. Group feed intake levels were recorded weekly throughout the study, and food conversion ratios calculated. In addition, each group of pigs was observed five times per day (at 20 minute intervals) during the 2-day period immediately after moving to finishing accommodation. The frequency of occurrence of aggressive behaviours such as fighting, headthrusting, biting, chasing, and displacing from feeders or drinkers were recorded for 1 minute periods, and total levels of aggressive behaviour were calculated. Data were analysed by analysis of variance using Genstat 5.

Results Effects of forming uniform or mixed weight groups on coefficient of variation in weight are presented in Table 1. In groups formed at 4 weeks of age, forming uniform weight groups led to reduced coefficient of variation in 10-week weight, but not in slaughter or carcass weight, relative to mixed weight groups. The coefficient of variation in weight increased substantially in uniform weight groups during the growing period (between 4 and 10 weeks of age). Forming uniform weight groups at 10 weeks of age led to reductions in coefficient of variation in slaughter and carcass weight relative to mixed weight groups formed at this age ($P<0.05$). Mean growth rate, feed intake and food conversion ratio did not differ between uniform and mixed weight groups ($P>0.05$).

Table 1 Coefficient of variation in live weight at different ages and in carcass weight

	Groups formed at 4 weeks of age				**Groups formed at 10 weeks of age**			
	Uniform	Mixed weight	SEM	Sig.	Uniform	Mixed weight	SEM	Sig.
4 week weight	0.07	0.16	0.003	***	-	-	-	-
10 week weight	0.13	0.15	0.004	**	0.08	0.15	0.007	***
21 week weight	0.11	0.11	0.008	NS	0.09	0.12	0.014	*
Carcass weight	0.10	0.10	0.005	NS	0.08	0.10	0.005	*

Regrouping at the start of the finishing period led to a significant increase in the frequency of aggressive behaviour during the 2-day post regrouping period (regrouped 0.946, non-regrouped 0.450, SEM 0.0912 min^{-1}, $P<0.001$). Regrouping at this stage did not significantly affect growth rate, feed intake or food conversion ratio during the finishing period ($P>0.05$).

Conclusions There are benefits in forming uniform weight groups at the start of the finishing period at 10 weeks of age in terms of reducing within-group variation in slaughter and carcass weight. In addition, regrouping at this stage had no long-term adverse effects on performance. However, aggressive behaviour was significantly increased by regrouping at this stage, which suggests that welfare was adversely affected. Future research should aim to reduce variation in growth during the growing period, so that forming uniform weight groups at weaning leads to reduced variation in weight at slaughter.

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Influence of different types of environmental enrichment on the behaviour of finishing pigs in two different housing systems

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Introduction It is generally accepted that environmental enrichment improves the welfare of growing pigs through the provision of substrates for exploratory and manipulatory behaviour. EC Directive 2001/93 and The Welfare of Farmed Animals (England) (Amendment) Regulations 2003 state that pigs must have permanent access to materials to enable proper investigation and manipulation activities, and give as examples straw, hay, wood, sawdust, mushroom compost and peat. However, the use of particulate rooting materials in slatted systems can cause difficulties for slurry management and it is important to establish whether alternative enrichment forms, such as hanging objects, can be equally effective. The aim of this study was to assess the effects of environmental enrichment with either hanging manipulable toys or rootable substrates on the behaviour of finishing pigs in two contrasting housing systems.

Materials and methods A total of 1056 Landrace x Large White pigs were selected at 35 kg liveweight. Intakes of 128 pigs were allocated between 4 pens within a single room in either a straw-based (ST) building, where straw bedding was replenished daily, or a fully-slatted (FS) building of otherwise similar design (Scott et al, 2004), to give a total over time of 16 pens in each building. Pigs in both houses received the same liquid diets *ad libitum*. In each house, half of the pens received additional enrichment in the form of the commercially available Bite Rite object, with plastic chewing arms, which was suspended on a chain at pig level. In the ST house the other pens were enriched only by the straw bedding. In the FS house the other pens were provided with a double-spaced hopper containing shreds of unmolassed sugar beet pulp as a form of rootable enrichment. In each pen 3 males and 3 females were chosen as 'focal' pigs for detailed behavioural scans at three key stages: week of entry, week before group size reduction at ~60 kg and week before slaughter. Scan samples were taken every 10 minutes for three 2-hour periods in the day. Data were analysed using ANOVA with the pen as the statistical unit, and Tukey's test was applied for appropriate pairwise comparisons.

Results Results for the mean percentage of time spent in different behaviours are given in Table 1. Pigs in the ST house spent 16.1% of their time in straw-directed behaviour. The provision of additional environmental enrichment in the form of a Bite Rite had no significant effect on the level of straw manipulation. In the absence of straw, pigs in the FS house redirected behaviour towards other substrates in their environment. This resulted in an increase in behaviour directed to pen components, but did not increase pig directed behaviour. The level of Bite Rite manipulation was significantly higher in the FS house than the ST house, and this was reflected in the level of chewing damage to the devices measured at the end of the trial period (FS=16.7cm of chewing arm remaining v ST=22.2cm, $P<0.001$). Within the FS house, pigs spent significantly more time occupied with sugar beet pulp than the Bite Rite. However, occupation time with both these substrates was low, and less than 12% of the occupation time provided by straw bedding.

Table 1 Effects of housing and type of enrichment on pig behaviour (mean % of observations over 3 time periods)

	Straw Based		Fully Slatted		SEM	P
	Control	+ Bite Rite	+ Bite Rite	+ Sugar Beet Pulp		
% Behaviour towards:						
Straw	15.9	16.3	-	-	0.9	ns
Enrichment device	-	0.4^{a}	1.1^{b}	1.9^{c}	0.2	***
Other pigs	7.3	6.5	7.4	8.0	0.7	ns
Pen parts	4.9^{a}	4.8^{a}	10.5^{b}	10.6^{b}	0.7	***

Means within rows with different superscripts are significantly different ($P<0.001$)

Conclusions Neither form of additional environmental enrichment was able to provide anywhere near the same level of occupation as straw bedding. Recent legislation has highlighted the urgency in identifying suitable enrichment that will meet the behavioural needs of the pig in unbedded systems. The reasons behind the difference in occupation time between straw manipulation and enrichment object interaction require further study, since ideally functional enrichment should occupy animals to a great extent to divert them from performing adverse behaviour (Van de Weerd et al, 2003).

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Using sociometric methods and feeder order to assess social position in early finishing pigs

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Introduction Competition resulting in high social status and maintenance of that status within farmed pigs may have both welfare and economic consequences. Aggressive behaviours, associated with the establishment and maintenance of a dominance hierarchy, may cause poor welfare and skin damage reducing the value of pigs at slaughter. In order to investigate the impact of social status on welfare we first need to establish the status of individuals relative to their peers. In this paper we compare two alternative indicators of pig rank, namely: (i) aggressive interactions between individuals - the occurrence of aggressive behaviour from pig A to pig B is often assumed to imply social dominance of pig A over pig B; and (ii) the order in which pigs stand at the feeder - an advantage of attaining high social status in many populations is priority of access to food. Social rank of individuals based on observed aggressive behaviour can only be assigned once evidence for a linear or quasi-linear hierarchy has been established (Langbein and Puppe, 2004). In a population with a purely hierarchical structure we expect all triads of individuals to be transitive, that is A→B, B→C implies A→C. For observational studies it is unlikely that interactions between all individuals will be observed. Here we present a novel methodology by which we can assess the linearity of the dominance structure that is not affected by missing or null interactions between individuals. By conducting a census of all types of triad in a social network we can assess whether the subset of interactions observed provide evidence of a linear or quasi-linear hierarchy. Transitive triads provide evidence of linear hierarchy whilst intransitive triads, such as A→B, B→C, C→A, contradict the presence of a linear hierarchy.

Materials and methods Fifty-two Large White/Landrace pigs, aged approximately 120 days, were kept in four pens of 13 ± 1 animals. To assess rank from aggressive interactions, behavioural data were collected by whole group scan sampling every 5 minutes for 10 hours of data collection per pig, during a three-week period. We defined dominant behaviours as mounting, nosing and sucking other pigs, and displacement as fighting was rarely seen. Pigs were defined as having a dominant link with another if one of these interactions occurred at least once between them. A triad census (Moody, 1998; Skvoretz, 2004) was conducted on the dominant behaviour matrix and the observed distribution of triads was weighted using both transitive and intransitive weighting vectors and compared with expected values to obtain the τ-statistic value (see Wasserman and Faust, 1997 for details). We accept the alternative hypothesis that a social structure is linear or quasi-linear if there are significantly more transitive triads than expected by chance and significantly fewer intransitive triads than expected by chance. The rank of pigs in groups where there was evidence of a hierarchical structure was generated from the dominant behaviour matrix using the Corrected David Score (Gammell *et al.*, 2003). To assess rank from feeder order, the pigs were fed using a wet feed system three times a day. We considered the best position to be that closest to the central pipe since the feed arrived there first so allowed pigs near the pipe to have greater access. The position of each pig was recorded over 7 sessions with each position having a score that increased as they stood further from pipe. The feeder order rank was obtained directly by ordering the total score over the sessions.

Results Two of the four pens (Pen 1 and Pen 3) showed significantly more transitive triads (τ = 3.54, P = 0.0004; τ = 2.47, P = 0.014 respectively) and significantly fewer intransitive triads (τ = -1.97, P = 0.049; τ = -2.99. P = 0.0028 respectively) than expected by chance. This provides evidence of a linear or quasi-linear hierarchy and allows ranks to be assigned. There was no correlation between the ranks generated by feeder order and Corrected David Score for pen 1 and 3 (P = 0.121, P = 0.262 respectively, Spearman's Rank Correlation Test, GenStat Release 7.2).

Conclusions This work highlights the importance of testing for the presence of a linear or quasi-linear hierarchy before assigning ranks. Evidence for hierarchy was only found in 2 out of 4 pens. The present data do not support the presence of a linear hierarchy in two of the pens, which is consistent with recent findings by Langbein and Puppe (2004). However this may be an artefact of our experimental design and we are planning to collect focal data from video recordings of these pens. Where there was evidence of hierarchy using the dominant behaviour data, the ranks were not positively correlated with the ranks based on feeder order. This may be due to the different motivations involved in social behaviour and competitiveness for feeder position, in particular, the lack of necessity to compete for feed in modern high input systems. It is clear from this study that further work is required to investigate the presence of social ranking in farmed pigs before an association between stress indicators and social status can be investigated.

Acknowledgements E Genever was supported by a BBSRC studentship. C Webb was jointly supported by Tetra-Laval Research Fund and the Isaac Newton Trust.

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Induction of experimental sub-clinical post-weaning colibacillosis in pigs

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Introduction Newly weaned pigs are at least partially protected against sub-clinical gastrointestinal disorders through the provision of in-feed antimicrobials. Possible associations with antibiotic resistance to life threatening bacterial infections in humans and environmental pollution will result in their ban. As a consequence, gut health and pig performance will be compromised. Current research is aimed at reducing, and eventually overcoming, such consequences through novel nutritional strategies. Effects of the latter on the consequences of sub-clinical infection may be assessed in an infection model, since the absence of in-feed antimicrobials does not always lead to gastrointestinal disorders, due to e.g. variation in infectious environmental conditions. A common gastrointestinal disorder is post-weaning colibacillosis (PWC), which is caused by enterotoxigenic *E. coli* (ETEC), and is associated with diarrhoea and reduced food intake, and hence reduced performance. Existing ETEC infection models, which have yielded variable results and employed relatively large infective doses of ETEC, have focused on clinical PWC (Madec *et al.*, 2000). The objective of our experiment was to assess whether sub-clinical PWC can be induced through experimental infection with ETEC, and whether such sub-clinical PWC is sensitive to the level of infection used.

Materials and methods Twenty four male Large White x Landrace pigs, weaned at three weeks of age, were purchased from a high health farm. They were transported on the day of weaning, housed individually in the experimental facility and divided into four groups of six piglets each, which were balanced for body weight (mean 7.20±0.20 kg) and litter origin. They were offered a standard food (23% CP, 16 MJ DE), free of antimicrobials, which was gradually introduced over the first three days upon arrival, and *ad libitum* available thereafter. Five days post arrival (day_0), piglets were given 10 ml of phosphate-buffered saline containing either 0 (sham-infection, control, C), 10^6 (L), 10^8 (M) or 10^{10} (H) colony-forming units of ETEC. These ETEC were derived from clinical cases of PWC (VLA, Surrey, UK), had been characterised as having the required virulence factors to induce PWC, and were given through stomach tubing. Feed intake and faecal consistency (assessed through subjective scoring on a scale from 1 through 4, where 1= firm faeces and 4=projectile diarrhoea) were measured daily. Pigs were weighed every other day, and slaughtered on day_6. Small intestinal tissue samples were collected from duodenum, mid-jejunum and distal ileum, and were subjectively scored for PWC associated pathophysiology. Post infection results were analysed through analysis of variance, which used pre-infection results as covariate.

Results One M and two H pigs developed clinical signs of PWC, and were excluded. Body weight gain of the remaining pigs averaged 318, 297, 188, and 168 g/d (s.e.d. 58 g/day; $P<0.05$) for the C, L, M and H pigs, respectively. Figure 1 shows an interaction between time and treatment for food intake and faeces score ($P<0.05$). Food intake of the C and L pigs were similar. However, food intake of the M pigs reduced until day_3, followed by a full recovery by day_6. In contrast, food intake of the H pigs did not fully recover. The L and C pigs had similar low faeces score. However, faeces score of the M pigs was temporarily elevated, whilst that of the H pigs tended to increase throughout the infection period. Rectal temperature tended to be lower in the infected pigs ($P=0.10$). Infection did not affect any of the assessed PWC associated pathophysiology on day_6.

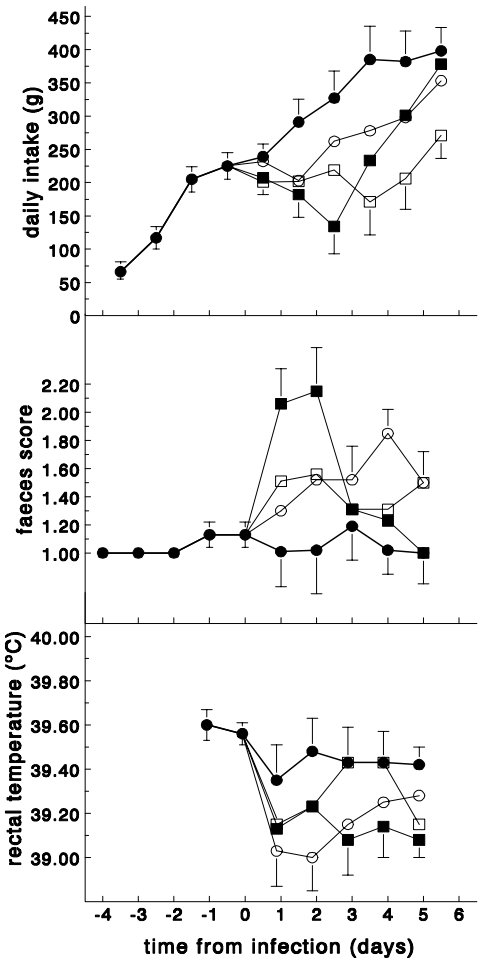

Figure 1 Least square mean intake, faeces score and rectal temperature (with standard error) of pigs, infected with 0 (●), 10^6 (○), 10^8 (■) or 10^{10} (□) cfu ETEC. Day_0 was five days post weaning.

Conclusion These results indicate that sub-clinical PWC can be induced through administrating of an appropriate dose of ETEC. Based on the temporal effects observed in food intake and faeces score, the data suggest that a level of 10^8 cfu ETEC would be appropriate for the assessment of effects of novel nutritional strategies to reduce the consequences of sub-clinical PWC. In addition, PWC associated pathophysiology may better be assessed at earlier stages of the infection.

Acknowledgements This work was supported by SEERAD.

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Effect of a bovine colostrum supplementation in piglet diet at weaning on growth performances, food ingestion and faecal *E. coli* concentrations

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Introduction In the perspective of the complete ban of antibiotic growth promoters use in animal food by 2006, many alternatives have been studied. However, most of them are not yet technically and/or economically competitive with antibiotics. In this way, the incorporation of bovine colostrum in piglet diets has been studied. Bovine colostrum was chosen for its high concentration in growth promoting and anti-microbial peptides (Playford *et al*., 2000) and for its high availability. The aims of this study were to measure the efficiency of a bovine colostrum supplementation on growth performances of newly weaned piglets and to evaluate its effects on the digestive and immunological troubles involved by weaning (Pluske *et al*., 1997 and Vega-Lopez *et al*., 1995).

Materials and methods 96 Belgian-Landrace X Pietrain piglets (48 males and 48 females) weaned at 28 days were used in this study. At weaning (D0), they were allocated to 2 treatments according to their sex and liveweight. Piglets of the "Colostrum" treatment received a commercial diet (SCAR, Herve, Belgium) supplemented with freeze-dried bovine colostrum serum provided by the CER (Marloie, Belgium) and the others were fed with the same commercial diet supplemented with bovine milk serum ("Control" treatment). During the two first weeks of treatment, the commercial diet was supplemented with 2 % of the tested sera. This supplementation was lowered to 1 % during the next two weeks. Piglets of each treatment were housed in 4 boxes of 12 piglets. The diets were distributed *ad libitum*. Each week, during four weeks, piglets were weighted, food intake of each box was recorded, faecal *E. coli* populations from 5 piglets of each box were followed by incubation on a specific media (TBX agar, Ledtechno, Hechtel-Eksel, Belgium) and blood analysis were registered with a cell counter (MS 4.5, Melet Schloesing Laboratoires, Cergy-Pontoise, France) and by flow cytometry (FACScan, Becton Dickinson, San Jose, CA, USA). The data were analysed by a two-way analysis of variance (treatment * initial liveweight).

Results During the first week (Table 1), the bovine colostrum supplementation induced an increase of average daily liveweight gain (P<0.01) and reduced faecal *E. coli* concentrations (P<0.05). It seems also to have increased the food intake and decreased the food conversion ratio, but the differences are not significative, according probably to the small number of observations (n = 4). During the 3 next weeks, these effects disappeared, but the average liveweight of the piglets receiving the "Colostrum" treatment remained statistically higher (Figure 1). The results of the blood analyses (not presented) showed no difference between the treatments during the four experimental weeks.

Table 1 ADG (g/d), ADFI (g/d), FCR and faecal *E. coli* concentrations (10^7 cfu/g faeces) of the piglets of both treatments during the first experimental week

	Control treatment	Colostrum treatment	SEM	P	n
ADG*	81	170	9.92	< 0.01	48
ADFI	264	337	23.3	= 0.09	4
FCR	3.44	2.29	0.44	= 0.14	4
E. coli	8.5	1.39	2.3	= 0.03	20

*ADG = average daily liveweight gain, ADFI = average daily food intake, FCR = food conversion ratio, cfu = colony forming unit, SEM = Standard error of mean, P = Probability, n = number of repetitions

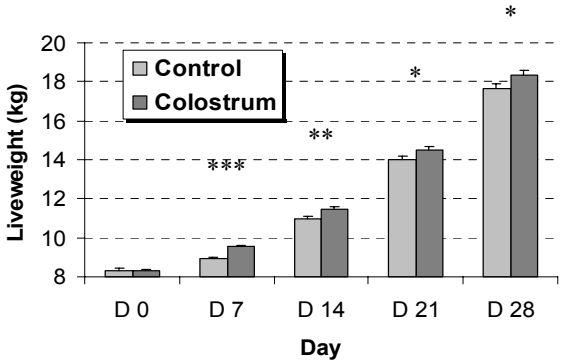

Figure 1 Piglets average liveweight evolution of both treatments during the 4 experimental weeks (* P < 0.05, ** P < 0.01, *** P < 0.001)

Conclusions Bovine colostrum supplementation in piglets diet stimulates food intake and reduces the faecal *E. coli* population during the first week after weaning, inducing a liveweight gain increase. A reduction of the food conversion ratio was also observed, suggesting a better nutrient assimilation by the piglets.

Acknowledgement The financial support of the DGA and the DGTRE of the Walloon Region is kindly acknowledged.

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The effect of lactose inclusion in finishing diets on nutrient digestibility, nitrogen excretion, lactobacilli concentrations and ammonia emissions from boars

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Introduction There is growing interest in the manipulation of dietary ingredients a means of reducing nitrogen excretion (NE) and ammonia (NH_3) losses from pig production. Significant quantities of lactose may reach the hindgut of the older pig undigested, yielding a substrate for bacteria (Kim *et al.,* 1978). It is hypothesised that increasing concentrations of lactose in finishing pig diets will alter NE patterns and reduce NH_3-N emission.

Materials and methods Thirty boars (58 kg) were assigned to one of five dietary treatments (six per treatment) in a complete randomised design as follows: T1) 0 g/kg Lactofeed 70 (860 g/kg whey permeate, 140 g/kg soya bean meal, Volac International, UK) (LF70); T2) 40 g/kg LF70; T3) 80 g/kg LF70; T4) 120 g/kg LF70 and T5) 160 g/kg LF70. After a 14-day adaptation period, pigs were housed in metabolism crates and faeces and urine were collected for nitrogen (N) balance and NH_3 emission. NH_3-N emission was measured over 10 days using a laboratory scale procedure. Following slaughter, digesta samples were aseptically removed from the caecum and colon for lactobacilli enumeration. The diets were formulated to have identical digestible energy (13.8 MJ/kg) and total lysine (11.0 g/kg) contents. LF70 replaced wheat in the experimental diets and all diets were offered in meal form. Linear, quadratic and cubic effects of LF70 inclusion were tested using the General Linear Model Procedure of Statistical Analysis System Institute (1985). An orthogonal contrast was used to compare the control *vs* lactose supplemented diets.

Results The effect of LF70 on apparent digestibility, N balance, NH_3-N emission and lactobacilli concentrations of finishing boars is presented in Table 1. Dry matter, energy and neutral detergent fibre digestibilities were affected by dietary LF70 inclusion (quadratic, $P<0.05$, $P<0.05$ and $P<0.1$ respectively). T1 had a higher urinary N and total N excretion ($P<0.1$) than the LF70 supplemented diets. T1 had a higher NH_3-N per g of N intake from days 0 to 4 ($P<0.05$) than the LF70 supplemented diets. In the caecum and colon lactobacilli concentrations were affected by dietary LF70 inclusion (cubic, $P<0.05$ and quadratic, $P<0.05$ respectively).

Table 1

Treatment	1	2	3	4	5		Significance			
Lactofeed (LF70)(g/kg)	0	40	80	120	160	sem	Cont[a]	Linear[b]	Quad[c]	Cubic[d]
Apparent Digestibility Coefficients										
Dry matter	0.883	0.893	0.893	0.902	0.884	0.0058		*	*	
Gross energy	0.882	0.895	0.894	0.902	0.885	0.0053	*	*	*	
Neutral detergent fibre	0.613	0.623	0.640	0.666	0.602	0.0197		$	$	
Daily Urine N excretion (g/d)	27.49	26.42	24.41	21.41	23.31	2.015	$			
Total N excretion (g/d)	34.20	33.34	31.41	27.06	31.42	2.143	$			
NH3-N (mg/g N intake)										
0-4 days	47.73	36.15	38.76	37.43	42.12	4.078	*			
0-10 days	109.75	86.08	99.15	87.5	101.71	9.537				
Lactobacilli (log cfu/g)										
Caecum	6.515	7.714	7.285	7.020	7.249	0.3458	*	*	*	*
Colon	5.827	8.634	7.635	8.122	7.260	0.6665	**	*	*	

Probability of significance; *, $P<0.05$; **, $P<0.01$; ***, $P<0.001$, $, $P=0.10$
[a]=Contrast statement (T1 *vs* all other treatments); [b, c and d] = linear, quadratic and cubic response to LF70 respectively

Conclusions The incorporation of lactose in finisher diets for pigs reduces total NE and NH_3 emission, and increases nutrient digestibility and the concentration of lactobacilli in the large intestine.

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The presence or absence of transgenic and endogenous plant DNA fragments in the blood, tissues and digesta of broilers consuming genetically modified dietary ingredients

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Introduction The global area sown to genetically modified (GM) crops has increased rapidly from 1.7 million ha in 1996 to 67.7 million ha in 2003 (James, 2003). While GM crops have been shown to be substantially equivalent (e.g. Clarke and Ipharraguerre, 2000), the use of GM crops (e.g. maize grain) or components/products from them (e.g. soyabean meal) in livestock diets has raised a number of safety concerns including, the potential for transgenic DNA to transfer to animal-derived products intended for human consumption. Therefore, the aim was to determine the presence or absence of transgenic and endogenous plant DNA fragments in the blood, tissues and digesta of broilers consuming GM-based diets.

Materials and methods Four treatment diets, designated T1-T4, were each fed to 24 as hatched male broiler chicks. T1 and T2, contained the near isogenic non-GM maize grain (MG; hammer milled; 3 mm screen) whereas T3 and T4, contained GM MG (*cry1a(b)* gene); T1 and T3, also contained the near isogenic non-GM soyabean meal (SBM) whereas T2 and T4, contained GM SBM (*cp4epsps* gene). Four days prior to slaughter at 39 to 42 days-old, 0.5 of the broilers on T2-T4 had the source(s) of GM ingredients replaced by their non-GM counterparts. Detection of specific DNA sequences in feed, tissue and digesta samples was completed by polymerase chain reaction analysis. Seven primer pairs were used to amplify fragments (~200 bp) in duplicate from single-copy genes (maize high-mobility protein and soya lectin and transgenes in the GM feeds) and multi-copy genes (poultry cytochrome b and maize and soya rubisco). PCR acceptance/rejection criteria were established prior to the start of the study and were used to give the number of positive, negative and inconclusive detections for each of the amplicons in each tissue and digesta sample. Only the number of positive detections is reported in Table 1. The growth performance data was analysed by analysis of variance.

Results The isolated DNA from SBM was highly degraded (2 kb to 500 bp) while that from MG contained DNA fragments >23 kb. Treatment diet had no significant (P>0.05) effect of on the measured growth performance parameters (e.g. mean liveweight gain (g/d) 47.7, 49.5, 52.7 and 48.8 for T1-T4 respectively). Of 3,780 blood and tissue DNA samples examined, there was a positive detection of only one endogenous (not ransgenic) single-copy gene in one sample (unsubstantiated). However, the multi-copy rubisco gene was detected in a proportion of samples from each of the tissue types studied (0.23 of total across all treatments and tissues) and in low numbers in both the serum and white blood cell fractions (Table 1). Feed-derived DNA was found to survive complete degradation up to the large intestine. Transgenic DNA was only detected in gizzard digesta 96 h after the last feeding of treatment diets containing a source of GM MG and/or SBM (T2-T4).

Table 1 Positive detection of rubisco in the broiler tissues examined (n=24 for T1; n=12 for all other treatments).

	Treatment diet							Proportion +
Tissue type	T1	T2	T2/T1	T3	T3/T1	T4	T4/T1	detections
Heart	7	1	0	2	5	2	0	0.18
Liver	2	1	2	2	0	2	0	0.09
Kidney	13	2	2	2	1	6	1	0.28
Bursa	5	9	2	2	8	5	1	0.33
Spleen	5	2	0	5	5	1	1	0.20
Breast	7	3	1	3	0	1	1	0.17
Gizzard	8	9	9	9	1	0	1	0.39

Conclusions Within the limits of detection for each amplicon used, the results of the present study show that only fragments of rubisco DNA can be detected in the tissues of broilers consuming GM-based diets. This finding suggests that the presence of fragments of rubisco in broiler tissues is a natural consequence of eating. The efficiency of degradation of feed-derived DNA across the gasto-intestinal tract of broiler is incomplete.

Acknowledgements
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Is there a role for chicory in controlling internal parasitism in organic sheep?

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Introduction The potential antiparasitic effects of chicory (*Cichorium intybus*) are currently investigated as an alternative means to control parasitism in organic sheep production systems. Previous studies showed that parasitised lambs grazing on parasite-clean chicory swards had improved growth and lower faecal egg counts (FEC) compared to those grazing on parasite-clean grass pastures (Athanasiadou *et al,* 2004). The objective of this experiment was to investigate whether chicory can have a role as a potential means to control parasitism in lactating ewes and their lambs grazing on previously parasite contaminated pastures.

Materials and Methods Fifty-six twin-rearing, certified organic Shetland cross ewes, which carried a natural mixed parasite infection were used in a 2x2 factorial experiment, with forage species and level of parasite contamination as the two factors. Following parturition, half of the ewes were moved onto low contaminated pastures of grass or chicory, whereas the rest were moved onto high contaminated grass or chicory pastures (two replicates for each treatment; groups of ewes were balanced for FEC). The low and high parasite contaminated pastures were established following grazing of periparturient ewes drenched or not with an anthelmintic during the previous grazing season. Ewes and lambs remained on the experimental plots until weaning (day 118 after birth). FEC of ewes and lambs were monitored throughout and were analysed by ANOVA for repeated measurements. FEC were log (x+1) transformed prior to analysis. Liveweight gain of lambs was also monitored throughout and analysed by ANOVA.

Results All measurements obtained from the replicates of the same treatment were similar. Ewes grazing chicory had similar FEC to those grazing grass; similarly, ewes grazing on low parasite contaminated pastures had similar FEC to those grazing on high parasite contaminated pastures (Fig 1). FEC of lambs grazing on chicory were significantly lower than those grazing on grass until day 84 after birth (Fig 2). FEC of lambs grazing on low contaminated pastures were lower than those of lambs grazing on high contaminated pastures throughout the experiment. Lambs grazing on chicory grew better than lambs grazing on grass (235 vs 212 g per day, sed: 8.0; P<0.001). Lambs grazing on low contaminated pastures grew better than those grazing on high contaminated pastures (229 vs 211 g per day, sed: 7.0; P<0.001).

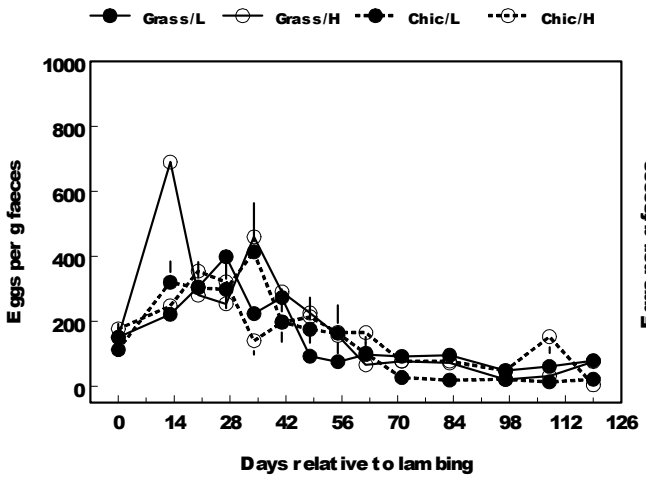

Figure 1 Backtransformed FEC of ewes grazing either on grass or chicory, low (L) or high (H) contaminated pastures, with 95% confidence intervals.

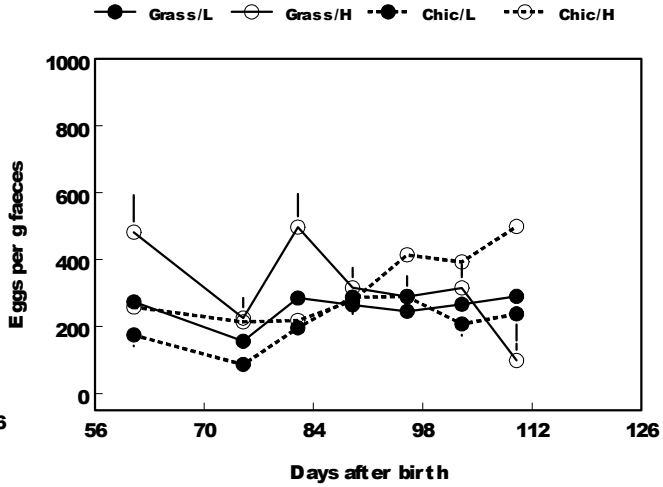

Figure 2 Backtransformed FEC of lambs grazing either on grass or chicory, low (L) or high (H) contaminated pastures, with 95% confidence intervals.

Conclusion Grazing on chicory did not affect the level of parasitism in lactating ewes grazing on low or high parasite contaminated pastures. However, lambs grazing on chicory grew better than those grazing on grass, both in high and low contaminated pastures. There was also evidence that lambs grazing on chicory excreted fewer eggs per gram faeces compared to their counterparts grazing on grass. These data support previous evidence on antiparasitic effects of chicory on growing lambs and their lack in lactating ewes. The low FEC of lambs could be attributed to effects of chicory against incoming parasites, and thus was not observed in ewes that carried an established parasite population.

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Supplementation of ewe diets with algal biomass rich in Docosahexaenoic acid for different time periods before lambing affects measures of lamb viability

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Introduction The improvement of neonatal viability by maternal nutrition during gestation has been widely studied in numerous species. Recent investigations have explored the role of long chain omega-3 essential fatty acids (EFAs) in maternal diets during pregnancy. These are the major fatty acids, docosahexaenoic acid (DHA) in particular, in brain and nervous tissue, with specific roles in neural development and cognitive function. Studies in monogastric species have shown that supplementing maternal gestation diets with EFAs positively influences neonatal survival and growth (Rooke *et al*., 2001), but work in ruminant species is scarce. Previous investigations have predominantly used fish oil as the source of omega-3 EFAs but alternative, more sustainable, sources are desirable. To date, the effect of period of inclusion of EFAs in gestation diets has not been thoroughly explored. The period of rapid brain growth in the ovine foetus occurs between 10 and 6 weeks prior to birth (Turley *et al.,* 1996). This study explored the effects of feeding an algal source of EFAs, with a high content of DHA, during different time periods on measures of lamb viability.

Materials and Methods 48 twin-bearing English mule ewes were allocated to treatment groups at 9 weeks prior to predicted lambing date in a randomised block experiment. Ewes were fed, during different time periods, either a control diet based on silage and a commercial ewe concentrate feed, or a similar diet containing algal biomass (AB) to provide 12g DHA/ewe/day. Diets were balanced for macro-nutrients. There were 4 treatment groups: ewes fed solely on the control diet for 9 weeks prior to lambing (C); ewes fed the AB diet for the first 3 weeks of the trial (3wk) then returned to control diet; ewes fed the AB diet for the first 6 weeks of the trial (6wk); and those receiving AB diet for 9 weeks up to parturition (9wk). After lambing all ewes received the standard concentrate. Blood samples were taken from all ewes at 3 weekly intervals during the 9 weeks prior to expected lambing date, to monitor the uptake of EFAs from the diet, and taken from both ewes and lambs after parturition. At lambing, assistance level, lamb time-to-stand and birth weight were recorded. Colostrum samples were taken from each ewe before lambs suckled. Samples were analysed for fatty acid composition by gas liquid chromatography. Analysis of variance was used to compare treatment effects on lamb viability measures.

Results AB supplementation tended to increase gestation length. There were no significant differences in lamb birth weight between groups, either with or without the inclusion of gestation length as a covariate. Lambs born from ewes in the 6 and 9 week groups stood significantly sooner after birth than lambs born from ewes in the 3wk and C groups. There was also an overall trend for lambs born from ewes with longer gestation lengths to stand more quickly, however this was not significant (P=0.08). Lamb growth rates to 5 weeks of age did not differ significantly between treatments.

Table 1 Effects of feeding DHA-rich algal biomass during different periods in late gestation

	Control	3weeks	6weeks	9weeks	SEM	Sig
Gestation Length (d)	145.2	147.1	147.5	148.0	0.8	0.08
Birth wt (kg)	5.2	5.4	5.2	5.3	0.19	NS
Colostrum DHA (g/kg)	0.09	0.28	0.35	0.87	0.08	< 0.001
Time to stand (min) Δ	31.0	27.9	21.6	22.6	2.8	< 0.05
Wt gain in first 24h (kg)	0.26	0.21	0.09	0.29	0.08	NS
DLWG in first 5 weeks	0.43	0.47	0.45	0.46	0.02	NS

Δ with adjustment for level of assistance (P<0.005)

Conclusion Ewes fed algal biomass for 9 and 6 weeks in late pregnancy gave rise to lambs that stood more quickly after birth than those of ewes in the 3wk and C groups. This was not a consequence of change in birthweight. Capper et al. (2003) showed a decreased latency to suckle from DHA inclusion as fish oil in gestation diets, but data on latency to stand were ambiguous. In contrast to the results of Capper et al., lamb growth rate was not reduced by long-chain EFA supplementation, which may be due to the cessation of supplementation at birth in this experiment. The mechanism by which EFA supplementation influences vitality requires further investigation.

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The effects of feeding sainfoin hay in sheep parasitised with *Trichostrongylus colubriformis*

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Introduction Sainfoin *(Onobrychis viciifolia)* is a Mediterranean forage rich in tannins, which has been shown to reduce the faecal excretion of nematode parasites in goats, when offered as hay supplement (Paolini et al, 2003). The use of conserved forages for parasite control may be preferred when either the climatic or agronomic conditions are not appropriate for the grazing of such forages. The aim of this experiment was to investigate whether the consumption of sainfoin hay could reduce the viability and fecundity of adult gastrointestinal parasites, when offered to parasitised sheep at different time points during the course of a parasitic challenge.

Materials and Methods Forty (n=8) Charolais x Grayface sheep were infected on day 1 of the experiment with a single dose of 8,000 infective larvae of the intestinal nematode *T.colubriformis*. On the same day sheep were introduced to the experimental hays. Two groups of sheep were offered either sainfoin (S) or lucerne (L) hay throughout the experiment (42 days). Lucerne hay has similar nutritional value as sainfoin but low condensed tannin content. The three other groups were offered sainfoin hay at different time points during the course of a parasitic infection, i.e. during days 1-14, 14-28 or 28-42, whereas they were offered lucerne hay for the remaining days. Hay intake was recorded daily and liveweight weekly. Faecal egg counts (FEC) were monitored throughout and were analysed with ANOVA for repeated measurements, with hay type as factor. Total egg output was calculated following the estimates of in vitro dry matter digestibility with an enzymatic procedure (NCGE). Hay intake and daily egg output were also analysed with one-way ANOVA for repeated measurements

Results Sheep offered sainfoin hay had significant lower intake compared to sheep offered lucerne hay throughout the experiment (Figure 1, P<0.001). A significant Hay type X time interaction was observed; animals reduced their intake when changed from lucerne to sainfoin hay (P<0.001) and increased it when changed from sainfoin to lucerne hay. Sheep given access to sainfoin hay throughout the experiment reached a significant lower liveweight at the end of trial when compared to those offered *ad libitum* lucerne hay (35 vs 42 kg, sed:0.52 respectively). FEC of all sheep were similar; however as the digestibility of sainfoin and lucerne hay was very similar, the egg output of sheep given lucerne hay was significantly higher then that of sheep offered sainfoin hay throughout the experiment (Figure 2, P<0.01)

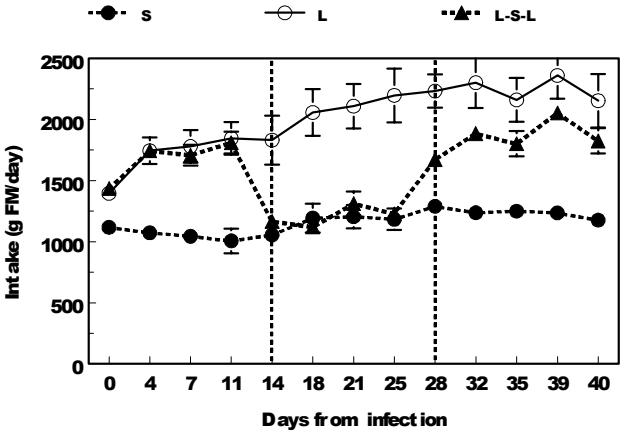

Figure 1 Daily intake of sheep offered either sainfoin (S) or lucerne (L) hay during the course of a parasitic infection. The bars represent standard errors.

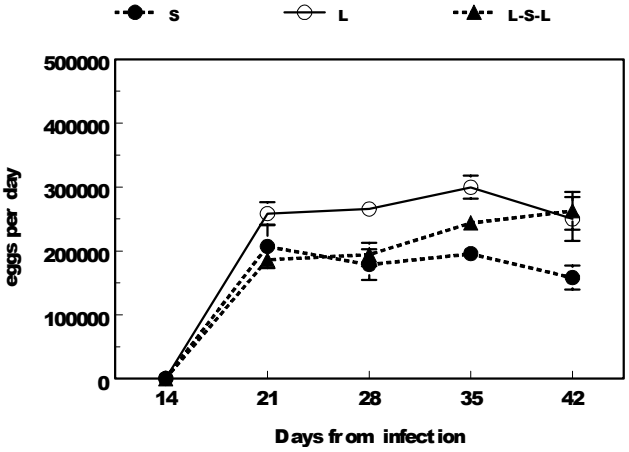

Figure 2 Daily faecal output of sheep offered either sainfoin (S) or lucerne (L) hay during the course of a parasitic infection. The bars represent standard errors.

Conclusion The consumption of sainfoin hay resulted in a reduction of the daily egg output of sheep parasitised with *T.colubriformis*. With other things being equal, this reduction could be attributed to either reduced fecundity of worms or reduced number of worms. As the reduction in the egg excretion observed in sheep offered sainfoin was reversible within a few days following the change of hay, it is highly likely that it was due to a reduction in the fecundity rather than the number of worms in the gastrointestinal tract of sheep. It is not clear yet why sheep fed on sainfoin hay had lower intake compared to those fed on lucerne hay. As the digestibility of both hays was similar (about 60%), one possibility might be that the higher condensed tannin content of sainfoin compared to that of lucerne hay may have acted as deterrent of feeding. Long term experimentation is required to determine the effects of sainfoin consumption on the performance of parasitised sheep.

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The effect of supplemental zinc source in late pregnancy and early lactation on the health and performance of ewe and lambs

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Introduction Zinc is an essential trace element necessary for the activity of numerous enzymes. Supplemental zinc is considered normal for ruminant livestock to ensure that requirements are met. Although zinc deficiency is not generally recognised in the UK, there is considerable evidence that this supplemental zinc is beneficial. The aim of this study was to investigate the effect of partially replacing zinc oxide with a zinc proteinate in the diet of ewes in late pregnancy and lactation on performance and health of ewes and lambs.

Material and methods Forty twin-bearing Suffolk-cross ewes 6 weeks prior to lambing were individually penned and blocked by liveweight and parity, and were then allocated to one of two dietary treatments with 20 ewes per treatment in a random block design. The ewes were bedded on straw and allowed access to water at all times. Ewes were fed isoenergetic and isonitrogenous concentrate diets (11.9 MJ/kg DM ME and 200 g/kg DM CP) from 5 weeks prior to lambing until 4 weeks post lambing and were offered straw *ad libitum* to meet their requirements. Ewes were initially fed twice per day at a level of 0.8 kg concentrates per day, which was increased gradually by 0.1 kg/week to 1.3 kg per day at lambing. Ewes continued to be fed 1.3 kg/day throughout lactation. The two diets were supplemented with an additional 50 mg zinc /kg either as zinc oxide (ZnO) or zinc proteinate (BioZn) (Bioplex Zinc™, Alltech Inc., Nicholasville, USA). The levels of zinc in the two diets was 288 mg/kg DM in the ZnO and 260 mg/kg DM in the BioZn. Ewe liveweight and condition score was recorded weekly, and blood samples were collected fortnightly to measure plasma zinc (PlZn) and iron (PlFe) concentrations by atomic absorption spectrometry. Milk samples from the ewes were collected at 21 days of lactation and analysed for composition (lactose, fat and protein). Lamb birth weight, and weekly liveweights were recorded. Blood samples were collected from the lambs at 7 and 21 days of age to assess serum IgG concentration (Sheep RID, Bethyl Laboratories Inc, USA) and plasma zinc and iron concentrations. Statistical analysis was performed using ANOVA using Genstat version 7.2.

Results There was no significant effect of zinc source on ewe liveweight or condition score throughout the study. There was no effect on milk yield at 21 days post partum, however, there was a trend for the ewes supplemented with the zinc proteinate to have higher lactose concentrations compared with the ewes supplemented the zinc oxide (48.4 mg/kg versus 46.9 mg/kg respectively; s.e.d. 1.82; $P<0.1$). There was no effect of zinc source on plasma zinc or iron concentrations of the ewes, except at 4 weeks when the BioZn ewes has significantly higher plasma iron concentrations ($P<0.05$)and a trend to have higher plasma zinc concentrations ($P<0.1$) compared with the ZnO supplemented ewes (PlFe: 24.8 μmol/l versus 20.5 μmol/l; s.e.d. 1.62; PlZn: 9.8 μmol/l versus 8.5 μmol/l; s.e.d. 0.62 for BioZn ewes and ZnO ewes respectively). There was no significant effect of zinc source on lamb birth weight. However, there was a trend for lambs from the ewes supplemented with BioZn to be heavier at 4 weeks of age (Table 1). Lambs from BioZn ewes also had a significantly higher daily liveweight gain compared with the lambs from ZnO ewes (Table 1). There was no significant effect of zinc source on plasma zinc or iron concentrations of the lambs. There was also no significant effect of zinc source on lamb plasma IgG concentrations at 7 or 21 days of age.

Table 1 Effect of ewe supplementation with zinc on lamb performance

Liveweight (kg)	BioZn	ZnO	s.e.d	Sig
Birth	4.51	4.56	0.248	NS
7 days of age	6.36	6.41	0.295	NS
14 days of age	8.74	8.43	0.349	NS
21 days of age	10.36	9.81	0.427	NS
28 days of age	11.96	11.15	0.477	P<0.1
Growth rate (kg/day)	0.264	0.232	0.0125	P<0.05

Conclusions Supplementation of the ewes with BioZn significantly increased the performance of the lambs. Both Plasma zinc and iron are relatively poor indicator status as they accumulate in the liver as part of the acute phase response responses (Verheijden *et al.*, 1982). Therefore, the difference in the plasma mineral concentrations between treatments of the ewes at 4 weeks post partum are likely to be due to an inflammatory response in the ewes supplemented the zinc oxide compared with the ewes supplemented with the BioZn.

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The effect of *trans*-10, *cis*-12 conjugated linoleic acid on milk fat synthesis in lactating sheep

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Introduction *Trans*-10, *cis*-12 conjugated linoleic acid (CLA), a biohydrogenation intermediate produced in the rumen, is a potent inhibitor of milk fat synthesis. Data from a number of studies where various doses of *trans*-10, *cis*-12 CLA have been abomasally infused demonstrate a curvilinear relationship between the percent reduction in milk fat yield and both the dose of *trans*-10, *cis*-12 CLA infused and the milk fat content of *trans*-10, *cis*-12 CLA. In addition to a reduction in milk fat output, under some circumstances an increase in milk yield and milk protein output are observed. To date, there has been no examination of the effects of *trans*-10, *cis*-12 CLA on milk fat synthesis in lactating sheep. The current study was therefore designed to determine if *trans*-10, *cis*-12 CLA would inhibit milk fat synthesis in lactating sheep. In order to test the effectiveness of *trans*-10, *cis*-12 CLA in inhibiting milk fat synthesis we used a lipid-encapsulated *trans*-10, *cis*-12 CLA supplement (LE-CLA) as a means to provide the *trans*-10, *cis*-12 CLA isomer post-ruminally.

Materials and methods Twenty multiparous ewes that weighed 56 (± 6.2) kg were individually penned and machine milked twice daily throughout the study. The ewes were fed a standard ewe concentrate at the rate of 1.8 kg/ewe/day provided in three equal meals at 0800, 1300 and 1600 h, with grass hay and water available *ad-libitum*. When ewes were ~5 weeks postpartum they were randomly allocated to one of two dietary treatments, based on their milk and constituent yield, liveweight and condition score measured on 3 occasions during the week prior to allocation. The treatment diets were: standard concentrate fed either unsupplemented (Control: C) or supplemented (S) with LE-CLA (BASF AG, Ludwigshafen, Germany) at the rate of 25 g/d, providing 2.4 g/d of *trans*-10, *cis*-12 CLA. The LE-CLA was mixed into the appropriate ewes concentrate allocation on a daily basis. The experimental design was a 2 period crossover with 10 day treatment periods separated by a 10 day change-over period. Milk yield was recorded daily at each milking, and samples taken for subsequent analysis of fat, protein and lactose. On the final day of each treatment period an additional milk sample was taken at both milkings for fatty acid analysis.

Results The LE-CLA supplement significantly reduced milk fat content and yield by 23 and 16%, respectively (Table 1). The temporal pattern for milk fat content and yield demonstrated a progressive reduction for sheep receiving the LE-CLA supplement (Figure 1). The yield of all milk fatty acids was reduced during LE-CLA supplementation, but the reduction was greatest for *de novo* synthesized fatty acids; as a consequence the profile of milk fat shifted to contain increased long-chain fatty acids. *Trans*-10, *cis*-12 CLA was undetectable in milk fat of unsupplemented animals (<0.01 g/100 g fatty acids) and increased to 0.12 g/100 g fatty acids during LE-CLA supplementation. The transfer efficiency of *trans*-10, *cis*-12 CLA into milk fat was 3.8%. The CLA-induced reduction in milk fat synthesis was associated with a significant increase in milk yield which was 9.5% greater for supplemented animals compared with unsupplemented animals on days 9 and 10 of treatment. Milk protein content (g/kg) was not affected by treatment whilst protein yield (g/d) was higher (7%) in ewes fed the LE-CLA supplement. There was no effect ($P > 0.05$) of treatment on daily DMI, average live weight or condition score.

Table 1 Milk production and composition of ewes unsupplemented (C) or supplemented (S) with lipid-encapsulated CLA

	C	S	s.e.d.	*P*-Value
Milk yield (g/d)	1471	1611	45.2	0.007
Fat (g/kg)	64.3	49.3	2.60	<0.001
Protein (g/kg)	46.1	44.7	0.11	0.242
Fat (g/d)	94.6	79.7	3.58	<0.001
Protein (g/d)	67.6	72.5	2.15	0.039
Fatty acids (mmol/d)				
<C16	129.6	83.8	3.83	<0.001
C16 and C16:1	120.4	97.7	4.79	<0.001
>C16	165.6	144.2	7.85	0.015

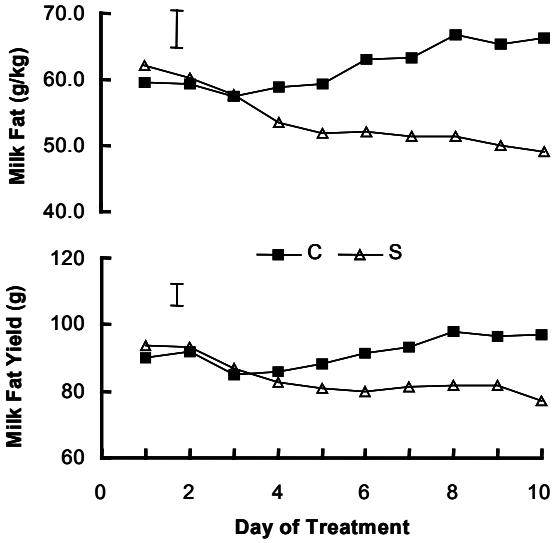

Figure 1 Temporal pattern of milk fat content and daily yield of ewes unsupplemented (C) or supplemented (S) with lipid-encapsulated CLA. Values represent means from 20 ewes (s.e.d. indicated by error bars)

Conclusions The results of the present study demonstrate that *trans*-10, *cis*-12 CLA reduces milk fat synthesis in lactating sheep. The temporal changes in milk fat content and yield, and changes in milk fatty acid profile indicate that the mechanism of action for the reduction in milk fat synthesis appears similar to that previously observed in lactating dairy cows. Furthermore, the energy spared by the reduction in milk fat coincided with an increase in milk and milk protein yield. Further studies are required to verify and extend these results and to elucidate the mechanism of action for the effects observed with *trans*-10, *cis*-12 CLA supplementation.

Estimation of protein fermentation in the colon of pigs with the gas production technique

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Introduction Techniques to determine N availability and fermentation characteristics of protein in the hindgut of pigs are not available. The gas production technique (Cone et al., 1996) determines fermentation characteristics of OM and can also be used after pre-digestion of the samples with pepsin and pancreatic enzymes to determine fermentation characteristics of OM in the colon of pigs (Becker et al., 2003). The technique can be adapted to obtain gas production profiles reflecting the fermentation of protein (N availability). To achieve this, incubations have to be done with an excess of fast fermentable carbohydrates, in an N-free environment making N the limiting factor for microbial growth depending on the availability of N from the feed samples. The aim of this study was to investigate the possibilities to use the gas production technique to determine the fermentation characteristics of protein in the hindgut of pigs.

Materials and methods Fifteen feed ingredients were used and 4 concentrates with equal contents of protein, but with different inclusion levels of feather meal (0 % in A, 0 % in B, 1.5 % in C and 3.0 % in D). Samples were pre-digested with pepsin and pancreatin. After filtration the residues of the samples were dried at 70 °C and N content was determined, prior to incubations in the gas production technique. Incubations in triplicate were performed as described for use with a faecal suspension (Becker et al., 2003). Fresh faeces from 3 pregnant sows were mixed to get a 2 % faecal solution in an N-free buffer/mineral solution. Fast fermentable carbohydrates (maltose, 2.15 g/l; soluble potato starch, 1.08 g/l; xylose, 1.08 g/l; citric pectin, 1.08 g/l) were added to the suspension and incubated for 1.5 h at 39 °C to bind all available N from the faeces and to make N the limiting nutrient for microbial growth. Then a sample of the residue after pre-digestion, containing 5 mg N, was added to the buffered faecal suspension. Gas productions after 10 h were compared with a blank (no added N) and an incubation with 5 mg urea-N.

Table 1 Crude protein (CP, g/kg DM), % CP digested with pepsin and pancreatin, gas production after 10 h incubation (GP10) relative to GP10 of urea and the blank (in %). FCP is the calculated fermentable CP as % of CP content in the original samples.

	CP g/kg DM	digested %	GP10 %	sd	FCP % of CP	sd
Maize	92	76.5	47.7	4.8	11.2	1.1
Barley	114	80.8	58.8	3.9	11.3	0.8
Wheat	129	91.6	38.1	2.6	3.2	0.2
Palm kernel exp.	153	82.4	27.8	4.6	4.9	0.8
Wheat middlings	190	80.6	52.3	4.4	10.1	0.9
Pea meal	237	97.2	139.2	4.0	3.9	0.1
Sunflower meal (se)	319	94.4	65.7	6.1	3.7	0.3
Rapeseed meal (se)	406	79.5	57.7	6.8	11.8	1.4
Soybean meal (se)	539	94.8	102.6	8.0	5.4	0.4
Maize gluten meal	542	70.0	46.0	1.2	13.8	0.3
Fish meal	629	77.9	68.1	7.4	15.1	1.6
Poultry meat meal	633	85.2	45.3	4.1	6.7	0.6
Pig meat meal	648	77.4	38.9	2.9	8.8	0.7
Potato protein	863	85.2	75.5	2.4	11.2	0.4
Feather meal	921	52.5	92.2	4.7	43.8	2.2
Concentrate A	232	92.5	61.3	5.5	4.6	0.4
Concentrate B	235	91.6	58.3	3.5	4.9	0.3
Concentrate C	238	89.5	60.6	3.6	6.4	0.4
Concentrate D	239	82.3	69.9	2.0	12.4	0.4

Results Table 1 shows the CP content and the percentage CP digested by the pre-incubation with pepsin and pancreatin. Incubations with the gas production technique were performed with residue samples containing exactly 5.0 mg N, so with varying amounts of DM. The gas production profiles were linear between 5 and 15 h of incubation (r^2 = 0.90). The gas production after 10 h (GP10) was chosen to express the availability of N from the samples relative to urea and the blank. The % of CP which fermented (FCP) was calculated. Differences in % FCP ranged from 3.2 % in wheat to 15.1 % in fish meal. Only feather meal had a high % FCP (43.8 %). The concentrates showed an increasing amount of estimated FCP from concentrate A to D, as expected, based on the inclusion level of feather meal.

Conclusions It can be concluded that N availability in the large intestine of pigs can be determined with the presented modified gas production technique, after pre-digestion of the sample with pepsin and pancreatin, in an N-free environment. The gas production after 10 h incubation, relative to gas production of urea and blank, can be taken as a measure for degree of fermentation to estimate the content and percentage of available N. The gas production technique offers an inexpensive and fast alternative for analysis of N availability in the large intestine of pigs or in the caeca of poultry. However, the technique is an in vitro technique and does not account for endogenous protein.

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Molecular identification of gut lactic acid bacteria in pigs by macro-arraying techniques

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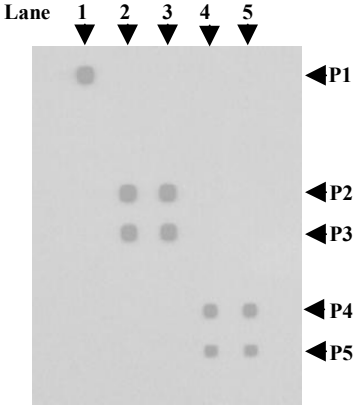
Introduction Lactic acid bacteria (LAB) consist of many genera, which contain numerous bacterial species. The LAB are Gram-positive, non-spore forming micro-organisms and typically give negative results to the catalase test (Stiles and Holzapfel, 1997). The current classification of LAB combines both phenotypic properties and genotypic examination. Phenotypic studies use the cell wall compositions (mainly for Bifidobacteria), protein fingerprinting which analyse the total soluble cytoplasmic proteins, and the patterns of certain isoenzymes. The gold-standard molecular method to identify LAB is DNA-DNA homology analysis, and molecular methods using specific genetic material patterns of LAB are increasingly being applied as an identification tool. The objective of this study was to develop potential specific oligonucleotide probes for the macro-array identification of LAB.

Materials and Methods Faecal samples were collected from the rectum of 55 weaned piglets, raised at the pig unit of the University of Newcastle upon Tyne, and cultured on MRS agar plates. Genomic DNA was extracted from fifty-five bacterial isolates by a boiling method (Hayashi et al., 2002). The PCR reactions were performed using 16S rDNA Eubacterial sequencing primers; 27f and 519r (Lane, 1991). The PCR products were sequenced on ABI 3700 DNA Analyzers. The sequence results were compared for similarity with the DNA from the available database using the NCBI-BLAST2 (Basic Alignment Search Tool) programme. Then, the compiled sequences were also aligned using ClustalW. The 16S rDNA sequences of bacteria from the GenBank were also aligned with the DNA sequences from the present experiment in order to investigate the homology. Phylogenetic trees based on comparative analysis of the 16s rDNA were established. Potential oligonucleotide probes were obtained from the aligned result and used in a macro-array method.

Results Phylogenetic analysis of the 16s rDNA sequence of isolates revealed the presence of *Lactobacillus acidophilus*, *Lact. animalis, Lact. gallinarum, Lact kitasatonis, Lact. salivarius, Streptococcus alactolyticus*, *Strep. hyointestinalis, Sarcina ventriculi*. Twenty-four (44%) representative colonies of the bacterial isolates were identified as *Lactobacillus reuteri.* The designed probes for *Lact. acidophilus*, *Strep. alactolyticus*, *Clostridium perfringens* were shown to be species specific (see figure 1) and not to cross-react with DNA of other species.

Figure 1 The result obtained from Reverse Line Blot (RLB) analysis
Note: Lane 1 = amplified DNA of *Lact. acidophilus*, Lane 2 = amplified DNA of *Strep. alactolyticus* sample 1, Lane 3 = amplified DNA of *Strep. alactolyticus* sample 2, Lane 4 = amplified DNA of *C. perfringens* sample 1, Lane 5 = amplified DNA of *C. perfringens* sample 2; P1- P5 are probes which were run in perpendicular dimension to the amplified DNA. P1 = probe for *Lact. acidophilus*, P2 = probe 1 for *Strep. alactolyticus*, P3 = probe 2 for *Strep. alactolyticus* and *Strep. hyointestinalis,* P4 = probe 1 for *C. perfringens* 1, P5 = probe 2 for *C. perfringens* 2



Conclusions It is evident from the 16S rDNA sequences that the majority of the isolates were *Lactobacillus reuteri*, suggesting that this species predominates in the population of pigs investigated. These species-specific probes may be used to identify LAB in pig digesta samples and, as more probes are validated, it will become possible to identify many of the LAB in the pig gastrointestinal tract. These oligonucleotide probes can then provide a tool to evaluate the impact of different pig diets on LAB microflora in relation to health and performance.

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The effect of litter origin upon the structure of the small intestine of piglets at weaning

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Introduction The purpose of this study was to determine whether litter origin had an effect upon the structure of the small intestine in newly weaned piglets. The gut of the newly weaned piglet undergoes significant structural changes such as a decrease in villus height and an increase in crypt depth following commercial weaning. Litter origin has been shown to influence piglet performance immediately post weaning (Slade and Miller, 1999) and to have a significant influence upon blood metabolite concentrations in the newborn piglet (Ilsley and Miller, 2003). Litter origin therefore may also influence the structure of the small intestine in the piglet, which in turn would affect the experimental sampling strategies used in trials investigating effects on gut structure. This study was carried out to test the null hypothesis that litter origin would not have an effect upon the structure of the small intestine in the newly weaned piglet.

Materials and methods The litters of eight (A-H) multiparous (JSR Healthbred) sows were randomly selected at weaning and weaned into standard flat deck accommodation at a mean weaning age of 28.3 ± 0.62 days of age (mean ± s.e.m.). Piglets were weaned into mixed sex pens of 8 pigs per pen. Feed (15.7 MJ DE/kg, 200g CP/kg, 15.7g lysine/kg) and water were provided ad libitum. Piglets were weighed at weaning and 6 days post weaning. On day 6 post weaning 4 piglets from each litter (3 pigs from litter H) were sacrificed. Samples of gut were collected from 0.25, 0.50 and 0.75 along the small intestine and once fixed, sections were cut and stained with haematoxylin and eosin. Villus height, crypt depth and villus width were measured at four points along each of the sections. Average daily gain (ADG) for days 1 to 6 was calculated for individual piglets and used as a measure of feed intake as individual feed intake was not recorded. Data were analysed in Minitab 13.0 using ANOVA, General Linear Model. ADG was used as a covariate when significant.

Results Litter origin was found to have a significant effect ($P<0.05$) upon the villus height, crypt depth and crypt: villus area along all sites of the small intestine measured (Table 1). ADG was found to be a significant covariate only for villus height at the 0.75 site, its effect was to increase the significance of litter of origin.

Table 1 Effect of litter upon small intestine structural measurements in newly weaned piglets

	Sow ID									
	A	B	C	D	E	F	G	H*	s.e.m	P
Villus height 0.25 (μm)	257	199	237	308	231	168	244	224	23.5	0.030
Crypt depth 0.25 (μm)	289	194	297	272	253	169	281	266	19.7	0.002
Crypt:villus area 0.25 (μm^2)	199684	112844	169361	218093	144793	92810	177960	144278	18062.6	0.001
Villus height 0.50 (μm)	296	186	254	302	254	172	271	211	28.1	0.031
Crypt depth 0.50 (μm)	254	200	223	293	209	169	233	259	14.3	0.000
Crypt:villus area 0.50 (μm^2)	193292	111028	144381	219707	170144	109115	190068	156024	19035.7	0.005
Villus height 0.75 (μm)	223	183	225	215	201	157	238	211	16.9	0.042
Crypt depth 0.75 (μm)	217	143	226	246	214	165	243	221	12.5	0.000
Crypt:villus area 0.75 (μm^2)	145831	95270	145357	161568	128755	91152	155948	155077	13323.9	0.006

(* s.e.m. for litter of 3 pigs are 27.1, 22.7, 20856.8, 32.4, 16.5, 21980.5, 19.5, 14.5 and 15385.1 respectively)

Conclusion The results of this study illustrate the significant effect that litter origin has upon the structure of the small intestine in the newly weaned piglet. Average daily gain was shown not to be a good predictor of gut parameters as it only had a significant effect upon villus height at the 0.75 site of the small intestine. This study confirms that it is important to take into account the effect of litter origin and to balance treatments for litter when looking at post weaning performance in the piglet, especially if the effect of treatment upon the structure of the small intestine is to be investigated.

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The interaction between threonine level and avilamycin inclusion on piglet performance and diet digestibility post weaning

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Introduction The increase in the prevalence of post weaning diarrhoea in pigs due to the progressive ban of antibiotic use has necessitated the use of alternative management and nutritional strategies (Le Bellego and Noblet, 2001). During immunological stress, amino acids are redistributed away from protein production towards tissues involved in inflammation and immune response. This can disturb normal body processes, which can in turn induce specific amino acid requirements. Threonine utilization by the gut is higher than that of any other amino acid because it is involved in the synthesis of intestinal mucin. Mucin plays a key role in the defence of the mucosa, however it is indigestible. Thus, when the positive effects of an antimicrobial growth promoter are removed, increased levels of dietary threonine may benefit piglets due to additional reserves of threonine being present to compensate for the portion of dietary threonine that becomes unavailable due to the increased synthesis of intestinal mucin. The objective of the experiment was to investigate the interaction between threonine level and avilamycin inclusion on piglet performance and diet digestibility post weaning.

Materials and methods The experiment was designed as a 3 x 2 factorial (3 threonine (Thr) levels (8.6, 10.5 and 12.1 g/kg) x 2 avilamycin levels (0 or 60 ppm). Three hundred and sixty weaned piglets, 24 d of age, 5.9 kg live weight were blocked on the basis of weight and assigned to one of six treatments. Diets were formulated to have similar digestible energy (16 MJ/kg) and total lysine (16g/kg). The pigs were offered their diets for 28 days post-weaning. Data on growth performance and feed intake was collected at 7 day intervals while faecal samples were collected twice daily from day 14 – 21 of the study to facilitate nutrient digestibility analysis. The data were analysed using the general linear model of the Statistical Analysis Systems Institute (1985). The statistical model used included both linear and quadratic effects of threonine level and avilamycin inclusion, and the associated interactions between the linear effect of threonine and avilamycin inclusion and the quadratic effect of threonine level and avilamycin inclusion.

Results There was no significant effect of threonine level or avilamycin inclusion on average daily gain, feed intake or food conversion ratio (FCR) (Table 1). There was a significant interaction between threonine level and avilamycin inclusion in the apparent digestibility of dry matter, organic matter, nitrogen, ash, neutral detergent fibre (NDF) and gross energy as well as digestible energy content (DE). In the absence of avilamycin, there was a linear increase in nutrient digestibility to increased threonine levels in the diet. However, in the presence of avilamycin there was a quadratic response to increased threonine levels (Table 2).

Table 1 Interaction between threonine level and avilamycin inclusion on pig performance

Threonine Level	8.6		10.5		12.1			Significance	
Avilamycin inclision (ppm)	0	60	0	60	0	60	s.e.m	Avilamycin	Threonine
Daily gain (g/day)	0.400	0.392	0.404	0.407	0.371	0.401	0.014	n.s.	n.s.
Feed Intake (g/day)	0.543	0.555	0.549	0.557	0.550	0.558	0.017	n.s.	n.s.
FCR (kg/kg)	1.36	1.42	1.36	1.39	1.43	1.40	0.036	n.s.	n.s.

Table 2 Interaction between threonine level and avilamycin inclusion in apparent nutrient digestibility

Threonine level (g/kg)	8.6		10.5		12.1			Significance		
Avilamycin inclusion (ppm)	0	60	0	60	0	60	s.e.m	Avilamycin	Linear†	Quadratic§
Dry Matter	0.866	0.869	0.873	0.895	0.871	0.880	0.003	**	***	**
Organic matter	0.878	0.881	0.884	0.905	0.888	0.891	0.003	**	**	*
Nitrogen	0.827	0.833	0.829	0.870	0.845	0.844	0.009	**	***	***
Ash	0.663	0.658	0.681	0.727	0.687	0.681	0.007	***	***	***
NDF	0.170	0.177	0.202	0.369	0.242	0.271	0.003	*	**	*
Gross energy	0.856	0.862	0.865	0.887	0.869	0.872	0.003	*	***	**
DE content (MJ/kg)	14.88	15.53	15.50	16.11	15.66	15.81	0.001	*	*	*

† = Linear threonine x avilamycin § = Quadratic threonine x avilamycin

Conclusion The results of the present study indicate that there was a linear increase in nutrient digestibility to 12.1g/kg threonine in the absence of avilamycin. In the present study, 10.5g/kg dietary threonine was adequate in the presence of avilamycin. Optimum piglet performance was achieved at a threonine level of 8.6g/kg and there was no advantage to avilamycin inclusion under current conditions

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Effect of ascorbic acid supplementation of sows and piglets on health and performance of piglets

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Introduction Pigs are able to synthesise their own ascorbic acid (AA), however a number of studies have shown benefits of supplementation. It is thought that additional ascorbic acid may be required in pig diets during periods of stress, infection or due to the increased demands for growth. The neonatal pig has an immature immune system and is also under physiological stress due to the rapid development of the gastrointestinal tract. The aim of this trial was to investigate effects of AA supplementation of sows in late pregnancy and lactation and oral drenching of piglets from birth to weaning on piglet performance and health during the suckling period.

Materials and methods Sixteen sows and litters were used in a 2 x 2 factorial designs, where two batches of 8 sows were blocked by parity and allocated to either receive AA supplementation (SA) (2g/day) or not (SC), from one week pre farrowing up to weaning at four weeks post farrowing. The piglets were weighed at birth, day 6 and weekly thereafter until weaning at 4 weeks of age. At 4 days of age the piglets were blocked by birth weight within litter and allocated to receive oral AA (PA) (100 mg/day) or a placebo (PP) twice weekly. The oral drench contained 50 g/l AA and 50 g/l dextrose and the placebo contained 50 g/l dextrose. Blood samples were taken at 6, 13 and 27 days of age by jugular venipuncture. Haematology profile was measured using a Vet ABC animal blood counter (ABX diagnostics), and serum AA concentration was measured. Piglet serum IgG concentration was measured by radial immunodiffusion (Bethyl Laboratories Inc). Statistical analysis was performed using ANOVA using Genstat version 7.2.

Results There was no significant effect of AA supplementation to either the sows or to the piglets on piglet liveweight or liveweight gain. There was also no significant effect of AA supplementation on piglet serum IgG concentration. Piglets from sows supplemented with ascorbic acid and that did not receive oral AA had a significantly higher serum AA concentration compared with their litter mates that received oral AA (P>0.05) (Figure 1).

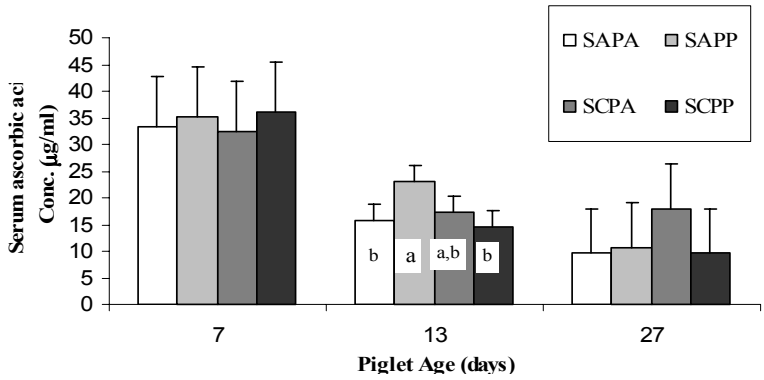

Figure 1 Effects of ascorbic acid on serum ascorbic acid concentration in piglets

There was no significant effect of ascorbic acid supplementation on piglet haematological profile at 7 or 27 days of age. However, at 13 days of age, piglets receiving oral AA supplementation had a significantly greater mean corpustular volume (MCV) (P>0.05) and greater mean corpustular haemoglobin (MCH) (P>0.05) compared with the control piglets (Table 1).

Table 1 Effects of supplemental ascorbic acid on selected haematological profiles in piglets

		SA		SC			Significance		
Blood parameter	Age (d)	PA	PP	PA	PP	s.e.d	Sow	Piglet	Interaction
MCH (pg)	7	23.76	22.93	22.73	22.43	0.58	0.067	NS	NS
MCH (pg)	14	22.93	21.46	22.22	21.86	1.066	NS	*	NS
MCV (μm^3)	14	70.25	65.94	68.56	66.94	1.621	NS	*	NS

Conclusions Previous works has shown beneficial effects of AA fed to piglets around the time of weaning (Blaken *et al.,* 2003). However, in this study, piglets were not subjected to stress or disease challenge, therefore there was no benefit on piglet health and performance. The effect on serum AA may be due to suppression of the of activity of liver L-gulono-γ-lactone oxidase (the crucial enzyme in AA biosynthesis) in SAPA piglets by excess AA intake, as previously reported by Ching *et al* (2001).

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Effect of replacing fishmeal with HP 300 on growth performance of piglets from weaning to 28 days post weaning under commercial conditions

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Introduction The recent ban on animal protein sources as livestock feed has lead to an increased demand for alternative protein sources (Salgado *et al*., 2001). Soya protein has been suggested as a potential alternative to fishmeal in weaner diets in sustainable pig production systems. However, the digestion of soya products is known to be reduced by the presence of antinutritional factors such as protease inhibitors and lectins (Lallès, 1993). Several methods have been devised to refine soya thereby increasing ileal digestibility's (Shon *et al,* 1994). Some of the refined products include isolate soy protein and soybean protein concentrate. The objective of this experiment was to compare the effect of replacing fishmeal (FO) with HP 300 a soya isolate product on growth performance of piglets from weaning to 28 days post weaning under commercial conditions.

Materials and Methods Weaning pigs (n=760) age 27± 3 days were allocated to two dietary groups run over four replicates and offered either HP 300 (13.1%) or fishmeal (10%) of diet designed to supply the same level of crude protein for two weeks. After two weeks all the animals were offered HP300 or fishmeal in liquid diet for a further two weeks. Pigs were weighed weekly. Weights were compared statistical using the general linear model analysis of variance (ANOVA), (Minitab 13.0, Mintab, Inc, PA. USA), weaning weight was used as covariate. Significant differences are reported at ($P<0.05$).

Results At weaning and up to 7 days post weaning, there were no significant differences ($p>0.05$) in weight between pigs allocated to the HP300 or FO, however after 14 days FO piglets were significantly lighter ($P<0.05$) than those fed the HP 300 diet. At 21 days post weaning, there were no significant differences in weight between the two groups. At the end of the experimental period FO feed piglets were heavier than HP300 fed piglets. Overall total gains were higher for the FO than HP300, although FCR was higher for the HP300 group.

Table 1 Effect of replacing fishmeal with HP 300 on growth performance of piglets from weaning to 28 days post weaning under commercial conditions

Period	HP 300 (n=380) Mean ± SEM	Fishmeal (n=380) Mean ± SEM	Significance
Wt at weaning (kg)	7.5±0.81	7.6±0.09	NS
Wt at 7 days p/ weaning	8.9±0.09	8.8±0.09	NS
Wt at 14 days p/ weaning	11.5±0.12	11.0±0.12	*
Wt at 21 days p/ weaning	15.2±0.17	15.4±0.16	NS
Wt at 28 days p/ weaning	19.3±0.20	20.1±0.21	*
Total gain (kg)	11.81	12.55	-
FCR*	1.69	1.52	-

Values are means ± SEM. Means with different superscripts on the same row are significantly different $p<0.05$. *Based on group replicates

Conclusion The results from this study shows that HP300 had a greater influence than fishmeal on growth performance during the first 14 days post weaning, but this effect is not sustained into the second period where fish meal produced better growth performance in the piglets.

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Effect of supplementing piglet diets with Rovimix® Stay C® 35 and/or iron on total iron biding capacity and total antioxidants

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Introduction The balance between cellular oxidants and antioxidants is important in the maintenance of cellular homeostasis and functionality. Vitamin C is a potent antioxidant with strong chelating properties, which enhances the absorption of ferric and non –heame iron from the gut (Fishman *et al.,* 2000). However, vitamin C is unstable in the presence of alkali and is susceptible in the duodenum (Arrigoni, and De Tullio, 2002). This study tested the ability of a stable preparation of Vitamin C, Rovimix® Stay C® 35 (DSM Nutritional Products), to regulate iron uptake as measured by total iron binding capacity (T.I.B.C) and as an antioxidant as measured by total antioxidant status (TROLOX) in weaned piglets.

Materials and methods One thousand and eighty three piglets were weaned at a mean age of 24 days and allocated according to treatment on to fully slatted pens (50 piglets per pen). Treatment diets were as follows: Control 1 (C1): standard weaning diet with 200mg/kg of dietary iron. Control 2 (C2): standard weaning diet with 120 mg/kg of dietary iron. Treatment 1(T1): standard weaning diet with 120 mg/kg of dietary iron plus 50mg of L-ascorbyl-2-phosphate (Rovimix® Stay-C® 35) containing 35% Vitamin C. Treatment 2 (T2): standard weaning diet with 120 mg/kg of dietary iron plus 200 mg of Rovimix® Stay-C® 35. The experiment was done over 4 replicates each with approximately 200 piglets. Within each replicate 50 piglets were allocated to each treatment. Within each replicate fourteen animals from each dietary treatment were blood sampled at weaning, fourteen-days and twenty-eight days post weaning. Plasma T.I.B.C and TROLOX were analysed using ABX diagnostics kits ABX Diagnostics Ferrozine iron Kit (Ref. A11A00091 and NX2332). Plasma concentrations were compared by statistical analysis using the General Linear Model (GLM) (Minitab 13.0, Mintab, Inc, PA. USA). Significant treatment differences were reported at ($p<0.05$).

Results At weaning and fourteen days after weaning there were no significant differences ($P>0.05$) in T.I.B.C values between animals allocated to the four different dietary treatments. However, at twenty-eight days post weaning animals in C1 and C2 had significantly higher ($P<0.05$) capacity than T1 and T2. Plasma total antioxidant (TROLOX) in animals allocated to C1 was significantly higher ($P<0.05$) than C2, while C2 and T1 were not significantly different ($P>0.05$) T2 at weaning. Fourteen days after weaning values in C1 were significantly higher ($P<0.05$) than values for animals allocated to T1. There were no significant differences ($P>0.05$) between C1 and C2 or C2 and T1 or T2. However at twenty-eight days post weaning, there were no significant differences ($P>0.05$) in plasma TROLOX levels between all the groups.

Table 1 Effect of Rovimix® Stay C® 35 on plasma total iron binding capacity and total antioxidants at weaning, 14 days and 28 days post weaning

		Control 1 (n=56)	Control 2 (n=56)	Treatment 1 (n=56)	Treatment 2 (n=56)
T.I.B.C	Day 0	98.4±3.2	96.5 ±2.6	95.2 ±2.5	92.5 ±2.4
	Day 14	89.9 ±2.0	91.9 ±2.0	91.3 ±1.8	90.6 ±2.6
	Day 28	103.0^{ab} ±1.7	110.7^{b} ±1.7	89.3^{a} ±1.9	89.9^{a} ±1.1
TROLOX	Day 0	0.73^{b} ± 0.01	0.70^{a} ± 0.01	0.70^{a} ± 0.01	0.69^{a} ± 0.01
	Day 14	0.64^{b} ± 0.01	0.63^{a} ± 0.01	0.60^{a} ± 0.01	0.60^{a} ± 0.01
	Day 28	0.75 ± 0.01	0.74 ± 0.01	0.75 ± 0.01	0.73 ± 0.01

Values are means ± SEM. Means with different superscripts on the same row are significantly different $p<0.05$

Conclusion Due to the redox status of iron present in labile iron pool and its role in ROS and free radical formation, LIP iron levels must be carefully regulated (Kakhlon et al., 2002). The results from this experiment indicate that feeding piglets on a stable Vitamin C source (Rovimix® Stay-C® 35) reduces free iron in plasma but this effect leads to utilisation of available antioxidants as indicated by TROLOX values especially in the first 14 days post weaning. This could have implications on growth and immune system functionality in newly weaned piglets exposed to different stressors.

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The effect of inclusion of Natupro in the grower pig diet on nitrogen utilisation, retention, excretion and digestibility

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Introduction With the ban on the use of mammalian protein in the EU and the implementation of restrictive use of fishmeal in animal diets coupled with the increased legislative pressures to reduce nitrogen output from animal production, there is an increased requirement for an alternative protein source, which is lower in overall crude protein percentage while still meeting the animal's optimum amino acid requirement. Natupro is an alternative nutritionally enhanced GMO free vegetable protein, which carefully matches all of the above criteria, as it is low in crude protein (36%) with a controlled release of amino acid mechanism (Natupro amino acid analysis Table 2). Glucosamine is the inspiration behind Natupro, the combination of sugars and amine moites gave rise to the concept of a sugar carrier, which is the mechanism Natupro uses for the consistent controlled release of amino acids over time. The objective of this current experiment is to access the effect of inclusion of Natupro in the grower pigs diet on nitrogen retention, utilisation, excretion and digestibility.

Materials and methods Twenty-four boars (mean live weight 51kgs) were assigned to 3 dietary treatments (diet analysis Table 1) for this nitrogen balance/digestibility trial. The pigs were housed in metabolism crates following 14-day acclimatization. The three trial diets were 1. (0) A control grower diet with 0-grams/kg Natupro and balanced with synthetic amino acids 2. (3.5bal) Grower diet with 35-grams/kg Natupro inclusion and balanced with synthetic amino acids and 3. (3.5ubal) Grower diet with 35-grams/kg Natupro inclusion and unbalanced for amino acids (diet composition Table 3). Urine and faeces were collected separately over a five-day nitrogen balance/digestibility period entailing total excreta collection and total intake measurement. Orthogonal contrasts were used to compare the treatments.

Results The 35-grams/kg Natupro grower diet balanced for amino acids had a significantly lower daily nitrogen excretion, and urinary nitrogen excretion and had significantly higher daily nitrogen retention and nitrogen utilization than the control diet (Table 4). There was a numerical tendency for 35-grams/kg Natupro balanced for amino acids to increase digestibility of dry matter (Table 4). There was no significant difference in any of the measured variables between the control diet and the diet with the 35-grams/kg Natupro inclusion unbalanced for amino acids (Table 4).

Table 1 Diet Analysis

Treatment	0	3.5bal	3.5ubal
CP g/kg	162.4	159.3	159.1
GE MJ/kg	17.32	17.22	17.27
DE MJ/kg	14.83	14.85	14.85

Table 2 Natupro Amino Acid Analysis %

Lysine	5.4
Methionine	2.2
Meth & Cysteine	2.7
Threonine	0.55
Tryptophan	0.55

Table 3 Diet Composition (g/kg)

Treatment	0	3.5bal	3.5ubal
Barley	427	500	246.5
Wheat	311	232.3	500
Soya 48	158.2	136	136.2
Soya Oil	55	59	47.9
Natupro	**0**	**35**	**35**
Mins/Vits	25	25	25
Rapeseed	18.7	9.3	9.4
Lysine	3	1.95	0
Methionine	1.1	0.71	0
Threonine	1	0.68	0

Table 4 Nitrogen balance and digestibility results

	Treatment				P-values	
	0	3.5bal	3.5ubal	sem	0v3.5bal	0v3.5ubal
Nitrogen Intake	54.98	53.05	53.67	1.12	0.247	0.411
Urinary Nitrogen daily g/d	20.05	16.98	19.26	1.01	*	0.584
Nitrogen excreted daily g/d	27.04	23.13	25.89	1.25	*	0.515
Nitrogen retention daily g/d	27.93	29.93	27.77	0.79	*	0.881
Nitrogen digestibility %	87.28	88.41	87.72	0.75	0.315	0.685
Nitrogen utilisation %	50.89	56.47	51.74	1.69	**	0.723
DMD%	85.13	85.97	85.61	0.36	0.122	0.353

Conclusion The inclusion of 35-grams/kg Natupro in a grower pig diet balanced with synthetic amino acids improved both daily nitrogen retention and utilisation while also reducing both total and urinary nitrogen output daily. The grower diet with 35-grams/kg natupro and unbalanced for amino acids performed to the same level as the control even though it had substantially lower levels of amino acids. Natupro is an effective alternative protein source for inclusion in grower pig diets.

The effect of cereal type and exogenous enzyme supplementation on nutrient digestibility, intestinal microflora, volatile fatty acid concentration and manure ammonia emission from pigs

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Introduction Ammonia and volatile fatty acids are significant sources of pollution. In wheat, xylans predominate as the primary non-starch polysaccharide while in barley β-glucan predominates. β-glucans have also been shown to support the growth of lactobacilli and bifidobacteria. By increasing bacterial activity in the hindgut, the pattern of nitrogen excretion and VFA production may be augmented. Exogenous enzymes may increase nutrient digestibility by degrading the β-glucan. It is hypothesised that the addition of an exogenous enzyme mix to a barley-based diet would result in a benefit in terms of increased nutrient digestibility however; this benefit may be reduced by an associated increase in ammonia emissions.

Materials and methods The experiment was designed as a 2 x 2 factorial comprising four dietary treatments. The experimental treatments were as follows: (1) Wheat-based diet, (2) Wheat based diet supplemented with a β-glucanase / β-xylanase mixed enzyme supplement, (3) Barley-based diet, (4) Barley based diet supplemented with a β-glucanase / β-xylanase mixed enzyme supplement. The diets were formulated to have identical concentrations of net energy (9.8 MJ/kg) and total lysine (10.0 g/kg). The enzyme dosage level provided 100 U/kg. 16 finishing boars (four boars per treatment) (80kg) were used in this experiment. The pigs were allowed a 14-day dietary adaptation period after which time they were transferred to individual metabolism crates which facilitated total but separate collection of urine and faeces. Ammonia emission from the manure was measured over 240 hours in a laboratory scale set-up. Digesta samples were aseptically removed from the caecum and colon of each animal immediately post slaughter and bacterial enumeration and VFA analysis was conducted. Bacterial enumeration was conducted by spread plating 0.1ml of sample onto selective agars. The experimental data was analysed according to the General Linear Model procedure of SAS (1985).

Results There was a significant interaction between cereal type and enzyme inclusion in the digestibility of dry matter, gross energy and nitrogen, as well as in manure ammonia emissions, microbial populations in the caecum and colon, and in volatile fatty acid production in the caecum and colon. The inclusion of the enzyme to barley-based diets significantly increased ($P<0.05$) the digestibility of dry matter, gross energy and nitrogen compared to unsupplemented barley-based diets, however there was no effect of enzyme supplementation in wheat based diets. Pigs offered the unsupplemented barley-based diet had a lower population of *E. Coli* ($P<0.05$) in the caecum and a higher population of bifidobacteria ($P<0.05$) in the caecum and colon compared to supplemented diets. Pigs offered the unsupplemented barley diet emitted significantly less ammonia ($P<0.05$) compared to the enzyme supplemented barley diets. Pigs offered unsupplemented barley-based diets had significantly lower proportions of isobutyric acid ($P<0.05$) and isovaleric acid ($P<0.01$) than wheat based diets. However, in the presence of an enzyme, there was no effect of cereal type on any of these parameters.

Table 1 Effect of treatment on apparent digestibility, ammonia production, intestinal microflora and volatile fatty acid profile

Treatment	1	2	3	4	s.e.m	Significance		
Digestibility coefficients						Cereal	Enzyme	Cereal x Enzyme
Nitrogen	0.890	0.881	0.843	0.883	0.009	**	n.s.	*
Neutral Detergent Fibre	0.552	0.630	0.446	0.537	0.049	*	n.s.	n.s.
Gross Energy	0.870	0.871	0.796	0.817	0.010	***	n.s.	*
Ammonia production (mg/g N intake)	74.40	73.63	57.42	116.59	13.02	n.s.	*	*
Intestinal microflora (cfu/ml)								
Caecum Lactobacilli	7.87	7.37	8.60	8.29	0.442	*	n.s.	n.s.
Caecum Bifidibacteria	6.05	6.92	7.51	5.40	0.881	n.s.	n.s.	*
Caecum *E.coli*	6.40	5.80	4.87	6.05	0.454	n.s.	n.s.	*
Colon Lactobacilli	7.54	7.46	8.83	8.73	0.759	n.s.	n.s.	n.s.
Colon Bifidobacteria	6.31	7.64	8.11	6.73	0.750	n.s.	n.s.	*
Colon *E.coli*	6.33	6.38	6.04	6.50	0.296	n.s.	n.s.	n.s.
Caecum Volatile Fatty Acids (mmol/l)								
Isobutyric	0.010	0.005	0.004	0.004	0.001	*	*	*
Isovaleric	0.021	0.009	0.008	0.008	0.02	*	*	*
Colon Volatile Fatty Acids								
Isobutyric acid	0.018	0.014	0.010	0.014	0.002	*	n.s.	*
Isovaleric acid	0.034	0.024	0.018	0.025	0.004	n.s.	n.s.	*

Conclusion Barley based diets depressed nutrient digestibility compared to wheat based diets, however, they were more beneficial for the environment. The inclusion of an enzyme to barley increased nutrient digestibility but also increased ammonia emissions.

Occurrence of mycotoxins in straw used in pig deep litter systems in Australia

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Introduction Mycotoxins are secondary metabolites produced by fungi under certain stress periods (Smith and Seddon 1998). When ingested, mycotoxins cause insidious losses, ill thrift and reduced disease resistance. Zearalenone is known to cause hyperestrogesium in pigs and hence a reduction in fertility in both sows and boars can occur (Binder 2004). Certain mycotoxins such as zearalenone (ZEA) and deoxinivalenol (DON) are produced by fungi of the fusarium species on crops in the field. *Fusarium pseudograminearum* **(**Crown Rot) produces both DON and ZEA in decreasing levels up the tiller of winter cereals (Blaney *et al.* 1987). Most studies carried out so far analysed the occurrence of mycotoxins in the grain and less is known about the prevalence of mycotoxins in the straw of the crop. Housing of sows during gestation on straw is becoming a favoured production system due to environmental and public perception pressures. The intake of straw by weaners on straw based systems has been found to account for 11.5% of total feed intake (Barneveld *et al*. 2004), such that there could be a considerable risk for increased ingestion of mycotoxins in animals on straw based systems. The objective of this study was to investigate the occurrence of mycotoxins in straw used for deep litter in Australian deep litter pig production systems.

Materials and Methods A total of 22 samples of straw were colleted at random from pig production units around Australia. Representative samples of 0.5-1kg of straw were collected from either from inside the production sheds or from unused storage bales on the selected farms. Sub-samples of 200g were then ground using a Romer Mill and were analysed for Aflatoxin B1, B2, G1, G2, ochratoxin deoxynivalenol, zearalenone and fumonisins. The samples were tested by Romer Labs Singapore by HPLC. Detection limits for the mycotoxins were Aflatoxin B1 <5ppb, Aflotoxin B2, G1, and G2 <3ppb, Ochratoxin <2ppb, ZEA <32ppb, DON <50ppb and Fumonisin B1 and B2 <100ppb. Data were analysed using the statistical program Minitab® 12.2.

Results Of all samples analysed 9 samples gave a positive result for aflatoxin B1, 17 samples were contaminated with zearalenone and 14 were positive for deoxinivalenol. The average ZEA contamination was 660ppb.

Table 1 Mean mycotoxin content of straw samples from Australian commercial pig farms

	AFB1	AFB2	AFG1	AFG2	OTA	ZEA	DON	FUM B1	FUM B2
No. of samples analysed	22	22	22	22	9	21	22	22	22
No. of samples below detection level	13	20	22	22	6	4	8	22	22
No. of samples within detection level	9	2	0	0	3	17	14	0	0
Average contamination in samples within detection level (μ/kg)	8.9	16	-	-	2.7	660	539	-	-
Maximum Levels (μ/kg)	11	17	-	-	4	3551	1860	-	-
SEM	1.96	1	-	-	0.67	211	123	-	-

Conclusion Although this is only a preliminary study it does highlight a risk for pigs with access to straw for ingestion of mycotoxins produced from Fusarium mould in straw, particularly ZEA and DON. Further work is required to quantify the effects of prolonged sub-acute toxicity by mycotoxins detetected in straw and on the subsequent effects on performance and immune suppression.

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Evaluation of the effect of dietary crude protein reduction, with or without fishmeal, on post weaning performance

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Introduction The post-weaning phase is a critical period in pig growth. The transition from sow milk to solid plant or animal proteins together with the physiological development of the intestinal tract can sometimes lead to digestive disorders depressing growth and impacting upon the lifetime performance of the pig herd. Lowering feed protein level or changing the type of protein offered appears as a practical solution to decrease the incidence and severity of digestive disorders leading to diarrhoea. It is crucial that in reducing crude protein levels that the balance of amino acids are maintained to meet the pigs requirement for growth. Fishmeal is often used in diets as a source of protein and amino acids. It also is said to be an aid to palatability. The objective of this experiment was to evaluate the performance of post-weaned piglets offered diets that differed in crude protein content and in protein source from weaning until 43 days post-weaning.

Materials and methods 831 piglets were weighed on the day of weaning and allocated to one of four treatment groups and one of three weight groups (large, medium and small). The piglets were grouped in pens of 11 (0.5 m^2 per piglet) with 2 nipple drinkers and 6 spaced *ad lib* hoppers. The environment was computer controlled and temperatures recorded daily. The feeding programme consisted of two diets (Pre-starter – 1-21days post-weaning and Starter – 22-43days of age) divided into four treatment groups (A. standard protein 220/200g/kg + fishmeal, B. standard protein 220/200g/kg – fishmeal, C. low protein 190/185g/kg + fishmeal and D. low protein 190/185g/kg – fishmeal). The total amino acid level in the diets was set at lysine 15g/kg (prestarter) and 13g/kg (starter) with the other amino acids in ratio to lysine at M+C 0.56, threonine 0.66 and tryptophan 0.20. The diets contained zinc oxide (3100mg/kg) and colistine sulphate (120 mg/kg - starter only) as anti-microbials. Data were analysed using GLM ANOVA procedure. Amino acid analysis of the feed was confirmed by Ajinomoto Eurolysine using exchange ion chromatography. Diets were manufactured by SCA Iberica.

Results The results showed no significant differences between treatments either for the pre-starter (1-21 days post-weaning) or for the starter (22-43 days post-weaning). The general health status of the piglets throughout the trial was good with no animals treated or removed from the trial. Table 1 shows the overall results obtained for the whole period (1-43 days).

Table 1 Overall performance data for days 1-43 post-weaning

	A	B	C	D	Std Error	P
Number of piglets	210	205	209	207		
Initial weight (kg)	6.23	6.24	6.24	6.23	0.124	1.00
Final weight (kg)	24.02	23.93	23.80	24.17	0.133	0.78
DLWG (kg)	413.6	411.45	408.53	417.24	3.100	0.78
DFI (kg)	539.3	527.1	546.72	542.12	5.555	0.63
FCR	1.3	1.29	1.34	1.3	0.0130	0.47

Conclusions The use of low protein diets, where amino acid levels were balanced in line with BSAS Nutrient Requirement Standards for Pigs, showed similar performance to standard protein diets. Replacing fishmeal with alternative vegetable protein sources also had no negative effect on performance. The ability to reduce crude protein content of piglet diets, as a potential means to reduce digestive fermentation and potential *E.coli* colonisation is of great interest to the industry.

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Effect of slaughter weight on slaughter value and meat quality of fattening pigs

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Introduction Fattening and slaughter value of fattening pigs and the dietetic properties of pork depend, among others, on sex, breed, crossbreeding scheme, and age and body weight at slaughter (Weatherup *et al.* 1997). The degree of carcass meatiness and meat quality depend largely on the breed of the crossed boars (Davey and Bereskin, 1978). The aim of the present experiment was to analyse the effect of crossbreeding, slaughter weight and feeding on the slaughter value and meat quality of fattening pigs.

Materials and methods This experiment involved crossbred finishing pigs (gilts and barrows) representing 5 crossbreeding schemes: LY (♀ Landrace × ♂ LW), LYD [♀(♀ Landrace × ♂LW) × ♂ Duroc], LYH [♀(♀ Landrace × ♂LW) × ♂ Hampshire], LYP [♀(♀ Landrace × ♂LW) × ♂ Pietrain], LY990 [♀(♀ Landrace × ♂LW) × ♂ 990line] which were slaughtered at 95-100 kg or 111-120 kg of body weight (8 pigs in each weight range for each crossbreeding scheme). Pigs from 30 kg of body weight to slaughter were fed *ad libitum* with a complete mixture (Central Soya). At the desired weight, the pigs were slaughtered and hot carcass weight determined. This was followed by backfat thickness measurements according to the post-slaughter analysis methods applied at Pig Testing Stations, and carcass meatiness was measured by ultrasonography (PIGLOG-105). Meat samples were taken from between 4 and 5 lumbar vertebrae of the *longissimus* muscle and from the *semimembranosus* muscle. Muscle tissue was assayed for the content of ether extract. Ether extract of loin and ham was analysed with gas chromatograph. The tissue samples were also determined for the content of cholesterol according to the methods of Rhee *et al.* (1982). The data were analysed by analysis of variance.

Results Table 1 presents the results of slaughter analysis of crossbred pigs slaughtered at various body weights. Two-breed pigs LY and three-breed pigs LYH and LYP were distinguished by the best meatiness when slaughtered at 95-100 kg of body weight, while three-breed pigs with a proportion of Duroc or line 990 boars when slaughtered at 111-120 kg of body weight. At more than 110 kg of body weight, crossbred pigs representing all crossbreeding schemes were characterized by thicker backfat and higher ether extract content of ham and loin muscles.

Table 1 Slaughter value of crossbred fatteners slaughtered at different body weights

Slaughter weight [kg]	Crossbreeding type					SEM
	LY	LY D	LY H	LY P	LY 990	
			Meatiness acc. to EUROP system [%]			
95-100	50.83	$50.40^{a\,r}$	$53.45^{Ab\,r}$	52.80^{A}	49.65^{B}	4.33
111-120	$49.30^{\,aA}$	$53.34^{B\,s}$	$51.58^{b\,s}$	51.63	50.49	4.80
			Average backfat thickness of 5 measurements [mm]			
95-100	29.44^{A}	29.42^{A}	$25.86^{B\,r}$	28.70	$31.38^{AC\,r}$	6.56
111-120	40.65^{aAC}	31.70^{B}	$30.70^{aB\,r}$	30.98^{B}	$36,52^{bC}$	7.85
			Loin – content of cholesterol (mg/100 g of fresh tissue)			
95 – 100	41.26	42.61^{r}	42.12	40.21	40.98	1.61
111-120	44.01	48.11^{s}	44.60	44.15	43.48	1.53
			Loin – ether extract - level of unsaturated fatty acids (%)			
95 – 100	62.84	62.50	62.61	61.50	62.42	0.27
111-120	61.98	62.11	62.51	64.20	62.03	0.22
			Ham – content of cholesterol (mg/100 g of fresh tissue)			
95 – 100	48.10^{aAC}	47.88^{aC}	44.20^{AB}	$42.30^{B\,r}$	45.21^{b}	0.79
111 – 120	49.21^{a}	48.30^{a}	44.60^{b}	$43.12^{b\,s}$	46.12	0.93
			Ham – ether extract - level of unsaturated fatty acids (%)			
95 – 100	63.98	64.16	64.90	63.28	64.78	0.25
111 – 120	62.19	61.92	61.85	62.68	62.98	0.23

values in the same rows with different letters differ significantly a, b, c - P≤ 0.05; A, B, C, D - P≤ 0.05
values in the same columns with different letters differ significantly r, s - P≤ 0.05

Conclusions The optimum age and slaughter value of a pig depend on the breed or crossbreeding scheme. Crossbred pigs with a proportion of Duroc or line 990 can be slaughtered at higher body weights compared to pig crossbreds of other meat breeds without a negative effect on carcass quality.

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The effect of addition of β-carotene, vitamins C and E in feed mixture enriched with CLA on sensory traits and oxidative status of pork meat

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Introduction There is some concern that meat and eating quality can suffered as a result of dietary CLA supplementation through the influence on fatty acids metabolism and it content in meat. CLA addition to pigs' diet requires simultaneous addition of antioxidative vitamins' taking part in stabilization of double bonds of CLA inbuilt in phospholipids complex of cell membrane (Livisay *et al.,* 2000).

Material and methods The experiment was carried out on 50 fatteners of Polish Large White breed randomly divided into 5 groups (5 sows and 5 barrows in one group) with body weight 50-105 kg. The experimental factor was the addition of vitamins C, E and β-carotene to pigs diet. Vitamins were added in following amounts (mg/kg): group I- standard premix 30 vitamin E; group II- 200 β-carotene; group III- 200 vitamin C; group IV- 300 vitamin E; group V- 200 β-carotene, 200 vitamin C and 300 vitamin E. In all groups 1% CLA addition has been used (Edenor UKD 6010, Henkel). The mixture consisted of: 13.0 MJ metabolizable energy, total protein 17.0%, raw fiber 3.6%, raw fat 2.1%, total phosphorus 0.52%, calcium 0.91%, methionine with cysteine 0.59% and tryptophane 0.19%. The fatteners were slaughtered at 105 kg of body weight. Sensory analysis of eating quality was carried out on loin steaks (20 mm thickness) which were stored for 24 h at 4 ºC and later cooked using a Toshiba (Japan) plate grill. The steaks were cooked for approximately 5 min to an internal temperature of 85 ^{o}C. The cooked muscles were allowed to cool for 2 min and cut into 4 pieces. These were assessed on a 5-point scale (0=insufficient, 1=sufficient, 2=satisfactory, 3=good, 4=very good, 5=excellent) for tenderness, juiciness, flavour and palatability (intensity and quality) according to Baryłko-Pikielna (1975). Eating quality was assessed by the 8 sensory panellists during 30 tasting sessions. Chromatographic analysis of α-tocopherol and retinol was evaluated by HPLC according to modified method (Ueda & Igarashi, 1987). In samples, the malonaldialdehyde (TBARS) content was measured according to Salih (1987) after 90 days of storage at –19°C. Obtained results were analyzed statistically by two-factors variance ANOVA and Tukey test using Statgraphic Plus 4.0 program.

Results **Table 1** Effect of different vitamins addition in the diet containing CLA on sensory traits and oxidative stability of pork

Item	Groups					Sex		SE
	I - basal	II - basal+ β-carotene	III - basal + C	IV- basal + E	V - basal + β-car.,C, E	gilts	barrows	
Tenderness (point)	4.73	4.69	4.91	4.76	4.78	4.76	4.78	0.03
Juiciness (point)	4.71	4.66	4.84	4.69	4.76	4.72	4.74	0.03
Flavour:								
Intensity (point)	4.79	4.77	4.87	4.79	4.87	4.77	4.82	0.03
Quality (point)	4.81	4.78	4.88	4.86	4.88	4.82	4.86	0.02
Palatability :								
Intensity (point)	4.73	4.71	4.83	4.82	4.79	4.79	4.76	0.03
Quality (point)	4.67	4.69	4.79	4.77	4.73	4.73	4.73	0.03
TBARS (mg/kg^{-1})	0.45	0.51	0.47	0.41	0.42	0.43	0.48	0.01
α-tocopherol (µg/mg)	1.23^{a}	1.13^{a}	1.76^{b}	2.88 C	3.06 C	2.03	1.99	0.11
retinol (µg/mg)	nd	nd	nd	nd	nd	-	-	-

$^{a-b}$P<0.01

Conclusion The addition of higher doses of vitamins E, C and β-carotene in feed mixtures enriched in CLA did not influence the sensory traits of pork. Higher addition of vitamin E (group IV) and mixture of vitamins E, C and β-carotene significantly influenced the content of vitamin E in pork (P<0.01) and at the same time it caused the decrease of TBARS level but the differences appeared not significant.

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Characterisation of 3-beta-hydroxysteroid dehydrogenase from pig liver and testis in relation to boar taint

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Introduction Boar taint is a major meat quality defect, which affects about 10% of entire male pigs. It is due to an excessive accumulation of skatole and androstenone in adipose tissue. One of the reasons for accumulation of these compounds is a low rate of their metabolism. Androstenone is metabolised in liver via the enzyme 3-beta-hydroxysteroid dehydrogenase (HSD). This enzyme is well characterised in the testis, where it participates in the synthesis of steroids, while its properties in liver are unknown. The aim of the present study was to characterise and compare properties of HSD from pig liver versus pig testis when metabolising androstenone.

Materials and methods Liver and testis samples were collected from 5 Large-White pigs immediately after slaughter. Microsomes were isolated by differential centrifugation and frozen at –80^{o}C until use. Microsomes were incubated under different conditions in order to determine HSD kinetic parameters and metabolic rates with androstenone as substrate and NADH as cofactor. Rates were estimated by recording the appearance of the main metabolite, β-androstenol (β -ol), by high-resolution gas chromatography. For kinetic experiments the incubation conditions were: 37 ^{o}C, pH 7.4 and incubation time 20 min, except when different pH of the incubation media were used for determining the optimum pH. Different concentrations of androstenone as substrate and trilostane as a HSD specific inhibitor were used. The amount of HSD protein in isolated microsomes was determined by Western Blotting using specific antibodies. ANOVA was used for the statistical analysis.

Results The rate of androstenone metabolism was higher in liver than in testis (Figure 1). The kinetic study revealed that hepatic HSD has lower affinity for androstenone as a substrate in comparison with testicular HSD. However, hepatic HSD is able to metabolise androstenone faster than the testicular enzyme. Differences were observed in the optimum pH range as well (Table 1). Inhibition studies showed that hepatic HSD was more sensitive to trilostane than testicular HSD (Figure2). In both cases competitive inhibition occurred. Western Blotting results showed no differences in the amount of HSD protein in pig liver and testis (Table1).

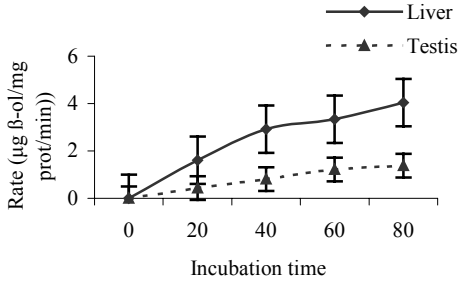

Fig 1 HSD time-dependent curve for androstenone metabolism

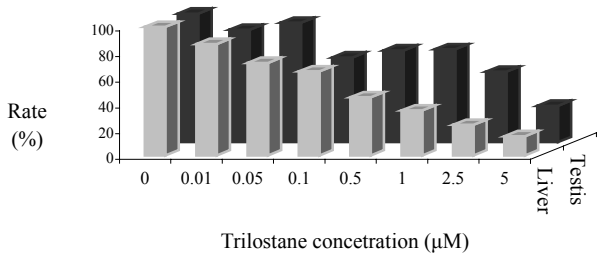

Fig 2 Trilostane effect on hepatic and testicular HSD

Table 1 Metabolic rates, kinetic parameters and expression of HSD in pig liver and testis

Parameter	Liver	Testis
Metabolic rate (µg ß-ol/mg prot/min)	1.28*	0.24*
Km (µM)	253* (±38.9)	59* (±24.3)
Vmax (µg ß-ol/mg prot/min)	2.3* (±0.5)	0.5* (±0.1)
Optimum pH	7	6
Kind of inhibition of trilostane	competitive	competitive
Amount of HSD (arbitrary units)	90 (±4)	92 (±9)

(* denotes statistical significance, $p<0.05$)

Conclusions The results of this study demonstrate that HSD activity and kinetic characteristics differ in pig liver and testis. However, the amount of HSD protein expression was similar in both tissues. Therefore we conclude that there might be different HSD isoforms in pigs and their distribution is tissues specific. This study will be extended to different breeds in order to identify an apparent polymorphism in HSD. Such a polymorphism could be used to develop a genetic test for boar taint.

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The author wishes to thanks to BBRSC, Genesis Faraday and Meat Livestock Commission for their financial contribution to this work as well as Stegram Pharmaceuticals for the kind donation of trilostane.

Comparison of the relative expression of caspase isoforms across muscle types

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Introduction Toughness is a determinant of meat quality and a common cause of unacceptability in meat products. Calpain proteases are believed to be involved in meat tenderisation by post mortem degradation of myofibrillar proteins (Sensky *et al.,* 2001). However other proteases are likely to contribute to the proteolysis involved in meat-conditioning (Sentandreu *et al.,* 2002). Caspases are proteases involved in protein degradation in apoptosis. Like calpains caspases are activated early in pathological events associated with hypoxia/ischaemia, which is not dissimilar to the hypoxic conditions in muscle after slaughter. Caspases specifically cleave a number of proteins that are also targeted by calpains during post mortem proteolysis and also degrade the calpain-specific inhibitor calpastatin. The caspase system has a hierarchy of initiating isoforms (such as caspases 8 and 12) which activate effector caspases (such as 3 and 7) that cleave specific substrates. Caspases are regulated by inhibitors such as apoptosis repressor with caspase recruitment domain (ARC). Our hypothesis is that caspase activity may contribute to early post mortem proteolysis and tenderisation, similar to the calpain system. The aim of this study was to characterise the caspase system in various porcine skeletal muscles.

Materials and methods Large White pigs (n=4) were slaughtered, samples of longissimus dorsi (LD), trapezius (TZ), psoas (PS) and semi tendinosus (ST) muscles were removed and immediately snap frozen in liquid nitrogen. Crushed tissue (1g) was homogenised in 3 ml extraction buffer (25mM HEPES (pH 7.5), 0.1% Triton X-100, 5mM $MgCl_2$, 2mM DTT, 74µM antipain, 0.15µM aprotinin, 1.3mM EDTA, 20µM leupeptin, 15µM pepstatin). Proteins from equivalent wet weight (w/w) tissue were separated by electrophoresis on 15% sodium dodecyl sulphate polyacrylamide gels and transferred onto PVDF membrane by Western blotting. Replicate blots were immunoprobed with anti-human caspase 3, 8, 12, or ARC antibodies (MERCK), the protein bands detected using ECL Plus detection system (Amersham Biosciences) and their intensity quantified (Quantity-One Multi Analyst, BioRad). Caspases 3 and 7 activities were measured using Promega's fluorescence based Apo-One Caspase 3/7 assay using a FluoStar Galaxy spectrometer (BMG). Data was analysed using one-way analysis of variance (Genstat 5.1).

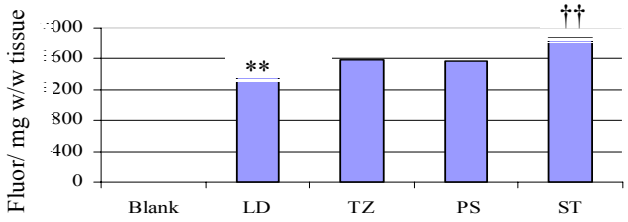
Results Components of the caspase system were expressed in skeletal muscle. Caspase 3/7 activity (Fig 1), intensity of caspase 12 and ARC protein (Table 1) was significantly lower in LD than other muscle types (P<0.01). ST had the highest caspase 3/7 activity and the highest level of caspase 12 (P<0.01). Caspase 8 expression in TZ was significantly higher than other muscle types, with PS also being significantly higher than LD (P<0.01). Caspase 3 activation results in the cleavage of caspase 3 from 32kDa to 20kDa. There were no significant differences in 32 kDa caspase 3 band intensity between muscles, however the 20kDa caspase 3 band was significantly lower in TZ (P<0.01) than PS and ST.

Table 1 Protein levels of caspase isoforms and ARC in different muscle types

	LD	TZ	Ps	ST	s.e.d.
Casp 3 (32kDa)	0.23	0.42	0.33	0.40	0.13
Casp 3 (20kDa)	1.25	0.77	1.32	1.73	0.25**
Casp 12	0.11	0.97	1.02	1.53	0.17**
Casp 8	0.12	0.70	0.38	0.20	0.13**
ARC	0.35	0.92	1.07	1.23	0.17**

Intensity of immuno-positive bands on W-Blots (absorbance/ mg w/w tissue). Expression is comparable between muscle types within isoforms only. **P<0.01

Fig 1 Caspase 3/7 activity in different porcine skeletal muscles



**LD has significantly lower caspase 3/7 activity than TZ, PS and ST (P<0.01). ††ST has significantly higher activity than LD, TZ and PS (P<0.01) s.e.d = 89.2

Conclusion Detection of caspases within skeletal muscles indicates that proteolysis mediated by these enzymes could occur. In contrast to the similar levels of effector caspase 3 there was a larger variability in the levels of initiator caspases 8 and 12 across muscle types, implying different activation pathways are involved. Likewise the variability in the levels of ARC indicates that there is a further differential in potential inhibition across muscles. Differences in caspase 3/7 activity between muscles but similar caspase 3 protein levels could be attributed to different levels of the effector caspase 7 in muscle types. We are currently undertaking studies to examine the relationship between changes in caspase activity, substrate degradation and inhibitor levels during the post-mortem conditioning period, with focus on tenderness.

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Phosphorus and calcium metabolism in growing horses fed diets with different calcium levels

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Introduction Phosphorus and calcium deficiency in horses represents an important factor responsible for the low equine production in Brazil. The basic mechanisms of P and Ca metabolism differ substantially among species. Regulation of P and Ca metabolism is less well understood in horses than in others species. With the use of the isotopic dilution technique is possible to evaluate the metabolism for this mineral. The aim of the present experiment was to study the effect of different Ca levels in the diet on P and Ca metabolism in horses.

Material and methods Twelve male colts, twelve months years old, an average body weight of 221.0 kg were used in a random design. Treatments consisted of three Ca levels (0.15, 0.45 and 0.75%) and adequate (0.22%) P level. The basal diet was composed by Tifton 85 hay, maize grain, soybean meal and mineral vitamin nucleus. Animals received the diet for 30 days, and after this period they were allocated in individual metabolism cages for 10 days. The animals were injected with 7.4 MBq of ^{32}P and ^{45}Ca via right jugular vein. Blood samples were taken after 5 min, 1, 2, and 4, 6 h after injection and then after each 24 h during 7 days. Urine and faeces samples were taken each 24 h during 7 days after ^{32}P and ^{45}Ca injection. P and Ca specific activity in plasma and faeces, endogenous P and Ca and net and true absorption were estimate by Vitti et al. (1998). Means were compared by analysis of variance, standard error of difference between means (sed) and Tukey test at probability level of 5% (SAS, 2000).

Results Means values of P and Ca metabolism data are given in Table 1. The levels of Ca did not affect P absorption, retention and excretion in faeces. P availability was high for all treatments and was not influenced by Ca levels. Ca concentration in the diet affected P excretion in urine, and the there was a decrease in P in the urine with increase of Ca level in diet. Ca availability did not differ between treatments, but net absorption was low for the lowest Ca level in the diet. Ca retention and Ca excreted in faeces was affected by treatments. Animals fed low Ca level had lowest Ca retention. Although Ca in urine was not statistically significant, values were increased with increasing Ca in the diet and this could indicate that urine Ca excretion is an important factor that influences Ca homeostasis in horse, besides Ca excretion in faeces.

Table 1 Effect of different calcium levels on phosphorus and calcium metabolism in growing horses

Parameters	Treatments*			sed**
	0.15%Ca	0.45%Ca	0.75%Ca	
P in plasma (mg/dL)	5.06[a]	4.98[a]	4.60[a]	1.09
Body weight (kg)	223.47[a]	218.26[a]	221.28[a]	69.99
Total P intake (mg/kg LW/d)	66.21[a]	66.03[a]	62.02[a]	17.64
Total P in faeces (mg/kg LW/d)	24.72[a]	22.93[a]	22.23[a]	9.65
Endogenous P in faeces (mg/kg LW/d)	18.01[a]	11.75[a]	14.95[a]	8.56
P net absorption (mg/kg LW/d)	59.40[a]	54.85[a]	54.73[a]	16.72
P true availability (%)	89.26[a]	81.99[a]	88.86[a]	5.91
Total P in urine (mg/kg LW/d)	11.03[a]	1.34[b]	0.44[b]	4.80
P retention (mg/kg LW/d)	30.04[a]	42.66[a]	38.44[a]	16.22
Ca in plasma (mg/dL)	11.63[a]	11.94[a]	11.70[a]	0.67
Body weight (kg)	223.47[a]	218.26[a]	221.28[a]	69.99
Total Ca intake(mg/kg LW/d)	49.55[a]	141.50[b]	216.37[c]	36.37
Total Ca in faeces(mg/kg LW/d)	24.24[a]	38.45[a]	79.41[b]	10.06
Endogenous Ca in faeces (mg/kg LW/d))	17.20[a]	17.32[a]	28.04[a]	9.76
Ca net absorption (mg/kg LW/d)	42.49[a]	120.37[b]	165.00[b]	32.80
Ca true availability (%)	84.63[a]	84.16[a]	76.32[a]	5.60
Total Ca in urine (mg/kg LW/d)	0.93[a]	5.28[a]	10.38[a]	8.83
Ca retention (mg/kg LW/d)	24.37[a]	97.76[b]	126.58[b]	28.02

** sed: standard error of difference between means

[a, b, c, d] means with different superscripts, within rows, are significantly different ($p < 0.05$)

Conclusions Although P excretion in urine was affected by the level of Ca in diet, the amount of P excreted was very small for all treatments indicating that this route of P excretion was not important to maintain P homeostasis in horses. Ca levels in diet affect Ca metabolism in horses by increasing retention, absorption and losses of Ca in faeces and urine.

Acknowledgements Authors would like to thank FAPESP and CNPq for financial support.

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A pilot study to estimate the intake of grass by ponies with restricted access to pasture

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Introduction It has been shown that horses and ponies at pasture usually graze for 15-17 hours per day, and consume between 16 and 33g dry matter (DM) /kg live weight per day, depending on animal size and physiological status. However, many predominantly stabled horses have restricted access to pasture, often only 1-3 hours/day. There is no information on voluntary food intake (VFI) of horses under such regimens. Therefore the aim of this pilot study was to determine the voluntary intake of fresh herbage by ponies when their access to pasture was restricted.

Materials and methods Three Welsh/Welsh cross geldings (average body weight 338.5kg $\pm$ 100.70kg) were individually housed in loose boxes bedded on rubber matting and shredded paper with *ad libitum* water and fed meadow hay at a level of 10g DM/kg live weight per day. The study period was two weeks; the first was an adaptation period and during the second measurements of VFI were taken. Ponies were stabled for 21 hours per day. During the remaining 3 hours per day ponies were allowed to forage freely on a one acre grass paddock of average sward length 26.5cm and average DM content of 136g/kg. During the second week fresh grass intake was determined by measuring live weight change over the grazing period (Gibb *et al.,* 1997). The ponies were weighed prior to being turned out and then weighed again on their return to the loose boxes each day for a total of 7 days. Ponies were observed throughout the grazing periods in week 2 so that any faecal or urinary outputs could be collected for each individual animal and weighed. The difference in live weight was taken as the weight of fresh forage consumed over three hours.

Results The mean VFI of fresh matter over three hours was 6.48 $\pm$ 1.429kg, which corresponded to 0.88 $\pm$ 0.195kg of DM over three hours. Although there was a wide range of body size between the ponies the average DM intakes of pasture over three hours represented 0.27% of their bodyweight (Table 1).

Table 1 Pony live weight, pasture voluntary food intake (kg/3hrs) of fresh matter (FM), dry matter (DM) and percentage of pony live weight consumed as DM per three hours

Pony number	Pony live weight (kg)	VFI (kg FM/3hrs)	VFI (kg DM/3hrs)	DM intake over three hours as a % of live weight
1	258.9 $\pm$ 0.89	4.86 $\pm$2.116	0.66$\pm$ 0.288	0.26 $\pm$ 0.110
2	304.9 $\pm$ 0.89	7.57 $\pm$ 1.618	1.03 $\pm$ 0.220	0.34 $\pm$ 0.072
3	451.7 $\pm$ 2.06	7.00 $\pm$ 1.291	0.95 $\pm$ 0.176	0.21 $\pm$ 0.039
Mean	338.5 $\pm$ 100.70	6.48 $\pm$ 1.429	0.88 $\pm$ 0.195	0.27 $\pm$0.066

Conclusion The average sum of the daily DM intakes of meadow hay and pasture represented 1.27% of pony live weight, which is lower than the recommended range of 1.35-1.8% bodyweight published by NRC (1989) for horses and ponies at maintenance. However, no change in pony live weight occurred over this short two-week study period, suggesting that the maintenance energy requirements of the animals were being approximately met through the combined intake of 10g DM/kg of LW / d as hay and 3 hours grazing. The herbage eaten by the ponies during the three-hour grazing period constituted 21% of their daily DM intake. As horses will naturally graze for around 15 hours per day, the ingestion of approximately one-fifth of their daily DM intakes whilst at pasture for 3 hours, may suggest a steady intake of DM over the grazing period. Alternatively, the ponies may have ingested the herbage at a rate at, or close to, their physical maximum limit, the high moisture content of the herbage precluding higher DM intakes during this period. Further work determining rates of ingestion by ponies of herbage of different DM contents for varying time periods would help elucidate this.

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Gas production technique in the evaluation of horse feeds using equine faeces and rumen liquid as inoculum source 1. Fermentation kinetics

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Introduction The in vitro gas production is a widely used technique for the evaluation of feeds for ruminant animals. Although it measures rate and extension of gas production during feed fermentation in culture medium, rumen inoculum from operated animals (fistulae) is required. Faecal microorganisms function similarly to those in the rumen; they decompose feed and do not require operated animals. The objective of the present experiment was to compare rumen liquor and equine faeces as source of inoculum in the gas production technique.

Material and methods Ovine Rumen Liquid (RL) and Equine Faeces (EF) were used as sources of inoculum. RL was collected by rumen cannula and EF were collected directly from the rectum. Preparation of inocula followed Theodorou *et al*. (1994). The following seven feeds, evaluated *in vivo* in several assays for the equines, were used as substrate sources: Tifton 85 hay (TH), Alfalfa hay (AH1), Alfalfa hay (AH2), Coast-Cross Hay (CH), Manioc Offshoots Hay (MH), High Moisture Corn Silage (HC) and Sunflower Seeds (SS), and submitted to EF and RL inocula. Inoculation was done with 10mL RL or EF injected in 160mL glass bottles with 90mL of culture medium and 1g of each substrate, dried at 60ºC and ground to 1 mm. Each substrate was repeated three times for each inoculum. Incubation lasted for 96 hours at 39ºC. Internal pressure was measured by a semi-automatic system at intervals 3, 6, 9, 12, 15, 21, 27, 33, 39, 48, 60, 72 and 96 hr after incubation. Microbial activity was stopped by dipping the bottles in water with ice cubes. Residues were immediately filtered and dried at 105ºC. Pressure was transformed in volume; lag-time was calculated by mathematical model suggested by France et al. (1993) and gas volume at each interval was assessed by equation suggested by Maurício *et al.* (1999). Assay was carried out in a factorial design (two inocula and seven substrates), Means were compared by by Tukey test at 5% significance and data were compared by Pearson's coefficient (r) using the SAS for Windows software (SAS, 2000).

Results There was no significant difference (P>0.05) in rates of total gas production among inocula EF and RL for different feeds tested. However, HC had higher rates, 337.40 and 332.70mL respectively. There was no difference between inocula (P > 0.05) for the adjusted parameters suggested by France et al. (1993). Lag-time, with non-correlated rates (P = 0.73 and r = 0.16), was the only exception. Since it had higher rates for EF, variation in initial microbial population among the different inocula was suggested (Table1).

Table 1 Total gas production and estimed lag-time to equine feeds utilizing equine faeces (EF) and ruminal liquor (RL) as inoculum

Feeds	inoculum	A (ml)	b (h^{-1})	c (h^{-1})	L (h)
Alfafa Hay (AH2)	EF	119.50	0.0765	-0.3501	6.3420
	RL	189.10	0.0653	-0.2191	2.8154
AlfafaHay (AH1)	EF	106.70	0.0700	-0.3087	6.2554
	RL	159.50	0.0640	-0.2402	3.5203
Cost-cross Hay (CH)	EF	144.10	0.0469	-0.1872	5.6430
	RL	224.20	0.0499	-0.2421	5.8759
Manioc Hay (MH)	EF	119.60	0.0610	-0.1890	4.0275
	RL	159.40	0.0371	-0.0134	1.3232
Tifton 85 Hay (TH)	EF	157.00	0.0443	-0.2039	6.1116
	RL	226.10	0.0557	-0.2829	6.4581
Sunflower Seeds (SC)	EF	53.96	0.0228	-0.1058	5.3654
	RL	74.34	0.0193	0.0132	1.3624
High Moisture Corn Silage (HC)	EF	337.40	0.0887	-0.5103	13.1691
	RL	332.70	0.1320	-0.5453	3.6542
sem		32.004	0.01129	0.06152	0.956

A: total gas production; b and c: France models parameters; L: lag time; sem: standard error of means

Conclusions Fermentation kinetics (total gas production and lag-time) from gas production technique offers a high prospective for the use of equine faeces as inoculum in studies of *in vitro* gas production utilizing equine feeds.

Acknowledgements Authors would like to thank FAPESP and CNPq for financial support.

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Gas production technique in the evaluation of horse feeds using equine faeces and rumen liquid as inoculum source 2. *In vitro* digestibility

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Introduction *In vitro* and *in situ* techniques for research on ruminants are currently much in focus. Since they have good correlations with *in vivo* data, they are feasible alternatives to predict the nutrition rates of feeds and may be applied in equine research on *in vivo* apparent digestibility. On the other hand, the disadvantage of these methods is due to the fact that fistulated animals are required to obtain the inoculum. Theodorou *et al*., (1994) developed an extremely promising gas production technique to assess feeds for ruminants, but still require rumen inoculum obtained from operated animals. Faecal microorganisms function similarly to those in the rumen and in the large intestine of equines. The objective this experiment was to compare rumen liquor and equine faeces as inoculum to determine *in vitro* digestibility of equine feeds.

Material and Methods Ovine Rumen Liquid (RL) and Equine Faeces (EF) were used as sources of inoculum. RL was collected by rumen cannula and EF were collected directly from the rectum. Preparation of inocula followed Theodorou *et al*., (1994). The following seven feeds, evaluated *in vivo* in several assays for the equines, were used as substrate sources: Tifton 85 hay (TH), Alfalfa hay (AH1), Alfalfa hay (AH2), Coast-Cross Hay (CH), Manioc Offshoots Hay (MH), High Moisture Corn Silage (HC) and Sunflower Seeds (SS), and submitted to EF and RL inocula. Inoculation was done with 10mL RL or EF injected in 160mL glass bottles with 90mL of culture medium and 1g of each substrate, dried at 60ºC and ground to 1 mm. Each substrate was repeated three times for each inoculum. Incubation lasted for 96 hours at 39ºC. Internal pressure was measured by a semi-automatic system at intervals 3, 6, 9, 12, 15, 21, 27, 33, 39, 48, 60, 72 and 96 hr after incubation. Microbial activity was stopped by dipping the bottles in water with ice cubes. Residues were immediately filtered and dried at 105ºC and *in vitro* digestibility calculated by Orskov and McDonald (1979). Pressure was transformed in volume and gas volume at each interval was by equation suggested by Maurício *et al.,* (1999). Assay was in a random design, statistical analyses were done by SAS (2000), and means were compared by Tukey's test at 5% probability.

Results There was no significant difference in effective digestibility coefficients of *in vitro* dry matter when inocula were compared. Since mean were 46.21 and 50.51% respectively, inoculum sources EF and RL had equal digestibility potential for the different feeds. In the case of the digestibility of dry matter, results showed that, when both inoculum sources were used, potential and effective digestibility failed to show any significant difference between *in vitro* and *in vivo* digestibility by preliminary assays, which were 69.01; 77.06, 46.21, 50.51 and 59.09%, respectively (Table 1).

Table 1 *In vitro* dry matter digestibility (%) to several equine feeds submitted at inoculum equine faeces (EF) and ruminal liquid (RL), using gas production technique

Feeds	*In vivo* Digestibility	Efective Degradability		Potential Degradability	
		EF	RL	EF	RL
Alfafa Hay (AH2)	51.24	51.65	52.75	69.82	71.47
Alfafa (AH1)	59.75	41.69	42.21	56.72	58.82
Coast-cross Hay (CH)	56.50	39.28	40.87	66.90	81.20
Sunflower seeds (SS)	49.76	53.14	63.23	94.23	106.42
High Moisture Corn Silage (HC)	86.66	63.14	75.07	82.25	90.47
Manioc Hay (MH)	50.69	35.01	34.59	41.69	46.02
Tifton 85 Hay (TH)	59.00	39.58	44.88	71.44	85.02
Means (^{se})	$59.09^{ab\ (4.85)}$	$46.21^{b(6.40)}$	$50.51^{b(3.79)}$	$69.01^{ab(7.64)}$	$77.06^{a(5.39)}$

^{a,b} means with different superscripts, within rows, are significantly different (P<0,05)

Conclusions *In vitro* dry matter apparent digestibility obtained by gas production technique, using equine faeces as inoculum, may predict the nutritional value of equine feeds when compared to those determined by *in vivo* assays.

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Effect of drying and urea treatments on tannins levels in browses from North-East Brazil

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Introduction Some herbaceous browses have shown a dry tolerance and had been used as animal feed. However, some of those plants have anti nutritional compounds such as tannins that can interfere on intake and digestibility. Tannins are polyphenolic compounds originated from the secondary metabolism of the plant as protection against insects, birds and as a result of drought, temperature or soil fertility. The objectives of this work were to evaluate the level and variation of tannins in important browses from the semi-arid of Brazil and to investigate the effects of different treatments (oven-, shade- and sun-drying and treatment with urea) on phenolics compounds.

Material and methods Plant material was collected from the semi-arid area of Pernambuco, located in the North-East Brazil. Six browse species with potential as forage were selected randomly in approximately 280 ha: Angico (*Anadenanthera macrocarpa*), Aroeira (*Astronian urundeuva*), Feijão bravo (*Capparis flexuosa*), Jurema preta (*Mimosa hostilis*), Malva branca (*Sida cordifolia*) and Maniçoba (*Manihot pseudoglaziovii*). The samples (leaves and stems) were collected at 2m height or inferior and with 5mm or less of diameter. The collections were made in the dry (March) and the wet season (October) with three replicates for each plant. In October, perennial plants were in late fruiting stage with mature leaves. In the dry season, Maniçoba and Angico had lost their leaves and were in the dormancy stage. Three drying treatments were tested: control, air oven (40^{o} C), sun and shade-drying and urea treatment (4g urea in 10 ml water/100 g DM). Total phenol (TP), total tannins (TT) and condensed tannins (CT) were analyzed as described by Makkar (2000). Results were subjected to analysis of variance in a factorial design (two seasons, six species and four treatments). Data were compared by Duncan test using SAS system (SAS, 2000).

Results The levels of TP, TT and CT are shown in Table 1. Not all the plants were found in the field in both collection periods. Angico and Maniçoba in the dry season and Feijão in the wet season were not available. There was considerable variation in the phenolics contents between browses ($P<0.05$): Aroeira had the highest concentrations of TP and TT, followed by Jurema and then Angico. Concentration of CT was highest ($P<0.01$) in Jurema followed by Aroeira. Total phenol and TT were significantly different between the two seasons ($P<0.05$), with mean values (eq-g tannic acid kg^{-1} DM): TP - 116 and 99; TT - 93 and 89; and CT - 48 and 22 for dry and wet seasons, respectively. Table 2 lists the levels of TP, TT and CT of plants treated in various ways. Mean values for TP were 125, 118, 114 and 23 (eq-g tannic acid kg^{-1} DM) for shade-, oven-, sun-dried and urea treated samples, respectively; the corresponding TT values were 112, 108, 102 and 19 (eq-g tannic acid kg^{-1} DM) and the CT values were 36, 37, 33 and 2 eq-g leucocyanidin kg^{-1} DM, respectively. Urea treatment resulted in a significant ($P<0.05$) decrease on TP, TT and CT contents in relation to the other treatments. There were no significant differences between oven- and sun-drying ($P>0.05$) for TP, TT and CT. Shade-drying, however, yielded significantly higher levels of tannins than oven- or sun-drying ($P<0.05$).

Table 1 Means of total phenol (TP), tannins (TT) (eq-g TA kg^{-1} DM) and condensed tannins (CT) (eq-g leucocyanidin kg^{-1} DM) of dried (40˚C) for six browses in dry and wet season

Plants	*Dry season*			*Wet season*		
	TP	*TT*	*CT*	*TP*	*TT*	*CT*
Angico	na[1]	na	na	119.4	111.2	11.3
Aroeira	201.1	188.9	83.3	171.8	157.2	29.4
Feijão	63.0	56.1	1.8	na	na	na
Jurema	182.0	165.3	106.7	156.6	140.3	49.0
Malva	18.5	13.1	0.4	11.4	7.9	0.1
Maniçoba	na	na	na	41.8	33.6	18.2

[1] not available at time of collection

Table 2 Means of total phenol (TP), tannins (TT) (eq-g TA kg^{-1} DM) and condensed tannins (CT) (eq-g leucocyanidin kg^{-1} DM) of foliage of browses in the North-East region of Brazil, treated in various ways

Treat. Plants	*TP*					*TT*					*CT*				
	Oven	*Sun*	*Shade*	*Urea*	*Means*	*Oven*	*Sun*	*Shade*	*Urea*	*Means*	*Oven*	*Sun*	*Shade*	*Urea*	*Means*
Angico	119	95	140	37	97.9^{b}	111	89	130	33	90.9^{c}	11	14	12	2	9.9^{c}
Aroeira	186	193	187	79	183.3^{a}	173	177	171	67	167.9^{a}	56	43	47	5	46.6^{b}
Feijão	63	46	51	6	41.4^{c}	56	40	44	3	35.9^{d}	2	2	2	0.2	1.5^{c}
Jurema	169	170	184	52	167.9^{a}	153	147	162	46	148.2^{b}	78	75	79	8	73.5^{a}
Malva	11	9	9	4	8.4^{d}	8	6	5	2	5.4^{e}	0.1	0.4	0.2	0.1	0.2^{c}
Maniçoba	42	36	27	11	30.9^{c}	34	30	22	8	25.1^{d}	18	14	11	0.5	11.8^{c}
Means	118.4^{A}	114.1^{A}	125.2^{A}	22.6^{B}		107.6^{A}	101.6^{A}	112.1^{A}	18.8^{B}		37.5^{A}	33.1^{A}	35.9^{A}	1.7^{B}	

SEM for treatments: 4.25, 4.15, 3.70 and SEM for plants: 5.71, 5.57, 4.97 respectively for TP, TT and CT. $^{a, b, c}$ values with different superscripts, within columns, $^{A, B, C}$ values with different superscripts, within rows, are significantly different (Duncan test; $P<0.05$)

Conclusion It was observed a seasonal effect on tannin concentration and activity in tropical browses in NE Brazil. The level of tannin was higher in the dry season than in the wet season. Urea treatment reduced assayable tannin concentrations.

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Comparing biological and linear models to estimate milk yields and lactation curve parameters

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Introduction The genetic evaluation of dairy cows is based primarily on milk production and its constituents. Many models have been developed and evaluated in order to estimate total milk yield (CTMY) and other characteristics of lactation curves. Frequently, the models are based on complex mathematical equations and their use demands a huge computational effort. The development of simple models as early predictors of TMY with a reasonable accuracy is important. The objective of this research was to compare the biological model described by Pollott (2000) with two linear models.

Materials and methods The 2,086 lactations used for this study were provided by the National Milk Records Ltd from a commercial dairy herd in England. Monthly test day records were analysed (> 6 < 16/lactation). Lactation number ranged from 1 to 7. Pollott multiplicative models with 2 and 3 parameters (M2 and M3 respectively) which have demonstrated to be accurate compared to other widely used models (Pollott and Gootwine, 2000) were used to estimate CTMY, day of peak (DP), peak yield (PY) increasing in daily production midway between the start and peak of lactation (GM) and decreasing in daily production midway between peak and the end of lactation (persistency; DM). These estimates were compared with the results of a linear regression (L) and spline (S) models of lactation. The curve parameters for M2, M3 and S were estimated using an iterative least squares procedure, while L model parameters were estimated using a simple linear regression model (SAS, 1989). In the iterative procedure the best parameters of the lactation curve were calculated when the difference between successive iterations was less than $<10^{-6}$. Correlations were calculated between TMY, DP, PY, GM and DM both within and between models.

Results Table 1 shows the mean and standard deviation the estimated values of the lactation curves. All models, with the exception of CTMY estimated by linear methods, similarly estimated CTMY, PY and DM. This was reflected in the correlations between the same value calculated from the four models. Correlations between CTMY calculated from the four models ranged from 0.95 to 0.99), for PY from 0.87 to 0.99, for DM from 0.76 to 0.94, for DP from –0.05 to 0.42 and for GM from –0.03 to 0.43. In general, PY was well correlated with CTMY (0.77) for all models except for L model (0.50). DM "persistency" was correlated (>0.74) with PY except in S model (0.54). DM was correlated with PY in M2, M3 and L (>0.74).

Table 1 Mean and standard deviation of the calculated values derived from the multiplicative models (M2 and M3), linear (L) and spline (S) models

	M2		M3		L		S	
	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.
CTMY (kg)	8507	2137	8413	2120	8609	3220	8386	2183
DP (day)	30.0	3.8	37.5	9.3	35.2	8.8	63.4	47.4
PY (kg)	37.4	8.5	37.7	8.6	39.8	9.5	37.2	9.4
GM (g/day)	260	80	501	340	411	686	561	634
DM (g/day)	80	35.5	84	35.8	94.0	40.1	99	55.8

Conclusions The models M2, M3 and S all gave similar results when fitted to the lactations. The linear regression model resulted in somewhat different curve characteristics. The spline model represents a reasonable alternative to the multiplicative model in order to estimate total milk yields as well as lactation curve characteristics such as peak yield and persistency; representing less complexity. Both PY and DM are highly correlated with total milk yield, even when using the linear regression model. Both the linear and spline models represent possible alternative approaches in the genetic evaluation of dairy animals. They would be simpler to use in random-regression based test-day models and lend themselves more readily to the calculation of a range of useful lactation curve characteristics.

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Estimation of (co)variance components across breeds by a test-day model adapted to New Zealand dairy cattle

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Introduction In New Zealand, crossbreeding is largely used by dairy farmers. Currently an important proportion of cows are crossbreds, mostly Holstein-Friesians (HF) x Jersey (JE). Crossbred bulls are currently being progeny tested in New Zealand. Actually, more than one third of the replacement dairy heifers are crossbred animals (Montgomerie, 2002). However currently available methods to model genetic contributions of purebreds to crossbreds take breed differences only partly into account and therefore do not permit an optimal use of crossbred data. The first objective of our study was to allow the modelling of different additive breeding values according to parental breeds to define overall additive breeding values as a function of breed composition.

Materials and methods Data was provided by Livestock Improvement Corporation, there were 223,141 animals in production and a total of 500,134 animals in the pedigree. Only animals of HF and JE breeds were kept to estimate (co)variance components. Presented research was limited to first lactation milk yield, which was recorded for 208,164 cow. A general model was written as $\mathbf{y} = \mathbf{Xb} + \mathbf{Q}_{HF}(\mathbf{Wh}_{HF} + \mathbf{Za}_{HF} + \mathbf{Zp}_{HF}) + \mathbf{Q}_{JE}(\mathbf{Wh}_{JE} + \mathbf{Za}_{JE} + \mathbf{Zp}_{JE}) + \mathbf{e}$ where **y** is a vector of first lactation test-day yields, **b** is a vector of unknown fixed effects, including indirectly heterosis and recombination by modelling breed or breed crosses specific age effects, **h**, **a** and **p** are vectors of unknown herd x calving year, permanent environmental and additive genetic random regression effects, **W** and **Z** are incidence matrices. The particularity was the definition of $\mathbf{Q}_{HF}$ and $\mathbf{Q}_{JE}$ that were defined as the covariate matrices for constant, linear and quadratic Legendre polynomials where each polynomial was multiplied with the percentage HF, respectively JE breed contributions. The main advantage of this approach was that every animal obtained two sets of breeding values one for HF and one for JE. This allowed the provision of different rankings for sires according to their use in crossbreeding or purebreeding. However, this model needed to address a certain degree of additive genetic differences across breed types. Therefore, the second objective of this study was to estimate (co)variance components across breeds and to assess to what extend additive breeding values are breed dependent.
Estimation of (co)variance components were estimated in several steps:

1. First (co)variance components were estimated inside HF and JE breeds using 3 HF samples and 2 JE samples obtained on a herd bases and a simplified model.
2. Then initial Legendre polynomials were transformed into new independent regressions based on the results from step 1. This assumes that the correlations across Legendre polynomials inside breeds were constant.
3. Finally the (co)variances across breeds were estimated among transformed regressions based on five independent samples containing HF, JE and their crosses. Transformed regressors were considered independent from each other on a breed level. Record weights according to breed composition adjusted for heterogeneous residual variances.

(Co)variances were estimated using EM-REML and AI-REML, the latter being faster but less stable.

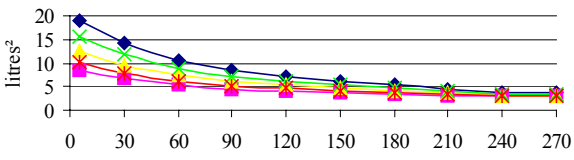

Figure 1 Evolution of phenotypic variances

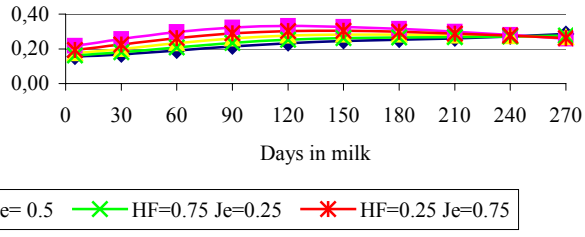

Figure 2 Heritability over time

Table 1 Genetic correlations between HF and JE breeds estimated from multi-breed model

Legendre polynomials	Correlations
Constant	0.926
Linear	0.807
Quadratic	0.604

Results Single breed analyses showed differences between both breeds. Only selected results from the across breed analysis are given here. Figure 1 shows the evolution of phenotypic variances over the lactation, Figure 2 shows heritabilities. Genetic correlations across breeds are shown in Table 1. Results are given back transformed to original Legendre polynomials. Correlation was very high for constant genetic effect, but went down to 0.6 for the quadratic regressions. This could indicate persistency differences between HF and JE cattle.

Conclusions The results of the present study showed that breed dependent additive breeding values can be modelled. The genetic correlations across breeds showed genetic differences, especially in linear and quadratic Legendre polynomials which are linked to persistency.

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Inbreeding depressions for global and partial economic indexes, production, type and functional traits for dairy cattle

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Introduction Modern genetic selection programs identify families with superior genetic merit and reproductive technologies which are used to disperse these genotypes throughout the population increasing relationships between animals (Weigel, 2001). However matings of related individuals unavoidably lead to inbred offspring. One of the main economic consequences of inbreeding is inbreeding depression, the reduction of the mean phenotypic value for economically important quantitative traits. The objectives of this study were to use an advanced algorithm to compute inbreeding and to estimate inbreeding depression for traits and indexes that are in the genetic evaluations for Walloon dairy cattle (production traits, type traits and somatic cell score (**SCS**)).

Materials and methods Pedigree and test-day data used were from the official Walloon genetic evaluation of February 2004 for Holstein animals. The pedigree file contained information for 956,516 animals born between 1913 and 2004. For production traits and SCS, data were limited to three first lactations. Data for yield traits consisted in total in 12,972,695 test-day records from 741,652 milking cows. Data for type included 75,373 type records with a maximum of 33 observed type traits from 69,246 cows. Models used in this study were the same models used in the current Walloon genetic evaluations for production and type traits and for SCS. Linear regression on inbreeding coefficient was introduced in each model to estimate inbreeding depression for each evaluated trait. Inbreeding coefficients were first estimated by an algorithm based on the algorithm of Meuwissen and Luo (1992). Our algorithm allowed to introduce relationships between genetic groups using a method derived from Auvray *et al.* (2001) and therefore provided inbreeding estimates for animals with unknown parents. The combination of the effects on inbreeding on separate traits according to the current economic indexes (global and partial) allowed to compute effects of inbreeding on these indexes too. The definitions of indexes are in Table 1.

Results Inbreeding decreased yield production of milk, fat and protein during a lactation by 19.68, 0.96 and 0.69 kg, respectively, per 1% increase in inbreeding. The regression coefficient of SCS per 1% increase in inbreeding was +0.005 SCS units. The inbreeding depression was thus relatively low for SCS but inbred animals seemed to have higher SCS than non inbred animals, indicating that inbred animals would be little more sensitive to mastitis than non inbred animals. As for SCS, regression coefficients for type traits were low. The most affected type traits by inbreeding were chest width, rear leg and overall development. Some estimates were positive. This may be an artefact of the preferential use of exceptional type bulls in voluntary inbred matings creating a confounding effect between additive genetic and inbreeding depression effects. Table 1 showed effects of inbreeding on global selection index and its components.

Table 1 Effects of 1% increase in inbreeding on different partial indexes and global economic index (V€G) used in the Walloon Region of Belgium

Index			
Global	Partial*	Second order partial **	€ per 1% increase in inbreeding
V€G			-3.88
	V€L		-4.77
	V€T		+1.05
		V€P	+0.54
		V€C	-0.63
		V€M	+1.14
	V€F		-0.13

*V€L : economic index milk, V€T : economic index type, V€F : economic index functionality
** V€P : economic index udder, V€C : economic index body; V€M : economic index feet and legs

Conclusions The results of the present study demonstrate that inbreeding had a deleterious effect on the global economic index. This means in practice inbred animal produce less than expected from their genetic merit. Inbreeding depression on global economic index was still relatively low but this index could be amended to include parameters such as fertility, longevity and health that may be more sensitive to inbreeding depression. The recognition of potential related animals prior to a mating and the optimal use of this information in matings can minimise inbreeding and the associated losses.

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The use of linear programming to investigate the impact of changes in feed price and milk value on gross margin of Taiwanese dairy farms

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Introduction The Taiwanese government assists their dairy industry by supporting domestic prices through a combination of import restrictions, price support, government purchasing and subsidised disposal of surpluses. As a result, dairy production in Taiwan is insulated from international price trends. However, these dairy assistance policies can not protect the domestic price after Taiwan joins the World Trade Organisation (WTO) at the end of 2001. To access the impact of an open market, linear programming (LP) is applied to model the influence of changing feed price and milk value on dairy farm profitability.

Materials and methods In this study the average Taiwanese dairy farm is considered i.e. one up to a maximum of 100 milking cows and 400 hours of home labour per month. This average is based on estimates by the Council of Agriculture (2003). The object was to maximize the profit subject to the following constraints - milk yield, nutritional requirements, replacement rate and age at first calving. The general structure of the model is shown below:
Maximize function $Z = cx$ Subject to $Ax \leq : \geq b$ $x \geq 0$
where x = n×1 vector of activities, c = n×1 vector of gross margins or costs per unit of activity, A = m×n matrix of technical coefficients, and b = m×1 vector of right-hand-side values.
Values for resource availability at farm level were obtained mainly from the Council of Agriculture (2003). The model was developed to consider how calving pattern may vary and its effects on profitability. Therefore, activities - herd enterprises, sale enterprises and purchasing enterprises (labour, forage and concentrates) - are considered on a monthly basis. Generally, in Taiwan cows are only replaced by spring heifers at 30 months of age with a 30% replacement rate. A calving interval of 12 months was assumed, with an even calf sex ratio. All male calves are sold. Female calves are either sold or retained and reared as replacements for the dairy herd. Dry matter intake, energy (ME) and crude protein (CP) requirements for a 550kg cow producing 3.5% milk fat were estimated from the recommendations of the Taiwanese Livestock Research Institute (TLRI). In the LP model, only the commonly used feeds - pangola grass, alfalfa cubes and concentrates - were included. The nutritional value of feeds was as estimated by TLRI.

Results The expected reduction in producer price of milk did not change the optimal plan. The optimal plans from all models required 40 heifers and 28, 19, 13 and 10 lactating cows in each of the 1st 2nd 3rd and 4th lactations respectively to maintain the herd structure. To achieve the maximum revenue the model suggests that all the cows calve in March. The objective value for the herd from the model using the present milk price (20 NT$*) is 5,804,865 NT$ (£ 96,750). With the same herd structure and calving month, the objective value is varied by the changes in milk value and concentrate price. The objective value reduced as the concentrate price increased and the milk value fell (Table 1). At the same level of change, milk price had 3x higher effect than concentrates. The objective value reduced by approximately 2.5% per 1% reduction in milk price, and by 0.8% per 1% increase in concentrate price.

Table 1 Percentage change in objective value following reduction in milk price and varying concentrate price

Milk Price / Concentrates Price	Present (20NT)	-5%	-10%	-15%	-20%	-25%	-30%
-15%	13	1	-12	-24	-37	-49	-62
-10%	9	-4	-16	-29	-41	-54	-66
-5%	4	-8	-21	-33	-46	-58	-71
present (10NT)	0	-13	-25	-38	-50	-63	-75
5%	-4	-17	-29	-42	-55	-67	-80
10%	-8	-21	-33	-46	-59	-71	-84
15%	-12	-25	-37	-50	-62	-75	-88

Conclusion. The reduction in the milk price after entry into WTO causes a huge impact on the profitability of dairy farms, although interestingly for optimal financial return, the farmers continue to operate with the same enterprise plan. The unpredictable concentrate price may also affect profitability.

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* 60 Taiwanese dollar (NT$) = £1

The use of linear programming to investigate the impact of replacement rate and age at first calving on gross margin of Taiwanese dairy farms

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Introduction Reproductive performance has a large influence on production and profitability. In Taiwan, survey data shows an average number of lactations of 2.87 with 67% being culled before their third lactation and a first calving age (CA) of 30 months (Chang, 1988). In order to indicate the impact of reproductive performance and calving pattern on revenue, linear programming (LP) is applied to model the effect of both replacement rate (RR) and CA.

Materials and methods In this study the average Taiwanese dairy farm is considered i.e. one up to a maximum of 100 milking cows and 400 hours of home labour per month. This average is based on estimates by the Council of Agriculture (CoA). The object was to maximize the profit subject to the following constraints - milk yield, nutrition requirements, RR and CA. The general structure of the model is shown below:

Maximize function $Z = cx$ Subject to $Ax \leq : \geq b$ $x \geq 0$

Where x = n×1 vector of activities, c = n×1 vector of gross margins or costs per unit of activity, A = m×n matrix of technical coefficients, and b = m×1 vector of right-hand-side values.

Data on resource availability at farm level was obtained mainly from the CoA (2003). The model considers the following activities on a monthly basis: herd enterprises, purchasing enterprises (labour, forage, and concentrates) and sales enterprises. In the original model, against which comparisons are made, cows can only be replaced by 30 month old heifers (CA30) with a 30% RR (RR30). Cows calve once a year (12 mo), with an even sex ratio. All male calves are sold whilst female calves are either sold or retained as replacements. Dry matter intake, energy and crude protein requirements of 550kg cows producing milk of 3.5% fat were estimated by the recommendations of the Taiwanese Livestock Research Institute. Only the commonly used feeds (pangola grass, alfalfa cubes and concentrates) were included. In order to realize the effect of RR and CA, 4 different RRs (20% (RR20), 25% (RR25), 35% (RR35), and 40% (RR40)) and 2 different CAs (24 months (CA24) and 36 months (CA36)) were considered.

Results The objective value from the original model (CA30RR30) gives a Gross Margin (GM) of 5,804,865 NT$ (£ 96,750). The percentage changes in the objective values by varying CA and RR are shown in Table 1. When the heifer rearing improves and the heifers calve at 24 months there is a 15.3 % increase in the annual GM from the 6 month shorter period. Conversely, poor conception rate reduced GM by 13.2% as the heifers first calved at 36 months. The results show that the effect of RR was not as high as that of CA. The objective value only increases by 2.7 % and 5.2 % as the RR reduced to 25% and 20% respectively. However, once the RR is considered together with the 24 month CA the objective value increases by 16.8 and 18.1% over the objective value from the original model (CA30RR30). All the cows calved in March in the solution to give the maximum objective value. Varying CA had minimal effect on the optimal plan. Breeding at 24 rather than 30 months, the inputs such as labour and feed were less. The optimal plans from the CA30RR20-40 model are shown in Table 2. The herd structure was altered by varying RR resulting in changed milk production and the requirements of labour and feed.

Table 1 Objective value changes (%) associated with varying age at first calving and replacement rate

	CA24	CA30	CA36
RR20	18.1	5.2	-6.6
RR25	16.8	2.7	-9.8
RR30	15.3	0	-13.2
RR35	13.7	-2.9	-17
RR40	12	-6.1	-21.1

Table 2 Annual optimal plans from the models with different replacement rates

	Heifer	Milking cow	Selling heifers	Selling bulls	Buying Labour	Selling Milk	Selling culls	Feed
	head	head	head	head	hour	tonne	head	tonne
CA30RR20	35	100	15	50	46	706	35	774
CA30RR25	38	100	12	50	76	709	38	787
CA30RR30	40	100	10	50	108	712	40	801
CA30RR35	44	100	6	50	143	716	44	817
CA30RR40	47	100	3	50	200	719	47	833

Conclusion The optimal calving month of March was not varied by the CA or RR. Varying RR changes the herd structure resulting in higher milk production. However, the income from the increased milk yield does not cover the increased cost of breeding heifer. Reducing the heifer rearing cost is a key factor to increase GM, as shown by the model with low CA.

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Body weight and measurements of Holstein heifers under intensive management in Indonesia

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Introduction Optimising heifer growth rates is an essential component of dairy replacement management in order to ensure sustainable heifer replacement stocks. Continuous evaluation of the growth pattern of heifers in a herd may be used to identify particular effects of nutritional management and the environment. Body weight is considered the most useful indicator of a heifer's growth rate, both in practice and experiment work, along with body measurements reflecting the skeletal growth of heifer. The aims of this research are to investigate: 1) body trait : age relationships, 2) ratio of body measurements to body weight , and 3) to predict body weight based on body measurements of Holstein heifers in Indonesia.

Material and methods Data of body traits of Holstein heifers were collected from an intensively managed dairy replacement station in Central Java, Indonesia, between 1994-2001. The data consisted of body weight (BW) (kg) and the following body measurements chest girth (CG), wither height (WH) and body length (BL) (cm). Most were recorded bimonthly within the ranges of ages 1-540 days (BW,CG,WH) and 15-180 days (BL) . The number of animals contributing data were: BW=288, CG=117, WH=77 and BL=88. Three main analyses were carried out: 1) determination of body trait–age relationships by regressing each of BW, CG, WH and BL on linear, quadratic, and cubic effects of age, 2) calculation of ratios of each body measurement to BW using two-month interval standardised body parameters (derived from individually fitted regression curves of heifers' growth records) and 3) prediction of BW from body measurements by either simple or multiple regressions for CG, WH and BL as independent variables.

Table 1 Regression equations for predicting Holstein heifer body weight and measurements from age (days)

Linear	R^2	Quadratic	R^2
BW=23.6+0.55X	94.4	BW=34.6+0.42X+0.00023X^2	94.8
CG =79.8+0.15X	96.2	CG =76.4+0.28 X–0.00043 X^2	96.6
WH=75.9+0.09X	93.9	WH=71.7+ 0.14 X– 0.00008 X^2	95.4
BL = 66.2+0.16X	88.0	BL = 65.5+ 0.18 X– 0.000092X^2	87.9

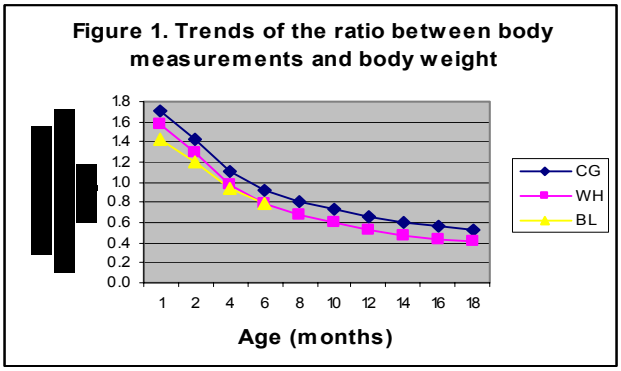

Table 2 Regression equations for predicting Holstein heifer body weight from various body measurements

Linear and quadratic	R^2
BW = - 264 + 3.55 CG	96.7
BW = 73.1 – 2.32 CG + 0.024 CG^2	99.3
BW = - 406 + 5.67 WH	92.9
BW = 340 – 9.71 WH + 0.077 WH^2	96.4
BW = - 134 + 2.53 BL	92.9
BW = - 109 + 1.93 BL + 0.004 BL^2	92.9
BW = - 228 + 4.24 CG – 1.18 WH	96.8
BW = 64.1–2.91CG+0.025CG^2+0.705WH-0.0004WH^2	99.3
BW = - 132 + 1.80 CG + 0.43 BL	97.5
BW = - 165+1.91CG+0.0003CG^2+2.9BL–0.049BL^2	97.7
BW = - 178 + 1.89 WH + 1.15 BL	94.3
BW = 32 - 4.31WH+0.037WH^2+2.30BL–0.007 BL^2	94.3
BW = - 137 + 1.74 CG + 0.209 WH + 0.344 BL	97.5
BW = - 162 + 1.84 CG + 0.0005 CG^2 – 6.65 WH + 0.041 WH^2 + 11.5 BL – 0.135 BL^2	97.8

BW : body weight; CG : chest girth; WH : wither height; BL : body length and X : age.

Results Table 1 shows that both linear and quadratic regression equations closely describe body trait–age relationships, as the models resulted in high R^2 values (93.9-96.6), with the exception of BL. The quadratic orders slightly increased R^2 over the linear models, however cubic expressions (equations not presented) resulted in no improvement in prediction. Figure 1 shows the ratios of CG, WH and BL to BW decreasing gradually with age; however, the declining ratios of BL to BW might be expected to be lower than those of CG to BW and WH to BW. Table 2 shows various regression models for predicting BW. Linear equations indicated that for each unit (cm) increase in body measurements BW (kg) increased by 3.55 (CG), 5.67 (WH) and 2.53 (BL) - lower than the prediction coefficients for BW of Holsteins in temperate regions (Heinrich *et al*., 1992). Quadratic equations to predict BW resulted in higher R^2 for CG and WH but gave no improvement in the case of BL. Inclusion of additional body measurements in various regression models to predict BW resulted in no increase in R^2 compared to the quadratic equation using only CG, agreeing with the earlier study of Wilson *et al*., 1997.

Conclusions The growth pattern of Holstein heifers can be described through the changes in BW and body measurements which can be fitted into linear regressions. Chest girth is a useful parameter in predicting BW of Holstein heifers. The regression equations developed indicated lower BWs and body dimensions of Holstein heifers in this location compared to those in temperate regions

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The influence of dam breed on maternal and progeny characteristics of the suckler herd

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Introduction The suckler beef industry in Northern Ireland comprises many differing dam breeds and breed crosses. However, there is a paucity of data on the influence of dam breed on parameters such as carcass weight, fatness and conformation, and on factors affecting management of the herd (e.g. dystocia and fertility). The latter are particularly important in view of the increasing number of part time beef farmers in Northern Ireland. The objective of the present study was to evaluate the influence of dam breed on production characteristics of the suckler herd in Northern Ireland.

Material and methods An extensive on-farm study involving 43 suckler herds across Northern Ireland was undertaken to evaluate breed differences in terms of maternal and progeny characteristics. Herd owners recorded data on dam genotype, with dams comprising 50% or more of a particular breed being denoted as that breed. Dam temperament (1 = very quiet, 4 = very poor temperament) and dystocia (100 = unassisted, 500 = caesarean section) were recorded by the individual farmers using specific scoring charts. Cow fertility was assessed as 'reappearance rate' at 390 d and 450 d, a measure of whether or not a cow had produced another calf within 390 or 450 d post-calving respectively. Carcass weight, conformation and fat classifications were recorded from progeny. Age at slaughter and carcass value (£) was subsequently calculated. Data recorded from individual dam genotypes were collated and analysed to produce values for main dam breeds, encompassing all data recorded from cow genotypes incorporating the breed of interest. Analyses were undertaken using the REML technique in Genstat 5, except for fertility data which were analysed using a binomial model with a logit link function.

Results The influence of dam breed group on dystocia, fertility and carcass parameters is presented in Table 1 (carcass data corrected to constant slaughter age). Angus-cross cows had amongst the lowest calving difficulty scores, significantly ($P<0.01$) lower than that of Belgian Blue-cross cows which tended to be poorest for this parameter. Dam breed had no significant ($P>0.05$) effect on reappearance rate at 390 d (mean 51%). At 450 d, Blonde d'Aquitaine cross cows had higher ($P<0.05$ or greater) reappearance than Hereford, Holstein-Friesian and Simmental cross dams, while Angus, Limousin and Holstein-Friesian cross dams also had higher ($P<0.05$ or greater) reappearance than Hereford cross dams. Dams of Limousin and Blonde d'Aquitaine breeding had poorer ($P<0.001$) temperament than other genotypes. Progeny carcass weight differed by only 7 kg between the dam breed crosses and, with the exception of the significantly ($P<0.05$) lighter carcass weights of progeny of Angus cross cows compared to progeny of Belgian Blue cross cows, none of the differences in carcass weights recorded reached significance ($P>0.05$). Conformation of progeny of Holstein-Friesian- and Hereford-cross cows was similar to that of Angus cross cows ($P>0.05$), but significantly poorer than progeny of all other breed crosses ($P<0.05$ or greater). Progeny of Belgian Blue- and Blonde d'Aquitaine-cross cows tended to have higher conformation scores than progeny of other dam breed crosses, but with the exception of the poorer conformation of progeny of Simmental cross compared to Blonde d'Aquitaine cross cows ($P<0.05$), conformation was similar to progeny of the other main Continental cross genotypes ($P>0.05$). Progeny of Hereford cross cows had significantly ($P<0.05$ or greater) higher fat class scores than progeny of any of the other dam breed crosses evaluated. In contrast, carcasses of progeny of Blonde d'Aquitaine cross dams had significantly ($P<0.01$ or greater) lower fat scores than all other breed crosses with the exception of progeny of Belgian Blue cross dams. Dam genotype accounted for differences in progeny carcass value of up to £16 per animal, with progeny of Angus cross cows realising significantly ($P<0.05$) lower carcass values than those of Belgian Blue-, Charolais- and Limousin-cross dams, and progeny of Hereford cross cows having lower carcass values than Charolais cross cows ($P<0.05$).

Table 1 The influence of dam genotype on dystocia, fertility and progeny characteristics

Dam genotype	Dystocia		Reappearance 450 d		No. Obs	Carcass weight (kg)	Carcass fat class[1]	Carcass conformation[2]	Carcass value (£)[3]
	No. Obs	Score	No. Obs	%					
Angus	1	147	1005	74	1018	316	3.00	3.26	531
Belgian Blue		166	157	68	197	323	2.90	3.42	544
Charolais		159	508	69	585	323	2.99	3.34	544
Blonde		153	179	79	182	321	2.78	3.43	541
Holstein-Friesian	2	159	1886	68	1903	320	3.02	3.21	536
Hereford		149	190	60	283	316	3.15	3.18	528
Limousin	1	155	1267	75	1264	322	2.98	3.36	543
Simmental	1	156	1227	70	1292	319	2.94	3.31	536
Mean SED		6.2		3.5		3.4	0.055	0.053	6.5
Significance		**		**		*	***	***	*

[1] 5 point scale: 1 = leanest, 5 = fattest; [2] EUROP = 5, 4, 3, 2, 1 respectively; [3] based on price grade structure in Northern Ireland

Conclusions Dam breed accounted for small but significant variations in the carcass parameters assessed in the present study. Progeny of Holstein-Friesian- and Hereford-cross dams had poorer conformation in comparison to other breeds. Traditional British breeds tended to produce progeny with lower carcass values than other breed crosses, but had more favourable dystocia scores. Overall, only 51% of dams in the study had produced another calf by 390 days post calving, indicating an inherent fertility problem in the Northern Ireland suckler herd.

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The influence of conformation of the suckler dam on dystocia and progeny characteristics

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Introduction The Northern Ireland beef herd currently incorporates a very diverse range of genotypes which produces a very varied product in terms of carcass weight, fatness and conformation (Kirkland *et al.*, 2004). However, factors other than genotype may also influence the expression of maternal traits and progeny carcass characteristics. The objective of the present study was to evaluate the influence of dam conformation, irrespective of genotype, on dystocia and progeny carcass traits.

Material and methods Data for the present study were obtained from an extensive on-farm study involving 43 suckler herds across Northern Ireland. Herd owners recorded data on the incidence and extent of dystocia using a specific scoring chart, while data on carcass weight and conformation classification were recorded from progeny. Age at slaughter and carcass value (£) were subsequently determined. Ten of the farms, representing a broad cross section of the Northern Ireland suckler beef herd, were selected from the study and a total of 1379 cows, encompassing a range of genotypes, from which calving details and progeny carcass data were collated, were assessed for conformation using the EUROP scale. Analyses were undertaken using the REML technique in Genstat 5.

Results The influence of dam conformation on dystocia and progeny carcass characteristics is presented in Table 1. The most poorly conformed dams were assessed as P grade, while the most highly conformed cows in the study were assessed as R grade. Dam conformation had no significant ($P<0.05$) effect on dystocia. Similarly, although there was a trend for dams with higher conformation scores to produce progeny with higher carcass weights, the differences were not significant ($P>0.05$). However, there was a positive relationship between dam conformation and conformation of the progeny, with progeny of dams assessed as R and O+ grades having significantly ($P<0.05$ or greater) higher conformation than progeny of dams assessed as O, O- and P grades. Overall, carcass conformation ranged by up to 0.25 units between progeny of the poorest and most highly conformed dams. The relationship between dam and progeny conformation scores is presented in Figure 1 and is described by the following regression equation :

$PC = 3.164 + (-0.183\ CC) + 0.0771\ CC^2$
($R^2 = 1.00$; $P<0.001$)

Where PC = progeny conformation and CC = cow conformation.

Differences in dam conformation resulted in differences in progeny carcass value of up to £14, with progeny of cows assessed as O+ realising significantly ($P<0.05$) higher carcass values than those of dams assessed as O- grade.

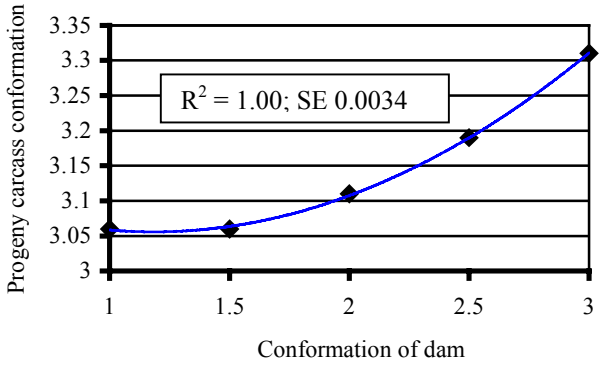

Figure 1 The relationship between dam and progeny conformation

Table 1 The effect of dam conformation on dystocia and progeny factors

Dam conformation	No. calvings	Dystocia score	No. calvings	Carcass weight (kg)	Carcass conformation[1]	Carcass value (£)[2]
R	83	137	92	319	3.31^{b}	533^{ab}
O+	206	130	252	318	3.19^{b}	531^{b}
O	411	124	536	314	3.11^{a}	523^{ab}
O-	226	130	393	314	3.06^{a}	521^{a}
P	57	138	106	313	3.06^{a}	519^{ab}
Mean SED		7.8		3.5	0.053	6.6
Significance		NS		NS	***	*

[1] EUROP = 5, 4, 3, 2, 1 respectively [2] based on price-grade structure in Northern Ireland

Conclusions The results of the present study indicate that selection of superior female breeding stock, based on a visual assessment of conformation, can lead to improvements in progeny carcass conformation and value of 0.25 units and £14 respectively, irrespective of cow genotype. Furthermore, there was no relationship between cow conformation (up to R grade) and dystocia score.

Acknowledgements This work was funded by DARD and AgriSearch.

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An evaluation of Norwegian dairy breed and Holstein-Friesian cattle for beef production

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Introduction In contrast to the Holstein-Friesian (HF) breed, Norwegian dairy cattle (NC) have been selected with emphasis on disease resistance and beef characteristics as well as milk production, and hence may be more suited to beef production than high genetic merit Holstein animals. The objective of this study was to evaluate the beef production potential of NC bulls, and to compare their performance with that of HF bulls.

Materials and methods A total of 64 bulls (33 HF, 31 NC), mean initial age 177.2 (SD 43.3) days and live weight 193.8 (SD 63.9) kg were used in a 2 x 2 factorial design encompassing 2 breeds and 2 slaughter ages. Cattle were blocked according to age and breed and penned, within breed, in groups of three animals. The two slaughter ages were approximately 16 (E) and 20 (L) months, with animals being blocked, within breed, prior to the initial slaughter date according to similarity of age. One animal from each block was allocated at random to each slaughter age treatment group. Diets consisted of grass silage offered *ad libitum* and sufficient concentrates to achieve 50% of the total dry matter (DM) intake from concentrates. The composition of the concentrates was changed when animals reached 350 kg live weight and contained the following ingredients (g/kg) : barley 550 and 380, soya bean meal 175 and 145, sugar beet pulp 150 and 150, maize meal 100 and 300, vitamin/mineral premix 25 and 25 for concentrates offered pre- and post-350 kg live weight respectively. Concentrate and total DM intake were recorded daily throughout the trial. All animals were weighed on two consecutive days initially and prior to slaughter, and at regular intervals throughout the study. A range of carcass measurements was recorded for all animals. Data on feed intakes and carcass parameters were analysed using the REML technique in Genstat 5 (release 4.1 Rothamsted, England). Live weight and age at the start of the study (within breed), and age at slaughter, were incorporated into the analysis as covariates.

Results The mean chemical composition of the concentrate offered pre- and post-350 kg live weight was (respectively) : DM 827 and 838 g/kg, crude protein 181.6 and 167.8 g/kg DM, acid detergent fibre 75.3 and 76.7 g/kg DM, neutral detergent fibre 184.1 and 198.7 g/kg DM, and ash 68.0 and 67.0 g/kg DM. Data on food intake and animal performance are presented in Table 1. No breed x slaughter group interactions (P>0.05) were recorded for any of the parameters evaluated in the study and hence only main effects have been presented. Holstein bulls had higher (P<0.001) intakes of concentrate and silage, and hence total intakes, than NC bulls, while mean daily intakes were similar (P>0.05) across the two slaughter age groups. Holstein bulls were significantly (P<0.001) heavier at slaughter than NC bulls (617.1 and 583.6 kg respectively), and tended (P=0.07) to have a higher rate of liveweight gain (1.13 and 1.08 kg/d respectively). Breed had no significant (P>0.05) effect on carcass weight (mean 311.6 kg) nor rate of carcass gain (mean 0.59 kg/d), while killing out proportion was higher (P<0.001) with NC compared to HF bulls (527 vs 509 g/kg respectively). Both final live weight and carcass weight was significantly (P<0.001) higher in the L compared to E slaughter groups, while slaughtering at an older age also improved (P<0.001) killing out proportion (0.511 and 0.526 for E and L groups respectively). Food conversion ratio (FCR) was significantly (P<0.01) poorer with HF compared to NC bulls (14.17 vs 12.84 kg DM / kg carcass gain respectively), while L group animals had a poorer (P<0.05) FCR than E group animals. Carcass conformation was significantly (P<0.001) higher with NC compared to HF bulls, but slaughter age group had no effect on this parameter (P>0.05). In contrast, carcass fat classification was similar (P>0.05) between breeds, but was significantly (P<0.01) higher in the L compared to E slaughter groups.

Table 1 The effect of breed and age at slaughter on animal performance

	Breed				Slaughter group [1]			
	HF	NC	SED	Sig	E	L	SED	Sig
Food intake (kg DM/d)								
Concentrate	4.01	3.79	0.048	***	3.87	3.94	0.048	NS
Silage	4.21	3.75	0.097	***	3.97	3.99	0.096	NS
Total	8.23	7.54	0.117	***	7.84	7.92	0.115	NS
Animal performance								
Final weight (kg)	617.1	583.6	9.56	***	545.1	655.7	9.60	***
LWG (kg/d)	1.13	1.08	0.026	P=0.07	1.14	1.07	0.026	**
Carcass weight (kg)	314.7	308.4	5.07	NS	278.8	344.3	5.09	***
Carcass gain (kg/d)	0.59	0.59	0.014	NS	0.60	0.58	0.014	NS
FCR carcass [2]	14.17	12.84	0.370	**	13.11	13.91	0.366	*
Kill out (g/kg)	509	527	2.8	***	511	526	2.8	***
Conformation [3]	1.56	2.20	0.096	***	1.85	1.91	0.096	NS
Fat class [4]	2.85	2.96	0.095	NS	2.77	3.03	0.095	**

[1] Animals slaughtered at 485 (E) or 610 (L) days; [2] food conversion ratio (kg DM/kg carcass gain); [3] 5 point scale: 1 = worst; 5 = best; [4] 5 point scale: 1 = leanest; 5 = fattest

Conclusions The results of the present study indicate that NC bulls convert food to carcass more efficiently than HF bulls, while also producing a more highly conformed carcass. Slaughtering bulls at 20 compared to 16 months of age improved killing out proportion, but resulted in a deterioration in food conversion ratio.

Using computerised tomography to assess pelvic dimensions linked to dystocia and maternal behaviour score in Scottish-Blackface ewes

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Introduction Recent CAP reforms for the sheep sector are likely to partially shift the emphasis from intensive to lower input, 'easy care' husbandry systems. The ability of sheep to lamb unaided would be crucial to the success of these systems. Dystocia is the most common cause of parturient lamb mortality, and pelvic dimensions are important factors in causing dystocia in ewes (Quinlivan, 1971). This study uses pelvimetry, based on both external and *in vivo* measures obtained by computed tomography (CT), to undertake preliminary studies on the associations among the incidence of dystocia, and other factors including maternal behaviour score (MBS) (Lambe *et al*., 2001).

Materials and methods Four external measurements (in cm) were made on 144 Scottish Blackface ewes of mixed age using a tape measure pulled taut across the fleece. These were between, 1) the inferior promontories of the tuber ishii (A), 2) the superior promontories of the tuber ishii (B), 3) the right-hand superior point of the ilial spine to the right hand superior promontory of the tuber ishial spine (C), and 4) from the left-hand superior point of the ilial spine to the left-hand superior promontory of the tuber ishial spine, (D). Using CT, a longitudinal scan (topogram) of each ewe was taken to obtain the pelvic dimensions corresponding to the external measurements (At – Dt). A cross-sectional scan (tomogram) at the hip joint where the pelvic bridge is clearly defined, was used for each ewe to obtain the transverse (Tr) and conjugate (Conj) diameters (in cm) of the pelvic outlet. The product of these two dimensions was used to define the pelvic outlet (Out). REML variance component analysis software in GENSTAT was used to analyse the data using a model that included no. lambs born, dam age, incidence of dystocia and MBS, measured on a 6-point scale, where 1= ewe flees at the approach of the shepherd, shows no interest in the lamb(s) and does not return to lamb during observation period and 6= ewe makes physical contact with the lamb(s) while they are being held (Lambe *et al*., 2001).

Results All correlations between the external and CT pelvic dimensions were small (< 0.3). The CV% for all external measurements were approximately twice those of the equivalent CT measurements. No significant effect of ewe age on pelvic anatomy was seen, but older ewes tended to have larger pelvic dimensions. The effects of pelvic measurements on the incidence of dystocia and MBS are shown in Table 1. More than 1.8 and 3 sd differences in pelvic dimensions were seen between max. and min. progeny group means for the external- and CT- measured pelvic dimensions respectively.

Table 1 Effects of pelvic anatomy on incidences of dystocia and on ewe maternal behaviour score

Pelvic Trait	Incidence of dystocia			s.e.d.	MBS		s.e.d.
(cm)	0	1	2		1	6	
A	5.22	4.80	4.79	0.873	4.84	5.52	0.663
B	8.93	9.45	7.77	0.813*	7.63	8.93	0.618
C	26.5	26.3	21.7	1.850*	25.53	23.59	1.406
D	26.9	25.8	21.7	1.659*	24.88	24	1.261
At	8.22	7.98	7.36	0.649	7.15	8.08	0.493
Bt	15.7	15.4	14.6	0.610	14.21	15.39	0.464
Ct	17.3	17.1	16.4	0.578	16.06	17.18	0.440**
Dt	17.5	17.1	15.9	0.526*	15.94	16.93	0.399**
Tr	7.15	6.99	6.51	0.295	6.3	7	0.224*
Conj	6.71	6.87	6.08	0.394*	6.27	6.76	0.299
Out	48.0	47.9	39.5	3.85*	39.3	47.5	2.928**

*P<0.05 **P<0.01

Conclusions Low maternal pelvic capacity is a contributing factor to the incidence of dystocia in a flock. Differences in some pelvic dimensions were seen between ewes with extreme MBS scores. Low correlations among external- and CT-measured traits that are anatomically the same warrant further investigation, including the use of a larger data set with repeated measurements on the same animals over different parities. However, the larger CV% for the external pelvic capacity measurements indicate that they may be less reliable measurements, compared to those undertaken on the CT topogram to be used in a selective breeding programme. Preliminary results showing differences in mean pelvic dimensions of daughters from different sires indicate that genetic variation in pelvic dimensions exist within-breed. However, larger trials are necessary to quantify genetic properties of dystocia and pelvic measurements and their relationship with other production traits before selective breeding for large pelvic capacity can be recommended.

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Using computed tomography (CT) to quantify bone properties in Scottish Blackface ewes

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Introduction Good bone quality in breeding ewes is important for the mineralisation of foetal skeletons and to sustain maternal dentition, as tooth loss is the main reason for culling sheep in the UK. Among other functions, bone is a storage depot for calcium and other key minerals that are mobilised to meet major demands such as during lactation. As other studies in humans and poultry have shown, there is substantial genetic variation (h^2 between 0.5 and 0.8) for bone properties, suggesting a similar situation in ewes. These properties, e.g. bone density, are key to successful production and nurturing of healthy lambs, which can be used in selective breeding strategies to extend breeding ewes' productive lives. CT has been shown to be a useful method of assessing bone properties in sheep (Rubin *et al*., 2001). This study quantifies the main bone types in Scottish Blackface ewes and investigates environmental factors affecting bone quality.

Materials and methods Spiral CT scan sequences from 144 mixed-age Scottish Blackface ewes were taken at pre-mating in November 2003 and at pre-lambing in March 2004. One cross-sectional image through the tibia from the right-hand hind leg of each ewe was used for analysis. Trabecular (spongy, SB) and compact bone (CB) densities measured in Houndsfield Units (HU, assigned by the scanner on a scale from –1000 to +1000) at the tibia transect diameter were taken together with the total areas (cm^2, of different grey scales corresponding to tissue type defined by HU) of each bone type in the scan image on both scanning occasions. REML analyses in GENSTAT were used to investigate the significance of ewe age, heft ('home range'), no. lambs born in 2003 (for pre-mating scan), no. lambs carried in 2004 (for pre-lambing scan), the cumulative number of lambs reared to 2003 and the effect of sire. T-test analyses were used to determine the significance of the differences between the means for the same bone traits taken at different times. Phenotypic correlations were estimated among bone properties measured at different times, average carcass fat and muscle depths (predicted from ultrasound), condition score and liveweight.

Results The area of SB decreased significantly by 27% from pre-tupping to pre-lambing and that of CB by 18%, however their relative proportions remained constant at both scanning events. The density of CB of the tibia increased significantly from pre-mating to pre-scanning but the mean density of the SB remained constant. All correlations were < 0.3. Dam age did not significantly affect bone properties at both scanning occasions although ewes aged 5.5 years tended to have have less SB area than ewes aged 2.5 or 3.5 years and CB area tended to increase with age. The mean SB density was similar for all ages. There were no significant differences between ewes grazed on different hefts (not shown). A significant increase in SB area was seen in ewes having borne twins in 2003, compared to those that had no lambs at the pre-mating scan. No significant differences in bone areas or densities were found between ewes carrying different number of lambs during pregnancy in 2004. Pre-mating, SB area was significantly greater in ewes having previously given birth to 4, 6 or 7 lambs vs. ewes never having produced a lamb. There were significant differences between sire progeny group means for areas of SB and CB.

Table 1 Summary statistics for bone properties according to scanning occasion.

Trait	Mean	s.d.	Scanning event
Trabecular area (cm^2)	256.7	39.4	Pre-mating
Trabecular area (cm^2)	195.6	39.3	Pre-lambing**
Compact area (cm^2)	461.0	68.9	Pre-mating
Compact area (cm^2)	386.2	50.4	Pre-lambing**
Trabecular density (HU)	-95.7	4.2	Pre-mating
Trabecular density (HU)	-95.7	4.0	Pre-lambing
Compact density (HU)	649.8	84.3	Pre-mating
Compact density (HU)	762.0	90.6	Pre-lambing**

**P<0.01. Refers to the differences between the same traits measured at different scanning events.

Conclusions Bone depletion followed a similar pattern to that of fat and muscle between mating and pre-tupping (Lambe *et al*., 2003). Age of dam and heft were not key factors affecting bone properties but the cumulative number of lambs born was. Bone properties showed weak relationships with body composition or live weight. Variation between sire progeny groups indicated that the genetic component to bone properties was significant. More data are required to determine when bone mass is repleted later in the year, to estimate genetic parameters for bone mobilisation and bone characteristics, and to assess further the key factors affecting bone properties.

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A survey of scrapie PrP genotype results and their relationship with coat colour and hornedness in selected UK rare breed sheep

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Introduction Scrapie is a transmissible spongiform encephalopathy (TSE) and belongs to a category of incurable diseases that include BSE in cattle. An association exists between the Prion-Protein (PrP) genotype of an animal and the risk of developing disease after exposure (Tongue *et al.*, 2004). This PrP genetic information is the basis of the National Scrapie Plan (NSP) which aims, through genotyping, to eradicate those individuals which have the susceptible alleles. Studies into scrapie risk (Jeffrey *et al*, 2002) have highlighted several alleles which confer scrapie susceptibility. The NSP have used these alleles to categorise individuals according to risk with group one being most scrapie resistant to group five being least resistant. VRQ alleles are synonymous with infection however the ARQ affords susceptibility but not the disease itself. Genotype may however not be the sole indicator of scrapie risk. There is an inference of a relationship between phenotypic characteristics (hornedness, coat colour) and scrapie risk. These alternative indicators of scrapie risk may affect the final choice of susceptible individuals. Scrapie risk studies carried out on the Shetland Isles (Jeffrey *et al.,* 2002) investigated the alleles concerned with scrapie infection. Results confirmed that VRQ alleles are synonymous with scrapie infection however the ARQ alleles, even though they afford susceptibility, do not necessarily confer disease, the animal still has to be exposed to the scrapie agent. Using survey-type questionnaires, the study investigated any potential relationship between the PrP gene, coat colour and hornedness.

Materials and Methods A postal survey was conducted in seven UK rare sheep breeds with a total of 905 questionnaires sent out. The sheep breeds were Shetland, Hebridean, Soay, Manx Loghtan, Castlemilk Moorit, Boreray and North Ronaldsay. Survey questions targeted: Scrapie genotype results, sex of sheep, age, colour, horns, dam horns, and sire horns. After testing for normality, colour and hornedness was displayed using histograms and survey results were examined using ANOVA.

Results Response rate of the survey was 34%. Of these, only 58% still kept sheep and were scrapie genotype testing their flocks. There were 239 flocks (4578 animals) in the study of which 100% of the animals were PrP genotyped. The results of the study for scrapie genotype frequency distribution by breed were compared with results from the NSP and RBST schemes and no discrepancies were observed. Although there was a high variability in results observed, 51% of the study flocks recorded genotypes (ARQ/ARH, ARQ/AHQ, AHQ/AHQ, ARH/ARH, AHQ/ARH and ARQ/ARQ) which confirms the prevalence of similar genotypes found in these particular sheep breeds. All breeds contained sheep with genotypes ARR/ARQ and ARQ/ARQ but frequency distribution varied. The PrP genotype ARQ/ARQ was most common result across these breeds with 31% a total of 1426 animals. The results for association between PrP gene and coat colour by breed, indicated highly significant association, $P<0.05$ in two breeds; Soay and Shetland (Fig 1). Results for association, $P<0.05$ between hornedness and the PrP gene were found in three breeds; Shetland, Soay (Fig 2) and North Ronaldsay.

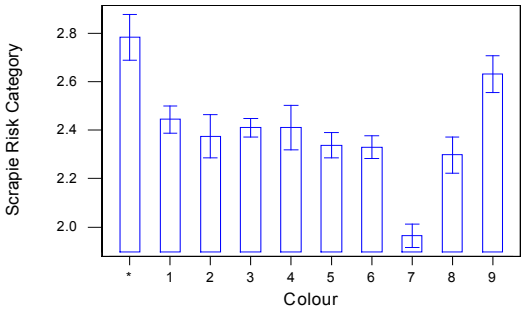

Fig. 1 Scrapie risk to colour in Shetland sheep

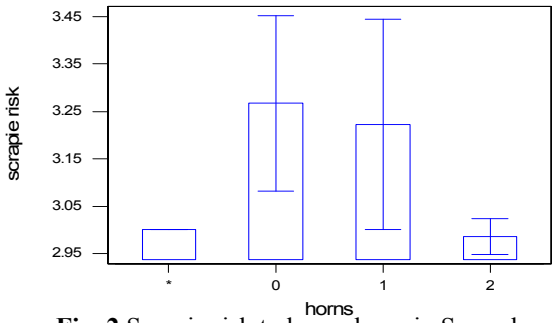

Fig. 2 Scrapie risk to hornedness in Soay sheep

Conclusion All the rare sheep breeds contained sheep with the genotypes ARR/ARQ and ARQ/ARQ but the frequency of distribution varied. This could be as a result of breed characteristics, flock to flock variation, population isolation or regional variation. Of the statistical associations found in this study between the PrP gene, coat colour and hornedness, degrees of significance vary from no correlation to highly significant associations. Whilst the protection of the general public from the risk of TSE infection is of paramount importance, before narrowing the gene pool of UK sheep breeds to scrapie risk groups 1 and 2, further investigation of scrapie risk group 3's interactions with other associated traits require careful consideration.

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Genetic analysis of dystocia and calf birth weight for first parity Holstein in Iran

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Introduction Dystocia is defined as a prolonged, or difficult, parturition and is one of the most economically significant secondary traits. Any attempt for decreasing dystocia rate will result in decreasing farming cost and improving animal welfare. The disproportion between calf size (birth weight) and pelvic opening of the dam is the major cause of calving difficulty. Heifers have smaller pelvic area and experience more incidence of dystocia. Calving difficulty in heifers is considered as a different trait from those of later parities (Weller *et. al*. 1988). Calf birth weight is the most important factor influencing dystocia. Calving difficulty and calf birth weight are characters influenced by maternal effects, so considering maternal effect in data analysis will increase model accuracy. The objective of this study was to estimate genetic parameters of calving difficulty and birth weight.

Materials and methods Calving observations between 1990 and 2004 of Iranian Holstein heifers were obtained from Animal Breeding Center. Data due to parturitions with stillbirth, twinning, unrecorded sire and birth weight of calf and those relating to sires with less than 10 calves and dams aged more than 30 month were removed, and a data file including 81376 observations was obtained, in which calving observations were scored from 1 (easy) to 5 (extreme difficult) and birth weight was recorded in kilogram, these are considered as traits of calf. Also pedigree file were made using all the available relationship information. Significant Factors on calving difficulty and birth weight were determined by PROC GLM of SAS. Duncan multiple range test was used to compare means. a mixed model containing sex of calf, age of dam (in 12 classes), herd_year_season, as classes and birth weight and gestation length as covariates respectively for calving difficulty and birth weight, and calf and dam effects as random factors were used to analyse data. The mixed model equation containing maternal effect was as: $Y=Xb+Z_dd+Z_mm+e$, Where Y is vector of observations on traits, b is vector of fixed effects, d and m are vectors of random direct and maternal additive genetic effects, e is vector of random residual, X, Z_d and Z_m are known incidence matrices that link effects to observations. Analyses were done with univariate and bivariate models with and without maternal effect. Estimation of (co)variance components was performed through REML procedure using REMLF90 package (Misztal *et. al.,* 2002)

Results Test of significance showed that sex of calf, age of dam, herd, year and season are significant factors on these two traits($p<0.0001$), birth weight was significant on calving difficulty ($p<0.0001$) but gestation length was not significant at level of $p<0.01$, gestation length was a significant factor for birth weight ($p<0.0001$). Comparison of means ($p<0.01$) indicated that male calves were heavier and faced to more calving difficulty than female calves, Heifers aged less than 22 month significantly encountered to dystocia more than older heifers, also calves came to birth in winter were heavier and experienced more dystocia. Direct and maternal heritabilities for two traits estimated with different models are shown in table (1), We didn't found any previous study on genetic parameters of calving difficulty of Holstein population in Iran.

Table 1 Estimated heritabilties with different models

Model		Calving difficulty		Birth weight	
		direct	maternal	direct	maternal
univariate	Without dam	0.024	-	0.168	-
	With dam	0.018	0.020	0.135	0.082
bivariate	Without dam	0.036	-	0.187	-
	With dam	0.069	0.078	0.133	0.108

It is found that when a pedigree file not perfect as possible is used, variances due to maternal effect will be much higher. Direct genetic correlation between calving difficulty and birth weight in model with maternal effect was estimated as 0.443.

Conclusions Heritabilities due to different models indicate that neglecting maternal effect will results in overestimation of direct heritability. A more perfect pedigree is necessary for variance estimation especially for those due to maternal effect. The correlation between two traits shows that EBV for birth weight is a suitable criteria for sperm selection for heifer breeding. Small heritabilities show that better management will be more effective for reducing dystocia rate. Magnitude of maternal heritability in comparison to direct one indicates its importance in sire selection programs for calving ease, Then sire evaluation for calving ease in both their daughters (for direct effect) and grand daughters (for maternal effect) will be more helpful.

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Use of productive data to predict length of productive life in Iranian Holstein cattle

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Introduction Improvement of longevity by direct selection of sires based on theirs daughters' longevity measures is impractical because of a low heritability and generation intervals prolonged by waiting until all cows complete their productive life. As an alternative to direct evaluation of sires for longevity is indirect prediction from genetically correlated production traits measures in the first lactation. The objectives this study were 1) to estimate genetic parameters of longevity and production traits 2) to examine relationships between longevity and first lactation milk production traits and 3) to determine selection index for sires' longevity based on production traits.

Materials and methods In this research data of 19838 Holstein cattle which collected from 1978 to 2004 were used to estimate the correlation coefficients between longevity and production traits. The data has been collected by Animal Breeding Center of Iran .Longevity is measured as the true length of productive life (TLPL), which was defined as the number of days between first lactation and culling date, and true herd life (THL), which was defined as the number of days between birth and culling date.The linear models for longevity and production traits were (1) and (2), respectively.

(1) $y_{ijk} = \mu + HYS_i + b_1(age_k - \overline{age}) + b_2(age_k - \overline{age})^2 + A_j + e_{ijk}$ (2) $y_{ijk} = \mu + HYS_i + b(age_k - \overline{age}) + A_j + e_{ijk}$

Where y_{ijk}= observed value per trait, μ = overall mean, HYS_i= herd, year and month of birth, $(age_k - \overline{age})$ =deviation of the age at first calving from the average age at first calving, A_j= random effect of genetic for animal, e_{ijk}=residual effect. The functional length of productive life (FLPL) was obtained by adjusting of TLPL for the effect of first lactation milk yield using Vukasinovic equation (1995).The correlation between longevity and production traits was obtained by multiple-trait REML method. The index to predict FLPL computed by $w = P^{-1}G$ equation where P = matrix of phenotypic (co) variance among production traits and G = matrix of genetic (co) variance between production traits and FLPL.

Results The estimated genetic correlation between TLPL and THL (equal to unit) was in agreement with result of Hoque and Hodges, 1980. This study shown that an intermediate age at first calving was associated with the highest TLPL. Heritability, phenotypic and genetic correlation of traits are presented in Table 1. Heritability values were lower than 0.1 for TLPL and FLPL similar to other research. Among production traits, 305-days protein yield has the largest correlation with FLPL but 305-days milk yield trait effect was negligible. Ultimately, according to these correlations, an index was formed for FLPL based on 305-days milk, fat and protein yield with coefficients of 0.052, 0.383 and –2.323, respectively, that precision of this index was 45.2%**.**

Conclusions Because data for the production is available relatively early in life and because this traits are more highly heritable than culling traits, production traits may provide useful additional information regarding FLPL genetic merit for many bulls that have recently been progeny tested. However, the stated accuracy of indices that are predicted based on a large number of traits can severely overestimate their real accuracy because of errors in genetic parameters estimation. Therefore, indirect predict of FLPL was computed from a limited number of traits in the present study. The results of this study (the presented index) demonstrate that 305-days protein yield trait has a main negative influence on involuntary culling decisions (84.2%). This index for FLPL is similar to RZM index in Germany, approximately, that we use it for the first time in Iran. However, we may increase precision of this index with enter somatic cell count trait to it in the next research.

Table 1 Heritability (on diagonal), genetic (below diagonal) and phenotypic (above diagonal) correlation among traits

	Milk (kg)	Fat (kg)	Protein (kg)	TLPL	FLPL
Milk (kg)	**0.28**	0.723	0.742	0.25	0
Fat (kg)	0.78	**0.17**	0.7	0.21	0.02
Protein (kg)	0.867	0.83	**0.2**	0.38	0.02
TLPL	0.47	0.54	0.49	**0.05**	0.72
FLPL	-0.006	0.131	-0.203	0.76	**0.03**

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Genetic analysis of lactation milk yield and age at first calving for Holstein heifers in Khorasan province of Iran

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Introduction The main aim of animal breeding programmes is to increase productivity and profitability of farm livestock through genetically improving the economic merit of farm livestock (Smith, 1998). This can be achieved by increasing the mean value of a population for one or several economically important traits by the genetic improvement of the animals in this population. In dairy cow husbandry, many traits of economic importance such as lactation milk yield and reproductive traits have long been of interests for breeders to increase profitability of dairy farms. Age at first calving is economically important because it determines when an animal begins its productive life and therefore could influence the lifetime productivity of an animal. Also, age at first calving can be considered as a measure of heifer fertility performance associated with reproductive efficiency. The main objective of the present research is to analyse genetic aspects of lactation milk yield and age at first calving for Holstein heifers in Khorasan province of Iran.

Material and Methods A total of 17,971 lactation milk yields (adjusted for 305d and two times a day milking, 2X) as well as age at first calving records obtained from 17,971 Iranian Holstein heifers in Khorasan province (northern east of Iran) calved between 1987 and 2003 (17 years) and distributed in 133 herds was utilised to estimate genetic parameters, genetic and phenotypic trends. To estimate variance and covariance components of additive genetic and residual effects a bivariate animal model was used. In the animal model, fixed effect of contemporary groups of Herd-Year-Season of Calving $(HYSC)_{it}$ and random effect of additive genetic $(add.gen.)_{jt}$ were fitted for the t^{th} trait of the j^{th} cow in the i^{th} contemporary group. The analysis was carried out using **ASREML** software (Gilmour *et al*., 2000) to obtain REML estimates of variance and covariance components. The mathematical model was as follows:

$$Y_{ijt} = \mu + (HYSC)_{it} + (add.gen.)_{jt} + (error)_{ijt}$$

Results In Table 1 REML (restricted maximum likelihood) estimates of additive genetic and residual variance components, heritability (in narrow sense, h^2) of 305-day, 2X milk yield and age at first calving along with estimated phenotypic and genetic trends for the traits under consideration are presented. The heritability of lactation milk yield was found to be higher than the heritability of age at first calving. Environmental (r_e) and genetic (r_g) correlations between two traits were +0.11 (SE=0.01) and -0.19 (SE=0.07) respectively. As shown in the table although no significant phenotypic trends (calculated based on regression of milk yield or age on year of calving) were observed, statistically significant genetic trends (calculated based on regression of breeding value of milk yield or age on year of calving) were obtained for two traits over the period of 17 years. The heritability estimate of lactation milk yield as well as age at first calving in Iranian Holstein heifers were found to be in the range of heritability estimates obtained for Holstein populations by other previous research workers (Lobo *et al.,* 2000).

Table 1 Restricted maximum likelihood estimates of variance components, heritability, phenotypic (ΔP) and genetic (ΔG) trends of the traits analysed in bivariate animal model

Trait	*Mean*	*Heritability (SE)*	*Genetic trend (SE)*	*Phenotypic trend (SE)*
305d, 2X milk yield	6199 Kg	0.27 (0.02)	$+11.00^{***}$ (2.32)	$+55.95^{ns}$ (44.36)
Age at first calving	26.87 Mon	0.15 (0.01)	-0.056^{***} (0.01)	$+0.086^{ns}$ (0.05)

*** significant at P<0.001, ns non significant (P>0.05)

Conclusion The results of the present study showed that age at first calving is of low heritability indicating that much of phenotypic variation in this trait is due to environmental variation. This suggests that low genetic improvement could be made when direct selection is practiced on age of first calving in Iranian Holsteins. Negative genetic correlation between lactation milk yield and age at first calving shows that animals with higher breeding value for lactation milk yield are expected to have lower breeding value for age at first calving which could be of great economic importance since cows calving at earlier ages are considered to have longer herd life. Furthermore, a decrease of age at first parturition has a positive direct effect on genetic progress as the generation interval decreases and the progeny test of sampling bulls is carried out earlier. With respect to significant genetic trends obtained for lactation milk yield and age at first calving, it can be concluded that breeding programmes practiced to make genetic progress for production traits of Holstein dairy cattle in Khorasan province of Iran has been to a some what successful over the period of time.

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Genetic characterization of three Iranian native buffalo populations (Khozestani, Azari and Mazandarani) using microsatellite markers

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Introduction Biodiversity among domesticated animals in developing countries is enormous. However, due to introduction of superior animal breeds with excellent performance, the native animal resources with good adaptability but lower productivity are in great danger. The list of extinct local breeds and deteriorated remaining ones are becoming longer every year. Erosion of genetic diversity in a breed may cause increase in the rate of inbreeding and genetic abnormalities thereby decrease in animal performance, particularly for reproductive traits. These will virtually reduce the global gene pool for future development and can be considered as a serious threat for universal food security. Therefore the urgency and need to conservation of genetic resources in animal biodiversity is clear particularly for those in the developing countries (Hall, et al. 1995). Buffalo play an important role in animal production in some province of Iran. Present study follow to evaluate the genetic diversity and existing relationship among three Iranian native buffalo populations by using microsatellite markers.

Materials and methods From each 3 Iranian buffalo populations (Azari, Khozestani & mazandarani) 30 animals were selected randomly. The samples DNA were extracted individually using an optimized phenol – chloroform protocol. The following 6 microsatellite loci, ETH10, ETH252, ETH225, INRA005, ILSTS005 and HEL13, were chosen to screen the populations:. Polymerase chain reaction (PCR) of individual microsatellites was carried out as follows: PCR reactions were performed with 30-50 ng of template DNA in 20 µl total volume using 1 unit *Taq* DNA polymerase in reaction buffer comprising: 50 mM KCl, 10mM Tris-HCl, pH 9.0, 2mM MgCl2, 1% Triton-x-100, 200 µM of each of dNTPs. In addition 0.3 µM of each primer was added. Amplifications were performed as follows: an initial 4-min denaturation at 94°C, followed by 35 cycles of 1min at 93°C, 30s at 54-57°C and 45s at 72°C and a final extension step at 72°C for 5 min. After heat-treatment at 93°C, 3µl aliquots of these mixtures were loaded onto 6% denaturing polyacrylamide sequencing gels. Data analyses were performed using POPGENE 1.32, NTSYSpc 2.02, Fstat and Arlequin 2.00 softwares.

Results The number of alleles per locus varied from 3 to 7 for INRA005 and ETH152 respectively with an average 3.4 (Table 1). Two loci (ETH10 and ETH 225) out of six microsatellite loci used in this study, were monomorphic within the three buffalo populations. Polymorphic information contents (PIC) values varied from 0.30 to 0.71 for ELST5005 and ETHI52 loci respestively. The most and the least expected heterozygosity belonged to ETH152 locus in Khozestani population (0.77) to ILST5005 locus in Mazanderani population (0.32) respectively. Genetic distance among populations was estimated by Fixation index (Fst). Maximum genetic distance among buffalo populations was observed between Khozestani and Mazandarani populations (55%); whereas the minimum genetic distance (31%) was observed between Khozestani and Azari populations. Genetic relationships among three populations investigated using cluster analysis.

Table 1 number of microsatellite alleles at each locus in each population.

Locus	Khozestani	Mazandarani	Azari	Total
	n	n	n	n
ILSTS005	3	2	4	4
INRA005	2	3	3	3
ETH225	1	1	1	1
ETH152	7	5	6	7
HEL13	4	4	6	6
ETH10	1	1	1	1
Mean	3	2.6	3.5	3.7

Conclusions The Azari and Mazanderani populations have the largest and smallest size of buffalo populations respectively. Small size of population can cause more similarity and reduction of heterozygosity. This could justify the lower genetic diversity observed within Mazanderani buffalo population. Genetic distance between Khozestani and Azari populations was the lowest and was not significant ($P<0.05$). Khozestan and Azarbaijan provinces are the origin and habitat of the Khozestani and Azarbaijani populations, respectively. They are very distinct in terms of climatic conditions such as temperature and humidity. The two provinces are geographically far from each other and the low genetic distance was not expected from this two populations. This apparently unexpected result led us to search for the origin of the two populations. According to collected information, we found out that Azari breeders had selected their young bulls from Khozestan region. This selection was conducted since 1963 for the advantages such as high milk production, milk quality, meat quality and also high body strength.

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Comparison of genetic response and inbreeding coefficient when the MOET technique and different proportions of proven and young bull semen were used in dairy herds

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Introduction Breeding schemes with multiple ovulation and embryo transfer opens up a possibility to enhance genetic improvement through intense female selection and short generation intervals. The potential improvement in genetic response may increase when elite cows produce a number of embryos, instead of one calf per year. Also different ratio of proven bull and young bull semen may be used to inseminate cows in the herd. The objective of this project has been to investigate genetic response and coefficient of inbreeding, when elite cows produce number of embryos during a year, instead of reproducing one calf per year. Also genetic response and inbreeding coefficient were estimated when different ratio of proven bull and young bull semen were used to inseminate cows in the herd.

Materials and methods In this study, performance of multiple ovulation and embryo transfer technique (MOET) with an annual production of one calf per cow were compared in two different schemes (A and B) utilising 5000 cows in five generations. In scheme (A), one percent of elite cows were selected. Then they were flushed five times per year instead of reproducing one calf annually. In scheme (B) all cows reproduced one calf annually. In order to inseminate herd with bulls, different proportions of proven bull semen and young bull semen ((0.00 and 1.00), (0.25 and 0.75), (0.50 and 0.50), (0.75 and 0.25) and (1.00 and 0.00)) were used respectively. The average breeding value and inbreeding were calculated for each generation to compare genetic response and inbreeding rate in all schemes. Herd size and selection intensity were fixed for every generation in all schemes. Also discrete generations were assumed and it was assumed that, every elite cow produced three or four transferable embryos in each flushing. For simulating the parental values in the base population, it was assumed that parents were unrelated and were sampled from an infinite base population in equilibrium. Additive genetic value of parents (A) in a base population could be simulated from a normal (0.00, 1.00) random number generator as follows: A=NORMAL (I SEEED)*ASD, where ASD = additive genetic standard deviation. Offspring additive genetic value (A_o) could be simulated from parental genetic value plus a term of Mendelian sampling (MS) as: A_o=0.5* (A_s + A_D) +MS and MS= Normal (ISEED)*ASD*((((0.5-0.25(F_s + F_D)) $^{0.5}$), where A_s and A_D were additive genetic value and F_S and F_D were inbreeding of sire and dam respectively. The program was extended according to Meuwissen and Leo algorithm to calculate the inbreeding coefficient of animals.

Results The average breeding value (BV) and inbreeding coefficient (F), when different ratio of young and proven bull semen were used in herd, are given in Table 1. It was clear that genetic response and inbreeding coefficient decreased when the proportion of proven bull semen, used in herd, was increased. Average breeding value and inbreeding coefficient in schemes (A) and (B) are given in Table 2. Results show that the average of breeding value was higher in scheme (A) than scheme (B) but the average of inbreeding coefficient in scheme (A) was inferior to the other scheme.

Table1 Average of breeding value and inbreeding coefficient in different proportion of proven bull and young bull semen

	1.00:0.00†		0.75:0.25		0.50:0.50		0.25:0.75		0.00:1.00	
Proportion	BV	F	BV	F	BV	F	BV	F	BV	F
Generation										
0	0.90	0.0	0.90	0.0	0.90	0.0	0.90	0.0	0.90	0.0
1	713.98	0.0	713.64	0.0	707.38	0.0	710.74	0.0	706.13	0.0
2	1187.98	0.2	1261.51	0.2	1286.04	0.1	1318.77	0.1	1353.29	0.1
3	1668.80	0.3	1825.51	0.5	1858.29	0.5	1919.36	0.5	2013.71	0.6
4	2118.39	0.7	2381.60	1.2	2417.35	1.3	2533.24	1.2	2657.32	1.4
5	2566.32	1.2	2942.78	2.3	2979.69	2.4	3153.16	2.4	3298.51	2.5

†First number shows the proportion of proven bull semen that inseminated to the herd

Table2 Average of breeding value and inbreeding coefficient in Scheme A and Scheme B

Generation	Scheme A		Scheme B	
	BV	F	BV	F
0	0.90	0.0	0.90	0.0
1	746.93	0.0	655.82	0.0
2	1394.93	0.1	1168.11	0.1
3	2049.03	0.6	1665.24	0.3
4	2696.36	1.5	2146.80	0.7
5	3346.00	2.7	2630.18	1.3

Conclusions The results of the present study demonstrates that genetic response was greater in scheme (A) because low rate fertility of female was improved in the herd and top cows had more chance to have more progeny than the other cows by MOET technique. The inbreeding coefficient in scheme (A) increased, when compared to Scheme (B), because most of the selected bulls and cows that produced the next generation were related and they themselves were produced by the MOET technique. It was found that using entirely young bull semen in a herd was better than the other proportion because the breeding value of selected young bulls, which produced by top cows and bulls, was better than the breeding value of selected proven bulls from the previous generations. Also the inbreeding coefficient was increased when the proportion of proven bull semen that inseminated the herd was decreased.

Genetic variation of income over feed costs as an individual trait in Holstein cows

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Introduction The goal of a breeding programme is to select animals that will be more profitable or efficient than their parents. Two main methods have been developed to allow selection on the breeding objective. The first method is use of selection index that combines individual trait breeding values with economic weights to provide a single measure on which to select animals. The second method measures the breeding objective (e.g. net profit or lifetime profit) directly and provides genetic evaluations for this measure (Visscher and Goddard, 1995). The profitability of a dairy cow is dependent on both outputs (incomes of milk, fat, protein, calving, etc.) and inputs (costs of feed, labour, facilities, etc). Outputs have received considerable attention in breeding objectives for dairy cattle, whilst there has been less consideration of inputs. Feed is a major cost input for dairy producers. Hence, breeding for increasing main gross incomes (milk, fat and protein) and reducing main variable cost (feed) potentially can be of considerable importance. This study was conducted to estimation of genetic variation in income over feed cost (IOFC), as a single trait, and its association with some of other traits in Holstein dairy cows.

Materials and methods In this study 3503 monthly records of individual feed intake and composition, milk yield and composition, and body weight were collected from 906 Holstein lactating cows in three herds. Daily income over feed cost (IOFC) was calculated, regarding to daily yield of milk and its components, and actual feed intake, according to prices and costs in 2003. Other studied traits were body weight (BW), milk yield (MY), 4% fat corrected milk yield (FCM), and yields of milk fat (FY), protein (PY) and solids-not-fat (SNFY). Genetic and phenotypic parameters were estimated using the derivative free approach of restricted maximum likelihood procedure (DFREML, Graser *et al.,* 1987) based on multi-trait animal models, with fixed effects of herd-year-season, parity number, lactation stage (months after parturition) and random effects of animal additive genetic and permanent environment. The DFREML software (Meyer, 1997) was used for estimating genetic parameters.

Results The results of this study showed that the income over feed cost (IOFC) is moderately heritable (0.22). Heritability of BW was 0.94 which can be due to repeated measures of body weight. Yield traits also were heritable (table 1). IOFC, genetically had high correlations with FY and PY (0.729 - 0.838), moderate correlations with MY, FCM and SNF (0.270 - 0.585). IOFC phenotypically had moderate correlations with MY, FCM, FY, PY and SNFY (0.134 - 0.296). BW was uncorrelated to IOFC and yield traits, both genetically and phenotypically.

Table1 Heritability, genetic and phenotypic correlations estimations for Income over feed cost (IOFC), body weight (BW), milk yield (MY), 4% fat corrected milk (FCM), and yields of milk fat (FY), protein (PY) and solids not fat (SNFY)*

	IOFC	BW	MY	FCM	FY	PY	SNFY
IOFC	**0.22 ± 0.021**	0.007	0.174	0.182	0.152	0.296	0.134
BW	0.004	**0.94 ± 0.010**	0.011	0.011	0.000	0.018	0.009
MY	0.585	0.008	**0.26 ± 0.057**	0.390	0.193	0.438	0.283
FCM	0.458	0.010	0.940	**0.29 ± 0.029**	0.194	0.413	0.157
FY	0.836	0.000	0.406	0.685	**0.15 ± 0.053**	0.230	0.149
PY	0.729	0.016	0.960	0.951	0.564	**0.34 ± 0.015**	0.276
SNFY	0.270	0.009	0.794	0.265	0.390	0.660	**0.38 ± 0.055**

*Heritabilities ± standard errors are on diagonal, genetic correlations below diagonal and phenotypic correlations above diagonal.

Conclusions IOFC is moderately heritable in dairy cattle, and profitability of lactating dairy cows can be improved by direct selection on income over feed costs, or indirect selection through correlated response to protein, fat, or milk yield selection.

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Genetic evaluation of productive life in Iranian Holstein using survival analysis

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Introduction Improvement of herd life increases profitability due to lower replacement costs of heifers, higher proportion of mature cows that produce at their maximum potential and increased opportunity for voluntary culling. Functional productive life (PL) after adjustment for production is the ability of a cow to remain healthy and delay involuntary culling (Ducrocq *et al* 1988). Survival or failure time analysis has replaced linear model approaches for routine genetic evaluation of dairy cattle in several countries (Sewalem *et. al.* 2003). It allows proper treatment of censored data, inclusion of time-dependent covariates and skewed or non normal distribution of data. Approximate estimates of the heritability of longevity traits typically range from 0.05 to 0.10 and 0.15 to 0.20 using linear models and survival analysis, respectively (Vollema *et. al*. 2000 and Caraviello *et. al.* 2004). The objective of this study was to apply survival analysis methodology for assessing the most important factor influencing PL, estimation of genetic parameters of productive life and genetic evaluation in Iranian Holstein dairy cattle.

Material and methods Longevity and production data of Iranian Holstein Dairy cattle were provided by the Animal Breeding Center. After editing, 288966 production and 105318 herd life data of cows with first lactation from 1987 to 2003 were available for the analysis. Longevity was defined as the number of days from first calving until culling or censoring. Data of cows from herds greater than 30 observations for PL was used. Breeding value estimated for the sires with at least 25 (at least 5 uncensored) daughters in 5 herds. Age of first calving ranges between 18 and 42 months. The following weibull proportional hazards sire-maternal grand sire model was used for analysis of length of PL:

$$h_{ijklmn}(t) = h_0(t)\exp[\,hys_i(t) + p_j(t_1,t_2) + AFC_k + m_l(t) + s_m + 0.5mgs_n\,]$$

$h_{ijklmn}(t)$ = hazard function at time t, $h_0(t)$ = Weibull baseline hazard function with scale parameter λ and shape parameter ρ, $hys_i(t)$ = time-dependent random effect of herd-year-season, assumed to be independently distributed, following a log-gamma distribution with parameter γ and with change points at first day of each season of each year, $P_j(t_1,t_2)$ =time-dependent combined effect of lactation number (lactations 1 to 5+) and stage of lactation, t_1 days after first calving and t_2 days after current calving (with changes at 120, 240 and 305 days of each lactation), AFC_k =time independent effect of age at first calving, $m_l(t)$ = time dependent effect of within herd-year quintile ranking for mature equivalent 305-d milk production, s_m and mgs_n =time-independent random effect of sire and maternal grandsire of cow, assumed to be distributed as multivariate normal with mean vector **0** and covariance matrix $\boldsymbol{A}\sigma^2_s$,where $\boldsymbol{A}$ is additive genetic relationship matrix between sires. The survival kit version 3.12 (Ducrocq & Solkner, 1998_b) was used for the analysis.

Results Estimation of parameters is presented in Table 1. 44.02% of data was right censored. All effects in the model had very significant effect on PL. The most important change in log likelihood was observed for milk production. Risk ratio in cows with milk production less than 1.5 and greater than 1.5 standard deviation of within herd-year average, were 2.45 and 0.84, respectively. Relative risk of culling increased as age at first calving increased. There were significant differences between sires for PL of their daughters. Vollema et. el. (2000) estimated heritabilities of 0.04 and 0.11 for functional longevity of Dutch Black and white cows on the log and original scale, respectively. Sewlem and Kistemaker (2003) and Caravielo *et. al*. (2004) found estimates of 0.14 and 0.18 for Canadian Holstein and US Jersey cattle, respectively.

Table 1 Estimation of parameters

Parameter	Estimate
Average censoring time	1159.76
Average failure time	1029.40
γ	1.346
ρ	1.891
Sire variance	0.043
Heritability on Log Scale	0.063
Heritability on original Scale	0.180

Conclusions Estimated heritability was greater than linear model. The same results suggested by Caraviello *et. al*. (2004). Great variation observed among sires for daughter longevity, thus selection of sires will result suitable genetic gain. In survival analysis all the available information could be properly used, thus for the analysis of longevity data, this approach has superiority over traditional linear models.

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Prediction of selection index coefficient for birth weight and three month weight in Baluchi breed of sheep

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Introduction The method for establishing a selection criterion for a given selection objective is referred to as selection index methodology. Usually in the flock sheep, The first selection for lambs that substitution ewes and rams, is at three month of age. Genetic and phenotypic correlations for weight traits at different ages are high and range of those were from 0.42 to 0.94 and from 0.06 to 0.56 respectively. Thus, the aim of this study was to predict the coefficient of selection index.

Material and methods The studied traits in this experiment were birth weight (BW), three month weight (3W) ,nine month weight (9W)and yearling weight (YW). Approximately 5913 records of Baluchi breed of sheep from Abas Abad sheep breeding station in north-east of Iran were used. Total heritability predict with this equation:
$h^2_T = (\sigma^2_a+0.5\sigma^2_m+1.5\sigma_{am})/\sigma^2_p$, where σ^2_a is direct additive genetic variance, σ^2_m is maternal additive genetic variance, σ_{am} is genetic covariance between direct and maternal effect and σ^2_p is phenotypic variance. Genetic and phenotypic correlations were predicted by using DFREML package. For predicting coefficient of selection Index, BW and 3W were consider as selection criterions and 9W and YW were as selection objective. Then P, C and G matrices were structured as follow ; Matrix P : phenotypic (co) variance between traits in selection index. Matrix C : additive direct genetic (co) variance between traits in selection objective . Matrix G : additive direct genetic covariances between traits in selection criterion and selection objective. By using $b = P^{-1}Ga$, predict coefficient of selection index .

Result Prediction genetic and phenotypic parameters and total heritability are presented in Table 1.

Table 1 prediction genetic and phenotypic parameters

trait	σ^2_a	σ^2_m	σ_{am}	σ^2_c	σ^2_p	h^2_T (S.e)
BW	0.03	0.025	0.0096	0.037	0.3	0.18 (0.039)
3W	0.87	0.527	0.037	1.32	12.67	0.09 (0.022)
9W	2.64	0.6	1.26	0.000003	18.63	0.25 (0.05)
YW	2.98	0.75	1.5	0.17	23.08	0.24 (0.043)

σ^2_a= direct additive genetic variance, σ^2_m= maternal additive genetic variance, σ_{am}= direct and maternal additive genetic covariance, σ^2_c= maternal environment genetic variance, σ^2_p= phenotypic variance, h^2_T= total heritability .
By using information on Table 2, coefficient of selection index for birth weight and three month weight estimated 125.7 and 27 respectively .

Table 2 Parameters for structure P , C and G matrices

	BW	3W	9W	YW	σ^2_p	a
BW	**0.18**	0.45	0.31	0.31	0.3	-
3W	-	**0.09**	0.5	0.61	12.6	-
9W	0.56	0.92	**0.25**	0.82	18.6	100
YW	0.59	0.94	0.95	**0.24**	23	100

Heritabilities in bold, are on the diagonal, genetic correlations are below the diagonal and phenotypic correlations are above the diagonal, a= economic value (in this study value 100 is correcting factor for solving matrices).

Conclusions Results of this study shows that direct additive genetic effects have more influences on weight traits at age after weaning than birth and three month weight. In this reason total heritabilities for weights at age after weaning are more than weights at early ages. This result shows that phenotypic and genetic correlations between weights at different ages are high and by using records of weight at early ages could select animals that have maximum weight on later age. Selection index is $I = 125.7\ x_1 + 27\ x_2$, that x_1 and x_2 are birth weight and three month weight . We can select lambs by substitution records of birth weight and three month weight on selection index and rank animals based on genetic merit.

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Comparison of growth and feed-lot traits in Kordi crossbred and purebred lambs (crossbreeding between some Iranian fat-tailed breeds)

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Introduction Meat production is the most important goal of sheep breeders in Iran. Crossbreeding between rams from relatively heavier breeds with ewes from light breeds (terminal crossing) is common method for increasing meat production in many countries (Bunch *et al.,* 2004; Guney, 1990; Macit *et al.,* 2001). The objective of this study was to compare the growth and feed-lot performance of crossbred lambs, resulted from Shall, Moghani and Afshari (three heavy breeds) rams and Kordi (a light breed) ewes. The performance of pure Kordi lambs was also adopted as a comparison benchmark.

Materials and methods 200 Kordi ewes were randomly allocated to four groups. The ewes were randomly distributed within age groups of which we tried to have equality in each of four groups. Each group of ewes was exposed to three rams of one of the mentioned breeds for mating. Lambs were weaned at 100±5 days and after weaning were divided into two almost equal groups including both sexes. The first group was fed a fattening diet for 15 weeks, while the second group was run on the crop remainder and brought to feed-lot after the first group. On feed-lot period, lambs were weighed every 3-weeks after feed limitation for 18 hours and water limitation for 12 hours. The data of birth weight (BW), weaning weight (WW), average daily gain from birth to weaning (WADG), feed-lot average daily gain (FADG), feed-lot dry matter intake (FDMI) and feed-lot feed conversion ratio (FFCR) were collected and analysed. Due to inequality in the number of observation at different subgroups, resulting data were analysed using generalized linear model (GLM) and least square means comparisons of SAS software.

Results The overall means for a number of traits are given in Table 1. The known effects of sex, dam age, dam weight, feed-lot period, etc. and their interaction with genetic group were taken into account for analysis of the data. Male lambs had significantly higher BW than females ($p<0.05$), but this difference for WW and WADG was not significant. Genetic group, sex and feed-lot period significantly ($p<0.01$) affected the FADG and FFCR, while only sex had significant effect on FDMI ($p<0.05$). The overall results of this study showed a higher FADG and better FFCR in second feed-lot period compare to first.

Table 1 The least square means of genetic groups and feed-lot period

Effect	Trait	Birth weight (kg)	Weaning weight (kg)	Average daily gain (weaning) (g)	Average daily gain (feed-lot) (g)	Dry matter intake (kg)	Feed conversion ratio
Ram breed	Shall	4.744	23.533	189.7	146.8^{a}	1.136	8.027^{b}
	Moghani	4.620	22.696	181.3	142.8^{a}	1.152	8.532^{ab}
	Afshari	4.512	22.814	182.5	139.9^{ab}	1.146	8.166^{b}
	Kordi	4.387	22.530	179.6	126.7^{b}	1.127	9.286^{a}
Feed-lot period	first	-	-	-	126.7^{b}	1.137	9.402^{a}
	second	-	-	-	150.9^{a}	1.143	7.604^{b}

^{a,b} Different letters in each column indicate significant ($p<0.05$) difference of means

Conclusions
The results of the present study demonstrate that crossbred lambs perform better than pure Kordi lambs, although some traits have not shown significant difference. Based on the results of this study, if desired, Shall and Moghani rams could be considered for terminal crossing over Kordi ewes.

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Genetic and phenotypic parameters of body weight and wool production in Iranian Moghani sheep

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Introduction In spite of the fact that there are many sheep breeds in Iran, few studies have been established with respect to their economical traits. Moghani sheep is one of the best Iranian meat type breeds with a 5.5 million population. Some specifications of this breed include Resistance to weather conditions, big body size and ability to producing heavy lambs. The aim of this research was to survey the environmental effects and estimates of genetic parameters for birth weight (BW), average daily gain from birth to three mounts of age (ADG_1), three months age weight (TRW), average daily gain from three to six months age (ADG_2), six months age weight (SIW), nine months age weight (NIW), yearly weight (twelve months age weight or TWW), lamb fleece weight (LFW) and yearly greasy fleece weight in mature sheep (YFW). The effect of birth year, ewe's gestation period (or age for yearling greasy fleece weight), birth type and sex as fixed effect and sires (nested in years) as random effect on aforesaid traits were studied.

Materials and methods In this study the data resulted from 1831 lambs, 83 rams and 555 ewes which had been recorded for 3 years was used. Two models used for this reason: $Y_{ijklmn}=\mu+Ye_i+Si_j+Ag_k+Bt_l+Sx_m+E_{ijklmn}$ for body weight, mean of daily gains and lamb fleece weight That μ=total mean, Ye_i=effect of birth year Si_j=random effect of ram, Ag_k= effect of ewes age at parturition, Bt_l=effect of birth type, Sx_m=effect of lamb sex and E_{ijklmn}= remained effect, and the second model $Y_{jklmn}=\mu+Ye_i+Si_j+Lg_k+Bt_l+Sx_m+E_{ijklmn}$ for yearly greasy fleece weight in mature sheep that Lg_k or effect of lamb age substitute Ag_k or ewes age at parturition. Data analysis carried out by Mixed model least squares and maximum likelihood program (LSMLMW), and DFREML soft wares.

Results Table 1 show the Least square means (LSM) for studied traits. The effect of birth year on the all growth traits was significant ($P<0.001$) and TWW was most significantly affected by year of birth. The effect of gestation period on the other growth traits with the exception of ADG2 and TWW, was significant ($P<0.001$) and this effect on the BW was maximum.

Table 1 Least square means for investigated traits

Traits	BW	ADG1	TRW	ADG2	SIW	NIW	TWW	LFW	YFW
LSM	4.5±0.043	0.19±0.002	22.1±0.187	0.17±0.003	37.72±0.294	40.42±0.254	43.13±0.27	0.672±0.02	2.1±0.04

Except for ADG2, other growth traits significantly affected by birth type, and this environmental effect on BW was highest. The effect of sex on the all growth traits was completely significant ($P<0.001$) and males as compared with females had superiority in all cases. In the case of fleece production traits, the year effect on the lamb fleece weight was significant ($P<0.05$) but didn't significantly affect yearling greasy fleece; and the effect of ewe's gestation period on the first trait was not significant, but had significant effect on the second ($P<0.001$). Lambs fleece weight was not significant affected by type of birth, while had significant effect on the yearling greasy fleece weight; and the effect of ewe's gestation period on the first trait was not significant, but had significant effect on the second ($P<0.001$). Lambs fleece weight was not affected significantly by type of birth, while had significant effect on the yearling greasy fleece weight ($P<0.05$). Meanwhile of sex on lamb fleece weight was significant ($P<0.001$), but was not significant on the yearling greasy fleece weight. Variance components and following that Heritability coefficients for the traits under this study were estimated based on third method of Henderson (TMH) and too (DF-REML), using an animal model, and heritability estimates for mentioned traits via these methods are in table 2. Some of the highest genetic correlations were consist in between BW and TRW, TRW - SIW, SIW - NIW, NIW - TWW and the corresponding values were 0.636, 0.630, 0.365 and 0.388 respectively.

Table 2 Heritability estimates for experiment traits by third method of Henderson (TMH) and (DF-REML)

Method	BW	ADG1	TRW	ADG2	SIW	NIW	TWW	LFW	YFW
TMH	0.097±0.04	0.074±0.04	0.068±0.04	0.071±0.04	0.087±0.05	0.089±0.06	0.079±0.1	0.031±0.12	0.119±0.06
DFREML	0.113±0.06	0.093±0.09	0.084±0.04	0.083±0.05	0.099±0.05	0.101±0.05	0.085±0.08	0.034±0.08	0.199±0.05

Conclusions It was witnessed that genetic and phenotypic correlations between growth traits frequently were positive and high, and in addition to, correlations between weight of close together were higher, and also correlations between them were reduced at one time away from one's**.** In fact, selection for one of these traits can improve others.

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Breeding objectives for commercial silkworm lines in Iran

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Introduction Animal breeding generally aims to obtain a new generation of animals that will produce desired products more efficiently under future farm economic and social circumstances than the present generation of animals (Groen, 2000). Definition of the breeding objective is generally regarded as the primary step in the development of structured breeding programmes (Ponzoni, 1988). Clearly defined breeding objectives are vital for effective genetic improvement of all livestock species. So, they stipulate the animal characteristics to be improved and the desired direction for genetic change. The breeding objective involves calculation of economic values for all biological traits that have an impact upon profitability. This study focuses on the derivation of a breeding objective based on a profit function for three commercial silkworm lines in Iran and effect of limitation in production system size on economic values.

Materials and methods The present investigation has been carried out on three commercial varieties which were produced in Iranian sericulture research center including 110, 107 and 101433. In order to derive economic values of single cocoon weight, shell weight, shell percentage, fecundity, fertility and hatchability (at the animal level) using data simulation (system analysis) method, a deterministic model was defined as follows:
P=N(R-C)=N[(nfhvxr)-(nfhvxm+t)]
where P is annual production system profit, N is breeding moth number, R and C are annual production system return and costs per moth, respectively and n, f, h, v, x, r, m, t are mean fecundity, fertility, hatchability, cocooning percentage, cocoon weight, cocoon price per gram, cocoon cost per gram and fixed costs per breeding moth, respectively. Also, potential magnitude of variation in economic values were estimated when calculated for some alternative limitations in system size including fixed breeding moth number, fixed input and fixed output.

Results The absolute and relative economic values of production and reproduction traits were different in three scenarios (Table 1). Economic values of cocoon weight and reproduction characters are related to profit per one gram cocoon (r-m), when breeding moth number was considered fixed. They have direct relation with fixed costs and inverse relation with the mean trait. In the fixed input scenario, economic values of above characteristics increase when return to cost ratio decreased. Absolute economic values of shell weight and shell percentage were equal in all the scenarios. They are related to best cocoon percentage and shell price per gram. On the other hand, relative economic values of these traits (to cocoon weight economic value) are different in three kinds of limitations in system size. They are higher when input or output is restricted. So, in cocoon saturated market, the breeding objective is focused on improving cocoon shell weight and shell percentage rather than cocoon weight. Relative economic values of reproduction traits have a direct relation with cocoon weight and inverse relation with mean trait.

Table 1 Economic values of traits in different scenarios[†]

Scenario	cocoon weight	shell weight	shell percentage	fecundity	fertility	hatchability
fixed breeding moth number	nfhv(r-m)	nfhvP_bs	nfhvxP_bs	fhvx(r-m)	nhvx(r-m)	nfvx(r-m)
fixed output	t/x	nfhvP_bs	nfhvxP_bs	t/n	t/f	t/h
fixed input	nfhv[r-m(R/C)]	nfhvP_bs	nfhvxP_bs	fhvx[r-m(R/C)]	nhvx[r-m(R/C)]	nfvx[r-m(R/C)]

[†] P_b and s are best cocoon percentage and shell price per gram, respectively. Other symbols are presented in the text

Conclusions The results of the present study demonstrate that breeding objective must be defined with respect to market and production situations. Defining future scenarios for agricultural production and deriving economic values of genetic improvement for these scenarios is a useful tool in developing breeding strategies that are robust to changes in markets and politics.

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Study on genetic parameters of some economic traits in Iranian indigenous silkworm races

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Introduction Silkworms are well-known industrial insects, which produce natural fiber silk. Because of economic importance for silk yarn, an effort to breed new silkworm variety has been made for thousand years. High cocoon yielding due to high resistance, high silk reeling ability and productivity, better silk quality in neatness and lousiness is essential for new silkworm variety to increase silk productivity. Today, several hundred varieties have been bred accordingly various interests and purposes (Kang *et al.*, 2001, 2002). Pupation rate, single cocoon weight, cocoon shell weight and cocoon shell percentage are the main factors affecting the high yielding of cocoon (Kang *et al.*, 2001, 2002). Native silkworm varieties have the low performance and could not be commercially employed. Indigenous strains are valuable genetic resources. They have been affected by natural selection in the successive generations and adapted to indigenous diseases and environmental conditions. Genetic and phenotypic characterization of locally available native silkworm populations provides essential information to make rational decisions for the improvement and development of effective breeding programmes. Hence, the present study was undertaken to identify genetic potential of indigenous silkworm for designing suitable breeding programmes.

Materials and methods The study included five indigenous silkworm breeds viz. Baghdad (B), Khorasan Orange (KO), Guilan Orange (GO), Khorasan Pink (KP) and Khorasan Lemon (KL). The data used were approximately 2000 records on cocoon characteristics including cocoon weight (g), shell weight (g) and shell percentage (%) obtained from four generations (12 full sib families reared in each generation) in each group. Reproduction traits including fecundity (no), fertility (%) and hatchability (%) were also studied. Variance and covariance components of six characters were estimated on the basis of full sib's data by REML method using derivative free algorithm in the animal model. The phenotypic and genetic heritability of the traits were estimated.

Results The highest mean cocoon weight (gram), shell weight (gram) and shell ratio (%) belonged to GO (1.722±0.0077), KP (0.318±0.0011) and KP (19.41±0.044) and the lowest that to KL (1.617±0.0064, 0.236±0.0009 and 14.71±0.039), respectively. The analysis of variance showed highly significant variability for cocoon characters. B, GO and KO breeds had better reproductive performance than others. shell weight (0.508), cocoon weight (0.451), hatchability (0.443) and shell percentage (0.326) had higher pooled heritability than fecundity (0.122) and fertility (0.087). The maximum heritability for cocoon weight, shell weight and shell percentage was obtained in GO (0.431±0.076), KP (0.493±0.063) and KO (0.410±0.090) groups, respectively. Selection based on above characters will be highly effective for improvement. There was positive and high genetic correlation between cocoon weight and shell weight (0.854) as well as shell weight and shell percentage (0.567). The correlation between cocoon weight and shell percentage ranged from -0.418 (KO breed) to 0.382 (KP breed). Cocoon weight and shell weight revealed positive genetic correlation with fecundity and were negatively correlated with fertility and hatchability (Table 1). Therefore, it is expected that selection on these traits in successive generations will increase fecundity and decrease other two reproductive traits.

Table 1 Pooled heritability (diagonal axis) and genetic correlations (non diagonal axis) of the traits

studied trait	cocoon weight	shell weight	shell percentage	fecundity	fertility	hatchability
cocoon weight	0.451±0.027	0.854	0.116	0.352	-0.476	-0.292
shell weight		0.508±0.026	0.567	0.213	-0.426	-0.127
shell percentage			0.326±0.031	-0.050	-0.203	0.153
fecundity				0.122±0.045	0.108	0.257
fertility					0.087±0.049	0.791
hatchability						0.443±0.091

Conclusions The results obtained demonstrate that genetic variability of the most important economic characteristics is very high in native silkworm. Therefore, they can be easily improved by individual selection. Some indigenous breeds have promising future and could play an important role in Iran's sericulture industry.

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The effect of three strains of *Pleurotus* on the *in vitro* dry matter digestibility and subsequent nutritive value of wheat straw to ruminant animals

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Introduction Straw constitutes a vast, valuable, and under utilised agricultural by-product, which has a great potential for utilisation as an animal feedstuff. However, due to the way in which it is constructed, the digestible sugars, cellulose and hemicelluloses, are tightly chemically bound by heavily lignified cell walls which provide the wheat plant stem with its strength and structure, but in doing so greatly inhibit the digestibility and nutritive value of the material to ruminant animals. Therefore, the utilisation of this resource as an animal feed can only be realised effectively, if the nutritional and digestibility values of the material can be improved by the innovation and successful application of an effective treatment method, be that physical, chemical or biological. Previously devised methods of upgrading the digestibility and nutritive value of forages, with the possible exception of urea treatment, have proven either insufficient, environmentally unsound, or economically infeasible to those concerned, particularly those in developing world. Therefore, there is a distinct need to develop techniques which can avoid these pitfalls and still yield the desired results in the context of animal nutrition. Previous research has indicated that members of the genus *Pleurotus* white rot fungi, have great potential for application in the biological upgrading of wheat straw. Therefore, the objective of this work was to investigate biological techniques, using 3 strains of *Pleurotus* fungi which may have the potential to be utilised in the biological upgrading of wheat straw.

Materials and methods The wheat straw (*Triticum aestivum*) was collected from the University research centre, Abergwyngregyn, and sub-sampled according to MAFF (1986) standard technique. The straw was then divided into two groups, with one group being kept dry, and one group being soaked for one week prior to fungal inoculation. The strains of *Pleurotus* employed in this study were: *P. ostreatus* (387889); *P. ostreatus* (027); and *P. eryngii* (DSM8264). All of the *Pleurotus* strains used in this experiment were initially grown on 4% malt agar plates for two weeks. The mycelium was then agitated into aqueous suspension and transferred into conical flasks containing the respective substrates which were used to introduce the fungi to the wheat straw. The introductory (starter) substrates which were used in this experiment were sweet corn (SC) and wheat seed (WS). The fungi were added to these substrates and left to incubate for a further week (20°C) before being introduced, along with approximately 5g of the introductory substrate, to the wheat straw samples. The control measure that was used for this treatment was the introduction of mycelium suspension (MS) direct from the agar plate to the wheat straw substrate. After inoculation into bags containing approximately 50g of straw, the bags were left to incubate for two weeks at 22°C. The CP was determined according to the standard Kjeldahl procedure for organic nitrogen determination (Halliday, 1985). The IVDMD was determined using the faeces liquor method for *in-vitro* estimation of dry matter digestibility of forages (Omed *et al*., 1987). The lignin content was determined according to the Effland (1977) method.

Results: A summary of the soaked (S) and unsoaked (U) straw treatment means, for all treatments is shown below.

Fungal treatment:		Unsoaked data				Soaked data			
	Introductory medium	Treatment code	CP (%)	Lignin (%)	IVDMD (%)	Treatment code	CP (%)	Lignin (%)	IVDMD (%)
P. ostreatus (387889)	SC	U-SC-1	5.22	13.96	46.04	S-SC-1	3.30	20.27	34.33
P. ostreatus (027)	SC	U-SC-2	5.23	12.52	43.26	S-SC-2	3.98	19.28	35.5
P. eryngii (DSM8264)	SC	U-SC-3	5.46	9.70	47.97	S-SC-3	3.49	17.51	44.84
P. ostreatus (387889)	WS	U-WS-1	4.96	12.77	35.71	S-WS-1	3.90	20.00	33.97
P. ostreatus (027)	WS	U-WS-2	5.44	14.54	45.85	S-WS-2	3.24	18.41	25.66
P. eryngii (DSM8264)	WS	U-WS-3	5.22	13.51	45.26	S-WS-3	3.45	15.73	38.48
P. ostreatus (387889)	MS	U-MS-1	4.51	14.08	45.03	S-MS-1	3.62	18.42	32.46
P. ostreatus (027)	MS	U-MS-2	4.89	10.94	45.36	S-MS-2	2.98	17.51	36.27
P. eryngii (DSM8264)	MS	U-MS-3	4.72	15.73	48.61	S-MS-3	2.81	16.62	36.49
(Control)	CONTROL	U-CON	4.58	11.81	56.13	S-CON	2.97	16.61	43.46
		Mean:	5.02	12.96	45.92	Mean:	3.37	18.04	36.15

Conclusions The removal of water soluble polysaccarides during soaking was found to have a significant negative impact on the crude protein content, IVDMD, and lignin content of the wheat straw after treatment (P=0.01), suggesting that this is not an effective method of substrate preparation for these fungal treatments. The use of a pre-inoculated and incubated introductory medium (substratum), to provide improved colonisation rates when introduced to the wheat straw, overall yielded no significant improvement in protein content, IVDMD, or lignin content of the wheat straw substrate (P=0.05). None of the *Pleurotus* strains used in this study yielded significant reductions in the lignin content, nor improvements to the crude protein content or IVDMD of the wheat straw substrate (P=0.05). This was attributed to unselective lignin degradation on behalf of the strains used.

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Effect of tannins in the rumen microbial growth measured by ^{32}P incorporation

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Introduction The phenolic compounds are substances which reduce feed intake, protein digestibility and reduce ruminal activity in sheep and goats. To reduce the effects of tannins a lot of synthetic materials, for example PEG (polyethylene glycol) is tested as tannin-binding agent, and let protein free for the digestibility. The aim of this work was to test the effect of tannins in the rumen microbial growth using the in vitro ^{32}P incorporation technique.

Material and methods Leaves of *Stylosanthes guianenses* cv mineirão, *S. guianenses* cv campo grande and *Leucaena leucocephala* were used, oven-dried and grounded (1mm sieve). Plants were chemically characterized following AOAC (1995), Van Soest (1991), Van Soest (1973), Makkar *et al.* (1993) and Porter *et al.* (1986). The *in vitro* ^{32}P incorporation was determined based on the method presented by Van Nevel and Demeyer (1977). Rumen liquor from sheep was used as inoculum. Samples (1g DM) were incubated at 39ºC for 8h with inoculum (16ml) and buffered solution (4ml) in plastic tubes plus 25µl of ^{32}P solution (3700Bq) used as tracer of microbial protein. Substrates were incubated with or without 2g of PEG. The results of chemical analysis were compared by Tukey test and the results of microbial incorporation were compared by Student t test, using the software SAS for Windows (SAS, 2000).

Results The results of chemical constituents are presented on Table 1. Values of CP for *S. guianenses* cv campo grande were shorter than expected for legumes. The opposite happened for the values of NDF, ADF and ADL. *L. leucocephala* had significantly higher contents of total phenols and tannins ($P<0.05$). The other legumes showed similar values of total phenols and tannins. *S. guianenses* cv mineirão and *L. leucocephala* showed the highest values of condensed tannins. The effect of PEG observed for *L. leucocephala* (Table 2) was the expected due to its highest value of TP, TT and CT. Although the *S. guianenses* cv campo grande showed lower values of TP, TT and CT than *S. guianenses* cv mineirão (Table 1), the effect of PEG in the microbial growth (Table 2) was as evident as for *S. guianenses* cv mineirão.

Table 1 Chemical composition of tested feeds

Feed	*MM* $g\ kg^{-1}$	*NDF* $g\ kg^{-1}$	*ADF* $g\ kg^{-1}$	*ADL* $g\ kg^{-1}$	*CP* $g\ kg^{-1}$	*TP*[(1)] $eq\text{-}g\ kg^{-1}$	*TT*[(1)] $eq\text{-}g\ kg^{-1}$	*CT*[(2)] $eq\text{-}g\ kg^{-1}$
L. leucocephala	49.7 b	294.5 c	177.9 c	78.2 a	192.5 a	7.6 a	5.6 a	4.6 a
S. guianenses cv. mineirão	74.1 a	445.5 b	291.6 b	68.9 a	104.5 b	2.8 b	2.0 b	3.5 a
S. guianensis cv campo grande	56.4 b	560.9 a	392.6 a	85.3 a	56.4 c	1.7 b	1.2 b	0.4 b

(1) tannic acid equivalent; (2) leucocyanidin equivalent; a,b,c: means with different letters, within rows, are significantly different (Tukey test; $P<0.05$)

Table 2 Microbial nitrogen synthesis estimated by in vitro ^{32}P incorporation technique

Feed	*microbial nitrogen (mg* g^{-1} *DM)*	
	without PEG	with PEG
L. leucocephala	2.04 b	12.05 a
S. guianenses cv campo grande	0.83 b	6.42 a
S. guianenses cv mineirão	0.90 b	6.08 a
Means	1.26 b	8.18 a

a,b,c means with different letters, within rows, are significantly different (Student t test; $P<0.05$)

Conclusions The effect of tannins in the rumen microbial growth can be measured by ^{32}P incorporation. This technique also highlighted the different reactivities of tannins.

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The effect of condensed tannins on *Haemonchus contortus* in sheep experimentally infected

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Introduction Clinical and sub clinical parasite infection depresses live-weight gain, feed intake, milk and wool production and can impair soft tissue deposition and skeletal growth. To date these infections have been controlled using anthelmintics, however the increasing prevalence of multiple anthelmintic resistance points towards the urgent need for alternative methods to reduce our reliance upon chemoprophylaxis. In addition, the worldwide growth of organic agriculture, in which the use of synthetic products is strongly restricted, needs alternatives for helminthes control. The aim of this experiment was to evaluate the effect of dietary condensed tannins (CT) on *Haemonchus contortus* infection in sheep.

Material and methods Twenty five worm-free Santa Ines lambs that had been born and reared indoors were randomly allocated into five groups balanced on the basis of live weight. Lambs in four of the groups were experimentally infected with 5,000 L3 of *H. contortus* the fifth group serving as uninfected controls. The lambs were fed daily with concentrate (13% crude protein) twice a day plus hay *ad libitum*. Thirty days post-infection (p.i.), for two days in G4 and nine days in G2 and G3, the animals received a daily dose of 10 g of condensed tannin per kg of diet dry matter from tanniniferous *Sorghum vulgare* grains (G2); *Leucaena leucocephala* fresh branches (G3). The animals in G4 were drenched with *Acacia molissima* extract at the same dose rate as the other two groups but only for two days. Animals in G1 provided infected control data. Faecal egg counts (FEC) were determined using a modification of the method of Gordon & Whitlock (1948) on days 0,7,14, 21, 23, 25, 27, 29 and daily from day 31 to 40 p.i.. Larval cultures were performed using the technique of Robert & O'Sulloivan (1950) every seven days throughout the trial. The results were compared by analysis of variance using the SAS software. Non-parametric values (FEC) were statistically transformed by Ln (x + 10).

Results Animals of G4 showed lethargy and anorexia on the second day of treatment and lasted for two days after. Larval cultures of all groups showed only *Haemonchus contortus* and FEC of G5 showed negative values throughout the trial. Treated groups showed statistical difference ($P < 0.01$) for FEC after day 31 p.i. (average for nine days of 638, 1051, 519 and 139 (SD 417.8) epg respectively for G1, G2, G3 and G4). Figure 1 shows the FEC variation for all infected groups. The time taken for the treated groups to reduce theirs FEC to 50% of G1´s was statistically different ($P < 0.05$), with G2, G3 and G4 taking respectively 7.8, 3.8 and 1.8 (SE = 1.39) days. At the last day of the trial (day 40 p.i.) the average reduction in FEC compared to the control group was -34.4, -24.1 and -97.9 % respectively for G2, G3 and G4.

Conclusions: Acacia extract administered as a drench over two days provided some useful reductions in the egg counts of sheep experimentally infected with H. contortus albeit with some evidence of toxic effects on the treated sheep. The key question for further trials using this approach concerns the possibility of achieving a good reduction in egg output using a lower dose level ideally one which had minimal effect on the treated animal. If this is possible then it may feasible to exploit this approach in the field as a means of reducing pasture contamination and thus minimising the risk of disease in both conventional and organic production systems.

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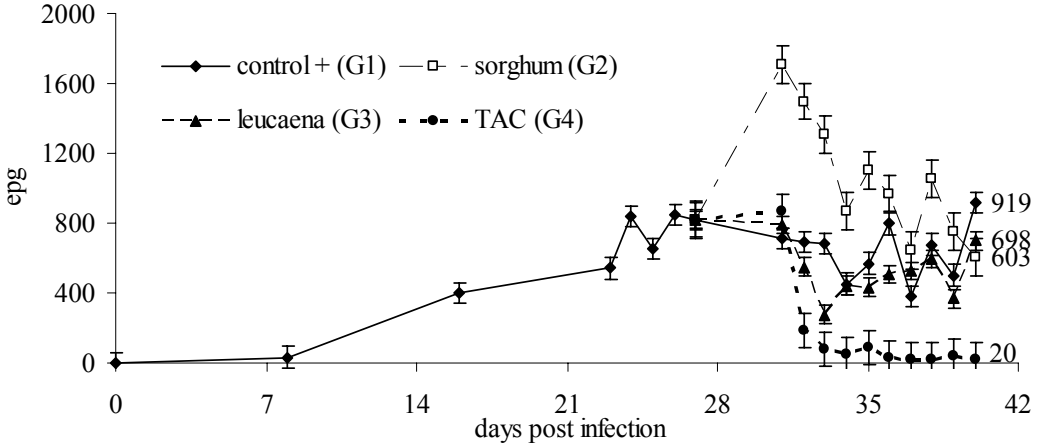

Figure 1 Fecal egg counts for all infect groups (from day 0 to 40 p.i.)

Effects of sequential short-term grazing on different bioactive forages on viability and fecundity of established adult population of *Teladorsagia circumcincta* in sheep

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Introduction Bioactive forages such as chicory (*Cichorium intybus*) or tanniferous legume sulla (*Hedysarum coronarium*), have been reported to lower the parasite intensities or faecal egg counts (FEC) of parasitised ruminants (Waller and Thamsborg, 2004). To our knowledge, there is no report studying the effects of these forages on established worm populations when grazed in combination. This knowledge could guide us towards optimum grazing management using special forage species as de-worming paddocks. The aim of the present study was to use the bioactive forages alone or in combination for a short period to test their effects on established *T. circumcincta* adult population in sheep. The tested bioactive forages were chicory and sulla, with grass/clover (*Lolium perenne/Trifolium repens*) providing the control forage.

Materials and Methods Forty-eight, parasite naive, three-month-old Texel sheep (mean liveweight ± S.E.M.: 29.8 ± 0.49 kg) were dosed with 15,000 infective larvae of *T. circumcincta* on day 1 and day 2 of the experiment (total 30,000 L_3 per animal). On day 15, the animals were randomly allocated to eight groups (n=6) balanced for sex and liveweight and moved into experimental plots for four weeks. All experimental plots used were parasite free prior to the trial and grazing treatments were replicated (two replica plots, 0.1ha each, per treatment). The first two-week period (P1: days 15-28) lambs grazed on either chicory (C) or grass/clover (GC) plots (24 animals per forage). The following two-week period (P2: days 28-43), lambs were allocated to new allotments of either sulla (S) or grass/clover (GC) plots according to the design (P1-P2): C-S, C-GC, GC-S, GC-GC. All animals were slaughtered on day 44 for worm recovery, while measurements of live-weights and faecal egg counts (FEC) were monitored regularly throughout the experiment. Live-weight gain (g/day) was estimated by linear regression of the weights (least square method) and are reported as arithmetic means. FEC and worm numbers were log-transformed ($\log_{10}$ (x+1)) and are reported as backtransformed means with 95% confidence intervals. ANOVA was used to assess the effects of the feeding treatments on live-weight gains and parasitological data.

Results Grazing treatment did not affect liveweight gain of the lambs during the four weeks of the experiment (overall mean ± SEM: 220 ± 9.5 g/day). FEC (eggs per g faeces) showed large variation within the groups and followed similar patterns (Fig.1). During P1, FEC of the animals grazing on chicory were lower (significantly only on day 22; $P < 0.05$) compared to those fed on grass/clover (GC). During P2, there were no significant differences between the group means at any time point. Worm burdens recovered at the end of the experiment (day 44) were similar with no significant differences observed among the groups (Fig.2). Immature worms were not recovered. All measurements obtained from replicate plots were similar.

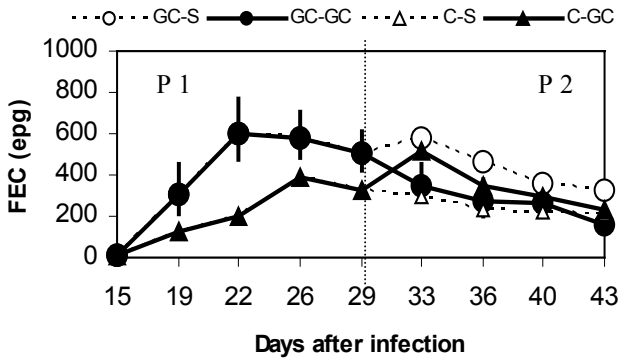

Figure 1 Faecal egg counts (FEC, eggs per g faeces) of lambs grazing on different feeding treatments (where GC:grass/clover; C:chicory; S:sulla)

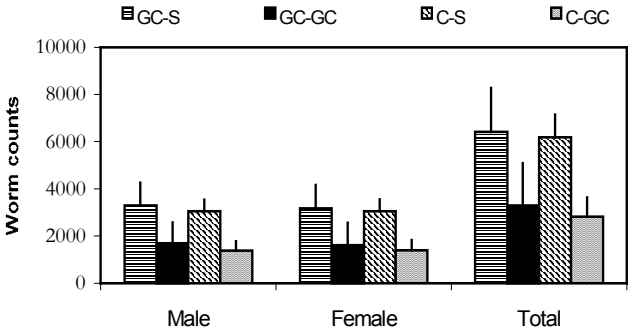

Figure 2 Male, female and total worm burdens recovered from lambs grazing on different feeding treatments (where GC:grass/clover; C:chicory; S:sulla)

Conclusions Although FEC of the sheep grazing chicory tended to be lower compared to those obtained from sheep grazing grass during the first two-week period (P1), this effect was not observed during the following two-week period (P2). In addition, given the similar worm male or female burdens recovered from the different groups suggests that in the present trial, no anti-parasitic effect was exerted against adult *T. circumcincta* populations during a two and four week period grazing on mono-specific and combined species pastures, respectively.

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Effect of source and level of fish oil for ewes in late pregnancy on subsequent performance

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Introduction Lamb mortality represents a major loss to the sheep industry with up to 10% of lambs born dead and a further 12% dying from birth to weaning (Dawson and Carson, 2002). Supplementing ewes in late pregnancy with fish oil has been demonstrated to improve lamb vigour at birth (Capper *et al*., 2002). However, Annett *et al*. (2004) observed that fish oil supplementation severely reduced colostrum yield and lamb output at weaning. The aim of the current study was to evaluate the effect of level and source of fish oil on ewe and lamb performance in order to minimise the negative effects on colostrum production and performance up to weaning.

Material and methods Sixty, twin-bearing, Texel X Greyface ewes (live weight 76 ± 8.0 kg, body condition score 3.7 ± 0.20), mated with Texel, Lleyn and Charollais rams were individually housed, six weeks prior to the predicted mean lambing date and allocated to one of five treatments (n=12 per treatment) balanced for live weight, condition score, ewe breed, sire breed and litter size. Ewes were offered grass silage at a constant rate of 0.4 kg dry matter (DM) per day plus approximately 500 g per of a supplement containing barley, xylose-treated soyabean (soypass) and urea. The five treatments comprised two sources of fish oil (herring/mackerel versus salmon-based oil), offered at zero, 20 or 40 g/day. Silage was offered daily at 0930h and concentrates were offered in two equal feeds at 0930 and 1600h. Intakes of silage and concentrates were recorded daily. Ewe live weight and condition scores were measured at 6, 4 and 2 weeks prepartum, 6 weeks post partum and at weaning. Colostrum yield at parturition was determined by hand milking at 1, 10 and 18 h post-lambing following intramuscular administration of 10 i.u. oxytocin. Lambs were weighed within 1 hour of birth, at 6 weeks of age and fortnightly thereafter until weaning. Lamb growth rate was determined by linear regression. Data were analysed in a 2 fish oil source X 2 fish oil feeding level + zero fish oil (control) factorial by analysis of variance (ANOVA) with ewe breed and sire breed included as fixed effects and litter size as a covariate.

Results Source of fish oil had no significant effect on ewe or lamb performance. However increasing the level of fish oil in the diet produced a linear reduction in colostrum yield of 12 ml per g increase in fish oil inclusion in the diet ($P<0.05$). Ewes offered the intermediate level of fish oil (20 g/d) had a greater number of lambs reared ($P<0.05$), a greater total lamb weight at six weeks of age ($P<0.05$) and total weight of lamb weaned ($P<0.05$) per ewe compared with those offered zero fish oil.

Table 1 Effect of source and level of fish oil supplementation in late pregnancy on ewe and lamb performance

	Level of supplementation (g/ewe/day)				Fish oil source			Significance†	
	0	20	40	sed	Herring/ mackerel	Salmon	sed	Level	Source
Colostrum yield (ml)	1921	1500	1351	195.1	1501	1350	154.3	NS	NS
No. lambs reared	1.4[a]	1.9[b]	1.7[ab]	0.19	1.9	1.8	0.15	*	NS
Total lamb weight/ewe lambed									
Birth weight (kg)	8.5	9.7	9.3	0.53	9.7	9.3	0.43	NS	NS
6 weeks	15.7[a]	19.9[b]	16.1[ab]	1.94	18.3	17.6	1.59	*	NS
Weaning	45.6[a]	60.7[b]	52.1[ab]	6.28	55.6	57.2	5.05	*	NS
Lamb growth rate (birth – weaning) (g/d)	245	286	266	21.9	277	274	17.7	NS	NS

† no significant interaction between level and source of fish oil

Conclusions Source of fish oil had no significant effect on ewe or lamb performance. The results of the study indicate that supplementation of ewe diets in late pregnancy with 20 g fish oil per day leads to improved lamb survival to weaning.

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Effect of two contrasting ryegrass varieties and their management on the performance of finishing lambs

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Introduction Perennial ryegrass varieties bred to express high water-soluble carbohydrate (WSC) concentrations have been shown to improve liveweight gain in pre-weaned lambs of grazing ewes (Lee *et al*., 2001) compared to conventional ryegrass. Studies have shown that the largest differential in WSC between ryegrass varieties bred for high WSC concentrations and control ryegrasses occurs 5-6 weeks after the plant is allowed to re-grow following cutting or grazing (Miller *et al*., 2001). Therefore, the benefits, in terms of lamb performance, of using these grasses with high WSC concentrations may be best achieved when they are rotationally rather than continuously grazed. The aim of this experiment was to compare lambs rotationally or continuously grazing either a ryegrass variety bred for high WSC concentrations or a control ryegrass.

Materials and methods An experiment was conducted at Trawsgoed Research Farm (52º25'N, 4º05'W). Male pure-bred Cheviot lambs (80) grazed replicate 0.65 or 0.8 ha plots of two perennial ryegrass varieties under two grazing regimes. The two ryegrass varieties compared were: AberDart, bred to express elevated concentrations of WSC; and, Fennema. Four weeks prior to the start of the experiment, each plot was divided into two, one for each grazing treatment, to provide 8 plots in total. Plots for the continuous grazing treatment were kept and grazed as one plot but the rotational grazing treatment plots were further split into 5 subplots. These 5 sub-plots were then managed by weekly sequential grazing with lambs so that there was 4 weeks re-growth on each sub-plot at the start of grazing. Each subplot was grazed by a core group of 10 lambs, restrictively randomised to each treatment according to liveweight (25.5, s.e. 0.15 kg) and body condition score (2.4, s.e. 0.01). Replicate forage samples were taken at the same time of day every 7 days during the grazing period to determine WSC concentrations. Sward quality was managed by using spare lambs in a 'put and take' system to control sward height (target 5-7cm) on the continuously grazed plots and as a 'mob grazing' for one day after lambs finish grazing each sub-plot on the rotationally grazed treatment (target residual height 5-7cm). Forage WSC concentrations were compared using repeat measures analysis of variance (ANOVA). Animals were weighed at the same time of day at 7 day intervals. Linear regressions were performed on the liveweights of individual animals and the slope of the regressions (i.e. liveweight gain) were analysed by ANOVA.

Results The WSC concentrations of AberDart were higher than that of Fennema but there was no effect of grazing treatment on forage WSC (Table 1). Lambs that were rotationally-grazing both high WSC and control ryegrass varieties had a higher liveweight gain than lambs that were grazing the same forages. There was a tendency for lambs grazing AberDart and also grazing AberDart with 4 –weeks regrowth to have a higher final liveweight than lambs on other treatments (Table 1).

Table 1 Effect of treatment on WSC concentration (g/kg DM), final liveweight and liveweight gain (kg/d) of lambs

	AberDart		Fennema					
	C	R	C	R	F effect	G effect	F x G effect	F x G s.e.d.
WSC	115	113	100	100	*	ns	ns	7.4
Final Lwt	29.3	33.0	29.2	30.9	†	***	†	0.82
Lwt gain	47.1	98.4	51.5	71.7	ns	***	†	12.94

C, continuous; R, rotational; F, forage; G, grazing; ns, not significant; †, P <0.10; *, P < 0.05;***, P < 0.001

Conclusions Rotational grazing over a 4 week period was not found to further increase the differential in WSC concentration between AberDart and Fennema. Although there was a tendency for lambs grazing AberDart and also grazing AberDart with 4 –weeks regrowth to have a higher final liveweight than other lambs, the liveweight gain data showed that lambs on rotational grazing had higher liveweight gain than those on continuous grazing. This indicates that factors other than forage WSC concentrations were influencing lamb liveweight gain.

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Effect of breed and age on stearoyl co-enzyme A desaturase expression in the omental adipose tissue of Texel, Beulah and Soay sheep

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Introduction Adipose tissue becomes more saturated and less unsaturated with age (Kemp *et al*., 1981). Desaturation of stearic acid to the oleic acid is catalysed by stearoyl-CoA desaturase (SCD) and increasing the degree of desaturation of lamb is likely to be beneficial in terms of human nutrition. By altering the levels of ovine SCD mRNA, the supply of oleic acid to the tissue could be manipulated, resulting in a practical method of changing the fatty acid profile of the animals meat. Previous work in our laboratory has shown variability between adipose tissue depots in their expression of SCD and that this variability is associated with changes in oleic acid content (Daniel et al, 2004). Such differences in SCD expression between depots implies that there may be even larger variation in SCD expression between breeds. A sheep breed with particularly high level of SCD mRNA could then be exploited through breeding programmes to produce animals with increased desaturase activity and therefore increased oleic acid content. Three sheep breeds, Texel, Beulah and Soay, were therefore used to study the influence of breed and age on SCD expression.

Materials and Methods Using Multiple Ovulation and Embryo Transfer (MOET), pure-bred embryos from Texel, Beulah and Soay sheep were produced. These embryos were singularly implanted into surrogate ewes (Welsh Mountain x Border Leicester or Scottish Blackface x Blackface Leicesters), to guarantee a constant maternal environment for the developing foetus, and then lambs were reared naturally by their surrogate mothers. At 8-10 weeks old the lambs were individually housed and fed *ad libitum* a concentrate diet with small amounts of hay. The composition of the diet was 537.5 g/kg barley, 100 g/kg maize, 130 g/kg molassed beet pulp, 200 g/kg soyabean meal, 2.5 g/kg sodium chloride, 25 g/kg vitamins and minerals and 5 g/kg limestone. Due to differences in size and rate of maturity of the different breeds, lambs were slaughtered at various ages at equivalent points of mature size, and as far as possible pairs of animals, one male and one female, were selected at each age. All animals were killed with a lethal dose of pentabarbitone and samples of omental adipose tissue depot were snap-frozen in liquid nitrogen and stored at -80^{o}C for quantification of mRNA levels and fatty acid analysis. The changes in fatty acids and SCD mRNA with age were assessed by fitting a general regression line and significant effects of age and breed were determined using analysis of variance.

Results Soays had the lowest growth rates, approximately half that of Texel and Beulahs; Texels lambs were heaviest at slaughter and Soay lambs the lightest. The ratio stearic:oleic acid increased ($p<0.001$) with age, but there was no difference between the breeds ($p=0.192$; Figure 1).There was a tendency ($p=0.090$) for SCD mRNA levels to fall with age, however, this was not different between the three breeds ($p=0.445$; Figure 2). It should be noted that all lambs were fed the same ration to eliminate the possible influence of diet on tissue fatty acid content.

Figure 1 Stearic to oleic acid ratio

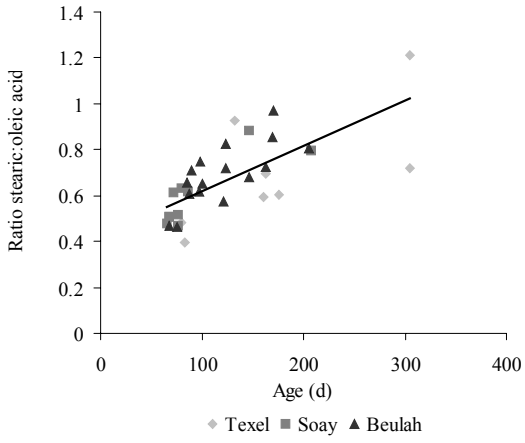
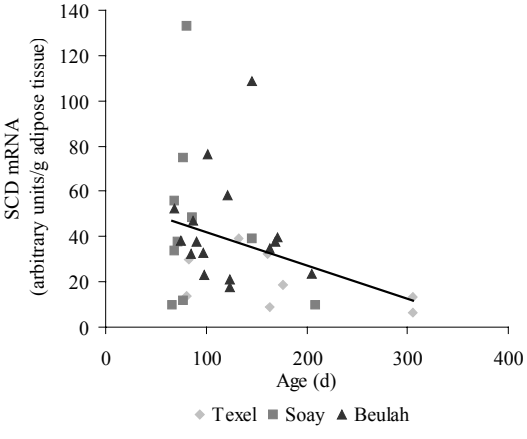


Figure 2 SCD mRNA levels



Conclusion The tissues ability to desaturate fatty acids, expressed as stearic:oleic acid ratio and SCD mRNA levels, decreased with age but there were no differences between the three sheep breeds studied. This suggests it is unlikely that breed differences could be exploited to improve the saturated:unsaturated content of sheep meat.

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Influence of phytate on calcium excretion

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Introduction Concentrate mixtures fed ruminants generally are composed by cereals where phosphorus is present mainly in phytate form or phytin (Maga, 1982). Phytate phosphorus is thought to be completely available to ruminants due to the presence of phytase enzyme that hydrolyzes phytate phosphorus making it available for absorption. Researches have shown that this fact is not always true, depending on different conditions (Park *et al.,* 2000). The aim of this paper was to study the influence of phytate phosphorus on calcium availability.

Materials and methods The study was carried out with sixteen Brazilian breed male sheep, housed indoors in metabolism cages, receiving hydrolyzed sugarcane bagasse and a basic diet supplemented with limestone, Lucerne hay, citrus pulp and oyster shell meal (T_1, T_2, T_3 and T_4 respectively) (Table 1) during twenty-one days. The basic diet was composed of corn, soya bean and mineral mixture. After 21days of adaptation to the diets, feces and urine were collected every 24 hours for 7 days and analyzed for total phosphorus, phytate and calcium. Total phosphorus was determined using vanadate-molibdate reagents and the method of Latta and Eskin was used (Latta & Eskin, 1980) for determination of phytate present in treatments and faeces. Experimental measurements were analyzed as a completely randomized design and General Linear Models Procedure (SAS, 1991) was used for comparison of means.

Results The average phytate phosphorus intake was 2.13; 3.16; 2.32 and 2.74 g/d for T_1, T_2, T_3 and T_4 respectively ($P<0.05$). Phytate P excreted in faeces was 0.50, 0.98, 0.62 and 0.71 g/d. Calcium intake was approximately constant. Ca excreted in faeces was 3.09, 6.39, 6.46 and 5.54 g/d. Phytate P excreted in faeces had a linear relationship with total Ca excreted in faeces: $y = 4.24x + 2.38$ ($n=16$, $r^2 = 0.47$, $P<0.01$). Total P excreted in faeces had a linear relationship with total Ca excreted in faeces: $y = 0.76x + 2.0$ ($n=16$, $r^2 = 0.51$, $P<0.01$). The excretion of P in faeces seems to be related to total Ca excreted in faeces due to the correlation found between these parameters even when Total Ca in faeces is compared to phytate P excreted in faeces. Because these correlations are close it can be suggested that likely phytate excreted in faeces was present in calcium phytate form. If so it can be inferred that when phytate is not hydrolyzed calcium availability is impaired.

Table 1 Chemical composition of ingredients

Ingredients	Ash	P	Ca	NDF	ADF
	%DM				
Soya bean	6.63	0.73	0.28	19.11	12.19
Corn	1.78	0.25	0.03	47.67	4.55
H.S. bagasse[2]	6.97	0.05	0.09	58.85	54.35
Limestone	99.44	0.01	38.60	-	-
Lucerne h.	8.46	0.39	1.15	40.92	29.47
Citrus pulp	6.54	0.12	1.55	23.78	28.86
Oyster S.M.	97.50	0.05	41.10	-	-

[1] P = phosphorus, Ca = calcium, NDF = neutral-detergent fibre, ADF = acid-detergent fibre
[2] H.S. bagasse = hydrolyzed sugarcane bagasse

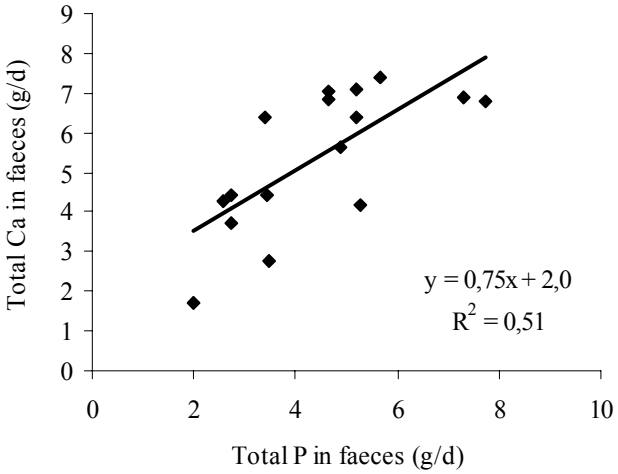

Figure 1 Linear relationship between total Ca in faeces and total P in faeces

Conclusions Phytate P excreted in faeces influenced Ca excretion. Future experiments should be done to clarify phosphorus and calcium availability in phytate for ruminants.

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Sheep production in Spanish dry mountain areas: 1. Effects of Spring management on ewe live weight, milk yield and lamb performance in Churra Tensina breed

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Introduction Traditional sheep producers in the South European countries fed lambs with concentrate, in order to obtain light carcasses of young animals. As a consequence of this lamb production system, large grazing areas have been abandoned. However, some producers are taking into consideration the extensive grazing systems to reduce costs and at the same time to obtain subsidies established by the Common Agricultural Policy of the EU. Moreover, the increasing demand of healthy and safe meat products is stimulating the interest in pasture-based production systems. However, in our dry mountain conditions, this grazing system can be associated to poorer ewe and lamb performances. The present study sought to compare the productive parameters of ewes and lambs obtained in four different management strategies.

Materials and methods The experiment involved 47 spring-lambing Churra Tensina ewes rearing single male lambs. After lambing, they were randomly allocated to four experimental lots: Indoors (Ind), permanently inside with *ad libitum* access to a total mixed ration (8.63 MJ ME/kg DM); Indoors-Grazing (Ind-Gr), ewes grazing from 08:00 h to 16:30 h and remaining indoors with their lambs the rest of time, ewes being supplemented with 500 g/d of barley meal; Grazing with supplement for lambs (Gr+S), permanent in meadow; and Grazing (Gr), permanent in meadow. The lambs from the first three lots had *ad libitum* access to concentrate (185 and 175 g CP/kg DM, first month and fattening period, respectively). The lambs from Ind and Ind-Gr lots were weaned at 45 days old whereas lambs from Gr+S and Gr lots remained with their dams in natural meadows (0.5 ha/lot. 215 CP and 496 NDF g/kg DM; 665 Grass and 189 Legumes g/kg DM) until slaughtering. All lambs were slaughtered when they reached a live weight (LW) of 22-24 kg. Animals were weighed once a week, and body condition was scored at the beginning (lambing) and at the end of experiment (lamb slaughter). Milk yield and composition was measured fortnightly, by the oxytocin and machine milking technique. A preliminary economic study was performed including the ewe and lamb feed cost and the lamb sale ingress. Data were analysed by PROC GLM of SAS. The model contained management strategy as a fixed effect and body condition at lambing as a covariate. Simple correlations between variables were also performed.

Results The production system did not affect neither weights nor body condition during the experiment (Table 1). However, milk yield was significantly higher in Gr+S lot. As far as milk composition is concerned, the Ind lot showed the greatest fat content and the lowest protein concentration throughout the lactation. Lamb average daily gain showed a significant correlation with their mother milk yield ($r= 0.54$; $P<0.001$). Thus, lambs from Gr+S had the highest average daily gain and the lowest age at slaughtering. Dressing percentage reached the highest values in Gr+S lambs. Nevertheless, the amount of carcass internal fat (mesenteric-omental and pelvic-renal areas) was similar in all lots. The preliminary economic study revealed the poorest margin in Ind lot.

Table 1 Effects of livestock production system on productive parameters of ewes and lambs

	Gr	Gr+S	Ind-Gr	Ind	s.e.d.	Sign. †
n	12	12	11	12		
LW at lambing (kg)	44.2	42.7	46.1	43.9	2.9	NS
LW at weaning (kg)	46.1	45.5	46.0	46.2	2.8	NS
Body condition score at lambing (units)	2.6	2.8	2.7	2.7	0.2	NS
Body condition score at weaning (units)	2.4	2.6	2.6	2.7	0.2	NS
Milk yield (ml/d)	1078^{a}	1386^{b}	1072^{a}	1130^{a}	174	*
Milk fat content (g/l)	49.6^{a}	46.1^{a}	50.2^{a}	58.9^{b}	3.2	***
Milk protein content (g/l)	50.0^{b}	48.0^{b}	49.4^{b}	41.9^{a}	1.7	***
Lamb LW at birth (kg)	3.7	3.8	3.9	3.8	0.3	NS
Lamb age at slaughter (d)	77^{b}	62^{a}	65^{a}	72^{b}	4	***
Lamb average daily gain (g)	252^{a}	302^{c}	289^{bc}	274^{ab}	18	**
Carcass dressing percentage [#]	45.7^{a}	49.7^{b}	47.0^{a}	47.8^{ab}	1.6	**
Carcass mesenteric-omental fat (g)	496.9	508.5	509.4	528.9	52.5	NS
Carcass pelvic-renal fat (g)	214.1	279.5	291.0	273.3	44.8	NS
Incomes (€/kg sold lamb LW)	2.14	2.07	1.81	1.25	-	-

† * $P<0.05$, ** $P<0.01$, *** $P<0.001$, NS $P>0.05$
[#] Dressing percentage = Cold carcass weight/ LW at slaughter
Different letters in the same line indicate statistical differences ($P<0.05$)

Conclusions Ewes permanently grazing meadows and rearing lambs supplemented with concentrate presented the lowest lamb age at slaughter, together with the highest carcass dressing percentage and similar carcass internal fat to the rest of the lots. In addition, this production system offered a scarce housing cost. Results obtained suggest that in mountain areas, which can supply good meadow productions with low annual investments, this extensive production system can be a good alternative in order to achieve high quality products and maintain pastures surface.

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Sheep production in Spanish dry mountain areas: 2. Dietary supplementation of lambs on grazing behaviour of Churra Tensina ewes and their lambs

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Introduction Churra Tensina is a coarse-wooled hardy breed usually managed in semi-extensive systems in Spanish Pyrenees. Grazing natural meadows in spring together with lambing season could be involved in the alternatives of its production system. The aim of this experiment was to study the effect of dietary supplementation of lambs on grazing behaviour of Churra Tensina ewes and their lambs during lactation in natural meadows.

Materials and methods Twenty-four Churra Tensina ewes on week two of lactation (LW 42.4±0.89 kg) suckling single male lambs (LW 7.9±0.27 kg) were used. After lambing they had been allocated to two paddocks (n=12) in a randomized factorial block design. Ewes were grazing a natural meadow (0.5 ha/paddock) under continuous stocking and lambs remained with their dams until slaughtering. Treatments conducted were grazing ewes rearing supplemented lambs (Gr+S) and ewes whose lambs were non-supplemented (Gr). The concentrate (185 and 175 g CP/kg DM, first month and fattening period, respectively) was offered *ad libitum* and it was placed in creep feeders at pasture. Grazing behaviour was registered weekly by visually observation from week two to seven after turning out. Sward height (HFRO sward stick), herbage mass (twenty 0.25 m^2 quadrats per ha randomly distributed) and chemical composition were measured the previous day of behaviour records. The initial sward heights were 8.0±0.25 cm and 8.5±0.20 cm, for Gr and Gr+S, respectively. Grazing time of ewes and lambs was recorded every 15 min from 6:00 to 22:00 h. Ewe bite rate was simultaneously measured by counting the number of bites over two minutes during the grazing period. Data were analysed by means of a general linear model procedure. Simple correlations between variables were also performed.

Results and discussion Differences in average herbage availability and chemical composition during the experiment were not significant between paddocks (1396±142.8 kg DM/ha, 169±6.8 g DM/kg; 880±2.4 OM, 472±15.0 NDF, 242±4.5 CP, g/kg DM). In contrast, treatment affected significantly sward height ($p<0.05$) and that was negatively correlated with ewe rate of biting ($r= -0.24$, $p<0.001$), as stated Penning *et al.* (1991). Furthermore, daily rate of biting was significantly higher in Gr (Table 1) and the latter was greater after midday in both groups ($p<0.001$). Nevertheless, no differences in ewe bite frequency throughout lactation were observed (Figure 1). As far as lambs is concerned, they started grass intake on 3rd week old in both lots and then they increased gradually the grazing time. Neither ewe nor lamb grazing time was statistically different between treatments. Hence, Gr lambs did not increase grazing time during the experiment to get over the lack of supplementation and it could have influenced the lowest average daily gain showed (Sanz *et al.*, 2005). The relationship between grazing time and week at pasture was quadratic in Gr+S ewes ($R^2 = 0.89$, $p<0.05$) whereas it was quadratic for Gr+S lambs ($R^2 = 0.91$, $p<0.05$) but linear for Gr lambs ($R^2 = 0.97$, $p<0.001$). On the other hand, patterns of ewes daylight idling activity were similar except for standing time, which was higher in Gr+S than in Gr due to a lower grazing time.

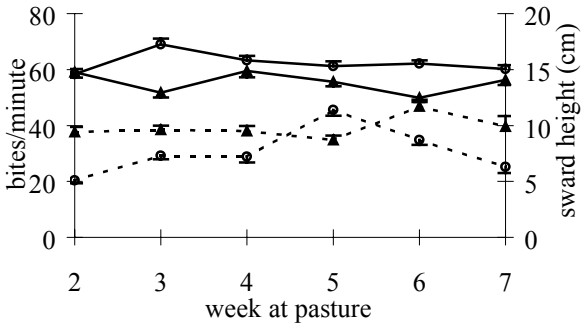

Figure 1 Rate of biting throughout lactation (—) and sward height (--) in treatments Gr+S (▲) and Gr (○)

Table 1 Effect of treatment and week at pasture on ewe biting rate (bites per minute), ewe grazing and daylight idling time and lamb grazing time (min per 16 h) †

	Treatment			*P*	
	Gr	Gr+S	s.e.d.	T	W
Grazing time					
Ewes	496	460	17.5	NS	**
Lambs	208	150	35.5	NS	*
Ewe biting rate	63	55	1.0	***	NS
Ewe daylight idling					
Lying	248	221	16.5	NS	*
Standing	130	200	16.8	**	*

T=Treatment effect; W=week effect; ***=P<0.001;
† **=P<0.01; *=P<0.05; NS=P>0.05

Conclusions According to our results, ewes rearing non-supplemented lambs compensate the greater requirements increasing the rate of biting but not the grazing time. Moreover, in conditions of *ad libitum* feeding, ewe rate of biting is maintained throughout lactation despite sward surface height variations. Patterns of lamb grazing time suggest that subsequent differences might appear afterwards.

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Sheep production in Spanish dry mountain areas: 3. The effect of fattening system on carcass traits, fat and muscle colour and meat texture in light lambs of Churra Tensina breed

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Introduction The lambs production system in the South-European countries is characterised by producing light carcasses (< 13 kg) of young animals, less than 90 days old, and fed with the ewe milk and supplemented with concentrates. However, there is an increasing concern on the study of forage production system in growing lambs as a consequence of the interest in diversifying products and producing healthy and safe meat. When forage is included in the fattening diet a reduction of average daily gain is observed and carcasses have a lower degree of fatness, in comparison to the drylot system. The modification in the traditional type of carcass must be evaluated in order to assure that the final product meets the consumer demands. The objective of this experiment was to evaluate the effect of the lambs fattening system on the carcass characteristics and meat quality especially on the instrumental analysis traits as colour and texture.

Materials and methods Forty-four Churra Tensina lambs were reared in four treatments: Indoors (Ind, lambs fed with ewe milk and concentrate *ad libitum*); Indoors-Grazing (Ind-Gr, lambs fed with ewe milk and concentrate *ad libitum*, grazing ewes); Grazing with supplement for lambs (Gr+S., lambs fed with ewe milk, grass and concentrate *ad libitum*); Grazing (Gr, lambs fed with ewe milk and grass, non concentrate). The ewe management are explained in Sanz *et al*. (2005). Lambs were slaughtered when they reached 22-24 kg of liveweight. At 24 h post-mortem, carcass classification was carried out according to Community Scale for Classification of Lamb Carcass and Carcasses of Light Lambs (Regulation EEC 2137/92, 461/93) and ultimate pH was measured at M. *longissimus dorsi*. At this moment, subcutaneous, caudal and perirenal fat colour were determinated using a spectrophotometer Minolta CM-2006d in the CIELAB space, and colour of M. *longissimus thoracis* (T10) was assessed at 0 (24 h post-mortem), 3 and 6 days after cutting. The lightness (L*); redness (a*) and yellowness (b*) were recorded, and hue (H*) and chroma (C*) were calculated (Miltenburg *et al.,* 1992). Samples of M. *longissimus thoracis*, 7 d of ageing (T11-T12), and *lumborum*, 4 d of ageing (L1-L3), were removed from the left half carcass. The maximum load and toughness were assessed using a Warner-Bratzler device in an Instron 5543, shearing cooked samples of 1 cm^2 in cross-section. Statistical analyses were performed with SAS using GLM procedure on two-ways, 4 systems x 2 aging times for meat texture, and one-way for the rest of variables.

Results The carcass classification from Gr lambs was O+2-, different from Ind and Ind-Gr lambs (R-3-) ($P<0.01$), while Gr+S lambs had an intermediate conformation and fat score (O+2+) between them. There were not differences on meat ultimate pH, since all groups had a normal value about 5.5. The subcutaneous (Table 1), caudal and perirenal fat colour of the extensive animals presented significantly higher b* value and C* than intensive. Although extensive animals presented fat with cream colour appearance, no differences were found on L* (82, 73 and 72 for subcutaneous, caudal and perirenal fat, respectively), a* (0.3, 3.1 and 4.3) or H* (88.3, 79.0 and 72.1).

Table 1 Effects of fattening system on subcutaneous fat colour and meat toughness of lambs

Treatment (No. of an.)		Gr (11)	Gr+S (12)	Ind-Gr (11)	Ind (12)	s.e.	Sign. †
Subcutaneous fat colour	Yellowness (b*)	10.84^{a}	9.24^{a}	6.24^{b}	6.00^{b}	0.703	***
	Croma (C*)	10.88^{a}	9.38^{a}	6.41^{b}	6.03^{b}	0.698	***
Toughness, $kg \cdot cm^{-2}$	4 days aged	1.03^{b}	1.26^{ab}	1.39^{ab}	1.51^{a}	0.098	**
	7 days aged	0.70	0.81	1.02	1.07	0.110	ns

† ** $P<0.01$, *** $P<0.001$, ns $P>0.05$. Different letters in the same line indicate statistical differences ($P<0.01$)

The muscle colour at cutting time presented lower a* and higher H* on intensive lambs ($P<0.01$). These differences had disappeared at 3 d, but at 6 d the Gr lambs had slightly higher b* and C* ($P<0.01$). The colour display of lamb meat during 3 days was not affected by the fattening system. Ageing time was more significant than fattening system on texture evaluation. No differences were found on maximum load among systems at 4 days of ageing, while the Gr lamb meat had significantly the lowest toughness and the Ind lambs had the highest. However, these texture differences between systems disappeared at 7 days of ageing. The texture values of this study were lower than those reported by Sañudo et al. (2000) with meat of 3 days of ageing of light lambs fed with concentrate.

Conclusions Muscle and fat colour and meat texture of lamb light carcasses showed slight but significant differences between extensive (Gr, Gr+S) and intensive systems (Ind, Ind-Gr). Carcasses from extensive lambs tended to have fats with creamer colour, higher chroma in muscle colour and more tender meat. However, the small instrumental differences among the products of different systems had no commercial constraint in the lamb meat market.

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Study of protein characteristics of rapeseed meal (canola) by the Cornell Net Carbohydrate and Protein System (CNCPS) model and its effects on the levels of thyroid hormones in finishing lambs

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Introduction The use of oilseeds is an important option for increasing the energy density of ruminant diets, in addition to supplying dietary protein to support high rates of production. Ruminal degradation of dietary feed CP is an important factor influencing ruminal fermentation and AA supply to dairy cattle. Ruminal protein degradation is described most often by first order mass action models. One of the more complex of these models is the Cornell Net Carbohydrate and Protein System (CNCPS). In the model, feed CP is divided into five fractions (A, B_1, B_2, B_3 and C) which sum to unity. The five fractions have different rates of ruminal degradation. Fraction C contains proteins associated with lignin and tannins and heat – damaged proteins such as the Maillard reaction products. The remaining B fractions represent potentially degradable true protein. Glucosinalate levels in the rapeseed meal reduce its feeding value as it makes meal unpalatable and toxic to animals. Several studies suggest that certain oils primarily through changes in peripheral deiodination of the inactive hormone thyroxine (T_4) to the active hormone triiodothyronine (T_3).

Material and methods An experiment was conducted in two stages to investigate the protein quality of rapeseed meal compared to cottonseed meal and some nutritional characteristics of rapeseed meal. In the first stage, glucosinolate was measured in rapeseed meal and then CNCPS parameters evaluations were done for rapeseed and cottonseed meals. In the next stage, a completely randomized design with 4 treatments and 5 replications (lambs) in each treatment was used to investigate the effects of different levels of rapeseed meals on T3 and T4 levels of lambs blood. Comparisons were carried out using Duncan's multiple range Test at 0.05 probability level. The experiment groups were different levels of rapeseed meal (0, 33, 66 and 100 percent) instead of cottonseed meal.

Results The results indicated that the rapeseed meal used in this experiment contained about 14.75 micromole per gram DM aliphatic glucosinolates. Present day oilseed rape variety have greatly reduced levels of glucosinalate and the norm is less than 18-20 mmol at present Moreover, evaluation of CNCPS showed that there are some differences between these meals specially in B2 fraction of crude protein. The results of the next stage, indicated that the effects of different levels of rapeseed meal on T3 and T4 levels was not statistically significant ($p > 0.05$).

Table 1 Means of T3 and T4 concentration in blood plasma of lambs for each treatment($p > 0.05$)

	Rapeseed meal replacment in diet(%)			
Percentage	0	33%	66%	100%
Hormon T3	1.75[a]	1.70[a]	1.66[a]	1.60[a]
Hormon T4	9.03 [a]	9.01 [a]	8.60 [a]	7.50 [a]

Table 2 Evaluation of models is the Cornell Net Carbohydrate and Protein System(CNCPS)

%	Rapeseed meal	Cottonseed meal
CP[1]	33.5	35.2
SCP[2]	6.53	6.09
NPN[3]	2.51	2.66
NDIP[4]	10	9.33
ADIP[5]	6.73	8
C	6.73	8
B_1	4.02	4.19
B_2	3.27	1.33
B_3	27.96	29.5

[1]Crude protein, [2]Soluble crude protein, [3]Non protein nitrogen,
[4]Neutral detergent Insoluble protein , [5]Acid detergent Insoluble protein

Conclusion We can substitute rapeseed meal for cottonseed meal without any nutritional problem. The amount of ADIP and NDIP in rapeseed and cotton seed meal was higher than these were reported by NRC (2001). In rumen a majority of protein in canola meal and cottonseed meal is in fraction B_3 and this would be degraded slower than fraction B_1 and B_2 (NRC, 2001).

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Comparison of ovarian oestradiol and progesterone secretion, *in vitro*, between ewe lambs and ewes

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Introduction Reproductive performance of ewe lambs is lower than that of adult ewes (Quirke 1979). This is mainly the result of preimplantation losses, which can exceed 50% of fertilised eggs. Previous evidence from this laboratory suggests that these losses may be associated with abnormal ovarian hormone production (Davies and Beck 1993). Khan (1999) demonstrated that blood progesterone levels during the oestrous cycle and pregnancy were lower in ewe lambs than in ewes. Furthermore, both progesterone and oestradiol concentrations were lower in ewe lambs, than in ewes, following gonadotrophin stimulation (Khan, Beck and Khalid 1999). These results suggest that ewe lamb corpora lutea and follicles secrete less progesterone and oestradiol, respectively, than those of ewes. The aim of this study was to determine whether there is a difference in vitro steroid hormone production by corpora lutea and follicles, from ewe lambs and ewes.

Materials and methods Ovaries were collected from ewes and ewe lambs post slaughter and transported back to the laboratory in warm saline. Corpora lutea (CL) were carefully dissected from ovaries collected from ewes (n = 41) and ewe lambs (n= 41) post slaughter on days 9 to 12 of the oestrous cycle (oestrus = day 0). Each CL was weighed, cut in half and washed three times. One half was frozen following the addition of 6ml DMEM (0 h) and the other half cultured for 2 hours at 37 decrees C in an atmosphere of 5% CO2 in air prior to freezing. These were then thawed, homogenised and assayed for progesterone. Medium (2 to 4mm) and large (5 to 8 mm) follicles were dissected from ewe (medium n = 61; large n = 107) and ewe lamb ovaries (medium n = 87; large n = 68) ovaries, washed 3 times and cultured individually in 2 ml TCM 199, with or without 10% fetal calf serum (FCS) for 24 hours. Media was assayed for oestradiol and progesterone. Data was analysed by two-way ANOVA with interactions, to determine the effects of age, CL weight and time (0 or 2h) on progesterone concentration or after log conversion, age, follicular size and FCS on oestradiol and progesterone concentration.

Results Mean CL weights were similar between age groups (ewes 702 mg; ewe lambs 713 mg SED 41.9). However, progesterone concentration (ng/mg) was greater in ewes than in ewe lambs at 0 h and after 2 h incubation (Figure 1; P>0.05). Oestradiol concentrations were greater in the media from ewe follicles than ewe lamb follicles (Figure 2; P>0.05), with large follicles secreting more oestradiol than medium follicles in both age groups (Figure2; P<0.05). The inclusion of FCS increased oestradiol secretion from ewe lamb follicles but not ewes (P<0.05). Progesterone concentrations were greater in media containing ewe follicles compared with ewe lambs (P>0.05; Log ewe means=0.22 and 0.23 Log lamb means=0.03 and 0.17, respectively; SED=0.065).

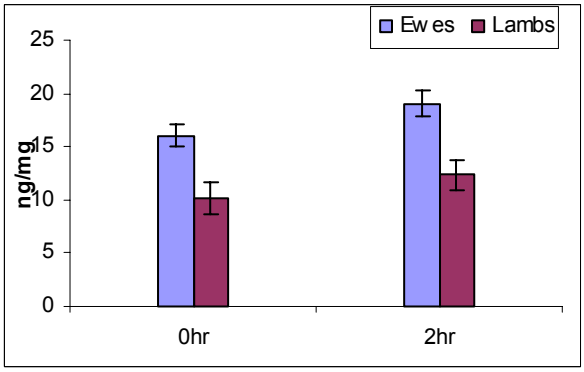

Figure1 CL Progesterone ng/mg 0hr (SED=1.8); 2hr (SED= 1.9)

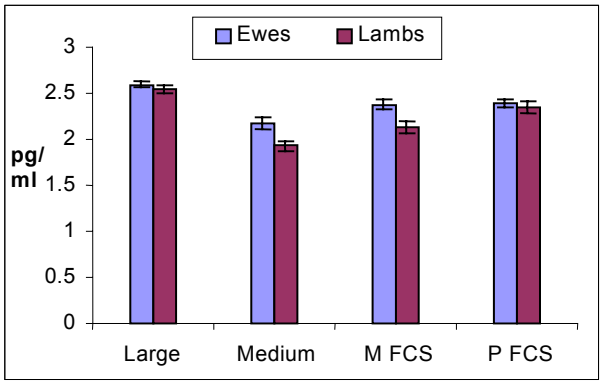

Figure 2 Log Oestradiol pg/ml from different follicles sizes (SED=0.072) ; with(P) or without (M) FCS(SED=0.067)

Conclusions The results of this study indicate that luteal and follicular tissue from ewe lambs secrete less progesterone and oestradiol, when cultured in vitro, than tissue from ewes. This reduced steroidal capacity may be associated with ewe lamb sub fertility.

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Effects of fat source in flushing diets on various reproduction parameters in Zandi fat-tailed ewes

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Introduction Fats in the diet can influence reproduction positively by altering both ovarian follicle and corpus luteum (CL) function and by increasing precursors for the synthesis of reproductive hormones such as steroids and prostaglandins (Mattos *et al.,* 2000). Fat supplementation positive effects include: increased size of the ovulatory follicle, increased numbers of ovarian follicles, increased plasma concentration of progesterone, reduced secretion of $PGF_{2\alpha}$, increased lifespan of the CL, and improved fertility (Staples et al., 1998). Lucy *et al.* (1992) suggested that it was fatty acids, and not the additional energy provided by the fatty acids, that stimulated ovarian function. Recently, new information has been published that demonstrates that the type of dietary fatty acids is important as individual fatty acids do not have the same effects on reproduction of the dairy cow (Petit *et al.,* 2001).The objective of this study was to determine the effects of dietary supplemental fat source on reproduction parameters in Iranian fat-tailed ewes.

Materials and methods Fifty-two non-lactating and non-pregnant 6-year old Zandi (Varamini) ewes were selected. Ewes were blocked by weight and divided among four experimental groups (n=13) receiving different fat-supplemented diets for flushing. Diets were: 1) without supplemental fat, 2) containing 4.5g/kg calcium salts of fatty acids from tallow, 3) containing 4.5g/kg calcium salts of fatty acids from soybean oil and 4) containing 2.25g/kg calcium salts of fatty acids from tallow + 2.25g/kg calcium salts of fatty acids from soybean oil. The main components of diets were alfalfa hay and barley grain. Diets were isoenergetic and isonitrogenous and provided maintenance and flushing requirements. The ewes received the experimental diets from 2 weeks before, until 3 weeks after, the introduction of the rams. Estrous synchronisation was performed by CIDR insertion for 12 d. Ram introducion was performed at CIDR removal day. Thirteen days after CIDR removal laparascopy was performed and follicles ≥ 3 mm and CLs on each ovary were counted. The number of CL found was designated the ovulation rate (OR) index. At lambing, number, weight and sex of lambs and ewes lambing date were recorded. Data were subjected to least squares ANOVA for a randomised complete block design with four treatments using the general linear models procedure of the SAS.

Results The results of this study are summarised in Table 1. The OR in Group 3 was higher than other groups ($p<0.05$). The number of follicles ≥ 3mm in Group 2 was lower than other groups ($p<0.05$). The pregnancy rate from first and two first service period in Group 3 was higher than other groups and in Groups 2 and 4 was higher than Group 1($p<0.05$). The interval from ram introduction to lambing (days) in Group 1 was nonsignificantly greater than other groups. Lambing rate and lamb crop from both service periods were highest in Group 3 and were lowest in Group 1 ($p<0.05$).

Table1 Effects of fat source of flushing diet on reproduction parameters in ewes

Diet	1	2	3	4	s.e.m.
OR	1.15^{b}	1.17^{b}	1.50^{a}	1.23^{b}	0.069
Number of follicles ≥ 3mm	1.23^{a}	0.50^{b}	1.25^{a}	1.00^{a}	0.139
Pregnancy rate from first service period	0.23^{c}	0.58^{b}	0.75^{a}	0.54^{b}	0.071
Pregnancy rate from two first service periods	0.38^{c}	0.67^{b}	0.92^{a}	0.62^{b}	0.069
Interval from ram introduction to lambing (days)	168.6	154.1	155.1	157.3	1.98
Lambing rate from first service period	0.23^{c}	0.83^{b}	1.17^{a}	0.77^{b}	0.114
Lambing rate from two first service periods	0.46^{c}	0.92^{b}	1.33^{a}	0.92^{b}	0.112
Lamb crop from first service period (kg)	0.98^{c}	3.09^{b}	4.44^{a}	2.76^{b}	0.411
Lamb crop from two first service periods (kg)	1.86^{c}	3.46^{b}	5.18^{a}	3.27^{b}	0.401

$^{a, b, c}$ Means within a row with a different letter differ ($P < 0.05$).

Conclusions Addition of fat supplement especially from rich sources of unsaturated fatty acids (i.e. soybean oil) to flushing diet had positive effect on the OR and other reproduction parameters of ewes. The results of this study suggests that, in ewes, the ovaries require essential fatty acids to function optimally. Further studies are required.

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Effect of defoliation intensity of barley when grazed as green forage by sheep on grain production at harvest

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Introduction Grazing of barley as green forage is a common practice in the Mediterranean area due to its active growth along autumn and winter, and its ability to recover after a mild grazing (Bonachela *et al*., 1995). However, grain production at harvest might be affected depending on the intensity of defoliation suffered by the plant (Yau, 2003). Those studies were carried out mainly by hand clipping or allowing only a few hours of grazing per day. Hence, the objective of this experiment was to establish the relationship between grazing intensity and grain production at harvest when animals are kept in the paddocks for the whole day. Moreover, the ability of barley height and/or residual biomass after grazing (kg dry matter/ha) to predict final grain production was also tested.

Materials and methods The experiment was carried out in two consecutive years (2003 and 2004). In 2003, 48 Rasa Aragonesa (60±7.0 kg W) and 42 Ansotana (61±8.0 kg W) adult sheep were grazing green barley for 28 days starting at the *lemma primordia* stage (14 March). Twelve paddocks of 1/3 ha each were used to test the effect of the stocking rate (15-9 Rasa and 6 Ansotana- and 30-15 Rasa and 15 Ansotana- sheep/ha) on grain production at harvest. Six replicates were used for each stocking rate. In 2004, 30 Rasa Aragonesa (51±3.6 kg W) adult sheep were assigned to the same two stocking rates (15 and 30 sheep/ha) with two replicates each (4 paddocks of 1/3 ha). Grazing started at the same stage of maturity but much earlier in the year (2 February) due to higher rainfall in the previous months. Each year an equivalent number of paddocks (6 and 2, respectively) was left ungrazed for contrast. Pasture height and total biomass in the grazed paddocks were recorded every week along the experimental period, and grain production from all paddocks at harvest (9 and 13 July, respectively). Regressions of grain production on either residual biomass or pasture height recorded at the end of the grazing period were obtained. A factorial ANOVA to test for the effects of year and stocking rate on grain production was also performed.

Results The effects of grazing year and stocking rate on grain production at harvest are presented in Table 1. There was a significant interaction between both factors indicating that in 2003 even low grazing pressures (15 sheep/ha) had an adverse effect on yield, whereas this did not happen in 2004. It must be pointed out that in 2003 the grazing period started much later than in 2004, even though the stage of maturity of the cereal was apparently the same. The interaction between year and stocking rate was also detected in the regressions of grain production on either plant height or total biomass at the end of the grazing period. Hence different equations were obtained for each year (kg grain = -177 + 0.21kg biomass/ha or kg grain = –425 + 27.6 pasture height (cm) for 2003, and kg grain = 790 + 0.63kg biomass/ha or kg grain = 949 + 68.7 pasture height (cm) for 2004, respectively). Pasture height at the end of the grazing period predicted grain production better than residual biomass, with overall r^2 values for the regression of 0.91 and 0.67, respectively. Consequently, the correlation between pasture height and residual biomass at the end of the grazing period was also poor (r^2=0.66).

Table 1 Effect of grazing year and stocking rate on grain production (kg/ha) at harvest

	2003	2004	Mean
Control	900_{a1}	1866_{b1}	1383
15 sheep/ha	453_{a2}	1986_{b1}	1220
30 sheep/ha	175_{a3}	1280_{b2}	728
Mean	509	1711	
r.s.d.	173.3*		

* For comparisons between years within stocking rates and between stocking rates within years
$_{a, b}$ Different letters indicate differences between years within stocking rates at $p<0.05$
$_{1, 2, 3}$ Different numbers indicate differences between stocking rates within years at $p<0.05$

Conclusions Grain production of barley after been grazed in mid-late winter was more dependent of the year than of the stocking rate. This latter had no effect at values of 15 sheep/ha when the year was good but did when increased to 30 sheep/ha even in the most favourable conditions. Plant height at the end of the grazing period was a better predictor of grain production at harvest than residual biomass, although the absolute values changed over years.

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Effect of different temperature treated of CASMEREA on ruminal degradability of goats

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Introduction Cassava root meal is a fine powder from the manufacture of chips and/or starch. Their disposal increases otherwise environmental pollution and health hazards. Nevertheless, ruminants can be fed on cassava tuberous roots, foliage, peel and residue obtained after processing cassava including cassava meal. Evidence so far shows that cassava meal is good source of energy which, when fortified, promote positive and high performance in cattle, sheep and goats. Cassava meal contains high level of energy and has been used as readily fermentable energy in the rations. However, the lack of nitrogen supplied from cassava meal that it is important to include nitrogen sources to balance the energy-nitrogen supply for the microbial activities in the rumen. The objective of this experiment was developing the new products from cassava meal namely, CASMEREA (cassava meal + urea) or commonly name "starea" or "casarea".

Materials and methods Six meat goats with an average weight of 21 $\pm$ 1.2 kg, each fitted with permanent rumen cannulae were used. Goats were randomized assigned into a 2x3 Factorial arrangement. Factors were three levels of temperature treated (80, 100 and 120°C) and two levels of time treated (30 and 60 min). Goats were fed a maintenance diets (NRC, 1981) consisted 70% fresh and 30% commercial concentrate supplements. The preliminary period lasted 14 days following by a 4 days experimental period. Dry matter (DM) and crude protein (CP) degradability in the rumen were determined in goats. Nylon bag made from polyester cloth with pore size of 45 µm were each filled feed test samples. All samples were prepared in duplicates and incubated in the rumen of each animal for 2, 4, 8, 12, 24, 36 and 48 hr, for the control, bags without incubation (0 hr). The bags were washed, weighted and tested following the procedure described by Ørskov and McDonald (1979). Analysis of the variance was calculated with the General Linear Model (GLM) procedure of the Statistical Analysis System Institute Inc. (SAS, 1989). Duncan's New Multiple Range Test was used to compare treatment means.

Results The DM and CP degradability in the rumen of CASMEREA treated with 30 min was higher ($p<0.05$) than that of 60 min, and treated with 80°C was higher ($p<0.05$) than 100 and 120°C, respectively. Crude protein degradability in the rumen of the control (untreated) was significantly higher ($p<0.05$) than those treatments (Figure 1). Nevertheless, CASMEREA treated with 80 and 100°C were not different significant, but both were significantly higher ($p<0.05$) than that of CASMERA treated with 120°C, respectively. Moreover, CASMEREA treated with 120°C for 60 min was burned and could not use for feeding animals.

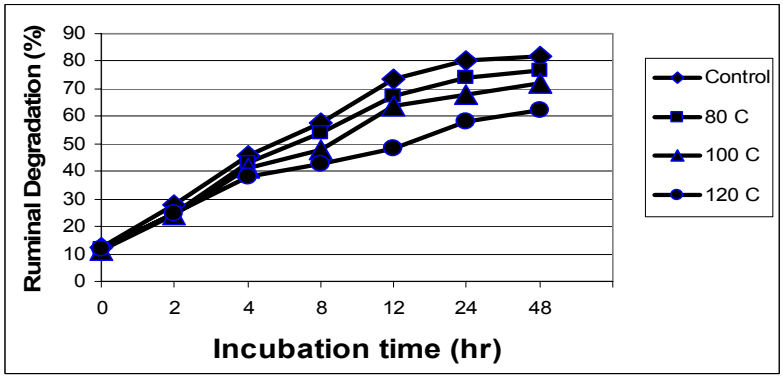

Figure 1 Crude protein degradability in the rumen of untreated (control,♦) (SEM = 4.15), treated with 80 C (▪)(SEM = 3.22), treated with 100 °C (▲)(SEM = 3.77) and treated with 120 °C (●)(SEM = 3.83) of CASMEREA , respectively.

Conclusions The results of the present study suggested that high temperature treatment of CASMEREA at 80 and 100°C for 30 min can be improved to delay rate of degradability, and enhanced the utilization of NH_3-N by rumen microbes.

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Chemical composition and metabolisable energy content of four aquatic plants for sheep

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Introduction Although some aquatic plants have been used for ruminant diets in some parts of Turkey there is a lack of information about their nutritive values. The aim of this study was to determine the chemical composition and metabolisable energy (ME) content of four different aquatic plants using *in vitro* gas production technique.

Materials and Methods *Apium nodiflorum*, *Myriophyllum verticillatum*, *Lemna minor* and *Nasturtium officinale* were collected in December, 2003, pooled and dried. 0.200 g of dry sample milled 1 mm screen were incubated in triplicate with rumen fluid obtained from two fistulated sheep fed a diet containing alfalfa hay (60%) and concentrate (40%) following the procedures of Menke *et al* (1979). Readings of gas production were recorded before incubation (0) and 3, 6, 12, 24, 48, 72 and 96 hours. ME values were obtained using equation (ME (MJ/kg DM) = 2.20 + 0.136GP + 0.057CP) (Menke *et al.* 1979). One way analysis of variance (ANOVA) was carried out to compare the chemical composition, the gas production and estimated parameters.

Results Analysis of four aquatic plants (Table 1) showed that the crude protein content ranged from 19.5 to 31.3 %, crude fibre from 15.4 to 27.4 %, ash from 17.5 to 24.6 %.

Table 1 Chemical composition (on a dry matter basis) of four aquatic plants

Constituents (%)	*A. nodiflorum*	*M. verticillatum*	*L. minor*	*N. officinale*	SEM	Sig.
Dry Matter (% of Fresh Matter)	94.5	94.1	94.1	94.6	0.508	NS
Crude Protein	26.3^{b}	20.4^{a}	19.5^{a}	31.3^{c}	0.359	***
Crude Fibre	27.4^{c}	20.7^{ab}	15.4^{a}	23.8^{bc}	1.231	***
Ash	17.5^{a}	20.5^{b}	24.6^{c}	17.6^{a}	0.265	***
Condensed tannin	1.7^{a}	3.8^{b}	1.6^{a}	1.8^{a}	0.143	***

Means in the same rows with differing superscripts are significantly different, SEM: Standard error mean, ***P<0.001

Data for gas production and estimated parameters are given in Table 2. There were significant differences (P<0.001) between aquatic plants in terms of gas production and estimated parameters. At all incubation times the gas productions of *M. verticillatum* and *L. minor* were significantly higher than those of *A. nodiflorum* and *N. officinale*. Therefore most of the estimated parameters for *M. verticillatum* and *L. minor* were significantly higher than the others. The low level of condensed tannin content does not seem to affect the nutritive of the four aquatic plants. The high crude protein contents of *A. nodiflorum* and *N. officinale* may be one of the reasons why they have a low gas production.

Table 2 Gas production (ml) and estimated parameters of four aquatic plants when incubated with rumen fluid

Incubation Time(h)	*A. nodiflorum*	*M. verticillatum*	*L. minor*	*N. officinale*	SEM	Sig.
3	21.6^{a}	25.2^{b}	24.5^{b}	20.5^{a}	0.552	***
6	32.5^{a}	36.8^{b}	37.3^{b}	31.8^{a}	0.456	***
12	42.5^{a}	46.8^{b}	48.2^{b}	43.2^{a}	0.612	***
24	54.8^{a}	59.1^{b}	59.1^{b}	56.0^{a}	0.443	***
48	63.6^{a}	67.6^{b}	68.3^{b}	63.2^{a}	0.565	***
72	69.5^{b}	72.5^{c}	74.8^{d}	68.0^{a}	0.390	***
96	73.3^{a}	77.0^{b}	79.0^{c}	71.5^{a}	0.565	***
		Estimated parameters				
c	0.078^{a}	0.097^{b}	0.088^{b}	0.085^{ab}	0.002	***
a	4.2^{b}	4.5^{b}	4.5^{b}	3.1^{a}	0.336	***
b	64.6^{a}	67.2^{b}	68.8^{c}	64.3^{a}	0.457	***
(a+b)	68.8^{a}	71.7^{b}	73.3^{c}	67.4^{a}	0.464	***
ME	10.8^{a}	11.4^{b}	11.7^{c}	11.6^{bc}	0.059	***

Means in the same rows with differing superscripts are significantly different, SEM: Standard error mean, Sig: Significance level, ***P<0.001, c: gas production rate (%), a: gas production (ml) from quickly soluble fraction, b: gas production (ml) from slowly fermentable fraction, ME: metabolisable energy (MJ/kg Dry Matter)

Conclusion The four aquatic plants studied have considerably high protein content, ME and so they have the potential value to be a good quality feedstuffs for ruminant animals. However further investigations are required to determine the effect of condensed tannin on voluntary food intake and animal performance.

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Effects of monensin and monensin and thiamine on feedlot performance of Mehraban male lambs given a high concentrate diet

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Introduction The addition of monensin to lambs feeding diets containing a high proportion of grain of results in improved feed efficiency (Joyer *et al*., 1979) and in some cases, increased daily gains (Calhoun *et al*., 1979) but thiamine deficiency can be a serious problem when high carbohydrate diets are fed (Loew, 1975). The objective of this experiment was to provide additional information on the possible benefits of the addition of monensin and thiamine to Mehraban male lambs fed with a high concentrate diet.

Materials and methods In a completely randomized design, arranged as a 3×4 factorial experiment, 70 Mehraban male lambs were assigned to one of 12 dietary treatments including group 1, without monensin or thiamine (mg/kg diet DM); group 2, thiamine (4mg); group 3, thiamine (6 mg); group 4, monensin (5.5 mg); group 5, thiamine (4 mg) plus monensin (5.5 mg); group 6, thiamine (6 mg) plus monensin (5.5); group 7, monensin (11 mg); group 8, thiamine (4 mg) plus monensin (11 mg); group 9, thiamine (6 mg) plus monensin (11 mg); group 10, monensin (22 mg); group 11, thiamine (4 mg) plus monensin (22 mg); group 12, thiamine (6 mg) plus monensin (22 mg). Basal diet consisted of 70% Barley, 10% wheat bran, 3% cotton seed meal, 8% alfalfa hay, 1.1% limestone, 7.5% corn silage and 0.4% mineral elements. Analysis of the diet indicated ME 11.5 Mj/kg DM, 12.05% crude protein, 25.46% NDF, 11.55% ADF and 1.3:1 Ca/P ratio. A 20-day adaptation period was applied and lambs were weighed every 20 days. Data were analysed according to the GLM procedure of the SAS and the differences amongst means were tested using SNK test ($P<0.05$).

Results Interaction of monensin and thiamine was only significant for feed gain ratio ($P<0.05$). All monensin levels resulted in lower DMI ($P<0.05$). Other effects were not significant.

Table 1 Mean (and EMS) of some of the measured parameters

	Groups					
Parameters	1	2	3	4	5	6
Initial BW (kg)	45.7	45.3	44.1	43.6	43.8	42.6
Final BW (kg)	55.6	58.0	57.8	55.5	55.2	55.2
Daily DMI (kg)	1.64	1.63	1.69	1.51	1.52	1.48
Daily gain (g)	141.7	180.9	196.4	170.6	162.9	180.9
Feed gain ratio	12.04^{a}	9.25^{ab}	8.91^{ab}	9.12^{ab}	9.57^{ab}	8.36^{ab}

Table 1 (continued)

	Groups						
Parameters	7	8	9	10	11	12	EMS
Initial BW (kg)	45.7	40.8	42.2	45.5	43.1	45.2	18.71
Final BW (kg)	56.2	54.2	54.5	57.7	53.6	56.5	7.73
Daily DMI (kg)	1.52	1.45	1.50	1.48	1.53	1.47	0.011
Daily gain (g)	151.2	191.7	176.2	173.8	150	161.4	1578
Feed gain ratio	10.61^{ab}	7.72^{b}	8.94^{ab}	8.76^{ab}	11.10^{ab}	9.29^{ab}	3.78

Means in the same row followed by similar superscripts do not differ at $P<0.05$.

Conclusions Supplementation of a high concentrate diet with 11 mg monensin plus 4 mg thiamine per kg diet DM resulted in a better feedlot performance of Mehraban male lambs.

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Effects of utilising sugar beet seed waste on feed lot performance of Chal male lambs

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Introduction Limited studies on evaluation of the nutritive value of sugar beet seed (*Beta vulgaris*) waste (SBSW**)** and its application in beef or lamb production have been carried out in its producing countries. SBSW is one of the side products of sugar beet seed which approximately a quarter of seeds can not be used in cultivation and is considered as waste. Consisting of 17% whole seeds and the rest as cracked seeds or hulls, SBSW contains 14.5, 32.5, 1.3, 16.9, 27.5, 39 and 49.9 percent CP, CF, EE, NFE, CF, Ash, ADF and NDF respectively .Also, SBSW contains 3.20 $Mcalkg^{-1}$ Potkanski and Urbaniak (1985) reported an improved average daily gain (ADG) and feed conversion ratio (FCR) in comparison to wheat straw because of its better essential amino acid index, which is close to wheat grain, but there is no report on its effects on fat tail composition. This trial was performed to examine SBSW replacement effects in fattening Chal lamb rations.

Materials and methods After basic studies on nutritive value of SBSW consisting of chemical composition, in vitro & in vivo digestibility and rumenal degradability, a fattening trial was carried out with 36 Chal lambs in a 100 days period. Mean weight of lambs were 29.5 Kg (±2.6) and they were 6-7 month aged. Based on randomized block experimental design with three weight groups (blocks) and 3 replicates for each block, lambs were fed by 4 levels of SBSW (0, 8, 16, 32%; DM basis) replacing the Alfalfa hay of base diet. Rations contained 56.5%barley grain, 2.5%cotton seed meal, 5%wheat straw, 1%mineral and vitamin premixes in addition to 35% of replacing forages as Alfalfa hay and SBSW as mentioned in Table 1. After a 21 days adaptation period, feed was individually delivered on the basis of body weight and their feed intake in the experimental period and wastes were collected and weighed every other day after oven drying for 72h in 60 ^{o}C. Lambs were weighed after a 16h fasting period, every other week. At the end of the trial, lambs were slaughtered and their empty body, fat free carcass and fat tail weights were determined and mean values were compared after analysis of Co-variance by Duncan's least significant range test while results had been corrected for age of the lambs as a covariate.

Results ADG, initial weight, final weight, and mean daily feed intake in the 84-d Trial period and also, Feed conversion Rate (FCR), Empty Body Weight (EBW), separable fat weight along with fat tail weight are shown in Table 1. Analysis of results showed that there is no significant difference while inclusion of SBSW instead of the base ration. Also, when different levels of SBSW were replaced in the rations used in this trial, Feed cost per kg ADG declined by 5, 9.2 and 19.8% for inclusions of 8, 16 and 32% SBSW respectively.

Table 1 Comparison of fattening parameters related to four rations containing sugar beet seed waste (SBSW)

Parameter	lambs	0%SBSW	8%SBSW	16%SBSW	32%SBSW	Diet Effect
Initial weight (kg)	36	28.8	30.6	29.1	29.6	ns[1]
Final weight (kg)	36	46.3	47.8	47.0	47.5	ns
ADG (kgd^{-1})	36	209	204	213	212	ns
Feed Intake($kgDMd^{-1}$)	36	1.34	1.33	1.43	1.41	ns
FCR (For Gain)	36	6.5	6.6	6.9	7.3	ns
EBW (kg)	36	23.7	24.6	24.3	33.7	ns
Visceral fat+ fat tail(kg)	36	4.8	4.6	5.2	5.3	ns
Carcass (% of BW)	36	51.2	51.5	51.7	49.9	ns
Visceral fat+ fat tail weight(%of BW)	36	20.0	18.6	21.3	22.3	ns

[1]ns: there is no significant difference between means

Conclusions No significant differences were observed in the production traits of Chal lambs offered feedlot diets containing up to 32% replacement with SBSW and, because of the low cost of SBSW in sugar beet producing regions, SBSW can be a good alternative in feedlot and maintenance diets.

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Chemical composition and *in vitro* organic matter degradability of various Iranian forages

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Introduction Saffron (*Crocus sativa*, SF) and Madder (*Rubia tinctorum,* MD) are planted for their stamen (used in food industry) and roots (used for dyeing) in northeast and central Iran respectively. *Artemisia siberi* (AR) is also a typical plant of the arid and semi-arid areas in Iran. The forage parts of these plants have been used as ruminant feedstuffs for many years. However, little is known about the nutritional value of these forages and so information about their composition and degradability characteristics is necessary in order to properly balance their use in ruminant diets. The objective of this study was to determine the chemical composition and extent of digestion of DM and OM of these plants compared with grass nuts (GN) as a reference feed by using an *in vitro* method (Chaudhry *et al*., 2002).

Materials and Methods The plant samples were harvested in April 2004, dried at 60°C for 72 h in a fan-assisted oven and their dry matter (DM) contents determined. Dried samples were then milled (<1 mm) and analyzed for CP, NDF, ADF and ash contents using standard laboratory procedures. Organic matter degradability (OMD) of each feedstuff was determined by using an *in vitro* fermentation method (Chaudhry *et al.* 2002). Rumen fluid was collected from two rumen fistulated sheep consuming fixed ratios (65:35) of grass hay and a concentrate. Rumen fluid from each sheep was squeezed through four layers of muslin and purged with deoxygenated CO_2 before its use as the inoculum. Approximately 0.5 g of each plant sample was weighed into a 50 ml plastic test tube to which 10 ml of the inoculum and 40 ml of a buffer (pH 7) were added. The tubes were flushed with CO_2 and capped with Bunsen valves. Duplicate tubes were incubated at 39°C for each inoculum from each sheep for 0, 4, 8, 16, 24, 48 and 72 h separately. After each incubation time, the tubes were chilled and then centrifuged at 3000 rpm for 15 minutes. Supernatants were then discarded and the residues were washed twice with distilled water. The samples were dried and weighed to determine the *in vitro* DM disappearance (DMD). The dried residues were then placed in a furnace using pre-weighed crucibles for ashing and subsequent determination of OM and OMD. Degradability parameters (a, b and c) were calculated using exponential equation of Orskov and Mcdonalds (1979) in FigP program. OMD data at different incubation times were also analyzed using GLM model in Minitab to determine the LS values for comparing means. The differences between means were declared significant if P <0.05.

Table 1 Chemical composition of feedstuffs

Feedstuffs	SF	MD	AR	GN
DM, *g/kg*	630	665	710	925
OM, *g/kg DM*	920	811	908	925
NDF //	334	386	525	547
ADF //	242	302	441	306
CP //	163	154	102	162
Ash //	80	189	92	75

SF: Saffron, MD: Madder, AR: Artemisia sp.
GN: grass nuts

Table 2 *In vitro* organic matter degradation (g/kg) of feedstuffs during different incubation times

Times	SF	MD	AR	GN	SEM
0	258^{a}	199^{b}	169^{b}	195^{b}	10.7
4	327^{a}	259^{b}	186^{c}	174^{c}	5.5
8	403^{a}	298^{ab}	210^{b}	248^{b}	24.9
16	516^{a}	398^{b}	279^{c}	400^{b}	17.8
24	625^{a}	490^{b}	343^{c}	504^{b}	14.1
48	720^{a}	627^{b}	413^{c}	651^{ab}	14.4
72	764^{a}	718^{b}	471^{c}	696^{b}	7.5

Means within rows without common superscripts differ (p<0.05).

Results Table 1 shows the chemical composition whereas Table 2 presents the OM degradation over various times of different feedstuffs. There was a significantly greater (p<0.05) washing loss (parameter a) of OM from Saffron compared to other feeds. In fact the OMD of this plant was significantly greater than other feeds at most times of incubation (P<0.05). OMD for Madder was almost comparable to that of grass nuts at most times although its ash contents were about twice higher than those of grass nuts. Artemisia showed lower OMD at each time and so a lower rate (c) of degradation compared with other feeds including grass nuts despite having the same level of NDF compared to grass nuts. The slowly degradable fraction (b) also differed for different feeds (P<0.05).

Conclusions Both the chemical composition and the degradability data suggest that the saffron forage perhaps had the higher nutritional value compared with other feeds of this study. The degradability profile of Madder was also comparable to that of grass nuts. The lower OMD of Artemisia compared with other feeds could be due to its lowest CP and highest ADF contents. However, due to its suitability for growth in many natural areas of Iran, its plantation and cultivation need careful attention. Further research should determine the nutritional value at various maturities of theses plants for their subsequent inclusions in diets to improve ruminant health and production.

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Crude protein content and ruminal degradation kinetics of eight pasture species

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Introduction Ration formulation systems require information on nutrient requirements of the animal and reliable values for rumen degradable and undegradable fractions of feed ingredients. Ruminally degraded protein in excess of microbial requirement results in nitrogen loss as ammonia and inefficient nitrogen utilization by ruminants. Protein degradation kinetics of most oilseed meals and some forages have been determined (Sadeghi et al., 2004; Wilkerson et al., 1995), but minimal information exists regarding ruminal protein degradation of pasture forages. The objective of this research was to determine ruminal dry matter (DM) and crude protein (CP) degradation kinetic parameters of eight pasture species.

Materials and methods Forage samples (*Vicia villosa, Bromus tomentellus, Hordeum bulbusum, Festuca ovina, Agropyron tauri, Agropyron trichophorum, Prangus ferulacea and Ferula orientalis*) were collected by hand after plotting at the pre-flowering stage in spring. Samples were placed in a forced-air oven (50°C) until dry, then analyzed for dry matter and nitrogen according to AOAC (1990). Three Varamini wethers (BW = 46.4 ±4.2 Kg) fitted with rumen fistulas were used to determine *in situ* disappearance characteristics of forage DM and CP (AFRC, 1992). The forage samples were incubated for 0, 6, 12, 24, 48 and 72 h. The exponential model of Orskov and McDonald (1979) were used to describe the DM and CP degradation parameters of forage samples. The effective rumen degradation (ERD) of DM and CP were analyzed by a variance analysis GLM procedure of SAS in a completely randomized design according to this model: $Y= \mu + Ti + Eij$, where μ is overall average, Ti is the forage effect and Eij is the residual error.

Results and discussion Crude protein contents of eight pasture species are shown in Table 1. The highest CP content was for *Vicia villosa* (19.7%) and lowest for *Agropyron trichophorum* (7.2%). The results showed that effective DM degradation of eight pasture forages in the rumen were significantly ($p<0.05$) different (Table. 1). The effective DM degradability at rumen out flow rate 0.02/h was highest for *Prangus ferulacea* (78.0%) and lowest for *Festuca ovina* (37.1%). Degradation rate of DM "b" fraction was highest for *Festuca ovina* (7.3%/h) and lowest for *Agropyron trichophorum* (3.7%/h).

Table 1 Crude protein content and *in situ* DM and CP degradation parameters of eight pasture forages

Pasture species	CP content	DM degradation traits			ERD	CP degradation traits			ERD	RSD
		a	b	c		a	b	c		
	% of DM	%	%	%/h	%	%	%	%/h	%	
Vicia villosa	19.7	31.0	43.7	5.5	63.0^{d}	34.5	50.6	9.6	76.3^{c}	3.2
Bromus tomentellus	14.3	29.1	56.3	4.1	67.2^{c}	37.2	58.3	10.2	85.9^{a}	2.4
Hordeum bulbusum	9.4	16.5	36.2	4.9	39.4^{g}	12.8	44.5	8.8	49.0^{ef}	1.9
Festuca ovina	5.4	11.3	33.0	7.3	37.1^{h}	10.8	45.6	9.1	48.1^{f}	3.6
Agropyron tauri	12.3	19.2	51.5	6.0	57.9^{e}	28.7	48.9	11.8	70.5^{d}	3.3
Agropyron trichophorum	7.2	19.9	45.0	3.7	49.4^{f}	22.3	43.5	8.6	57.6^{e}	2.5
Prangus ferulacea	12.2	41.6	48.3	6.0	78.0^{a}	31.3	59.5	12.2	82.4^{b}	1.6
Ferula orientalis	10.2	49.0	37.7	4.4	75.0^{b}	35.6	43.3	10.3	71.8^{cd}	2.9

a: immediately soluble fraction, b: potentially degradable fraction, c: degradation rate. ERD: Effective Rumen degradation at 0.02/h rumen outflow rate; level of significant: $p<0.05$; RSD: Residual Standard Deviation

The effective rumen degradation and degradation characteristics of CP were significantly ($p<0.05$) different (Table 1). The effective rumen degradation of CP at rumen out flow rate 2%/h was highest for *Prangus ferulacea* (82.4%) and lowest for *Festuca ovina* (48.1%). Degradation rate of CP "b" fraction was highest for *Prangus ferulacea* (12.2%/h) and lowest for *Agropyron trichophorum* (8.6%/h).

Conclusion The rate and extent of protein degradation were different among pasture species, therefore this parameters must be considered as main parameters in ration formulation of sheep and cattle under extensive production systems.

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The effect of live yeast (*Saccharomyces cerevisiae-1026*) on rumen fermentation parameters and blood metabolites of sheep

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Introduction Inclusion yeast in the diet of ruminants increases the density of active metabolic cells in rumen. These cells can stimulate the action of special kinds of microorganisms in the digestive tract (1). One of the most outstanding ability of yeast is to stimulate the cellulytic bacteria of rumen (7). Increased initial rate of cellulose digestion by yeast can improve the efficiency of feed and make available more nutrients for growth and milk production (2, 3). Furthermore, improved ruminal digestion may increase feed intake, and this effect specially for voluminous feed which are less consumed because of the physical limitation resulted from filled rumen is more prominent(7) . On the other hand enhanced bacteria population of rumen may result in increased synthesis of microbial protein and may increase the incorporation of microbial population in digestive tract. Lower concentration of ammonia in the rumen indicating incorporation of ammonia into microbial protein is the direct result of stimulated microbial activity (3, 4, 5, 6). This paper reports the effects of yeast culture *Saccharomyces cervisae* (1026) on ruminal fermentations and blood metabolites of an Iranian native breed of sheep.

Materials and methods Four Balouchi lambs at approximately 6 months of age and mean weight of 35±4 Kg were randomly assigned to two treatment groups. Yeast (1026) supplement contained 1-1.5 $\times$ 10^{10} live cells per gram with 96.6% of dry matter and 46% of crude protein. Samples were collected over a 108-day period at 27-dayintervals (including 10 days of transition period, 14 days of adaptation to the new diet and 3 days of sampling). Data were analyzed as a change-over split-split- plot design with one animal in each group, based on completely randomized design using the GLM procedure of SAS.

Results Yeast culture did not have considerable effect on ruminal fluid of lambs fed HY diet; only it slightly increased the pH from 6.38 to 6.58 during 3 hours after feeding. Also in lambs received CY diet, two hours after feeding an slight increase was observed due to yeast function (6.05 to 6.22). Both HY and CY treatments significantly affected the ammonia concentration of ruminal fluid; HY decreased ($p<0.05$) the ammonia contents of ruminal fluid during 1 to 4 hours after feeding and CY showed similar effect during 0.5 to 3 hours after feeding(table1). Blood urea was significantly decreased 3 hours after feeding by HY diet in compared with animals fed H diet (10.72 vs. 13.76mg/dl). CY significantly prevented the blood urea from increasing two hours after feeding in comparison with C treatment (10.69 vs. 13.74 mg/dl). The production of microbial protein exhibited slight increase in HY treatment (7.48 vs. 6.03 g) and for CY its increase was not significant, (5.85 vs. 5.53 g) enhance.

Table 1 Concentration of ruminal N-NH_3 in lambs (mg/dl)

	Time of sampling before and after feeding (Hour)								
Treatment	-0.5	0.5	1	2	3	4	6	8	SE
HY	10.34	10.79	11.92	9.97	8.34	6.58	9.94	7.83	0.46
H	12.99	13.03	15.89	16.48**	11.79	12.16**	12.05	8.52	0.73
CY	16.76	15.79	16.21	17.82	11.48	13.64	13.66	11.79	0.66
C	16.41	19.40	20.39*	24.25**	16.82**	12.57	12.12	9.99	0.97

** P< 0.01, * P < 0.05

Conclusions The results of present study show that yeast may increase the efficiency of nitrogen utilization due to increased ammonia consumption by microorganisms existed in rumen.

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The effect of β-glucanase supplementation on the apparent metabolizable energy and nutrient digestibilities of different barley cultivars for young broiler chickens

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Introduction Despite of high production of barley in Iran, its use in poultry diets is limited due to low energy content and problems such as sticky droppings. Barley cultivars have different nutritive value for broilers (Villamide, *et al*., 1997) and enzyme application may affect barley cultivar based diets differently. β-glucanase supplementation of barley based diets can eliminate β-glucan, the main anti-nutritional factor of barley, and improve nutrient digestibilities and apparent metabolizable energy. The objective of this trial is to study the β-glucanase effect on nutrient digestibilities and apparent metabolizable energy corrected for nitrogen (AMEn) of different barley cultivar based diets.

Materials and methods 200 one-week old Ross male chickens were allocated to 10 experimental diets with 5×2 factorial arrangement in a completely randomized design. Each treatment had 4 replicates and there were 5 chicks in each pen. The first factor was 5 barley cultivars (CB-74-2, Kavir, Makoie, Reyhan and Valfadjr) and the second factor was enzyme (Endofeed, containing 550 U/g β-glucanase and 800 U/g arabinoxylanase, GNC, Bioferm, Inc., Canada) addition with 2 levels (0 and 0.1% of diet). Excreta was collected for experimental assay twice a day following Cr_2O_3 (0.3% of diet) feeding over 18-21 d of age. Approximate analyses of feed and excreta samples were carried out according to methods of AOAC (1990). AMEn of diets was determined by the method of Sibbald and Slinger (1963). Barley extract viscosity was measured after extraction by KCl-HCl (pH=1.5) buffer using a Brookfield DV^{++} viscometer. The data were subjected to analysis of the variance, using the GLM procedure of SAS (SAS Institute, 1985) and Duncan's Multiple Range Test was used to compare treatment means.

Results Barley extract viscosities are shown in Table 1. Kavir had the highest viscosity. Digestibility of dry matter (DMD), organic matter (OMD), and fat (FD) of experimental diets as well as nitrogen retention (NR) and AMEn are illustrated in Table 2. Barley cultivar had a significant (P<0.01) effect on all parameters. Birds fed with Reyhan and Valfadjr based diets showed the highest values for all measured parameters. The lowest fat digestibility and AMEn were observed in birds were fed Kavir barley. Apart from nitrogen retention, all other parameter values were significantly (P<0.01) affected by the addition of enzyme. There were also significant barley cultivar by enzyme interactions for DMD (P=0.05) and FD (P<0.001).

Table 1 Extract viscosity of barley cultivars

Cultivars	CB-74-2	Kavir	Makoie	Reyhan	Valfadjr
Viscosity (cP)	3.03	4.11	3.21	2.29	1.71

Table 2 Nutrient digestibilities and metabolizable energy corrected for nitrogen of experimental diets on 18-21 days old male broiler chicken

	CB-74-2		Kavir		Makoie		Reyhan		Valfadjr		s.e.m.
	-	+	-	+	-	+	-	+	-	+	
DMD(%)	60.63^{el}	69.65^{bc}	68.01^{bcd}	72.10^{ab}	64.95^{cde}	63.49^{ed}	73.29^{ab}	75.90^{a}	71.29^{ab}	72.20^{ab}	1.074
OMD(%)	63.91	77.55	70.05	74.53	67.46	67.05	75.62	77.92	73.92	74.95	0.986
FD(%)	75.00^{c}	78.93^{bc}	63.35^{d}	80.96^{ab}	75.50^{c}	77.86^{bc}	82.23^{ab}	85.49^{a}	82.59^{ab}	82.11^{ab}	1.089
NR(%)	55.86	63.88	62.99	59.38	60.94	58.74	70.81	72.17	69.90	73.72	1.520
AMEn (kcal/kg)	2832	3145	2630	2865	2880	2860	2973	3078	2939	3045	45.896

[1]Means with different superscripts within a row are significantly different (P<0.05)

Conclusions under the conditions of this study, it can be concluded that β-glucanase supplementation did not have a similar effect on all barley cultivars. The most positive effect of enzyme addition was observed for the diet based on barley with the highest extract viscosity (Kavir).

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Use of silkworm pupae meal as protein supplement in the nutrition of broiler chickens

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Introduction Silkworm pupae meal is a silk industry by-product that in some countries is available as a local product. It contain up to 30% crude fat and 50% crude protein. The chemical score of silkworm pupae protein is 60 and tryptophan is its limiting amino acid. The silk worm pupae meal fat contains 25.7% linoleic acid (Udayasekhara Rao, 1994). Reddy et al (1991) reported that use of diets contain 5% 8% SWP so that replaced 50% of fish meal, lowered weight gain. The aim of this study was to measure the effects of substituting different levels of silkworm pupae (SWP) for soybean meal (SBM) in Arian (an Iranian strain) broiler rations.

Material and methods A control ration based on corn and soybean meals as the sole protein supplement (treatment 100% SBM) was formulated based on NRC 1994 (ME=2900 Kcal/Kg and CP= 20.84%, 18.13% and 16.3% for starter, grower and finisher diets respectively). In three treatments, 8, 16 and 24 percent of the crude protein contributed by the SBM was substituted by fishmeal (treatments 8% FM 16% FM and 24% FM respectively) and in the next four treatments 8, 16, 24 and 32 percent of the CP contributed by SBM was substituted by silkworm pupae meal (treatments 8% SWP, 16% SWP, 24% SWP and 32% SWP respectively). The experiment was conducted on a completely randomized design with 8 treatments and 3 replicates of 20 mixed sex broiler chicks. Body weight gain during 54 days period, feed intake and feed conversion rate were determined on a periodic basis at the end of the starter, grower and finisher periods. Carcass weight and dressing percentage were determined at the end of the rearing period. Data were analyzed by using the GLM procedure of SAS and significant differences between means separated by Duncan's multiple range test.

Results Table 1 show the chemical composition of silkworm pupae meal composition used in this experiment. The results in table 2 show that feed intake in diets containing FM in the starter, grower and finisher periods was higher than those containing SWP. The diets containing FM in the starter and grower periods had higher weight gains compared to diets containing SWP, although diets containing SWP had higher weight gains in the finisher period.
There was no significant difference in feed conversion rates between treatments containing FM and SWP in the starter and grower periods, although the diets containing SWP had lower feed conversion compared to those containing FM at the end of the finisher period ($P<0.05$). There was no significant difference in feed conversion between SWP and FM diets in the starter and grower periods, but in the finisher period, SWP diets had significantly lower feed conversion ($P<0.05$). No significant difference in carcass traits and mortality rats between FM and SWP containing, were observed.

Table 1 chemical composition of silkworm pupae meal

Dry matter	94.8%	ME	2900(Kcal/Kg)	P	0.53%	Met+Sys	1.93%
Ether extract	27%	CP	51%	Na	0.12%	Lys	3.26%
Ash	3.2%	Ca	0.6%	Met	1.4%	Trp	0.67%

Table 2 performance traits of experimental treatments*

	Feed Intake (g)			Weight Gain (g)			Feed Conversion Ratio		
Treatment	Starter	Grower	Finisher	Starter	Grower	Finisher	Starter	Grower	Finisher
100% SBM	754.1^{b}	2509^{b}	2150^{ab}	396^{bc}	1154^{bc}	745^{a}	1.90^{a}	2.18^{a}	2.74^{abc}
16% FM	758.9^{ab}	2641^{ab}	1947^{abc}	426^{ab}	1224^{ab}	673^{ab}	1.78^{a}	2.16^{a}	2.93^{ab}
24% FM	793.5^{a}	2671^{a}	1975^{ab}	432^{a}	1236^{a}	619^{b}	1.84^{a}	2.16^{a}	3.20^{a}
24% FM	753.0^{b}	2673^{b}	2105^{b}	431^{a}	1249^{a}	765^{a}	1.75^{a}	2.14^{a}	2.76^{abc}
8% SWP	688.5^{ab}	2688^{ab}	1760^{c}	389c	1295^{c}	739^{a}	1.77^{a}	2.12^{ab}	2.40^{c}
16% SWP	754.6^{b}	2603^{b}	1964^{ab}	416^{abc}	1223^{ab}	769^{a}	1.82^{a}	2.13^{a}	2.56^{bc}
24% SWP	724.9^{b}	2498^{b}	1894^{bc}	402^{abc}	1237^{ab}	792^{a}	1.81^{a}	2.02^{b}	2.34^{c}
32% SWP	723.7^{b}	2573^{ab}	1942^{abc}	404^{abc}	1189^{ab}	775^{a}	1.79^{a}	2.16^{a}	2.52^{bc}
MSE	11.5	48	60	9.8	24.6	38.2	0.05	0.034	0.147

*Means within a column with no common superscripts differ significantly ($P<0.05$)

Conclusions The treatment with the highest silkworm pupae meal content (32% SWP) had 9.8, 7.5 and 5.92 percent SWP for starter, grower and finisher diets respectively and results of this study indicating that silkworm pupae meal can be used as a dietary ingredient in broiler diets, but as a sole protein supplement it can affect bird's performance.

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Effects of mineral premix withdrawal or reduction on broilers performance

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Introduction Many studies have been carried out to reduce dietary mineral premix level with no adverse effect on broiler performance. Controversial results have been reported in this respect. Deyhim et al (1994) showed that at normal temperature and also under heat stress at 28-49 days of age, removing mineral and vitamin supplements cause reduction in performance, but withdrawal of mineral premix alone, didn't affect production. Christmas et al (1995) suggest that it is possible to removing vitamin and mineral supplements from finisher diets of broiler chickens at last week of raring period. The aim of this trail was study of effect of withdrawing or reduction mineral premix from diets with normal vitamin premix level on broilers performance.

Material and methods This experiment was conducted in a completely randomized design and included 280 Cobb broiler chicks (male and female) which divided into 7 groups with 4 replicates. Chickens were fed on a common starter diet with suggested mineral premix level (0.5%) at weeks 1, 2 and 3 and experimental period started from week 4. During the experiment, seven experimental groups (T1-T7) used diets with these mineral premix contents: T1- 0.5% at weeks 4 to 6, T2- 0.5% at weeks 4 and 5, and 0.25% at week 6, T3- 0.5% at week 4 and 0.25% at weeks 5 and 6, T4- 0.25% at weeks 4 to 6, T5- 0.5% at weeks 4 and 5 and zero at week 6, T6- 0.5% at week 4 and zero at weeks 5 and 6, and T7- omitting mineral premix at weeks 4, 5 and 6. All of the diets were isocaloric and isonitrogenous and formulated based on NRC 1994 with 2900 Kcal /Kg ME and 20.84 and 18.12 percent crud protein for starter and grower diets respectively. All commercial management practices were maintained. Each Kilogram of Mineral premix used was contain Mn 40000 mg/Kg, Zn 37000 mg/Kg, Fe 20000 mg/Kg, Cu 4000 mg/Kg, I 400 mg/Kg, cholin choloride 10000 mg/Kg and Se 80 mg/Kg. Feed intake and weight gain were measured at the end of each week and feed conversion ratio calculated. Data were analysed by analysis of variance using general linear model (GLM: Statistical Analysis System Institute (SAS)).

Results Table 1 show that reduction or withdrawal of mineral premix from diets in different weeks of grower period, did not affect feed intake mean ($P<0.05$). In weeks 4 and 5, there was not any significant difference in weight gain and feed conversion ratio ($P<0.05$), but in week 6, weight gain of treatment T1 was significantly higher and its feed conversion ratio was significantly lower than other treatments ($P<0.05$). There was not any significant deferens in these respects between other treatments.

Table 1 Feed intake, weight gain and feed conversion of experimental treatments*

	Feed Intake Mean (g/d)			Weight Gain Mean (g/d)			Feed Conversion Ratio		
	week			week			week		
Treatment	4	5	6	4	5	6	4	5	6
T1	94.3	130.5	152.2	46.7	60.1	76.5[a]	2.02	2.18	1.99 [a]
T2	94.2	130.9	152.7	46.9	61.5	70.2 [b]	2.01	2.14	2.18 [b]
T3	95.1	131.5	152.6	47.6	61.1	71.5 [b]	2.00	2.15	2.16 [b]
T4	94.8	131.2	153.3	48.1	62.1	72.5 [b]	1.97	2.02	2.13 [b]
T5	94.9	131.9	153.9	47.1	62.1	70.6 [b]	2.03	2.14	2.18 [b]
T6	95.1	131.8	154.1	48.8	63.9	70.2 [b]	1.95	2.09	2.20 [b]
T7	95.3	131.2	153.7	48.1	63.8	69.3 [b]	1.98	2.07	2.23 [b]
Mse	5.6	9.2	13.3	4.1	4.8	5.3	0.12	0.15	0.16

* means within a column with different superscript differ significantly ($P<0.05$)

Conclusions Results showed that commercial recommended levels for dietary mineral premixes can be more than broilers requirements and reduction or removing them from diets at part of growth period do not affect animal performance adversely, but longer withdrawal period can affect chicken growth.

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The effect of different dietary unsaturated to saturated fatty acids ratios on the performance and serum lipids in broiler chickens

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Introduction Fat saturation degree and the age of bird are two important factors for broilers' ability to digest fats. It has been shown that hepatic fatty acid synthetase activity is decreased by diets with added sunflower oil (rich in PUFA of n-6 series) compared with those fed lard and this can result in abdominal fat pad reduction. (Sanz *et al*., 2000). It is well known that dietary intake of n-6 and n-3 PUFAs is effective in lowering blood lipid level, but they differ in their effect on serum lipid concentrations. It has been observed that n-6 fatty acids lower serum cholesterol level, but not triacylglycerol; n-3 fatty acids lower both serum cholesterol and serum triacylglycerol level in experimental animals (Berr *et al*., 1993). The objective of this study was to survey the effects of different dietary unsaturated to saturated fatty acids ratio on performance, abdominal fat pad and serum lipids in broiler chickens.

Materials and Methods 360 one day old Ross male broiler chickens were randomly assigned to a completely randomized
design with 4 treatments and 3 replicates on body weight basis. All chicks were fed a standard starter diet from 1 to 10 day of age. They were then fed their assigned treatments. Tallow and sunflower oil were used to formulate four isoenergetic and isonitrogenous diets (ME=13.4 MJ/kg and crude protein=21% and 19% for grower and finisher periods respectively) with different unsaturated to saturated fatty acids ratios (U/S) (2, 3.5, 5 and 6.5). The birds had 24-h access to feed, water and light. All commercial management practices were maintained. At 28 and 42 d of the experiment body weight gain, feed intake and feed conversion ratio were measured and five birds in each treatment replicate were killed and their abdominal fat pad and carcass weights were measured. Simultaneous with slaughter, blood sample from 4 birds in each replicate was collected and their serum was separated. Serum cholesterol and triacylglycerol were measured. Data were analyzed by using the GLM procedure of SAS (SAS Institute, 1995) and significant differences between means separated by Duncan's multiple range test.

Results In the grower period (10-28 d) unsaturated to saturated fatty acids ratio did not have a significant effect on broiler performance, but in the finisher period (29-42 d) reducing dietary U/S ratio up to 2 significantly ($P<0.05$) reduced weight gain and increased feed conversion ratio. Chicks fed 2 U/S diet had a significantly higher serum cholesterol concentration at 28 and 42 days old ($P<0.05$). Serum triacylglycerol levels were not affected by dietary treatments at 28 d, but at 42 d were significantly decreased when 6.5 U/S diet was used ($P<0.05$). The diet with 3.5 U/S ratio significantly ($P<0.05$) reduced abdominal fat pad percent at 28 and 42 d old.

Table1 Means of performance parameters, serum lipid levels and carcass and abdominal fat pad percents*

	Grower period							Finisher period						
U/S	FI	Gain	FCR	Cho	TG	Car	Fat pad	FI	Gain	FCR	Cho	TG	Car	Fat pad
	(g/chicken/d)			(mg/dl)		(%)		(g/chicken/d)			(mg/dl)		(%)	
2	89.39	65.28	1.369	131^{a}	28	63.72	1.26^{a}	174.36	88.11^{a}	1.979^{a}	96^{a}	30^{a}	63.29	1.52^{a}
3.5	88.40	63.75	1.387	113^{b}	34	62.75	1.04^{b}	178.25	93.13^{b}	1.914b	87^{b}	37^{a}	61.60	1.28^{b}
5	88.27	65.09	1.356	114^{b}	31	62.22	1.11^{ab}	180.03	94.39^{b}	1.907^{b}	85^{b}	36^{a}	60.61	1.48^{a}
6.5	88.01	62.91	1.399	117^{ab}	27	63.02	1.28^{a}	177.31	92.16^{b}	1.924b	89^{b}	21^{b}	62.86	1.48^{a}
SEM	3.83	2.71	0.059	5.16	4.5	2.42	0.123	6.11	3.98	0.083	3.88	1.34	2.67	0.062

*means within a column with different superscript differ significantly ($P<0.05$)
FI=feed intake; FCR=feed conversion ratio; cho= cholesterol; TG=triacylglycerol; Car=Carcass

Conclusions Because weight gain in chickens fed 2 U/S ratio diet was significantly less than other treatments at finisher period, it seems that continued use of saturated fats can affect broiler performance. According to these data, reducing abdominal fat pad content was achieved in chickens fed 3.5 U/S diet but this reduction was not a linear function of U/S ratio. The changes in serum lipids indicate the role of dietary fat type and also age of bird on lipid metabolism.

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Performance and biochemical parameters of broiler chicks fed aflatoxin-contaminated and ammonia-treated corn

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Introduction Aflatoxins (AF), natural contaminants of food stuffs and are toxic metabolites produced by *Aspergillus flavus* and *A. parasiticus*. Aflatoxins damage the liver, kidney and thymus resulting in a variety of effects including decreased growth rate, poor productivity and immunosuppression. Recently we have reported that ammonia solution can directly inhibit aflatoxin production in *Aspergillus parasiticus* in culture growth (Namazi et al., 2001). A study was conducted to determine the efficacy ammoniation of contaminated-corn with aflatoxin in decreasing aflatoxin in diet of broiler chicks and its effects on production and biochemical parameters.

Materials and methods In this study 320 day-old male chicks (Ross 308) were used in four treatment with four replicate each with 20 chicks in completely randomized design. These treatments were as follows: Group-1, Control; basal diet, Group-2, Basal diet containing treated corn with 0.1% ammonium, Group-3, Basal diet containing corn with 2 ppm AFB1(The final AFB_1 concentrations was 1280 µg Kg^{-1} feed), Group-4, Basal diet containing corn with 2 ppm AFB1 and ammoniated (0.1% V/W) (The aflatoxin level was 10ppb). Aflatoxin was produced on rice as a natural substrate toxigenic *A. parasiticus* (isolate #14) was first cultured on rice by inoculating fungal spores ($6.5x10^6$ - $7.0x10^6$) on rice as a natural substrate. Aflatoxin in feedstuffs titrated by TLC and HPLC. A homemade 200-kg capacity ammoniation tank equipped with controlled temperature and moister control together with ammonia vapor generator was used to inactivate aflatoxins on the contaminated corn under controlled pressure, temperature (40-50^0), and moisture(18%). At the end of the process, (48-h) corn grains spread at room temperature for 6-7 days to allow drying to minimize unpleasant smell. Blood was collected in non-heparinized tubes from 20 birds in each treatment at the end of 3 and 6th week of age, then serum prapared and was stored for total protein, albumin analysis.

Results These experiment showed that pretreatment of corn with 1% aqueous ammonia in the inactivation unit for 48h almost completely removed aflatoxins, based on AFB level as the representative mycotoxin. The results showed that ammonia-treatment of contaminated-corn improved feed conversion ratio as well as body weight ($P<0.05$). Relative weight (g/100g.b.w.) of the livers in third group was significantly increased as compared with the control ($P<0.05$)(Data unshown). Serum total protein and albumin decreased significantly ($p<0.05$) in diets contaminated with aflatoxin.

Experimental group	Body weight gain(g/d)		Dietary intake (g/d)		Feed conversion Ratio	
	d.21	d.42	d.21	d.42	d.21	d.42
A(cont.)	20.3^a	38.5^a	36.1^a	75^a	1.78^a	1.95^a
B	20.8^a	39 ^{a}	35.6^a	79.1^a	1.71^a	2.03^a
C	14 ^{b}	26^b	28^b	60.7^b	2.02^b	2.32^b
D	19.7^a	36.8^a	36.4^a	75.6^a	1.84 ^{a}	2.05^a
s.e.m	0.48	0.85	1.2	2.8	0.22	0.18

Table1 Mean feed intake, body weight and feed conversion ratio*
*means within columns with no common superscripts differ significantly ($p < 0.05$).

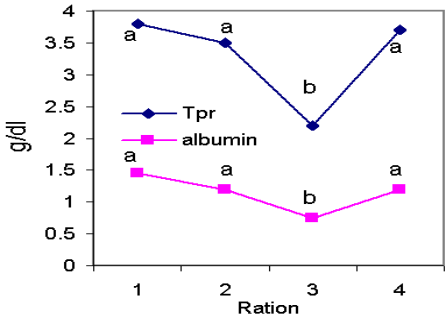

Figure 1 Effects of treatments on Total protein (Tpr) and albumin in 42 d of age.

Conclusions Aflatoxicosis is an important problem in poultry and livestock industry due to its profound effects on growth and the frequent contamination of feed by these mycotoxins. The increase in relative weight of liver could be attributed to increases lipid deposition due to impaired fat metabolism (Tung et al., 1972). The depression in body weight, feed intake and feed efficiency upon aflatoxin intake has been attributed to reduced protein synthesis, impaired nutrient absorbtion and reduce pancreatic digestive enzyme productions (Swamy and Devegowda.,1998). Impaired liver function and protein/lipid utilization mechanisms may also have affected growth and general health. Treatment of aflatoxin-contaminated corn in pilot-plant scale inactivated aflatoxins and feeding of this diet improved the feed intake, body weight gain and feed efficiency values. This study indicated that ammoniation process described effectively modulate the toxic effects of aflatoxin on production and biochemical parameters compared to controls.

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Effect of microbial phytase on apparent digestibility of amino acids and minerals in diet of female broiler chickens

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Introduction Phytic acid is the main storage form of P in grains and seeds. Cereals and grain legumes that are commonly used as poultry feed ingredients have similar phytate levels, approximating 0.25 percent of dry matter (Ravindran et al., 1995). There is not enough phytase activity in the digestive tract of chickens to digest phytate (Maenz and Classen, 1998). Phytate contributes to environmental pollution by reducing mineral and N bioavailability. The capacity of phytic acid to bind minerals reduces the utilization of P, Ca, Zn, Fe and N from plant ingredients by chickens (Sell et al., 2000). Phytate may form complexes with proteases, such as trypsin and pepsin in the gastrointestinal tract (Singh and Kricorian, 1982). These complexes may reduce the activity of digestive enzymes with a subsequent decrease in the digestibility of dietary proteins. It has been reported that microbial phytase improves the utilization of amino acids (Ravindran et al., 1999) and minerals in broiler chicks. The objective of the present study was to evaluate the effect of microbial phytase on the apparent digestibility of amino acids (AA) and some minerals in the diet of female broiler chickens.

Materials and methods 240 day-old female chicks of a commercial strain (Ross 308) were wing banded**,** weighed and randomly allocated to six treatment groups with four replicates of 10 chicks in each floor pen. The treatments involved supplementation of 0, 250, 500, 750, 1000 and 1250 FTU microbial phytase/kg of a commercial diet from 0 – 28 days of age. Ca, available and total P levels in the diet were 1.0, 0.46 and 1.0 % respectively. During days 21 to 24, excreta from 4 birds of each replicate were totally collected after transferring to battery cages. The excreta were freeze-dried, weighed and ground through a 1 mm mesh screen. Excreta and feed samples were hydrolyzed for 24 h with 6 M HCl at 110C for the determination of AA by HPLC using the Pico-Tag system. Ca, Fe and Zn levels were determined by atomic absorption spectrophorometry after wet acid digestion with concentrated HNO_3. Total P levels were determined by spectrophotometry at 400 nm after digestion with H_2SO_4. Analysis of variance and Duncan's new multiple range test were conducted using the GLM procedure of SAS (SAS Inc., 1988) appropriate for a completely randomized design.

Results Microbial phytase had a significant effect ($P<0.05$) on apparent digestibility of nondispensable amino acids (except threonine, alanine and valine), Fe and Zn. As shown in Table 1, 250 and 500 FTU of phytase/kg of diet, significantly increased apparent digestibility of amino acids but higher levels of phytase caused poorer digestibility. Phytase had no significant effect ($P>0.05$) on P and Ca apparent digestibility but increased apparent digestibility of Fe and Zn at the level of 250 FTU.

Table 1 Effect of microbial phytase on apparent digestibility of amino acids and minerals in female broiler chickens

Phytase	Amino acids (%)									Minerals (%)			
(FTU)	LYS	LEU	ILE	HIS	THR	ARG	ALA	VAL	PHE	Ca	P	Fe	Zn
0	88.1^{b}	86.4^{b}	84.3^{b}	88.0^{d}	86.0	91.4^{c}	86.2	79.8	87.2^{b}	54.5	77.4	70.6^{b}	62.7^{b}
250	92.2^{a}	90.4^{a}	89.1^{a}	92.4^{ab}	88.0	95.1^{ab}	85.7	84.1	91.4^{a}	56.0	80.0	79.3^{ab}	72.7^{ab}
500	93.1^{a}	90.8^{a}	89.5^{a}	93.2^{a}	88.6	96.0^{a}	85.7	84.3	91.8^{a}	55.1	81.4	78.7^{ab}	71.3^{ab}
750	90.1^{ab}	88.1^{ab}	86.0^{ab}	89.7^{cd}	84.2	92.4^{bc}	82.9	83.3	89.1^{ab}	54.9	79.3	76.8^{ab}	72.2^{ab}
1000	91.4^{ab}	88.5^{ab}	86.1^{ab}	90.8^{abc}	86.4	94.5^{ab}	82.1	83.0	90.3^{ab}	55.8	78.6	78.7^{ab}	71.2^{ab}
1250	90.7^{ab}	88.9^{ab}	87.1^{ab}	90.0^{bcd}	86.9	93.7^{abc}	88.5	83.9	90.4^{ab}	57.2	80.0	86.3^{a}	74.4^{a}
SE	0.99	0.96	1.10	0.81	1.73	0.83	3.24	1.98	1.03	1.2	1.6	3.9	3.3

^{abc} Means in the same column with a different superscript are significantly different ($P<0.05$)

Conclusions The results under the conditions of this study indicated that supplementation of 250 FTU phytase/kg of a commercial diet increased apparent digestibility of more essential amino acids, Fe and Zn in female broiler chickens.

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The effect of low crude protein diets supplemented with DL-methionine and L-lysine hydrochloride on male broiler performance

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Introduction Crude protein is an expensive nutrient in broiler diets and the supply of essential amino acids is more important than crude protein. Therefore it's possible to reduce crude protein level by supplementing diets with methionine and lysine as limiting amino acids. The object of this study was assaying low protein diets supplemented with DL-methionine and L-lysine hydrochloride on male broiler chicks.

Materials and methods In a completely randomized design experiment: 500 one-day chickens were distributed randomly to 5 treatments and 4 replications for each treatment in 20 pens of 25 male broiler chicks. The experimental diets were fed for 49 days. All of diets were formulated to supply 2900 kcal metabolizable energy /kg feed and other nutrients according to NRC (1994) recommendations. Crude protein level of diets has been showed in Table 1. In experimental groups, the crude protein levels of the diets were decreased by 5%, 10%, 15% and 20% of the control.

Table 1 Crude protein of diets in different periods (%)

Treatments	Starter (0-3 weeks)	Grower (4-6 weeks)	Finisher (7 week)
Control	20.84	18.12	16.3
T95	19.8	17.22	15.5
T90	18.76	16.31	14.66
T85	17.72	15.4	13.86
T80	16.67	14.5	13.05

Average weight gain, feed consumption, feed conversion ratio and protein efficiency ratio were measured periodically and at the end of experiment carcass traits included: dressing percentage, breast percentage and relative weight of abdominal fat, pancreas and gizzard were measured in one bird of each pen. Duncan's analysis was used for comparing between treatments.

Results Mean performance and carcass traits data for the experiment are given in Table 2.

Table 2 Comparison between mean of treatments on performance traits in broilers (0-49 days)

Treatment	weight gain (g)	feed intake (g)	FCR (g/g)	PER (g/g)	Dressing (g/g)	Breast (g/g)	Abdominal Fat (g/g)	Gizzard (g/g)	Pancreas (g/g)
Control	2362 ^{a}	4938 ^{a}	2.09 ^{b}	2.64 ^{d}	0.068 ^{a}	0.29 ^{a}	0.023	0.016	0.0017
± s.e.	±27	±38	±0.019	±0.023	±0 .005	±0.006	±0 .0009	±0.0004	±0.0001
T95	2293 ^{a}	4706 ^{b}	2.05 ^{b}	2.83 ^{c}	0.66 ^{ab}	0.29 ^{a}	0.017	0.016	0.002
± s.e.	±53	±27	±0.035	±0.052	±0.011	±0.005	±0.002	±0.001	±0.0001
T90	2302 ^{a}	4763 ^{b}	2.07 ^{b}	2.96 ^{b}	0.67 ^{ab}	0.28 ^{ab}	0.017	0.017	0.0018
± s.e.	±50	±87	±0.016	±0.024	±0.005	±0.008	±0.002	±0.001	±0.0001
T85	2144 ^{b}	4471 ^{c}	2.08 ^{b}	3.11 ^{a}	0.66 ^{ab}	0.28 ^{ab}	0.018	0.017	0.0017
± s.e.	±24	±31	±0.026	±0.037	±0.003	±0.003	±0.001	±0.001	±0.0002
T80	1920 ^{c}	4256 ^{d}	2.22 ^{a}	3.10 ^{a}	0.65 ^{b}	0.28 ^{b}	0.021	0.019	0.0018
± s.e.	±26	±56	±0.025	±0.033	±0.009	±0.009	± 0.003	±0.0004	±0.00006
Probability of treatment effect	0.0001	0.0001	0.0027	0.0001	0.1493	0.086	0.246	0.284	0.426

Mean values with different superscripts on the same column are significantly different (P<0.05).

Weight gain significantly decreased by more than 10% in treatments with reduced crude protein (T85 and T80). By reducing protein, feed consumption significantly decreased but feed conversion ratio did not show a significant difference (P>0.05) when protein decreased by 15% of control diets. The best protein efficiency ratio was observed in the T85 group. Dressing percentage and breast percentage were significantly decreased when crude protein level decreased more than 15% (T80). Generally a reduction of protein by 10% had no significant adverse effect on majority of traits, possibly because of improving amino acid balance and protein-metabolizable energy ratio in corn-soybean meal diets supplemented with DL-methionine and L-lysine hydrochloride.

Conclusions The results of the present study demonstrate that it is possible to reduce the crude protein level of diets without any adverse effect by adding essential amino acids.

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Mycology of some litter materials and effect of litter and preslaugther feed withdrawal on gut bacterioflora in broiler chicken

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Introduction One prerequisite for efficient broiler production is suitable litter. In addition to desirable chemical and physical characteristics, poultry litter must also be low in microbial load to minimize risk of incidence or transmission of diseases. This study was conducted to assess the mycoflora of six kinds of litter materials and evaluate the effect of litter kind and preslaugther feed withdrawal (PSFW) on gut bactrioflora of broilers.

Materials and methods Litter treatments were rice husk (T1), shredded paper (T2), barley stalks (T3), cow dung (T4), wood shaving as control (T5) and a mixture of all five litters (T6). All litters were subjected to microbial decontamination before study using 0.001 m^3 Formaldehyde (20% solution) per 0.22 m^3 in plastic bags for long time. Feed had been removed form the pens at 0, 2, 4 and 6 hours before slaughter. At the end of study (8-weeks) 273 samples were examined for monitoring the presence of eight fungi species in various litters. Bacteria contamination data (aerobic plate counts and coliforms including *E.coli*) were subjected to two-way analysis of variance using GLM procedure of SAS® (SAS Institute, 1991). Analysis of frequency and Fisher's exact test and *chi*^{2} test were used for myco-related data and determine the significant differences between frequencies of fungi utilizing same software.

Results Litters were significantly differed for total myco contamination. Shredded paper and wood shavings showed the higher and lower fungi counts, respectively (Table 1). Frequency of presence in litter was highly significantly differed for eight fungi species studied. Maximum and minimum frequencies were observed for *Aspergillus sp*. and *Fusarium* respectively (Table 1). In contrast to the litter kind the effect of PSFW on gut bacterioflura was significant (0.05). The gut bacterioflora in birds subjected to 0,2 and 4 hours PSFW were normal flora but *E-coli* was appeared only in longest PSFW time (6 hs.).

Table 1 Contingency table of fungus × litter for frequency analysis of 273 samples of litter

Fungi (sp.)	Statistics	Litters						Total
		T1	T2	T3	T4	T5	T6	
Mucor sp.	Frequency	14	9	3	7	5	3	41[a]
	Cell chi square	7.56	0.1	2.46	0.001	0.08	1.73	15.02
Penicillum sp.	Frequency	12	8	12	17	6	7	62[a]
	Cell chi square	0.31	1.48	0.11	4.11	0.8	0.67	22.71
Aspergillus sp.	Frequency	10	9	4	10	11	20	64[a]
	Cell chi square	0.03	0.06	4.67	0.06	0.49	10.47	23.44
Geothricum sp.	Frequency	5	18	8	9	8	5	53[a]
	Cell chi square	1.6	5.4	0.18	0.000	0.05	1.22	19.41
Monobelpharios	Frequency	2	0	5	0	1	4	12[cb]
sp.	Cell chi square	0.00	2.37	3.96	2.02	0.27	2.51	4.4
Alternaria sp.	Frequency	1	0	0	1	0	1	3[c]
	Cell chi square	0.52	0.59	0.53	0.48	0.42	0.63	1.1d
Rizopus sp.	Frequency	1	10	15	2	7	2	37[ab]
	Cell chi square	4.26	0.98	11.1	2.88	0.66	2.4	13.55
Fusariom sp.	Frequency	0	0	1	0	0	0	1[c]
	Cell chi square	0.16	0.19	3.86	0.16	0.14	0.15	0.37
	Total	45[b]	54[a]	48[b]	46[b]	38[bc]	42[b]	273
		16.5	19.8	17.6	16.8	13.9	15.4	100

[a-c] Means without similar superscript within the last raw and column differ significantly (P>0.01)

Conclusion The results showed that, despite of munificent diversity in physical and chemical properties, the litters studied have not substantial difference with wood shaving, for microflora contamination. The preslaugther feed removal time is of more importance than litter kind pertaining to the gut bacterioflora. It seems that waste paper acts as a favorable litter for different fungi to grow.

The effect of reduction or removal of dietary vitamin supplement on broiler chickens performance

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Introduction While vitamins naturally occurring in plant and animal based feed ingredients can supply a reasonable proportion of the birds daily needs, their contribution is rarely considered during formulation. This situation arises due to variability, especially in cereals and vegetable proteins, for example, the vitamin E content of corn can vary from 10 to 40 IU/kg. Because of this uncertainty in the natural supply of vitamins within a feed, the bird's vitamin supply is therefore met by the addition of synthetic vitamins, usually in the form of a so called premix, that contains all vitamins and perhaps some other micronutrients and feed additives. This premixes use according to producer suggestions and in some cases their doses can be higher than real requirements. Skinner et al (1992) removed vitamin premixes from 21 day of age and did not report any adverse effects. Gwyther et al (1992) showed sever performance reduction by vitamin premix withdrawal from 21 to 49 day of age. This experiment was conducted to determine the effects of Vitamin supplement levels on broiler chickens from 28 to 49 days of age.

Material and methods 300 one-day-old Lohmann commercial broiler chicks were used in a completely randomized design, with 4 treatments, 5 replicates and 15 chicks in each replicate. Levels of vitamins supplement in the experimental diets were 0.3, 0.2, 0.1 and 0%. Each of the four diets was given to each treatment from 28 to 49 days of age. Diets were isocaloric and isoprotein. Mean Live weight and feed consumption of each replicate were determined for 28 to 49 day of age and, daily gain and feed conversion were calculated. Percent of carcass components were determined. Data was subjected to statistical analysis.

Results Table 1 shows the means of weight gain, feed intake and feed conversion ratio during 28-49 days old. Treatment without the vitamin premix had lower weight gain and feed intake in comparison to other treatments but these differences were not significant statistically ($P>0.05$). These results are in agreement with Skinner et al (1992) findings. Carcass parameters also did not have any significant differences. The different findings of other researchers may be related to vitamins bioavailability of diet components, vitamin requirements variation between broilers chickens strains and effects of environment conditions such as heat stress that can raise some vitamins requirements.

Table 1 Effects of vitamin premix level on performance traits

Vitamin premix level (%)	Weight gain (g)	Feed Intake (g)	Feed conversion Ratio (g)	Final Body Weight (g)
0.3	1589.9	3834.06	2.41	2463.62
0.2	1596.13	3742.29	2.30	2510.89
0.1	1587.29	3755.98	2.36	2515.16
0	1544.62	3732.38	2.42	2461.32
mse	19.39	28.36	0.02	21.18

*Means within a column with different superscripts are differ significantly ($P<0.05$)

Conclusions Results indicated that reduction or removal of Vitamin supplements from 28 to 49 days of age did not have any significant effects on feed consumption, daily gain, feed conversion, live weight and carcass components. This can raise economic profit.

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Effects of natural zeolite (clinoptilolite) on eggshell quality

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Introduction Using inorganic additives is one suggested approach for improvement of performance or for preventing some disorders and poisoning of farm animals. One of those which use in animal diets is zeolite. There are more than 40 types of natural zeolites, of which one of the commonest is Clinoptilolite. Clinoptilolite has a relatively constant crystalline structure and has good adsorption properties. One of the most important problems in the poultry industry is low eggshell quality, particularly at end of lay. This leads to problems such as the breaking of egg in transport. Research on this has indicated positive effects of zeolites. Adding 1.5% clinoptilolite causes a significant increase in the calcium CA concentration of serum (Hossein *et al*., 1994). Olver (1989) observed a significant increase in eggshell thickness when 5% clinoptilolite was added to the diet of laying hens. The purpose of present study was to investigate the effect of different dietary concentrations of clinoptilolite on some blood parameters and eggshell quality**.**

Materials and methods A total of 360 Haylain w36 hens (70 weeks of age) were housed three to a 350 x 550 mm cage in a two tier system. A completely randomised block design with 4 blocks was used, with each block containing 6 treatments and each treatment including 5 adjacent cages. Dietary treatments included a basal diet (BD) without clinoptilolite(0% clino) and BD plus 10(1% clino), 20(2% clino), 30(3% clino), 40(4% clino) and 50(5% clino) g clinoptilolite per kg diet.
.all diets were isoenergetic and isonitrogenous and were fed *ad libitum*. The purity of clinoptilolite used in this study was 70-80%. Sterilised river sand was used to balance diets with different contents of clinoptilolite. The lighting was 15 h per d, by using artificial light. The statistical model used is present in below.

$Y_{ij}=\mu+B_I+C_j+E_{ij}$

Y_{ij}; observation, μ; mean of varieties, B_i; treatment effect, C_j; block effect, E_{ij}; experimental error. The varieties recorded in this study included the calcium and phosphorus concentrations of serum, and eggshell quality. For determination of eggshell quality, four varieties were measured: eggshell thickness, eggshell percentage, egg specific gravity and percentage of broken eggs. For determination of serum calcium and phosphorus, samples of blood were obtained from the brachial vein within 2 h after the egg was laid on d 1, 45, 90 of the experiment. Calcium and phosphorus concentrations of serum were measured by atomic absorption spectrophotometer according to the procedure of the Association of Official Analytical Chemists (1980).

Results The calcium and phosphorus concentrations of serum are presented in Table 1.Clinoptilolite increased serum calcium significantly (P<0.01) but had no effect on serum phosphorus that is consist with the results of (Roland 1990). Eggshell thickness, eggshell percent ,egg specific gravity and percentage of eggs broken are shown in Table 2. Clinoptilolite increased eggshell thickness significantly (P<0.05) that is agreement with results of Olver *et al* 1988. .there was a positive regression between eggshell thickness and eggshell percent.

Table 1 Calcium and phosphorus concentrations of serum

Treatment	1 (0% clino)	2(1% clino)	3 (2% clino)	4 (3% clino)	5 (4 % clino)	6 (5% clino)	SEM
Calcium (mg/dl)	15.73^{b}	11.61^{b}	12.18^{b}	15.70^{b}	21.20^{a}	14.94^{b}	1.47
Phosphorus (mg/dl)	4.86	7.15	7	6.45	3.5	6.57	0.61

$^{a-b}$ Means with differing superscripts within a row differ significantly (P < 0.01).

Table 2 Eggshell thickness, eggshell percent ,egg specific gravity and percentage of aggs broken

Treatment	1 (0% clino)	2 (1% clino)	3 (2% clino)	4 (3% clino)	5 (4 % clino)	6 (5% clino)	SEM
Eggshell thickness (mic)	40.43^{b}	41.03^{ab}	41^{ab}	41.31^{ab}	41.92^{a}	41.15^{ab}	0.34
Eggshell percent	8.37	8.38	8.41	8.41	8.41	8.42	0.11
Egg specific gravity (g/l)	1.068	1.068	1.068	1.068	1.068	1.068	0.001
Eggs broken (%)	1.08	1.77	1.19	0.9	0.84	1.04	0.15

$^{a-b}$ Means with differing superscripts within a row differ significantly (P < 0.05).

Conclusion Since clinoptilolite has cation-anion exchange properties, it can exchange its own calcium with phosphate from the diet. In addition Clinoptilolite also absorbs dietary phosphorus, causing a reduction in serum phosphorus, to which the bird responds by mobilising bone phosphorus, this may buffer serum phosphorus. Also, the mobilisation of bone to buffer blood phosphorus content is accompanied by the release of calcium. . Clinoptilolite also improved the eggshell quality; this may be due to the positive effects of clinoptilolite on serum calcium and the direct influence of calcium in forming the eggshell. It is also possible that the action-anion exchange properties of clinoptilolite enhance the bicarbonate ion content of the blood and therefore improve eggshell quality.

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Effect of induction of thermotolerance with vitamin C, E supplementation on performance broiler chickens reared at during heat stress.

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Introduction The stress of high environmental temperature may have a deleterious influence on the performance of broiler chickens by reducing feed intake, live weight gain and feed efficiency. Exposing chicks to 36-38°C for 24h at 5d of age reinforces the resistance of older (6 to 7 wk-old) broilers to heat stress (De Basillo et al., 2003). Several studies have revealed that antioxidant nutrient supplementation especially vitamin C and E can be used to alter the negative effect of environmental stress (NRC, 1984). Combination of antioxidant vitamins generally shows greater antioxidant activity than that of each component alone. The objective of this study was to investigate the effects of early age thermal conditioning and vitamin C, E supplementation on performance, carcass characteristic in broiler chickens reared under heat stress.

Material and methods A total of 576 one day-old chicks were used and divided into fully randomized blocks with a 4 x 2 factorial schemes, i.e. e., 4 vitamins (NRC recommendation, NRC+250mg vitamin C, NRC+250 mg vitamin E and NRC and combination of vitamins C and E (250mg form each vitamin)) and 2 early thermal condition (early heat stressed EHS; early unstressed; EUS) with 4 replicate and 18.birds per replicate. The birds were randomly assigned two groups. One group was exposed to heat stress (36±1°C) for 48h at age of 5-6d, and another reared at recommended temperature. From day 6 on, all of birds were reared under normal environmental condition. Between 35 and 49 d of ages all chicks were subjected to heat stress (31±1°C for 6h/d). From 35 to 49 d of age, birds were fed either a control diet recommended by NRC for nutrient and vitamins (NRC) or a control diet supplemented with vitamins as mentioned above. Birds consumed feed and fresh water adlibitum. Feed refusals were collected daily, feed intake and body weight was determined weekly. Weight gain and feed conversion ratio of birds were calculated. The data were analyzed using ordinary least squares (GLM, SAS, ® 2001). The model included early thermal condition and vitamin supplements as main effects. Interaction between main effects was included in the model. Mean separation was accomplished using Least Significant Difference.

Results Early thermal condition (ETC) and vitamin supplement (VS) had a significant effect ($P<0.05$ and $P<0.01$ respectively) on weight gain during the last two weeks of study. The ETC effects on thigh and spleen weight were significant ($P<0.05$) but this result was not observed for liver weight. However, vitamin supplementation had a significant effect on liver and spleen weight ($P<0.05$ and $P<0.01$ respectively). Heart mass was not affected by ETC and VS. There were no significant interactions between ETC and VS in any of the measured parameters.

Table 1 Effect of early thermal condition (ETC) and vitamins (VS) on broiler performance

Variable	Early thermal condition								Main effects	
	EUS				EHS					
	NRC	NRC +C	NRC +E	NRC+C +E	NRC	NRC+C	NRC+E	NRC+C +E	ETC	VS
Body weight										
35-42 d (kg)	1.97	2.12	2.07	2.15	2.10	2.22	2.13	2.17	*	*
42-49 d (kg)	2.45	2.74	2.67	2.71	2.63	2.82	2.69	2.77	*	**
Carcass characteristics										
Thigh (g)	650.2	691.0	692.0	709.3	712.3	732.0	730.4	736.6	*	ns
Heart (g)	14.26	13.60	14.88	14.32	14.28	14.42	14.84	14.88	ns	ns
Liver (g)	60.20	63.85	56.28	60.84	62.02	65.35	56.62	61.14	ns	**
Spleen (g)	6.738	4.959	4.584	4.938	4.747	4.987	4.250	4.463	*	*

Conclusion The results suggest that thermal conditioning at an early age in birds resulted in increased regulation of thermotolerance during subsequent heat stress conditions. However, short-term thermal conditioning during early life induced growth retardation, which was followed by immediate compensatory growth. The observations described suggest that exposing chicks during early life and using antioxidant vitamins induced beneficial effects on animal performance during summer heat stress.

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Effect of hyperthermia in growing broiler chickens on meat quality

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Introduction During growth period of 6 to 7 weeks, broiler chickens are exposed to different stressors, the effects of which are dependent on the type, duration and intensity of stress that affects the bird. Stress-induced changes in muscular metabolism alter the physico-chemical traits of meat, thus affecting its quality (Ali et al., 1999). The negative effect of ante-mortem thermal stress on the quality of broiler meat has been the object of many studies and is relatively well documented (Warriss et al., 1999). There is a scarcity of data on whether and to what degree hyperthermia in growing chickens affects the technological parameters of poultry meat. Therefore we carried out an experiment to determine the effect of 5-day heat stress in 4-week-old broiler chickens on their later meat quality.

Material and methods Day-old Cobb 500 chicks were randomly assigned to two groups and kept until 42 days of age at a stocking rate of 15 birds/m^2, and fed with all-mash starter, grower and finisher diets. To 3 weeks of age, all chickens were reared under uniform environmental conditions. To 4 weeks of growth, chickens of group II were kept for 5 days at 28^{o}C, which was 10^{o}C higher than in the control group (I). On day 42 of the experiment, 5 males and 5 females from each group were sacrificed to determine pH of breast muscles and leg muscles, L*a*b* colour (Minolta CR310), water holding capacity (Grau-Hamm method), drip loss after 24-h storage of meat at +4^{o}C, cooking loss and WB shear force of cooked breast muscles using Instron 5542. Muscles were cooked at 100^{o}C until its internal temperature reached 84 ^{o}C. The results were analysed statistically using variance analysis and Duncan's multiple range test.

Results The studies showed that thermal stress had no significant effect on the quality of chicken meat. There was only a tendency for slightly lower drip loss and more beneficial water holding capacity of breast muscles and leg muscles of birds exposed to heat stress. Lower thermal losses (by 1.75%) were characteristic of breast muscles of the control chickens. For leg muscles, thermal losses in both groups of chickens were highly similar. Colour of breast muscles was highly uniform, especially for a* (redness) and b* (yellowness) values, with a slightly higher L* (lightness) value in the control group. In the case of legs, muscles of chickens exposed to heat stress were brighter.

Table 1 Meat quality characteristics of broiler chicken in relation to rearing conditions (x±SD)

Item	Group I		Group II	
	Breast muscles	Leg muscles	Breast muscles	Leg muscles
pH_{15min}	6.37±0.04	6.48±0.04	6.39±0.04	6.41±0.05
pH_{24h}	6.10±0.03	6.37±0.03	6.13±0.04	6.41±0.04
L*	56.61±0.53	45.94±3.53	54.91±0.59	49.49±0.44
a*	12.79±0.31	15.24±1.18	12.81±0.29	17.08±0.17
b*	9.78±0.32	8.92±0.71	9.84±0.31	9.09±0.26
Drip loss $_{24h}$ (%)	0.59±0.05	0.62±0.13	0.52±0.06	0.53±0.07
Thermal loss (%)	17.58±0.58	31.03±0.96	19.43±0.78	30.76±1.33
WHC (%)	18.96±0.98	16.73±1.29	17.62±1.47	14.81±1.49
Shear force (N)	29.13±3.20	-	24.87±1.60	-

Means are not significantly different (P≥ 0.05)

Conclusions Heat stress of 4-week-old chickens did not cause permanent changes to muscle metabolism and had no effect on subsequent meat quality. Many research findings indicate that heat stress has a significant influence on the quality of poultry meat (Holm and Fletcher, 1997; Berri, 2000). McCurdy et al. (1996) report that excessive rearing temperature during summer heats contributes to pale colour, strong acidification and poor water holding capacity of breast muscles in turkeys but it might have been related to heat stress shortly before slaughter rather than the rearing conditions.

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The effect of oiling and antimicrobial spray on performance of broiler chickens reared on leaves and corncob litters under heat stress condition

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Introduction Accessibility of enviable litter materials and litter treating aimed at reducing ammonia and dust levels in poultry houses and pathogen population in litter are the points of interest in poultry research. A study was conducted to evaluate leaves and ground corncobs as alternative litters for broilers and examine the effect of surface spraying of antimicrobial solutions, oil and apply of both on performance of broilers.

Materials and methods Six hundred seventy five unsexed day-old broiler chicks were randomly assigned to 45 pens (at density of 0.12 m^2/bird) in a cross ventilated open system shed. The ambient temperature during day and night hours were ranged from 28-36 and 20-25 °c for first tree weeks and 32-37 and 25-30 °C for remains of experiment respectively. Three litter materials viz. wood shavings (WS), ground corncobs (GC) and leaves (0.015 m in length) had been subjected to surface spraying of oil (0.4 L/m^2 animal food grade sunflower oil), Anti microbial solutions (AMS) (3%) and mix treatment of both. Data on body weight, gain, feed-related traits, mortality, carcass traits and incidence of breast and food pad lesions along with certain litter characteristics (litter moisture, pH, dustiness and temperature) were gathered and analysed in a 3×3 factorial arrangement using the General Linear Models procedure of SAS® software. Treatments were separated by Duncan's test. Frequency analysis was conducted for the objectively assigned scores for incidence of foot and breast injuries, using Frequency Procedure of SAS software (SAS, Institute, 1998). Chi-square test was utilised to separate the means.

Results Final body weight (56d) for birds grown on leaf litter was significantly higher followed by ones on WS and GCC ($P<0.05$). Carcass weight and mortality were significantly influenced by the type of litter in favour of WS and leaves ($P<0.05$) (Table 1). The frequency of medium and sever damages on breast was significantly higher for GC litter but the results for footpad lesions were reversed. Litter type resulted in a significant differences for litter moisture levels at 28d, pH values at 14d and temperatures at 14 and 56d ($p<0.05$). No significant differences were observed for dustiness score between litters at all ages and final litter nitrogen content ($p>0.05$). Treating of litter using antimicrobial spray, oiling or both showed a significant influence on body weight at 28, 42 and 56 days of age as well as Feed consumption for 29-42 and 1-42d and mortality (Table 1). Litter temperature at 28 and 56d, and litter pH at 28 and 56d were significantly affected by litter treatment.

Table 1 Effect ($\overline{X} \pm SE$) of different litters and litter treatments on body weight, Carcass Weight (C.W.), Carcass Yield (C.Y.) and mortality (Mort)

	Body weight (g)					C .W.	C. Y.	Mort.
Main effects	1d	14d	28d	42d	56d	(g)	(%)	(%)
Grand mean	42.6	254	778	1540	2078	1685	70.9	9.2
Litter type								
WS	42.8^{a}	266^{a}	795^{a}	1557^{a}	2080^{ab}	1699^{a}	70.9^{a}	7.6^{b}
Leaves	42.5^{a}	261^{a}	781^{a}	1556^{a}	2120^{a}	1710^{a}	70.7^{a}	7.8^{b}
Corncob	42.5^{a}	235^{b}	758^{b}	1507^{b}	2031^{b}	1645^{b}	71.0^{a}	12.4^{a}
Treatment manner								
A. M. S.	42.4^{a}	258^{a}	793^{a}	1563^{a}	2019^{b}	1703^{a}	70.8^{a}	7.3^{b}
Oiling	42.7^{a}	253^{a}	781^{a}	1540^{ab}	2067^{a}	1691^{a}	71.1^{a}	11^{a}
Mixed	42.7^{a}	250^{a}	758^{b}	1516^{a}	2057^{a}	1661^{a}	70.8^{a}	9.5^{ab}

$^{a-b}$ Means within a row with no common letter differ significantly ($p<0.05$).

Conclusion Under the conditions of the present study, leaves and ground corncobs could be used as alternative bedding materials for broiler rearing. Taking in consideration the labor and cost, the approaches used for treating the litters through surface spraying of antimicrobial solutions, oiling and applying both could not be considerably effective as tools to promote the broiler's health and performance.

Immunoglobulin-Y (IgY) levels in domestic fowl exposed to red mite *(Dermanyssus gallinae)*

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Introduction Red mite (*Dermanyssus gallinae;* De Geer, 1778) is currently the most economically deleterious ectoparasite of layer hens in several countries (Chauve, 1998). *D. gallinae* is an obligatory haematophagous ectoparasite of both domestic and wild birds (Bruneau *et al*., 2001), only found on the host during darkness when obtaining a blood meal. The remaining part of its lifecycle is spent concealed deep in the house substructure, in cracks and crevices, with control typically implemented via chemical spraying. Mite exposure in laying hens generally results in irritation, restlessness, anaemia, and occasionally death and may subsequently lead to decreased egg production, poor shell integrity, blood staining and egg size reductions (Chauve, 1998; Cosoroaba, 2001). Natural exposure to mite-antigens during feeding activates humoral immunity of the fowl, in the form of immunoglobulin production. However, the magnitude of this serological response over a prolonged infestation period and at different mite population levels is unclear. Therefore the aim of this study was to determine the levels of anti-mite immunoglobulin present in egg yolks of laying hens in flocks infested with differing population levels of red mite over a period of 16 weeks.

Materials and methods The trial followed separate bird populations on 3 laying farms, with previously determined low, moderate or high *D. gallinae* populations. For the initial ten weeks of the experiment, 24 eggs per farm were collected every two weeks (24, 26, 28 and 30 weeks of age) and subsequently from weeks 30-38 eggs were collected monthly. In addition mites were trapped using 10 ADAS mite-monitors per site, at the same time intervals, after which they were filtered, preserved in ethanol and total population size was estimated by counting then multiplying up a subsample. Egg yolks were processed to remove chicken immunoglobulin-Y (IgY) via PBS-chloroform extraction (Mohammed *et al*, 1986). Purified IgY was then used in enzyme-linked immunosorbent assays (ELISA), in which 96-well plates were coated with unfed mite protein, followed by a blocking step, incubation with IgY and anti-chicken IgY, and finally colour developed using Tetramethylbenzidine (TMB) allowing for optical density measurement. Data were analysed using analysis of variance in MINITAB (V14) comparing levels of both mite infestation and optical density between farms. A correlation between IgY and mite population was also undertaken.

Results Statistical exploration revealed that there were significant differences between experimental groups. The group with high mite exposure showed significantly higher IgY level ($P<0.001$) in comparison to moderate and low groups (Fig. 1). No significant relationships existed between other groups, although it was apparent that the moderate group showed numerically higher IgY levels than the low group. A similar pattern could be seen in mite population levels (Fig. 2), this time with both moderate and high groups being significantly higher than the low group ($P<0.05$). However, no significant correlation existed between IgY optical density and mite population.

Figure 1 Weekly optical density levels on infested units

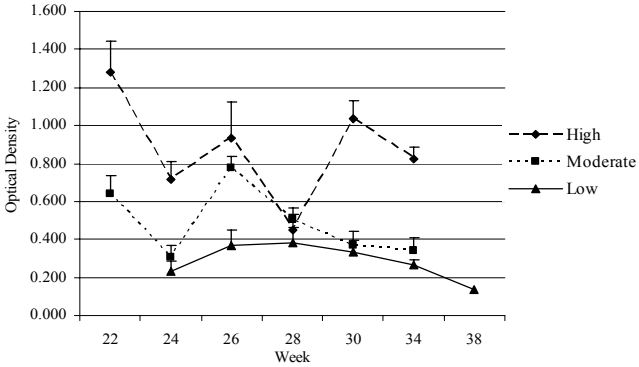
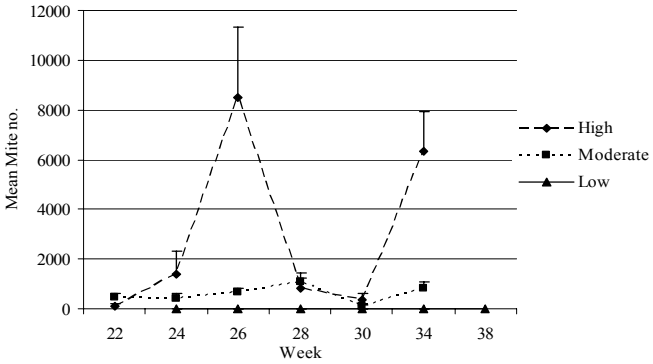


Figure 2 Mean weekly mite population



Conclusions Levels of anti-mite IgY detected in laying hens appeared to be related to levels of *D. gallinae* infestation, although there was failure to show this statistically, this can perhaps be accounted for by the large fluctuations in mite populations between weeks. However, significant differences did exist independently between IgY and mite levels which are potentially important considerations for future immunological assessment, such as vaccine development.

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The effects of grain storage and processing method and level of feeding on the meat quality of beef cattle offered two contrasting grass silages

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Introduction Feed is a major cost in beef production during the winter feeding period. One potential method of reducing cost is to purchase grain at harvest. However, grain must be processed either by rolling or milling prior to feeding and this is a labour intensive process. Currently labour is an expensive and scare resource on many beef units. Recently different techniques have been developed for storing and feeding grain to beef cattle, which involve the processing of the grain prior to storage. The objective of the current study was to evaluate the effects of grain storage and processing method, and grain feed level on the meat quality of beef cattle offered two contrasting grass silages.

Materials and methods The study involved a total of 132 continental cross beef cattle, which were allocated to 12 treatments in a factorial design, randomised block experiment for a mean feeding period of 111 days. High and low feed value silages were supplemented with either 3.5 or 5.9 kg concentrate dry matter/head/day. Wheat was harvested and ensiled either crimped and treated with 4.5 litres/t fresh weight of a proprietary acid-based additive, ensiled whole mixed with 20 kg urea and 30 litres of water/t fresh weight or harvested conventionally and treated with propionic acid. The concentrate consisted of 850 g/kg DM wheat and 150 g/kg DM citrus pulp. Cattle were slaughtered after constant intervals on experiment. Carcasses were hung tenderstretch and were chilled under standard commercial conditions. The methods used for meat quality assessment are detailed by Okeudo and Moss (2004). Sarcomere length of the *m. longissimus dorsi* (LD) was determined 48 hours post-mortem. The LD was dissected from the fore-rib joint 7 days post-mortem. Two 30 mm thick slices were cut from the LD, with the former used to determine 7 day cooking loss and Warner Bratzler shear force (WBSF), whilst the later was vacuum packed and aged for an additional 14 days for 21 day assessment of cooking loss and WBSF. A further 30 mm thick slice of LD was used to assess lean colour and ultimate pH 7 days post-mortem. Data were analysed as 3 (grain storage/processing methods) x 2 (grain feed levels) x 2 (grass silage feed values) factorial experiment using Genstat ANOVA.

Results Animal performance data from this study have been presented by Keady *et al*. (2005). The main effects of grain storage and processing method, grain feed level and grass silage feed value on meat quality are presented in Table 1. Urea treatment increased (P<0.05) cooking loss, assessed after 7 day ageing, and tended to decrease (P=0.06) colour lightness (L*) relative to conventionally stored grain. Increasing grain feed level increased WBSF assessed after 7 day ageing. Silage feed value did not alter (P>0.05) meat quality at 7 or 21 days ageing or lean and fat colour. There was a significant silage feed value by grain feed level interaction (P<0.05) for lean colour L*. For the high feed value grass silage L* values were 37.9 and 39.4, whilst for the low feed value grass silage L* values were 38.0 and 36.0 when supplemented with the 3.5 and 5.9 kg concentrate feed levels respectively.

Table 1 Effect of grain storage and processing method, and feed level and silage feed value on meat quality

	Processing method (PM)				Silage feed value (SIL)		Grain feed level (GFL)			Significance[†]		
	Convent-ional	Urea	Crimped	Sem	Low	High	3.5kg	5.9kg	Sem	PM	SIL	GFL
Sarcomere length (μm)	2.87	2.84	2.93	0.049	2.86	2.91	2.89	2.87	0.040	NS	NS	NS
7 day ageing												
Ultimate pH	5.55	5.55	5.52	0.008	5.54	5.54	5.55	5.54	0.006	NS	NS	NS
Cooking loss	26.8[a]	28.0[b]	27.5[ab]	0.333	27.6	27.3	27.3	27.5	0.272	*	NS	NS
WBSF (kg/cm^2)	2.59	2.59	2.63	0.058	2.61	2.60	2.53	2.68	0.048	NS	NS	*
21 day ageing												
Cooking loss	29.3	29.4	29.2	0.316	29.3	29.2	29.5	29.1	0.260	NS	NS	NS
WBSF (kg/cm^2)	2.48	2.40	2.45	0.047	2.44	2.45	2.41	2.48	0.038	NS	NS	NS
Lean Colour L*	39.0	36.8	37.6	0.741	37.0	38.6	37.7	37.9	0.605	P=0.06	NS	NS
A*	7.13	7.23	7.14	0.432	7.03	7.30	7.43	6.90	0.353	NS	NS	NS
B*	22.2	21.7	21.7	0.613	21.7	22.1	21.8	21.9	0.501	NS	NS	NS
Fat Colour L*	71.3	71.6	72.2	0.939	72.5	70.8	71.7	71.7	0.766	NS	NS	NS
A*	1.75	1.89	2.02	0.471	1.78	2.00	1.78	2.00	0.384	NS	NS	NS
B*	24.3	24.0	23.4	0.589	24.0	23.8	24.0	23.8	0.481	NS	NS	NS

[†] There were no PMxSIL, PMxGFL or PMxSILxGFL interactions There was a SIL x GFL interaction (P<0.05) for lean colour L*

Conclusions It is concluded that feeding crimped grain to beef cattle did not alter meat quality relative to conventionally processed and stored grain. However, urea treatment increased cooking loss and tended to decrease lean colour L*. Silage feed value had no effect on meat quality.

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Preliminary effects of altering plane of nutrition during different stages of the life cycle, and gender, on meat quality of beef cattle

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Introduction Cost effective performance from birth to slaughter must be achieved in order for beef producers to maximise income and survive in a subsidy-free, market led environment. The aim of the present study was to evaluate the effects of gender, plane of nutrition during the growing and finishing indoor feeding periods, and stocking rate and concentrate supplementation from weaning to finishing on meat quality.

Materials and methods The study involved a total of 128 spring-born continental suckled calves, 64 steers and 64 heifers, which were allocated to a total of 32 treatments, commencing in the autumn of their first year. The cattle were offered grass silage supplemented with either 0.4 or 2.4 kg concentrates/head/day during their first winter indoor feeding period (W1). On turnout to pasture the cattle were allocated to either a high (2750 kg live weight/ha) or low (1925 kg live weight/ha) stocking rate (SR) treatment. The cattle were supplemented (S) with either 0 or 2.5 kg concentrates/head/day from the 1st August during the grazing season. The cattle received either grass silage *ad libitum* supplemented with 4 kg concentrate/day or *ad libitum* concentrate supplemented with 5 kg fresh silage daily during the final indoor finishing period (W2). The heifers and steers were slaughtered in blocks after being offered the final indoor period treatments for a mean of 70 and 101 days respectively. Carcasses were hung tenderstretch and chilled under standard commercial conditions. The methods used for meat quality assessment are detailed by Okeudo and Moss (2004). Sarcomere length of the *m. longissimus dorsi* (LD) was determined 48 hours post-mortem. The LD was dissected from the fore-rib joint 7 days post-mortem. Ultimate pH was measured 7 days post-mortem. Two 30 mm thick slices were cut from the LD, with the former used to determine 7 day cooking loss and Warner Bratzler shear force (WBSF), whilst the latter was vacuum packed and aged for an additional 14 days for 21 day assessment of cooking loss and WBSF. Data were analysed as 2 (gender) x 2 (planes of nutrition during W1) x 2 (SR at pasture) x 2 (concentrate supplementation at pasture from 1 August) x 2 (planes of nutrition during W2) factorial experiment using Genstat ANOVA.

Results Animal performance data have been presented by Keady *et al.* (2005). The main effects of altering the plane of nutrition at different stages of the life cycle, and gender, on meat quality are presented in Table 1. Relative to heifers, meat from steers had an increased cooking loss after 21 days ageing and increased sarcomere length. Concentrate supplementation at pasture decreased (P<0.05) cooking loss assessed after 21 days ageing. *Ad libitum* concentrate supplementation during the final indoor finishing period tended (P=0.06) to increase WBSF assessed after 7 days ageing, whilst reducing (P<0.05) cooking loss assessed after 21 days ageing. In general the various factorial interactions were non-significant (P>0.05) apart from S x G and S x W2 for WBSF assessed after 21 days ageing.

Table 1 The effects of altering the plane of nutrition at different stages of the life cycle and gender on meat quality

	Gender (G)		Winter 1 (W1)		Stocking rate (SR)		Supplement (S)		Winter 2 (W2)			Significance[†]		
	Heifer	Steer	Low	High	Low	High	None	Conc	Low	High	Sem	G	S	W2
Ultimate pH	5.56	5.55	5.55	5.55	5.55	5.55	5.55	5.55	5.55	5.55	0.008	NS	NS	NS
Sarcomere length (μm)	2.58	2.74	2.68	2.64	2.65	2.67	2.66	2.65	2.61	2.71	0.047	*	NS	NS
7 day ageing														
Cooking loss (%)	29.4	28.9	29.0	29.2	29.0	29.1	28.8	29.4	29.5	28.7	0.323	NS	NS	NS
WBSF (kg/cm^2)	3.11	3.01	3.05	3.07	3.12	3.00	3.05	3.07	2.98	3.14	0.063	NS	NS	P=0.06
21 day ageing														
Cooking loss (%)	27.6	29.1	28.3	28.5	28.4	28.4	28.7	28.0	28.7	28.0	0.221	***	*	*
WBSF (kg/cm^2)	2.74	2.67	2.66	2.75	2.71	2.70	2.71	2.70	2.67	2.74	0.048	NS	NS	NS

[†] Winter 1 and stocking rate did not alter meat quality (P>0.05)

Conclusions It can be concluded that *ad libitum* concentrate feeding during the finishing phase tended to increase meat toughness after 7 days ageing. *Ad libitum* concentrate feeding during the finishing phase and concentrate supplementation at pasture decreased cooking loss after 21 days ageing. Steers had greater sarcomere lengths relative to heifers.

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The effect of slaughter weight on carcass characteristics of Holstein-Friesian male cattle

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Introduction The commercial value of beef carcasses can be assessed by several methods including the yield of primal joints and meat quality characteristics. However, it is also important to determine the composition of the carcass in terms of lean, fat and bone concentrations, and to evaluate individual fat components of the carcass, to provide an overall assessment of the commercial value of the carcass. The objective of the present study was to evaluate the effect of slaughter weight on carcass composition of Holstein-Friesian bulls and steers offered cereal-based rations.

Materials and methods A total of 180 Holstein-Friesian bulls, mean initial age 112 (SD 26.0) days and live weight 134 (SD 37.6) kg were used in the study. Animals were blocked according to live weight and age, and allocated at random to treatments. The seven treatments in the study comprised six different slaughter live weights with bulls, namely 300, 350, 400, 450, 500 and 550 kg, and a further treatment with steers slaughtered at 450 kg. Calves allocated to the steer group were castrated at 6 months of age. Animals were housed in slatted pens accommodating 4 animals within each slaughter weight group and offered a diet consisting of *ad libitum* concentrates and a restricted quantity of straw (nominally 5% of DM intake). The composition of the concentrates was changed when animals reached 350 kg live weight and contained the following ingredients (g/kg) : barley 500 and 535, soya bean meal 175 and 140, sugar beet pulp 200 and 200, maize meal 100 and 100, vitamin/mineral premix 25 and 25 for concentrates offered pre- and post-350 kg live weight respectively. Data on a range of carcass parameters were recorded from all animals post slaughter. The fore rib joint was removed from the left side of each carcass and fully dissected into separable lean, separable fat and bone contents. The composition of the carcasses of all animals in the study were subsequently estimated from the composition of the fore rib joints using standard equations for similar animal types. Data were analysed using the REML technique in Genstat 5 (release 4.1 Rothamsted, England). Live weight and age at the start of the study, and deviation of actual weight from target slaughter weight, were used as covariates. All variates were tested for the presence of linear and asymptotic trends between the range of slaughter weights evaluated (bulls only).

Results The mean chemical composition of the concentrate offered pre- and post-350 kg live weight was : DM 846 and 851 g/kg, CP 190.9 and 154.4 g/kg DM, ADF 80.9 and 78.8 g/kg DM, NDF 194.3 and 182.7 g/kg DM and ash 73.7 and 67.2 g/kg DM respectively. Data on carcass characteristics and composition are presented in Table 1. Eye muscle area, marbling score and depth of subcutaneous fat increased linearly ($P<0.05$ or greater), while weight of kidney, cod and channel fat increased in an asymptotic manner ($P<0.001$) with increasing slaughter weight. Dissection of fore rib joints indicated similar ($P>0.05$) proportions of separable lean and subcutaneous fat across the range of bull slaughter weights in the study, while the proportion of intermuscular fat and total fat in the fore rib increased linearly ($P<0.001$) with slaughter weight. In contrast, proportion of bone in the fore rib decreased ($P<0.001$) in a linear manner with increasing slaughter weight. Estimated carcass lean and bone concentrations declined linearly ($P<0.05$ or greater), while estimated fat concentration increased linearly ($P<0.001$) with increasing weight at slaughter. Slaughtering cattle at the same live weight either as bulls or steers did not affect eye muscle area ($P>0.05$), though weight of kidney, cod and channel fat was significantly ($P<0.001$) higher with steers. Steers also had higher ($P<0.05$) subcutaneous fat depth and tended to have higher marbling score ($P=0.07$) than comparable bulls. However, bulls had a significantly ($P<0.001$) higher proportion of separable lean, and lower proportions of intermuscular and total separable fat ($P<0.05$ or greater) in the fore rib than steers, while proportions of subcutaneous fat and bone in the fore rib were similar ($P>0.05$). Estimated carcass lean was lower ($P<0.001$) and estimated carcass fat higher ($P<0.01$) with steers compared to bulls slaughtered at the same live weight, while the estimated concentration of bone in the carcass was similar ($P>0.05$) for both.

Table 1 The effect of weight at slaughter and sexual status on carcass characteristics of Holstein bulls and steers

	Bulls						Steers	SED	Significance		Bulls v Steers[1]
Slaughter wt (kg)	300	350	400	450	500	550	450		Linear	Asymp	
Eye muscle area (cm^2)	45.3	47.2	53.7	53.8	58.4	57.4	52.7	2.76	***	NS	NS
Subcutaneous fat (mm)	1.6	2.1	3.1	3.1	2.8	3.0	4.2	0.45	*	P=0.07	*
Marbling score [2]	0.94	0.93	1.40	1.66	1.87	2.43	1.93	0.142	***	P=0.07	P=0.07
Kidney, cod and channel fat (kg)	4.21	5.87	6.48	8.54	10.02	12.53	12.09	0.842		***	***
Composition of the fore rib (g/kg)											
Separable lean	604	602	603	603	606	575	556	13.2	NS	NS	***
Subcutaneous fat	25	24	28	25	23	28	36	9.2	NS	NS	NS
Intermuscular fat	135	144	153	163	162	191	190	12.0	***	NS	*
Total separable fat	160	168	181	188	185	219	226	15.4	***	NS	**
Bone	236	230	216	209	209	206	218	8.4	***	NS	NS
Estimated carcass composition (g/kg)											
Lean	648	645	644	642	642	623	615	7.8	*	NS	***
Fat	149	155	165	170	170	194	195	9.9	***	NS	**
Bone	203	200	192	188	188	183	189	4.1	***	NS	NS

[1] Both slaughtered at 450 kg live weight; [2] 8 point scale : 1 = low marbling, 8 = high marbling

Conclusions The results of the present study indicated that eye muscle area and weights of internal fat depots increased with increasing slaughter weight of bulls. Furthermore, the estimated proportion of lean in the carcass decreased, while that of fat increased, with increasing slaughter weight.

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The effect of slaughter weight on meat quality characteristics of Holstein-Friesian male cattle

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Introduction Meat from Holstein-Friesian bulls, which are bred for dairy traits, is generally regarded as low quality and is usually destined for the commodity (mince) market. However, given their ready availability as a by-product from the dairy herd, it is important to determine if meat from these animals would be suited to higher-priced markets. Furthermore, meat from bulls is generally considered to be lower quality than that from steers, though there is a paucity of data comparing meat from both sources. Hence, the objective of this study was to evaluate the effect of slaughter weight on meat quality characteristics of Holstein-Friesian bulls and steers offered a cereal-based ration.

Materials and methods A total of 180 Holstein-Friesian bulls, mean initial age 112 (SD 26.0) days and live weight 134 (SD 37.6) kg were used in the study. Animals were blocked according to live weight and age, and allocated at random to treatments. The seven treatments in the study comprised six different slaughter live weights with bulls, namely 300, 350, 400, 450, 500 and 550 kg, and a further treatment with steers slaughtered at 450 kg. Calves allocated to the steer group were castrated at 6 months of age. Animals were housed in slatted pens accommodating 4 animals within each slaughter weight group and offered a diet consisting of *ad libitum* concentrates and a restricted quantity of straw (nominally 5% of DM intake). The composition of the concentrates was changed when animals reached 350 kg live weight and contained the following ingredients (g/kg) : barley 500 and 535, soya bean meal 175 and 140, sugar beet pulp 200 and 200, maize meal 100 and 100, vitamin/mineral premix 25 and 25 for concentrates offered pre- and post-350 kg live weight respectively. The *longissimus dorsi* muscle from the fore-rib joint was removed 48 h post-mortem and two, 50 mm thick slices of the muscle were vacuum packed and aged for 7 days post-mortem at 2°C. Assessments of ultimate pH, colour, Warner Braztler shear force (WBSF) (measure of toughness) and cooking loss were undertaken using the methods detailed by Moss *et al*. (1993). Data were analysed using the REML technique in Genstat 5 (release 4.1 Rothamsted, England). Deviation of actual weight from target slaughter weight was used as a covariate in the analysis. All variates were tested for the presence of linear and asymptotic trends between the range of slaughter weights evaluated (bulls only).

Results The mean chemical composition of the concentrate offered pre- and post-350 kg live weight was : DM 846 and 851 g/kg, crude protein 190.9 and 154.4 g/kg DM, acid detergent fibre 80.9 and 78.8 g/kg DM, neutral detergent fibre 194.3 and 182.7 g/kg DM and ash 73.7 and 67.2 g/kg DM respectively. Data on meat quality are presented in Table 1. There were clear trends for an increase in meat redness with increasing live weight at slaughter, with both a* (redness) ($P<0.01$) and chroma (saturation or purity of the colour) ($P<0.05$) values increasing linearly, and hue angle displaying a linear ($P<0.05$) decrease with increasing slaughter weight. Cooking loss was influenced by weight at slaughter, displaying a significant ($P<0.01$) linear decrease with increasing live weight at slaughter. However, these relationships had low associated R^2 values indicating that a major proportion of the variation remained unexplained (R^2 values of 0.05, 0.04, 0.04 and 0.05 respectively). No significant ($P>0.05$) trends were identified between ultimate pH, WBSF, L* (lightness) or b* (yellowness) values of meat and live weight of the bulls at slaughter. Furthermore, slaughtering cattle as bulls or steers had no significant ($P>0.05$) effects on any of the instrumental measures of meat quality carried out in this study.

Table 1 The effect of weight at slaughter and sexual status on meat quality of Holstein bulls and steers

	Bulls						Steers	SED	Significance		Bulls v
Slaughter wt (kg)	300	350	400	450	500	550	450		Linear	Asymp	Steers[1]
Colour											
L*	37.9	39.3	38.8	38.5	36.8	38.0	39.2	1.84	NS	NS	NS
*a**	16.2	16.4	15.9	17.4	17.9	18.0	19.6	1.13	**	NS	NS
b*	11.9	12.1	11.6	12.0	13.0	11.9	13.6	0.80	NS	NS	NS
Chroma	20.1	20.4	19.7	21.2	22.2	21.7	23.8	1.31	*	NS	NS
Hue angle (h^0)	36.2	37.0	36.0	34.9	36.4	33.3	34.5	1.24	*	NS	NS
Ulitmate pH	5.62	5.57	5.65	5.67	5.69	5.57	5.56	0.054	NS	NS	NS
Cooking loss (%)	27.9	26.4	27.4	25.7	25.0	25.7	24.3	1.31	**	NS	NS
7 day WBSF (kg/cm^2)	2.45	2.48	2.71	2.56	2.47	2.31	2.32	0.182	NS	NS	NS

[1] Both slaughtered at 450 kg live weight

Conclusions The data from the present study indicate that redness of meat increased and cooking loss decreased with increasing slaughter weight, while all bulls, regardless of weight at slaughter, produced sirloins which were acceptably tender. Furthermore, bulls produced beef with similar meat quality to steers slaughtered at the same live weight.

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The effect of slaughter weight on sensory quality of meat from Holstein-Friesian male cattle

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Introduction A considerable proportion of beef produced in the UK is a byproduct of the dairy industry. Young animals from this source are generally regarded as low in quality and meat from animals of this type is usually destined for the commodity minced beef market. The objective of the present study was to evaluate the effect of slaughter weight on sensory characteristics of meat from Holstein-Friesian bulls and steers offered a cereal-based ration.

Materials and methods A total of 180 Holstein-Friesian bulls were blocked according to live weight and age, and allocated at random to one of 7 slaughter weight treatments. The target slaughter live weights for bulls were 300, 350, 400, 450, 500 and 550 kg, while a further group were slaughtered as steers at 450 kg. All animals were offered concentrates *ad libitum* and a restricted quantity of barley straw (nominally 0.5 kg/head/d). The sirloins (*longissimus dorsi*) were removed from all animals at 3 days post slaughter an and silverside, packed in vacuum bags and stored for at 2^0C for 21 days prior to sensory analysis. Samples of silverside (*biceps femoris*) were removed from carcasses selected at random from animals slaughtered at 400, 450, 500 and 550 kg live weight, cut into 3 pieces cutting across the longitudinal axis (denoted proximal, centre, distal), and stored at -20^0C prior to sensory analysis. The distal section was not assessed presently. Following removal of fat and epimysium, samples were cooked to an internal temperature of 74 ºC in an electric fan assisted oven at 180ºC for an estimated cooking time of 30 minutes per 500g. The outer surface was then trimmed and the inner roast meat cut into portions (30-40g) which were allocated to taste panel sessions using a balanced design (PSA Systems Version 3.3, Oliemans, Punter and Partners, Utrecht, The Netherlands). Panellists scored samples for subjective attributes including acceptability of aroma, flavour, texture, and overall acceptability, and for objective attributes including intensity of aroma, intensity of flavour, tenderness and juiciness. Samples were also given a satisfaction score. Data were analysed by ANOVA, and all variates were tested for the presence of linear and asymptotic trends with carcase weight for the range of slaughter weights evaluated (bulls only).

Results Statistically significant differences between proximal and central sections of the *biceps femoris* (silverside) were observed for all sensory attributes of acceptability ($p<0.001$) and intensity scores ($p<0.05$). The proximal section had greater scores for acceptability of aroma, flavour, texture and overall acceptability than the central section. The intensity scores showed that the proximal section had a more intense, aroma, flavour and was more juicy and tender than the central section. Only 10% of panellists' scores for the proximal section were unsatisfactory, compared to approximately 24% for central section. Furthermore, the data indicated that differences in sensory characteristics between joint sections were more pronounced at the lower weight ranges. There were no statistically significant correlations between sensory attributes and carcase weight for the *biceps femoris*. Data on sensory characteristics of sirloin are presented in Table 1. There was a statistically significant asymptotic correlation with carcase weight for acceptability of aroma, ($p<0.05$), acceptability of texture ($p<0.001$) and intensity of tenderness ($p<0.05$). The asymptotic relationship between acceptability of tenderness and carcase weight explained only 17% of the total variation, indicating that predictions using this regression relationship would be unreliable as a major part of the variation remains unexplained In the comparison of bulls and steers slaughtered at a similar live weight, the data showed that panellists considered sirloins from steers to have significantly ($P<0.05$) more acceptable aroma, flavour and overall acceptability. However, acceptability of texture, intensity of aroma, flavour, tenderness and juiciness, and satisfaction scores were similar ($P>0.05$) between bulls and steers. It should be noted that the acceptability scores for all attributes of the sirloin for bulls were high (> 64 at least). None of the intensity scores for aroma, flavour, tenderness, juiciness or satisfaction rating were significantly different between bulls and steers. The average satisfaction rating for bulls was 2.4, indicating a rating between everyday quality and better than everyday quality.

Table 1 The effect of slaughter weight and sexual status on sensory characteristics of sirloin from bulls and steers

Slaughter wt	Bulls						Steers				Bulls vs
(kg)	300	350	400	450	500	550	450	ese	Linear	Asymp	Steers[1]
Acceptability[2]											
Aroma	71.5	69.9	68.7	68.5	70.9	70.5	71.5	0.98	NS	*	*
Flavour	68.7	65.5	65.4	64.5	69.7	64.4	69.8	1.17	NS	NS	*
Texture	69.1	66.4	66.2	65.3	69.3	61.3	67.4	1.81	NS	***	NS
Overall	69.5	67.4	66.4	65.5	71.2	64.1	69.9	1.29	NS	NS	*
Intensity[3]											
Aroma	52.1	53.0	50.4	51.3	54.8	54.1	51.8	1.68	NS	NS	NS
Flavour	51.8	53.2	50.6	50.2	53.4	50.4	54.1	1.52	NS	NS	NS
Tenderness	61.9	60.7	60.7	62.9	67.7	51.2	61.7	2.64	NS	*	NS
Juiciness	51.8	54.7	54.6	56.5	62.5	50.4	58.2	2.45	NS	NS	NS
Satisfaction [4]	2.5	2.4	2.4	2.4	2.6	2.2	2.6	0.06	NS	NS	NS

[1]Both slaughtered at 450 kg live weight [2]0=unacceptable; 100=extremely acceptable [3]0 = low intensity; 100=extremely intense
[4]4 point category scale where 1=unsatisfactory, 2=everyday quality, 3=better than everyday quality and 4=premium quality

Conclusions The results of the present study indicated that eating quality of sirloin was similar across the range of slaughter weights evaluated presently. However, there was evidence that eating quality of silverside may depend on position in the joint and slaughter weight. Furthermore, bulls produced beef with similar meat quality to that of steers slaughtered at the same live weight.

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Colour and fatty acid profile of beef subcutaneous fat depending on breed and feeding system

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Introduction Both breed and feeding system can affect the composition of fat depots in cattle. Furthermore, carcass fat colour may be influenced by forage-based diets due to the deposition of pigments, but also by changes in texture and firmness because of differences in the fatty acid (FA) profile. The objective of this work was to study the relationship between colour and FA profile of subcutaneous (SC) fat depending on breed and feeding systems in yearling bulls.

Materials and methods Twenty three yearling bulls "Asturiana de los Valles" (AV) and 29 bulls "Asturiana de la Montaña" (AM) breeds were studied. Seven AV and 14 AM were reared under extensive conditions and received a finishing diet composed of concentrate meal during the last 60 days. The rest of the animals (16AV & 15AM) were managed under intensive system fed with concentrate meal. Twenty four hours *post mortem* colour of SC fat was measured on the left half carcass by a colorimeter Minolta CR 200 (CIE L* a* b*), and Hue angle and Chroma were calculated. The 6th rib was extracted and dissected into lean, fat (SC, intermuscular), bone and other tissues. A sample of SC fat of the *longissimus thoracis* was vacuum packed and frozen at –80ºC for subsequent FA analysis by GC using $C_{21:0}$ as an internal standard. Stats: ANOVA between factors, PC analysis & Lineal Regressions of variables.

Results *Breed effect*: AV animals had significantly less SC fat content and a more yellow fat than AM animals.
Feeding effect: Animals from extensive system showed lower proportion of SC fat. This fat had higher values of yellowness (b*) and vividness (Chroma). Feeding system affected also to the proportion of some FA groups (saturated (SFA), branched (BFA), monounsaturated (MUFA), *n-3*FA) in SC fat. Referring to the FA profile, feeding effect was more pronounced in AM breed than in AV breed (Table 1). *Interaction:* Significant only for BFA group ($p \leq 0.05$).
The first two principal components explained 70.5% of the variation observed on colour parameters and FA profile (Figure 1). PC1 was positively related to colour parameters (Chroma, b*), SFA and BFA groups, and negatively related to MUFA group and SC fat content. PC2 was positively related to *n-6*FA and PUFA groups.

Table 1 Breed and feeding effect on SC fat content (%), colour parameters and fatty acid (FA) profile (%)

	AV		AM		Effects	
	Inten	Exten	Inten	Exten	Breed	Feed
%SC fat	2.20	1.23	3.35	2.33	**	***
b*	6.38	11.20	4.99	9.48	*	***
chroma	8.64	13.91	6.91	12.43	NS	***
%SFA	51.31	55.18	49.96	55.60	NS	***
%BFA	1.66	1.97	1.45	2.08	NS	***
%MUFA	42.90	38.63	44.75	38.23	NS	***
%*n-3*FA	0.65	0.70	0.65	0.77	NS	***
%*n-6*FA	3.11	2.87	2.86	2.81	NS	NS
%PUFA	4.12	4.22	3.83	4.08	NS	NS

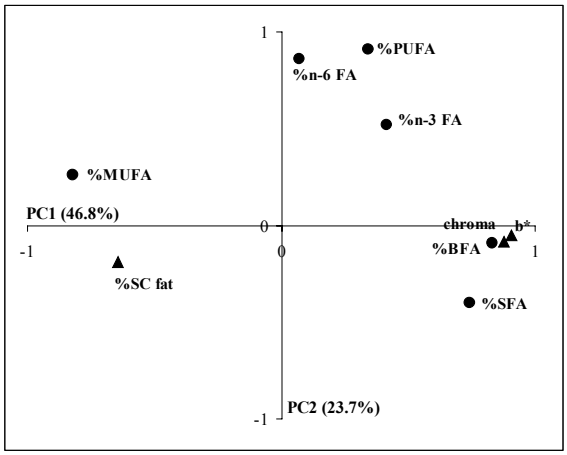

Figure 1 Biplot representation of principal components (PC1 & PC2) of variables studied on SC fat

Table 2 Correlations between colour parameters and FA groups in the SC fat

	Chroma	**b***
%BFA	r= 0.66 ***	r= 0.72 ***
%SFA	r= 0.53 ***	r= 0.55 ***
%MUFA	r=-0.58 ***	r=-0.62 ***
%PUFA	r= 0.17 ns	r= 0.24 ns

Fat colour (Chroma, b*) showed the highest correlation with BFA group, mainly *a*$C_{15:0}$, *i*$C_{16:0}$, probably due to an increased deposition of medium to long-chain (C_{14}-C_{18}) BFAs in forage + concentrate fed animals *versus* only concentrate fed ones, indicating different ruminal activity. The higher BFA content could affect fat firmness and colour as found by Miller *et al*. (1980) and Busboom *et al*. (1981) in lamb adipose tissue. There was a negative correlation between colour parameters and MUFA group, mainly $C_{18:1}c11$, $C_{18:1}t11$, $C_{18:1}c9$. This effect was found in concentrate fed animals which showed higher SC fat content and lower b* and Chroma (Table 2).

Conclusions In general, feeding effect on SC fat colour and FA profile was higher than breed effect. SC fat of extensively reared animals showed higher values of b* and Chroma, and higher content of SFA and BFA groups (positively correlated with colour) and lower content of MUFA group.

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Prediction of carcass weight from live weight in beef animals

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Introduction Beef production is the most important farm enterprise on Northern Ireland farms, accounting for 32.5% of Gross Agricultural Output. In beef production the end saleable product is carcass rather than live weight. When undertaking nutrition studies with beef cattle, it is essential to evaluate effects on carcass characteristics, as improvement in live weight may not transfer to improvements in carcass weight and characteristics due to change in gut fill effects. Undertaking carcass assessments in beef production studies increases experimental costs. To determine carcass gains it is essential to slaughter a representative batch of cattle pre-experimentally in order to develop a relationship between initial live weight and initial carcass weight. Slaughtering store cattle further adds to the costs of beef experimentation. The present study was undertaken to develop a relationship between live weight and carcass weight of beef cattle offered grass silage-based diets to facilitate the determination of initial carcass weight of store beef cattle at the point of initiation of nutritional studies.

Materials and Methods Live weight and carcass weights were available for 73 representative continental cross cattle which were slaughtered pre-experimentally from 8 experiments undertaken at the Agricultural Research Institute of Northern Ireland, Hillsborough. The sire breeds of the experimental animals were Charolais, Simmental, Limousin, Belgian Blue and Blonde d'Aquitaine. These cattle had been offered grass silage-based diets prior to allocation to the studies. The cattle were weighed on two consecutive days prior to slaughter. The cattle were slaughtered at an abattoir and carcass weight data were collated after the carcass had been dressed to meet commercial requirements.

Results Live weights ranged from 320 to 625 kg (mean 450 kg, s.d. 87.2 kg), carcass weights 161 to 344 kg and kill out proportion 0.465 to 0.645. Regression analysis using individual animal data was undertaken to develop a relationship between pre-experimental live weight and pre-experimental carcass weight.

This produced a linear relationship of the form:

CW = -24.82 (s.e. 7.65) + 0.5867 (s.e. 0.0167) LW R^2 = 0.95 *** rsd = 12.3

where CW = carcass weight (kg) and LW = live weight (kg)

For validation purposes, the dataset was randomly divided into two sub-groups of 49 and 24. The sub-group of 49 was used to develop a relationship between carcass weight and live weight. This relationship was validated using the remaining sub-group of 24. Linear regression analysis of the actual carcass weights and their respective predicted values from the model based on the sub-group of 49 was performed.

This identified a linear relationship described by the following equation:

PCW = 27.1 (s.e. 9.86) + 0.8639 (s.e. 0.0400) ACW R^2 = 0.95 *** rsd = 11.4

where PCW = predicted carcass weight (kg) and ACW = actual carcass weight (kg)

As the constant was not significantly different from zero (P>0.05) a further regression was undertaken with the constant term omitted. This line had a slope of 0.9707 with SE = 0.0104 and R^2 = 0.94 and rsd = 12.9 clearly indicating that carcass weight of the validation dataset was determined with a high degree of precision.

Conclusions It is concluded that the carcass weight of continental cross steers can be accurately predicted from its relationship with live weight, enabling pre-experimental carcass weight to be determined for beef cattle finishing studies.

Prediction of body weight and composition in lactating dairy cows: Prediction of empty body weight and carcass weight

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Introduction Empty body (EB) weight (EBW) is used to estimate the energy and protein requirements for maintenance for dairy cattle. It is predicted from live weight (LW), but the prediction can be influenced by a number of factors, e.g., feed and water intake, pregnancy and body condition. The objective of the present study was to develop prediction equations for EBW and carcass weight in lactating dairy cows using LW and other live animal data.

Material and methods One hundred and forty six Holstein Friesian lactating cows selected to represent a range of parity (29, 32 and 85 in parity 1, 2 and 3 or over respectively), body condition, genetic merit, stage of lactation and LW were slaughtered in 1999. The cows were subjected to a variety of nutritional and management regimes across a range of indoor feeding experiments, and offered mixed diets of grass silages and concentrate supplements, with forage proportions in diets ranging from proportionately 0.30 to 0.60 (DM basis). Live animal measurements were recorded 3 or 4 days prior to slaughter and included LW, body condition score (CS, 1 (very lean) to 5 (very fat) scales), milk yield (MY, last weekly mean before slaughter). Slaughter procedures for the determination of body composition were undertaken over a period of two weeks. The EBW was determined as LW minus weights of gut contents and foetus and associated fluid and membranes. Carcass weight was obtained by removing weights of head, tail, feet, hide and internal organs from EBW. Linear and stepwise multiple regression techniques were used to examine relationships of EBW and carcass weight with LW plus other live animal data.

Results There was a large range in LW (419 – 781 kg), EBW (293 – 606 kg), carcass weight (155 – 351 kg), parity (1 – 7), CS (1.1 – 4.0), MY (12.2 – 44.1 kg/d) and days in milk (21 – 498). Relationships between LW and EBW or carcass weight (Figure 1) and between EBW and carcass weight were all significant ($P < 0.001$) ($R = 0.93$ to 0.98). The EBW and carcass weight positively related ($P < 0.001$) to CS ($R = 0.60$ and 0.62), parity ($R = 0.52$ and 0.48) and days in milk ($R = 0.29$ and 0.29), while had no significant relationships with MY. A number of linear and multiple prediction equations for EBW and carcass weight have been developed (Table 1). These relationships are all highly significant ($P < 0.001$) and each predictor has a significant effect on the relationship ($P < 0.001$). The LW was used as the primary predictor for EBW and carcass weight (Eq. (1a) – (2b)) and addition of CS, MY or stage of lactation (LS = 1 for lactation days of 1 to 100, 2 for 101 to 200 and 3 for over 200) as secondary predictors increased R^2 values from 0.89 to 0.92 (Eq. (1a) vs. (1b)) or from 0.87 to 0.92 (Eq. (2a) vs. (2b)). Prediction of carcass weight using EBW alone or with CS generated even higher R^2 values (0.95 – 0.96, Eq. (3a) – (3b)).

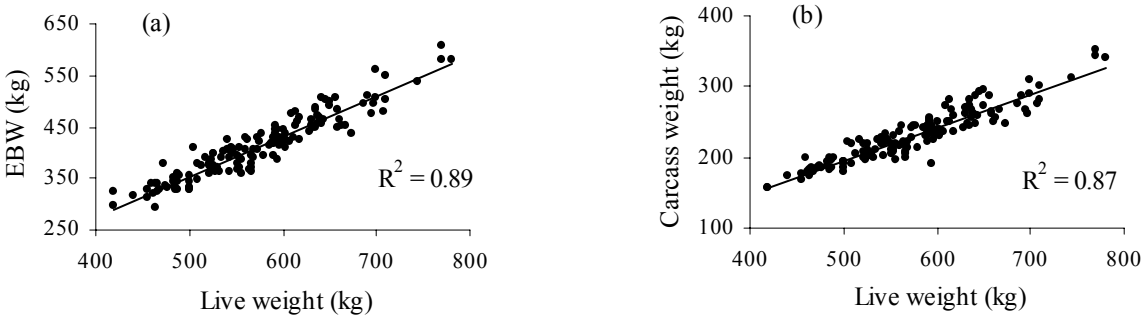

Figure 1 Relationships between live weight and EBW (a) and carcass weight (b) in lactating dairy cows

Table 1 Linear and multiple prediction equations (subscripted data in parentheses are s.e. values)

		Equations	R^2	Eq. No
Empty body weight (kg)	=	$0.779_{(0.023)}$ LW – $35.9_{(13.4)}$	0.89	(1a)
		[$0.586_{(0.032)}$ + $0.035_{(0.006)}$ CS + $0.012_{(0.004)}$ LS] LW + $9.6_{(13.0)}$	0.92	(1b)
Carcass weight (kg)	=	$0.469_{(0.015)}$ LW – $39.2_{(8.7)}$	0.87	(2a)
		[$0.381_{(0.023)}$ + $0.026_{(0.004)}$ CS - $0.0010_{(0.0003)}$ MY] LW -$12.1_{(8.1)}$	0.92	(2b)
		$0.593_{(0.011)}$ EBW – $13.9_{(4.5)}$	0.95	(3a)
		[$0.533_{(0.021)}$ + $0.012_{(0.004)}$ CS] EBW - $2.7_{(5.5)}$	0.96	(3b)

Conclusion Empty body weight and carcass weight are highly significantly related to LW in lactating dairy cows and addition of other live animal variables (CS, MY and LS) can further improve these relationships.

Acknowledgement Authors thank DARD for funding this work and their colleagues for assistance with this project.

Prediction of body weight and composition in lactating dairy cows: Prediction of crude protein contents in internal organs

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Introduction Heat production of animals is mainly derived from body protein metabolism and energy expenditure per unit protein in internal organs is much higher than skeletal muscle. The accurate estimation of CP mass in internal organs can thus improve rationing systems for farm animals. The objective of the present study was to examine relationships between CP mass in internal organs and empty body weight (EBW) with other live animal variables in lactating dairy cows.

Material and methods The CP mass in pluck (including trachea, lungs, heart, diaphragm, liver, kidneys and tail) (n = 146), guts (including urino-genital tract) (n = 134) and udder (n = 139) were derived from Holstein Friesian lactating cows. The animal and dietary information was reported by Yan *et al.* (2005). Lactation numbers were from 1 (n = 29), 2 (n = 32) to 3 or over (n = 85). The foetus and associated fluid and membranes were removed for pregnant cows. The EBW was determined as live weight minus weights of gut contents and foetus and associated fluid and membranes. Body condition score (CS) was determined using 1 to 5 scales (1 for very thin and 5 for very fat). Linear and stepwise multiple regression techniques were used to examine relationships between CP mass in internal organs and EBW with other live animal data.

Results There was a large range in EBW (293 – 606 kg), CS (1.1 – 4.0), milk yield (MY, 12.2 – 44.1 kg/d) and CP mass in pluck (2988 – 5673 g), guts (4118 – 9168 g) and udder (1473 – 3766 g). The CP masses in pluck, guts and udder were all positively related to live weight, EBW (Figure 1), parity range (PR, 1 for parity 1, 2 for parity 2 and 3 for parity 3 or over) and CS ($P < 0.01$ or less). There were positive relationships between MY and CP mass in pluck ($P < 0.001$) and udder ($P < 0.01$), and between CP mass in guts and stage of lactation (LS, 1 for lactation days of 1 to 100, 2 for 101 to 200 and 3 for over 200) ($P < 0.001$). A number of multiple regression equations have been developed for prediction of CP mass in internal organs using EBW and other variables (Table 1). These relationships are all highly significant ($P < 0.001$) and each predictor has a significant effect on the relationship ($P < 0.05$ or less). The R^2 values were ranged from 0.55 for prediction of CP mass in guts (Eq. (2) to 0.79 in pluck (Eq. (1)). Relating to total CP mass in these three organs produced the highest R^2 value (0.81, Eq. (5)).

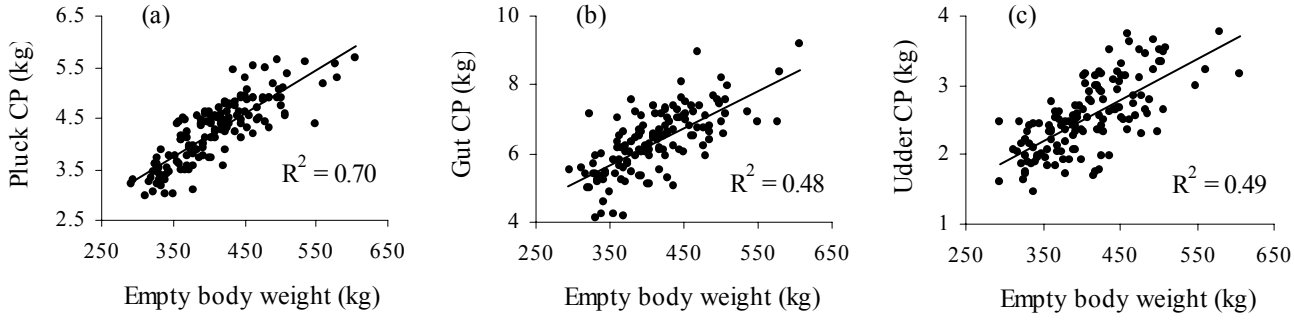

Figure 1 Relationships between EBW and CP contents in pluck (a), guts (b) and udder (c) in lactating dairy cows

Table 1 Multiple prediction equations (subscripted data in parentheses are s.e. values)

		Equations	R^2	Eq. No
Pluck CP (g)	=	$(7.940_{(1.050)} + 0.401_{(0.095)}$ PR + $0.027_{(0.012)}$ MY – $0.430_{(0.149)}$ CS) EBW + $831_{(252)}$	0.79	(1)
Guts CP (g)	=	$(11.15_{(2.31)} + 0.412_{(0.200)}$ PR + $0.587_{(0.191)}$ LS – $0.860_{(0.323)}$ CS) EBW + $1819_{(578)}$	0.55	(2)
Pluck+guts CP (g)	=	$(19.79_{(2.48)} + 0.898_{(0.215)}$ PR + $0.661_{(0.205)}$ LS – $1.417_{(0.346)}$ CS) EBW + $2615_{(621)}$	0.77	(3)
Udder CP (g)	=	$(4.040_{(1.130)} + 0.509_{(0.101)}$ PR + $0.031_{(0.012)}$ MY - $0.342_{(0.172)}$ CS) EBW + $500_{(271)}$	0.64	(4)
All organs CP (g)	=	$(24.55_{(2.99)} + 1.415_{(0.260)}$ PR + $0.493_{(0.244)}$ LS – $1.645_{(0.444)}$ CS) EBW + $3139_{(743)}$	0.81	(5)

Conclusion Relating CP masses in pluck, pluck+guts and pluck+guts+udder to EBW with other live animal variables produced relatively high R^2 values, indicating that CP mass in internal organs in lactating dairy cows can be accurately predicted from live animal characteristics.

Acknowledgement Authors thank DARD for funding this work and their colleagues for assistance with this project.

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Effect of ruminal degradable nitrogen deficit on nitrogen metabolism in growing double-muscled Belgian Blue bulls fed maize silage based diet

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Introduction As concerns for environmental damage instigated by agricultural processes increase, there is a greater need to develop more ecologically acceptable methods of producing agricultural products. Therefore, in beef production we have to minimise N excretion and maximise N retained. Urea recycling provides a mechanism by which N may be salvaged into bacterial matter that may be digested by the animal to supply amino acids for production purposes. According to Huntington and Archibeque (2000), the amount of recycled urea-N can be influenced by the ruminal ammonia concentration, the OM digestibility and the plasma concentration of urea. The objective of the present study was to examine the effect of different levels of ruminal degradable N (RDN) on nutrient digestion and N metabolism in double-muscled Belgian Blue (dm-BB) bulls fed maize silage based diet.

Material and methods Six dm-BB bulls initially weighing 304 ± 12 kg and fitted with a ruminal cannula were used in the study. The bulls received a diet made up of 60% DM of maize silage and 40% DM of concentrates at an intake level of 85 g DM/kg$^{.75}$ in two meals at 0830 and 2030. Three different concentrates were formulated to give similar diet's contents of intestinal digestible proteins (84 g DVE/kg DM), net energy for fattening (7.3 MJ/kg DM) and FOM (595 g FOM/kg DM) according to the Dutch system, but different levels of RDN. In this way, two diets characterised by two different levels of RDN deficit (LRDN1 and LRDN2) were compared to a diet providing a RDN excess (HRDN). The RDN:FOM ratio of the three diets reached 16.2, 21.4 and 26.3 g N/kg FOM and the CP contents amounted to 111, 133 and 153 g/kg DM, respectively for LRDN1, LRDN2 and HRDN. The bulls were allocated to three treatment periods in two juxtaposed 3 × 3 Latin squares. Rumen ammonia concentration was monitored. Bulls were blood sampled every 2h during 24h and after centrifugation samples analysed for plasma urea-N (PUN). Faecal output was measured using chromic oxide as an indigestible flow marker and the total urine collection was realised with an adaptation of the apparatus of Veenhuizen *et al.* (1984). Urine was analysed for N, and feed and faeces for N, OM and NDF. Results were analysed using analysis of variance. Differences between means were compared using the Newman-Keuls test.

Results Ruminal ammonia concentration was highly influenced by the level of RDN and attested the existence of deficiency in N supply in the rumen when LRDN1 was fed (Table 1). Moreover, plasma urea-N levels was lower in animals on LRDN1 and indicated that a global transfer of N from the blood to the rumen occurred. OM and NDF digestibility were not affected by the RDN level of the diet. As the diet CP contents were different, the N intake was highly influenced by the treatments. The N faecal losses were not found to differ and reached on average 50.9 g/d. Contrariwise, the urinary N output increased significantly with the RDN level of the diet. Compared to HRDN, urinary N outputs measured with LRDN 1 and LRDN 2 were 48.8 and 26.5% lower. Nitrogen retention, expressed in g/d, were affected by the treatments (P <0.001). However the total N excretion of the bulls fed the low RDN diets decreased largely, these reductions were not sufficient to compensate the decrease of the N ingested. Therefore, the RDN levels of the diet have no influence on the portion of the N ingested which was retained by the dm-BB bulls. On the other hand, the N retention as a percentage of N digested decreased significantly with the RDN level increase.

Table 1 Ruminal ammonia concentration, plasma urea-N, diet digestibility and N balance of bulls fed diets with different levels of RDN.

	Level of RDN			SEM	P
	LRDN1	LRDN2	HRDN		
Ruminal N-NH_3 (mg/dl)	1.8^a	4.7^b	8.9^c	0.46	<0.001
Plasma urea-N (mg/dl)	1.9^a	5.0^b	7.9^c	0.15	<0.001
OM digestibility (g/g)	0.69	0.71	0.70	0.006	0.260
NDF digestibility (g/g)	0.61	0.58	0.59	0.009	0.241
N digestibility (g/g)	0.58^a	0.65^b	0.68^c	0.006	<0.001
N intake (g/d)	120.1^a	141.1^b	164.7^c	1.67	<0.001
N faecal (g/d)	50.8	49.4	52.5	1.11	0.203
N urinary (g/d)	28.0^a	40.2^b	54.7^c	0.67	<0.001
N retained :					
- g/d	41.3^a	51.5^b	57.6^c	1.41	<0.001
- % N ingested	34.5	36.6	35.1	0.74	0.183
- % N digested	59.8^a	56.2^b	51.4^c	0.97	<0.001

^{a,b,c}: means with different superscripts, within rows, differ significantly (P < 0.05).

Conclusions These results indicated that feeding maize silage based diets supplying similar contents of intestinal digestible proteins and net energy for fattening but with ruminal degradable N deficit reduced significantly the N excretion of growing dm-BB bulls mainly in urine. Contrariwise, the bulls fed on these diets can not retain as much N as the bulls fed with a RDN excess.

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Comparative post-weaning growth and carcass characteristics in suckled, purebred Charolais and Limousin x Aberdeen Angus steers finished intensively on a cereal based ration

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Introduction Following commercial practice in France, there is increased interest in using specifically selected purebred maternal lines as suckler cow dams in the UK. Consequently, there is also a need to evaluate the finishing performance of the concomitant purebred male progeny from these maternal lines within typical UK suckled calf finishing systems. The objective of this study was to compare the post-weaning performance of purebred Charolais (CH) steers and crossbred Limousin x Aberdeen Angus (LIMxAA) steers when finished using a cereal-based ration.

Materials and methods 10 purebred CH and 9 LIMxAA steers were used in a continuous design experiment to determine liveweight gain (LWG) from weaning to slaughter and post slaughter carcass characteristics. All steers of both breed types were the progeny of either purebred CH or crossbred AAxLIM primiparious, spring calving suckler dams respectively. After weaning on 16th October 2003, all steers were housed in slatted pens and were initially offered cracked whole-crop barley *ad libitum* and 4 kg/d of a proprietary concentrate feed. During this initial 4 week acclimatisation period, all animals were gradually changed onto a cereal-based ration (DM: 866; ME: 12.6; CP 130) which was offered *ad libitum* from the end of week 4 until slaughter. The cereal-based ration contained rolled barley, rapeseed meal and minerals and a small amount (~1 kg/day) of unchopped barley straw was also given to avoid rumen acidosis problems. All steers were weighed on a monthly basis until near slaughter when they were weighed fortnightly and individual LWG figures determined by linear regression. For each of the two steer breed groups, the rate of change in LWG as steers grew to heavier weights was assessed by regression of monthly LWG against average monthly LW. After selection for slaughter at a minimum target condition of R4L, cold carcass weight (CW), killing out proportion (KO) and fatness (FAT) and conformation (CONF) scores on a 15-point scale were derived from carcass gradings for each steer. Age, growth and carcass data were analysed using the REML procedure in Genstat 5.

Results Average days on trial, age at slaughter (AGE), initial LW, final LW, LWG, CW, KO and carcass scores are given in Table 1. Purebred CH steers spent longer on trial ($P<0.001$), had heavier final LW ($P<0.01$), higher LWG's ($P<0.05$) and lower FAT ($P<0.05$) scores than LIMxAA steers. LIMxAA steers had a higher KO proportion ($P<0.05$) compared to CH steers. Overall R^2 values were very low due to individual animal variation, but the regression co-efficients in both linear and quadratic regression analysis indicated that the rate of LWG declined as CH steers increased in LW (Figure 2). However, given the minimal linear regression co-efficient in Figure 1, only quadratic regression indicated that LIMxAA steers decreased their rate of LWG as animals increased in LW.

Table 1 Growth and carcass characteristics in purebred CH and LIMxAA steers finished on a cereal-based ration

	LIMxAA	CH	sed	Sig		LIMxAA	CH	sed	Sig
Days on trial	194	226	6.4	***	Carcass weight (kg)	312	321	9.7	
AGE (days)	385	402	9.3		Killing out (g/kg)	602	560	8.2	***
Initial LW (kg)	274	249	20.1						
Final LW (kg)	519	575	17.4	**	FAT score (1-15)	8.75	7.80	0.396	*
LWG (kg/d)	1.36	1.51	0.062	*	CONF score (1-15)	9.94	9.80	0.818	

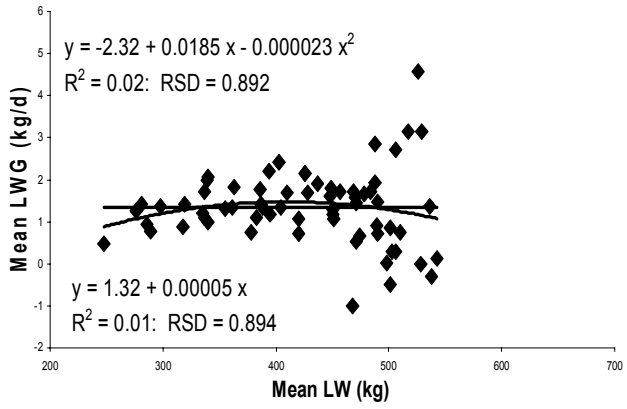

Figure 1 Change in LWG as LIMxAA steers get heavier.

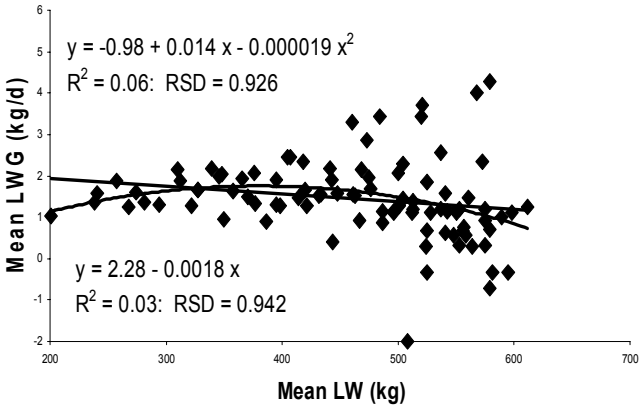

Figure 2 Change in LWG as CH steers get heavier

Conclusions Purebred CH steers produced commercially acceptable but leaner carcasses of similar weight compared with LIMxAA steers. They had higher growth rates from weaning to slaughter but lower KO proportions than LIMxAA steers. Further work is required to investigate feed intakes, feed conversion ratios and growth in purebred CH steers and bulls finished using typical UK production systems.

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Effect of various levels of imbalance between energy and nitrogen supplies in the rumen on nitrogen metabolism in growing double-muscled Belgian Blue bulls fed maize silage based diet

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Introduction In a previous study, Valkeners *et al.* (2004) reported that feeding a concentrate-based diet with an imbalance between energy and N release in the rumen did not greatly influence the N balance of double-muscled Belgian Blue (dm-BB) bulls if daily ruminal degradable N (RDN) and fermentable OM (FOM) ratio did not exceed 6.2 g RDN/kg FOM. The objective of the present study was to examine the effects of a higher level of imbalance between energy and N release in the rumen on microbial protein synthesis and N metabolism in dm-BB bulls fed maize silage based diet.

Material and methods Six dm-BB bulls initially weighing 341 ± 22 kg and fitted with a ruminal cannula and a T-type cannula at the proximal duodenum were used in the study. The bulls received the same diet, at an intake level of 76 g DM/kg$^{0.75}$, according to three different feeding patterns, so that three different levels of imbalance between energy and nitrogen supplies for the rumen microbes were created. The diet was made up of 47% DM of maize silage and 53% DM of concentrates and supplied 83 g of intestinal digestible proteins (DVE) and 7.5 MJ of net energy for fattening per kilogram of DMI according to the Dutch system. The feedstuffs were shifted between the 0830 and 2030 feeding to provide either a balance (L0) or an imbalance (L1 and L2) supply of OM and N to the rumen. The level of imbalance was measured by the variation of RDN:FOM ratio between the two meals of a day, while on a daily basis, this ratio was closed to 23 g/kg. For the 0830 feeding, the RDN:FOM ratios amounted to 23.0, 17.7 and 12.5 g/kg, respectively for L0, L1 and L2, and for the 2030 feeding, to 23.0, 28.1 and 33.3 g/kg. The levels of imbalance reached thus 0, 5.2 and 10.4 g RDN/kg FOM, respectively for L0, L1 and L2. The bulls were allocated to three treatment periods in two juxtaposed 3 × 3 Latin squares. Rumen fermentation was monitored by pH and ammonia concentration. Total digesta and microbial protein flows to the proximal duodenum and faecal output were measured using chromic oxide as an indigestible flow marker and purines content as a microbial marker. The total urine collection was realised with an adaptation of the apparatus of Veenhuizen *et al.* (1984). Results were analysed using analysis of variance.

Results Unlike pH, the ruminal ammonia concentration was highly influenced by the nature of the feed ingredients ingested and attested the existence of periods of excess and deficiency in N supply. The period of time that rumen ammonia concentration was below 5 mg/dl depended on the meal ingested and amounted to 8h, 10h and 11h over the 12h after the 0830 feeding, respectively for L0, L1 and L2, and to 8h, 6h and 4h over the 12h after the 2030 feeding. The N ingested and the duodenal N flows were similar among the three feeding patterns (Table 1). Efficiencies of microbial protein synthesis (ESPM) were not significantly affected by the level of imbalance and reached on average 26.5 g N/kg OM apparently digested in the rumen. The N excreted in faeces and the urinary N outputs were not significantly different among the three treatments and reached on average 47.7 and 41.5 g/d, respectively. The N retention were not affected by the level of imbalance between N and energy supplies for the ruminal micro-organisms. The level of imbalance did not negatively influence the portion of the N ingested or N digested which was retained by the dm-BB bulls. These observations supported the hypothesis that the ruminants and their microbes can detect asynchrony in the rate of nutrient supply and have developed mechanisms to overcome or minimise its effects. The movements of N across the gut play a major role in regulating the amount of ruminally available N and provide an overall plasticity to allow rapid response to any changes in metabolic status.

Table 1 N intake, duodenal N flows, ESPM (g N/kg OM apparently digested in the rumen) and N balance of bulls fed the same diet with different levels of imbalance between energy and N supplies for ruminal microbes

	L0	L1	L2	s.e.m.	*P*
N intake (g/d)	140.1	141.5	138.9	1.37	0.398
Duodenal flow (g/d):					
- Total N	153.4	148.1	144.3	4.53	0.414
- Non NH_3-N	148.5	143.8	140.0	4.45	0.437
- Microbial-N	73.5	72.1	72.5	3.92	0.972
ESPM	29.2	25.8	24.6	2.62	0.536
N faecal (g/d)	49.1	47.4	46.6	0.72	0.111
N urinary (g/d)	41.3	42.2	41.1	1.39	0.820
N retained :					
- g/d	49.7	52.0	51.3	2.09	0.740
- % N ingested	35.7	36.8	36.8	1.28	0.802
- % N digested	54.8	55.5	55.4	1.69	0.966

Conclusions These results indicated that feeding a maize silage based diet with an imbalance between energy and N release in the rumen did not greatly influence the microbial protein synthesis and the N retention of dm-BB bulls. It would appear that the smoothing capacity of growing dm-BB bulls can overcome daily RDN:FOM ratio's variations until 10.4 g RDN/kg FOM when maize silage based diet is fed.

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Effect of Bombesin on the amount and constituents of milk in the Sarabi cows

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Introduction It is now established that the process of milk production and its constituents are affected by different physiological factors, including hormones and neurotransmitters. Bombesin (BBS) is a tetradecapeptide that isolated and characterized from the skin of amphibian frog *bombina bombina* (Jontown *et al.,* 1995). Subsequently, several BBS-like peptides have been identified in mammals consisting of various forms of gastrin-releasing peptide (GRP) and neuromedin B (NMB), together with their distinct receptor subtypes (Jian *et al*., 1999). Nowadays, they have been found at different parts of the body such as neuron system, gastrointestinal tract and some nucleuoses of hyphothalamus of vertebrates and invertebrates. The bombesin family of peptides are biologically active in the central nervous system and periphery. Bombesin achieves to its functions by starting the secondary messenger of inositol triphosphate (IP_3). The effects of bombsin on production and constituents of the milk are not studied yet. The aim of this experiment was to determine whether injections of bombesin increase milk amount and constituents in the cows.

Materials and methods Nine Sarabi cows with average body weight of 420±20 Kg were used in a split-plot design study with 3 cows per treatment. Cows divided randomly into 3 groups. Each group received daily injections of either saline or 1, 2, 4 milligrams bombesin per kilogram (mg/kg) for 10 days. Milk samples were collected from 1- 5- 10 day of ex periment. Samples of milk were analyzed for fat (Gerber method, ILCA, 1988), protein and lactose (AOAC,1980). The daily amount of milk changes were determined throughout the experiments. The data were analyzed by using SAS software (1991).

Results The results indicate that injection of 1 and 2 mg/kg Bombesin increased 20.9 % and 2.53% respectively at milk production, after compare to the before injection period ($p<0.01$). The injection of 4 mg/kg bombesine increased 5.6% milk production during injection compare to the period of before injection ($p<0.01$). But, Bombesin injection did not have any significant effect on the percent of milk constituents (protein, lactose). Although, milk fat percent increased considerably at the period of injection ($p<0.01$).

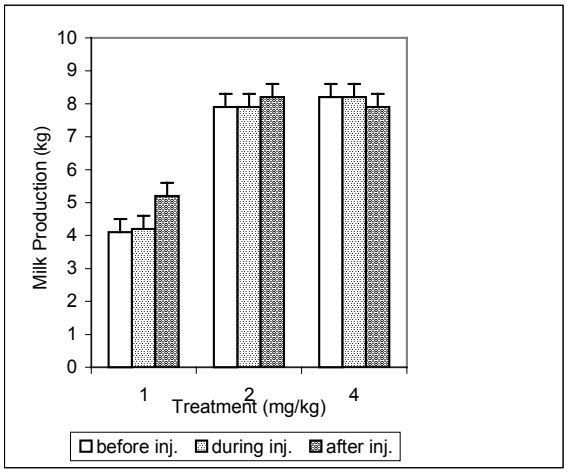

Figure 1 Milk production in the different treatments of experimental

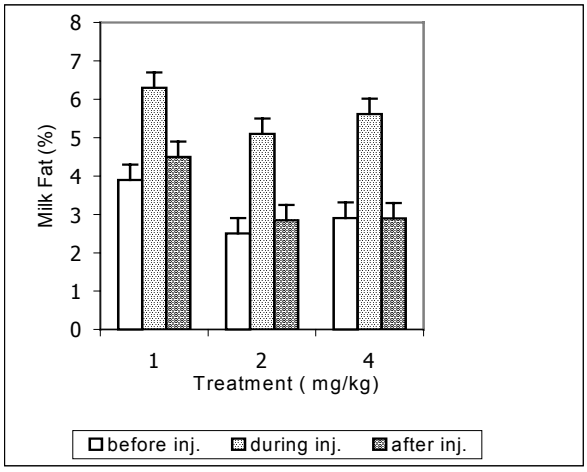

Figure 2 Milk fat percent in the different treatments of experimental

Conclusion This study provided evidence that the most milk production is related to the first treatment. Injection of 1 mg bombesin significantly increased the amount of milk 28.57% ($p<0.01$). Results of milk constituents indicated that only milk fat percent increased, but the other milk constituents did not change. Therefore, The injection of different bombesin doses may change milk production.

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Effect of offering two levels of crude protein and two levels of milk replacer on calf performance

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Introduction Recent reports from the United States propose new nutritional guidelines for calves (VanAmburgh 2003). They suggest an accelerated growth programme where calves are offered a high protein milk replacer (CMR) at a level sufficient to achieve a liveweight gain of 1000 g/d up to 8 weeks of age. This is in contrast to many European feeding programmes where calves are offered 25 kg of CMR over 42 days with an expected liveweight gain of 500 to 600 g/day. The objective of this experiment was to evaluate the accelerated growth system under Irish conditions.

Materials and methods In experiment 1, sixty-four 2 to 3 week-old Holstein/Friesian calves with an initial weight of 50 kg (+/- 1.8) were allocated immediately following purchase to the following treatments: (1) 23% crude protein CMR at 600 g/d (LL), (2) 23% crude protein CMR at 1200 g/d (LH), (3) 30% crude protein CMR at 600 g/d (HL) and (4) 30% crude protein CMR at 1200 g/d (HH). The milk replacer was offered warm by bucket with the daily allowance reduced to encourage solid food intake in the period 42 to 56 days. All calves had *ad libitum* access to a concentrate diet throughout the 16-week experimental period. In the initial 56-day period all calves were individually penned on straw with a pen area of 1.5 m^2 per calf. Thereafter groups were penned according to treatment on concrete slats. In Experiment 2 thirty-six 2 week old Holstein/Friesian calves with an initial weight of 45 kg (+/- 1.6) were allocated on purchase to the following treatments: (1) 23% crude protein CMR at 750 g/d (LM) and (2) 30% crude protein CMR at 1200 g/d (HM). Feeding and management of the animals was similar to Experiment 1. In Experiment 1 the data was subjected to a two-way analysis of variance. In Experiment 2 data was subjected to analysis of variance.

Results The level of protein did not affect feed intake or liveweight gain. In Experiment 1 level of feeding significantly decreased concentrate intake in the period 1 to 56 days but did not significantly affect liveweight gain in the period in the period 1 to 112 days (Table 1). In Experiment 2 the high level of feeding significantly reduced concentrate intake in the period 1 to 56 days but had no significant effect on liveweight gain (Table 2).

Table 1 Effect of level of feeding and level of protein in the CMR on calf performance (Experiment 1)

						Sig		
	LL	LH	HL	HH	Sem	L	P	L x P
Liveweight gain g/d								
1 - 56 days	690	760	720	870	48	*	-	-
57 - 112 days	1020	1140	1070	1110	67	-	-	-
1 - 112 days	860	950	900	990	48	-	-	-
Concentrate intake (kg/DM)								
1 - 56 days	34.0	28.2	41.1	23.2	4.12	**	-	-
57 - 112 days	180.5	189.6	168.2	211.9				
1 - 112 days	214.5	217.8	209.3	234.1				
CMR intake 1 - 56 days (kg/DM)	30.3	57.4	29.9	56.7				

Table 2 Effect of CMR programme on calf performance (Experiment 2)

	LM	HM	sem	Sig
Liveweight gain g/d				
1 - 56 days	550	640	45	-
57 - 112 days	1030	1070	85	-
1 - 112 days	790	860	55	-
Concentrate intake (kg/DM)				
1 - 56 days	29.0	17.4	2.75	**
57 - 112days	150.8	150.1		
1 - 112 days	179.8	167.5		
CMR intake 1 - 56 days (kg/DM)	29.6	46.3		

Conclusion Increasing the daily CMR allowances from 600 g to 1200 g increased LWG in the period 1 to 56 day and there was no response to increasing the level of crude protein from 23 to 30%.

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The performance of Holstein-Friesian and Jersey calves when fed two concentrations of a high protein milk replacer

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Introduction Artificial rearing is a common practice for rearing calves from the dairy herd, either for replacement heifers or for beef production. The period from birth to weaning is a critical period for the calf and nutrition is one of the components important to ensure successful rearing of calves. Improved nutrition that allows earlier weaning through a rapid calf growth has the potential to decrease costs. Moreover, it has been shown that healthy, vigorous and well-grown weanling heifers may enter the milking herd sooner (Davis and Drackley, 1998). The objective of this study was to examine the effect of feeding two concentrations of a high protein milk replacer on the health and growth performance of dairy calves until weaning.

Materials and methods 52 bull and heifer Holstein Friesian (HF; n=26) and Jersey (J; n=26) calves were assigned in a randomised block designed experiment to either a standard (control = C) or high (treatment = T) concentration of milk replacer (MR). All calves were fed colostrum for the first week of life at 2 and 3 litres per day for J and HF calves, respectively. From one week old calves were fed whole milk for 2 weeks, during which the amount gradually increased to 4 and 6 litres per day for J and HF calves, respectively. From 4 weeks old calves were fed a whey-based milk replacer powder (DM 969 g/kg, 300g crude protein (CP)/kg DM, and 20 MJ metabolisable energy (ME)/kg DM: Trouw UK Ltd, Wincham, Northwich, Cheshire, UK). Treatment C consisted of MR mixed with water at approximately 40ºC at a rate of 100g/litre. Treatment T consisted of the MR mixed at a rate of 200g/litre. Calves were fed 4 (J) and 6 (HF) litres per day, in two equal feeds. Calves were individually penned on straw and offered starter pellets (DM 873 g/kg, 180g CP/kg, 126 MJ ME/kg) and water. Weaning took place at the age of 6 to 8 weeks, depending on body weight, for HF calves, while the J calves were weaned at 12 weeks of age. The animals were weighed on the date of birth and once weekly thereafter until weaned. When calves were fed MR diets the amount of starter pellets and water offered and refused was recorded. Data were analysed by analysis of variance using GenStat 6 (Lawes Agricultural Trust, 2002).

Results There were no significant differences between different sexes of calves. There were no significant effects found for interaction between breed and MR diet. Effects of MR diet and calf breed on calf performance are shown in Table 1. Calves fed T diet had significantly higher weaning weight ($P < 0.05$) and growth rate ($P < 0.001$) than calves fed C diet. Calves fed T diet had lower starter pellet DMI but higher total DMI and water intake ($P<0.001$) compared to calves fed C diet. HF calves had significantly higher birth weight, weaning weight, growth rate and total DMI ($P < 0.001$) than J calves. There were no treatment or breed effects on feed conversion efficiency. There were no treatment or breed differences in the health of the calves, with 1 or 2 calves from each treatment or breed being treated for scour.

Table 1 The effects of concentration of MR diet and calf breed on live weight, growth rate, water and feed intake and feed conversion ratio

	HF		J			Significance	
	C	T	C	T	s.e.d.	Diet	Breed
Live weight							
Birth weight (kg)	40.0	41.0	25.1	24.4	0.824	NS	***
Weaning weight (kg)	66.2	72.9	60.8	61.5	1.702	*	***
Growth rate (kg/day)							
Birth to weaning	0.498	0.633	0.431	0.499	0.0223	***	***
Intake							
Water (litre/d)	1.11	1.81	0.85	1.62	0.153	***	NS
Starter pellets DMI (kg/d)	0.60	0.33	0.65	0.44	0.040	***	NS
Total DMI (kg/d)	1.18	1.49	1.04	1.21	0.040	***	***
Feed conversion efficiency							
Live weight gain:DMI (g/kg)	449	470	481	476	13.5	NS	NS

NS, Not significant; * $P < 0.05$; *** $P< 0.001$

Conclusions Feeding a high concentration of MR improved growth rate and weaning weight of HF and J calves as a consequence of increased DMI, whilst efficiency of food conversion was maintained.

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The effect of feeding an essential oil feed additive on dairy cow performance

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Introduction High-yielding dairy cows must produce large amounts of milk of a desired quality from a cost-effective diet in order for the farmer to remain in profit. Optimal rumen function and health is a key part of the process of converting nutrients into milk efficiently. Essential oils are steam-volatile or organic-solvent extracts of plants that have been shown to have beneficial effects on human digestion. They are mainly cyclic hydrocarbons and their alcohol, aldehyde or ester derivatives (Wallace, 2004). 'Crina Ruminants' is a blend of such essential oil compounds, designed to stimulate rumen activity and boost the population of beneficial microbes, through anti-microbial and digestive stimulant activity. In particular, it is believed to encourage an increase in fibre-fermenting bacteria and to counteract the acidotic rumen conditions that can be caused by feeding high starch diets. The aim of this experiment was to evaluate the effects of 'Crina Ruminants' on intake and milk production.

Materials and methods Sixteen Holstein-Friesian dairy cows in early lactation were blocked into groups based on milk yield, parity and liveweight, and allocated at random to four treatment diets in a Latin square design, using four 4-week feeding periods. The treatments provided increasing amounts of the product, from the control diet (C), to 0.5, 1.0 and 2.0g/h/d (T1, T2 and T3, respectively). The cows received, through individual feeding stations, a basal diet of *ad libitum* grass silage (predicted to be 10.5 kg DM/h/d) and 12 kg/h/d FW of an 18% protein dairy concentrate. The concentrate was fed in three equal meals a day, at 0730, 1200 and 1630 hrs, with the additive top-dressed onto the midday feed. The animals had constant access to fresh water. Feed intake was measured over the last seven days of each period. Milk yields of individual cows were recorded, and milk samples collected, on consecutive pm/am milkings on all seven days of the last week of each period, to be analysed for butterfat and protein. All cows were weighed and their body condition score assessed (Mulvanny, 1977) on the same day each week. Forage and concentrate samples were collected weekly and bulked into one sample per period, before chemical analysis.

Results Intake and milk yield, fat and protein production data from the experiment are shown in Table 1. Milk yield showed a significant ($P<0.05$) linear increase with increasing levels of 'Crina Ruminants' in the diet. There were no significant effects of treatment on the concentrations of fat or protein in milk ($P>0.05$). The increase in milk volume led to a significant increase in milk protein output for the three diets containing 'Crina Ruminants' compared to the control ($P<0.05$). There was also a significant overall linear dose effect for milk protein output ($P<0.05$) and an indication ($P=0.075$) of a similar effect for milk fat output. Treatment had no significant effect on silage intake ($P>0.05$). Calculated daily ME intakes were 2-3 MJ higher for the cows receiving 'Crina Ruminants' but this does not explain the observed milk yield response.

Table 1 Production data from cows fed treatments C, T1, T2 and T3

	C	T1	T2	T3	s.e.d.	P	P (linear)
Silage intake (kg DM/day)	10.3	10.6	10.5	10.6	0.27	NS	NS
Milk yield (kg/day)	31.1	32.5	32.8	33.1	0.83	0.084	**0.031**
Milk constituents:							
Fat yield (g/day)	1158	1203	1229	1228	37.3	NS	0.075
Fat content (g/kg)	37.7	37.4	37.6	37.4	1.08	NS	NS
Protein yield (g/day)	1049[a]	1106[b]	1118[b]	1125[b]	27.2	**0.033**	**0.015**
Protein content (g/kg)	33.9	34.2	34.1	34.2	0.30	NS	NS
Calculated MEI (MJ/d)	254	257	256	257			

Conclusions Addition of 'Crina Ruminants' to a conventional winter dairy cow diet increased output of milk, milk fat and milk protein. The responses were linearly related to dose of the additive and were not explained by increased intakes. 'Crina Ruminants' appeared to improve the efficiency of conversion of food energy to milk energy, perhaps by improving rumen function.

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Effect of the different ratios of effective rumen degradable protein to fermentable metabolizable energy on early lactating Holstein cow performances

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Introduction The efficiency of dietary N by dairy cows is generally low, and in part, may be related to an impaired utilization of N in the rumen. A major determinant of microbial protein synthesis is the availability of energy-yielding substrates (Castillo et al., 2001). It seems likely that low ratios of effective rumen degradable protein (ERDP) to fermentable metabolisable energy (FME) will restrict microbial protein synthesis and dry matter intake and, consequently, lead to reduced milk yield (Cabrita et al., 2003) . Nitrogen excretion in faeces and urine accounts for a high proportion of N intake, which may be more than 70% of the daily N consumption. Environmental pollution from N as ammonia and nitrates is regarded as a major potential problem world wide. Nutritional manipulations might be a way of significantly increasing N utilization and decreasing N pollution by dairy cows, and where as protein sources are expensive so, the cost of diet decrease (Castillo et al., 2001). The objective of this study was to examine the product and component of milk of dairy cows offered diets with different ratios of ERDP/FME.

Materials and Methods Multiparous (n=11), and primiparous (n=3) early lactation Holstein cows averaging 21 DIM (SD=16), 32 Kg/d of milk (SD=9) were used in the present experiment. Cows were assigned to a completely randomized design employing two treatments for seven weeks. The cows were kept in tie stalls with individual feed bins in an animal house, and had continuous access to water. The animals were fed with same ration in first week and the milk production and DMI data were used as covariate for the experimental data. Basal diet contained (DM) approximately 14.4% maize silage, 25.6% lucerne hay, and 61% concentrate containing maize 233, barley 220, cotton seed 160, soybean meal 160, wheat bran 105, cottonseed meal 58, fish meal 51 (for treatment 1), urea 10 (for treatment 2), dicalsium phosphate 3, calcium carbonate 3, sodium bicarbonate 9, magnesium oxide 4, mineral- vitamin mixture 13 (g/kgDM). Two iso-energetic diets with 9.7 (Treatment 1) and 10.7 (Treatment2) g ERDP/Mj FME achieved by replacing fish meal with urea. The diets were offered to the animals as a TMR for *ad libitum* intake at 08:30 and at 18:00. Dry matter intake and milk production was recorded daily. Milk was sampled one day each week, and samples used to determine milk fat, protein, lactose, and SNF by milko-tester (Foss Electric, conveyor 4000). All data were subjected to least square ANOVA using the mixed procedure of SAS (Version 8e, SAS Inst. Inc., Cary, NC).

Results Feed intake, milk production, and milk composition are presented in Table 1. ERDP/FME ratio had a significant effect ($p<0.05$) on feed intake, milk yield, and milk fat content.

Table 1 ERDP/FME ratio effects on means for feed intake, milk production and milk composition

Item	Treatment (g ERDP/ Mj FME)				Time effect	
	9.7	10.7	s.e.m	*P*	s.e.m	*P*
Feed intake (Kg/d)	21	21.7	0.28	0.03	0.48	0.01
Milk yield (Kg/d)	37.1	33.8	0.44	0.01	0.81	0.01
Milk fat (g/Kg)	25.5	21.0	0.15	0.03	0.16	0.12
Milk CP (g/Kg)	28.9	29.3	0.05	0.73	0.05	0.04
Milk lactose (g/Kg)	44.8	44.4	0.07	0.47	0.07	0.99
Milk SNF (g/ Kg)	84.5	83.8	0.12	0.96	0.12	0.85

Conclusions The results of the present study indicated that the diet used in this study which provided ERDP/FME ratio slightly lower than Agricultural and Food Research Council (1993) might decrease feed intake and increase milk yield significantly ($P< 0.01$). Supplying RDP in the excess of the amount necessary to match the amount of FME supplied by the diet and utilizable by rumen microbes, did not increase DMI or milk yield in dairy cows. Providing more synchronized N and energy supply for the rumen microbes to early lactating dairy cows led to higher milk yields due to increase in microbial protein synthesis (Cabrita et al., 2003).

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Effects of Monensin on fattening performance of Sarabi male calves

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Introduction Shortage of feed is the main constraint in livestock industry in Iran. High feed cost encourages the farmers to look for cheaper feeds or somehow reduce the feed conversion ratio in the farms. One of methods which may increase the feed efficiency is using of ionophores in feedlots. Monensin is a polyether ionophore produced by a strain of *Streptomyces cinnamonensis* that improves energetic efficiency of ruminal fermentation (Haney and Hoehn, 1967). There are limited studies to assess the effects of ionophores at farm conditions in Iran. The aim of this study was to assess the effects of monensin on fattening performance of Sarabi male calves. The monensin used in this experiment was supplied by Elanco Company.

Material and Methods 28 Sarabi yearling male calves were used in a complete randomized design to assess the effect of four levels of monensin (7 replications) on fattening performance. Animals were divided into 4 groups and received diets containing 51.2% concentrate and 48.8% forage. The base diet contained 10.98% CP, 1.63 and 1.03 Mcal/Kg NE_m and NE_g respectively. Four levels of monensin (0, 25, 50 and 75mg/Kg diet) were added to feeds. During the fattening period (112 days) animals were fed 3 times a day and had free access to water. The experiment was started after 14 days adaptation to feed. Initial and final weights were the average of weights taken on 4 consecutive records. Animals were weighed every 4 weeks throughout the feeding period. Feed was removed and water withheld approximately 16h before all weights were taken. Daily Dry matter intake was recorded and rumen liquor samples were collected from 3 animals in each treatment using stomach tubes for measuring pH, VFA and, NH_3-N. Ruminal VFA concentrations were determined using a Bendix model 2526-1 gas chromatograph with a flame ionization detector. Concentrations of NH_3-N of inoculum samples were measured calorimetrically according to the procedure of Chaney and Marbach (1962). Then, corrected data for age and initial weight as covariates were analyzed using ANOVA in a CRD based statistical design and mean values were tested using Duncan's least significant range test.

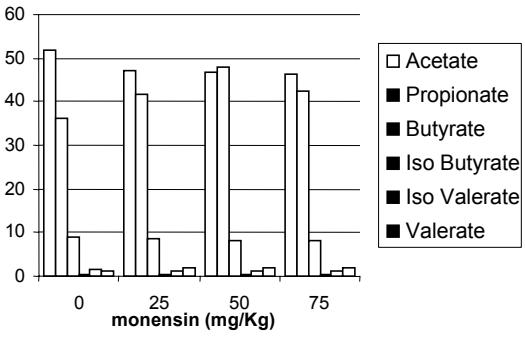
Results Results are presented in Table 1 and Figure 1. As is shown, monensin did not affect ADG but reduced DMI therefore improved FCR.

Table 1 Effects of Monensin on feed-lot performance of Sarabi steers

Monensin	DMI	ADG[1]	FCR	pH	NH_3-N[2]
0 (Mean)	5.596[a]	0.967[a]	5.78[a]	6.5[b]	2.19[a]
s.e.	0.0050	0.0410	0.217	0.055	0.127
25 (Mean)	5.573[c]	1.045[a]	5.33[b]	6.61[b]	1.89[b]
s.e.	0.0048	0.0667	0.400	0.010	0.006
50 (Mean)	5.581[b]	1.026[a]	5.43[a]	6.64[a]	1.94[a]
s.e.	0.0059	0.0294	0.182	0.003	0.006
75 (Mean)	5.586[b]	1.001[a]	5.57[a]	6.70[a]	2.03[a]
s.e.	0.0058	0.0367	0.213	0.052	0.073
s.e.m	0.0030	0.0219	0.127	0.027	0.046
s.e.d.	0.0108	0.0913	0.534	0.076	0.146

[1] Kg/d [2] mg/100ml

Figure 1 VFA Percent of Treatments



Conclusion pH and NH_3-N as a result of inhibition of gram positive bacteria were changed significantly ($p<0.05$). This is due to controlling the growth of uroelytic and proteolytic bacteria (Han *et al*., 2002) and the improvement was observed in rumenal pH could be a result of lower ruminal lactate production depressed growth of *S. bovis* (Dennis *et al*., 1981). Thus, a significant decrease ($P<0.05$) in acetate: propionate ratio was predictable, although total VFA concentrations were unchanged (Vagnoni *et al*., 1995).

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Biplot analysis to describe the relationships between plant and microbial fatty acids in ingested herbage

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Introduction The Dacron bag technique has been widely used to estimate degradation in the rumen. The drawbacks, such as variation in rinsing losses and inability to correct for microbial contamination, are well known. However, these effects also suggest the potential to use the technique in studies of microbial colonisation. Other studies in our laboratory have investigated the use of odd-chain fatty acids (C15:0 and C17:0) as markers of rumen microbial activity (Fievez *et al*., 2003) because they are generally rare or absent from feeds. The objective of this work was to use multivariate statistical analysis to explore the relationships between plant and microbial fatty acids in ingested herbage.

Materials and methods Two *in situ* experiments were conducted using two dry Holstein-Friesian cows, fitted with rumen cannulae, grazing perennial ryegrass pasture. In experiment 1, the effects of sample preparation method were investigated with perennial ryegrass: (M1) no further processing: grass was gently folded and placed into Dacron bags; (M2) chopping into approximately 1 cm lengths using scissors; (M3) crushing with a metal roller, but not chopping; (M4) chopping and crushing- a combination of (M2) and (M3); (M5) mechanical chopping (Lynhacker) for 30 sec; (M6) ingested bolus material, and (M7) freeze-dried and ground. Duplicate bags were incubated in each of two cows for both 2 and 7 hour periods. Experiment 2 investigated the effects of different washing procedures after removal of Dacron bags from cows. Approximately 7 g of DM was weighed into Dacron bags, which were incubated in each of two cows for 2, 8 and 24 hours. On removal of bags from the rumen, duplicate bags from each cow were washed according to one of four washing procedures: (W1) squeezing of the bag and its contents, so that no more liquid ran out; (W2) gentle hand washing by agitation in a sink of cold water: repeating until there was no further visible loss of bag contents; (W3) hand washing under a continuous stream of cold water: until the water ran clear; and (W4) machine washing in cold water for 50 minutes. Fatty acid methyl esters were prepared (methanolic HCl, 5%), extracted and determined by gas chromatography using tricosanoic acid (C23:0) as an internal standard. Biplot analysis (GenStat® 7) was used to examine the variation in the major plant and microbial fatty acids in these samples.

Results In both experiments, the concentration of odd-chain fatty acids increased with time of incubation while that of C18:2 and C18:3 decreased (data not shown). The biplot procedure (Figure 1) simultaneously showed variation in fatty acids and the effects of treatments on that variation. Generally, C18:2 and C18:3 behaved similarly, whilst the odd-chain fatty acids varied in a similar but opposite direction. The effect of the incubation periods, sample processing methods and washing procedures were clearly separated, indicating different degrees of microbial colonisation/contamination.

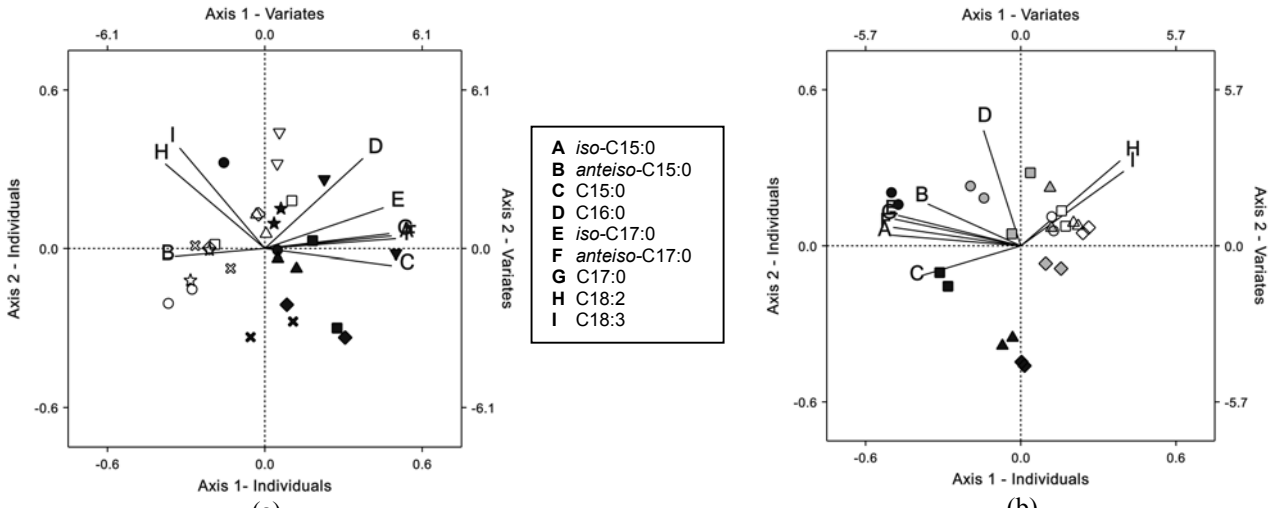

Figure 1 Biplot showing the relationship between treatments and selected fatty acids for experiment 1 (a: white and black coloured symbols for 2 and 7 hr incubation, respectively; for symbols M1 (●), M2 (★), M3 (■), M4 (◆), M5 (π), M6 (θ) and M7 (✖)) and experiment 2 (b; white, grey and black coloured symbols for 2, 8 and 24 hr incubation, respectively; For symbols W1 (●), W2 (■), W3 (π) and W4 (◆)

Conclusions Biplot analysis was successful in describing variation (86.1 and 86.8% for experiments 1 and 2) in, and treatment effects on, fatty acids profiles of ingested herbage. Concentrations of plant-derived fatty acids (C18:2 and C18:3) decreased over time, while microbially-derived odd-chain fatty acids increased in concentration with time.

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Effect of altering the protein intake of spring-born calves on calf performance

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Introduction Results of a recent study (Wicks *et al*. 2005) indicate that increasing the protein content of the milk replacer fed to autumn-born Holstein-Friesian calves reduced growth rates in the first 8 weeks of life. Van Amburgh *et al*., (2001) previously suggested that increasing both milk replacer intake and protein content maximised the growth of calves during this early phase of life. An experiment was undertaken to investigate the influence of level of milk replacer and crude protein content on calf performance during the first 8 weeks of life of spring-born calves.

Materials and methods One hundred spring-born calves (61 heifers and 39 bulls) were allocated to one of four treatments at 5 days old. Calves were weighed on entry to the calf house at <12 hours old (recorded as birth weight). Calves received colostrum for the first 5 days of life. From day 5 until weaning at 56 days, milk replacer was fed via automatic teat feeders, and calves were housed in groups of 25. A 2x2 factorial design was used which involved two levels of feeding: 5 l/d or 10 l/d with 120 g of milk replacer powder per litre, and two milk replacers with crude protein contents of 230 and 300 g CP / kg fresh milk powder. Animals were allocated so that treatments were balanced for birth weight, calf genotype, and sex. Live weight was recorded at weekly intervals and linear measures fortnightly, throughout the milk replacer feeding phase of the study. Live weight and linear measures were recorded at monthly intervals post-weaning Milk replacer intakes were recorded daily on 5 days per week. The data were analysed using repeated measures analysis of variance, fitting fixed effects for treatment, genotype, sex, age and their interactions, with birth weight as a covariate.

Results Calves fed 10 l/d gained on average an extra 6.3 kg (P<0.001) over the period from birth to 28 days and were 10.2 kg (P<0.001) heavier compared with calves fed 5 l/d by weaning on day 56 (Table 1). By day 56, calves on the 10 l/d treatments were taller (+ 4 cm (P<0.05)), longer (+ 10 cm (P<0.001)) and had greater heart girth diameters (+ 6.0 cm (P<0.001)) and higher body condition scores (P<0.01) compared with calves on the 5 l/d treatments. There were no significant differences in live weights at day 28 or day 56, or in linear measures of calves fed the standard or high protein milk replacer. The calves offered 10 l/d milk replacer drank only 7.8 l/d.

Table 1 Live weight and skeletal size of calves fed two levels of milk replacer containing two levels of crude protein (There were no significant interactions between plane of nutrition and crude protein content of the MR)

	Milk Replacer Offered (l/d)				Crude Protein Content			
	5 l/d	10 l/d	s.e.d	sig	230	300	s.e.d	sig
Average Intakes day 5-56								
Milk Replacer (l/d)	4.7	7.8	0.17	***	6.0	6.5	0.18	*
Live weight (kg)								
Birth	38.0	38.2	0.83	NS	38.1	38.1	0.83	NS
Day 28	44.7	51.0	1.11	***	47.9	47.8	1.10	NS
Day 56	56.3	66.5	2.10	***	61.6	61.2	2.10	NS
Day 180	140.1	148.3	4.75	NS	142.0	146.4	4.86	NS
Linear Measures – day 56 (cm)								
Wither Height	75.9	79.9	1.57	*	76.5	79.2	1.56	NS
Body Length	81.2	91.2	1.84	***	84.3	88.1	1.84	NS
Heart Girth	82.7	88.8	1.63	***	85.1	86.5	1.56	NS
Body condition score	1.51	2.14	0.153	**	1.77	1.88	0.153	NS

* = P<0.05; ** = P<0.01; *** = P<0.001

Conclusion Calves fed 10 l/d of milk replacer grew faster from birth to weaning at 56 days compared with calves fed 5 l/d, but there was no difference at 180 days. Results confirm previous findings that there is no benefit to increasing the protein content of milk replacer fed to calves.

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Effect of altering the protein intake of autumn-born Holstein-Friesian calves on calf performance

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Introduction Data from the US (Van Amburgh *et al*., (2001)) suggests that the current UK recommendations for feeding the neonatal calf (~500g milk replacer/d, at ~230 g crude protein per kg fresh milk powder) are inadequate to sustain high growth rates in early life. It has been suggested that increasing nutrition during the first 6-8 weeks of the calf's life will improve lifetime production, health and fertility. An experiment was therefore initiated to investigate the influence of level of milk replacer feeding and the crude protein content of the milk replacer on calf performance during the first 8 weeks of life, under UK conditions.

Materials and methods One hundred and one autumn born, Holstein-Friesian calves (57 heifers and 44 bulls) were allocated to one of the four treatments at 5 days old. Calves were weighed on entry to the calf house at <12 hours old and this weight was recorded as birth weight. Calves received colostrum for the first 5 days of life. From day 5 until weaning at 56 days, milk replacer (MR) was fed via automatic teat feeders, and calves were housed in groups of 25. A 2x2 factorial design was used which involved two levels of feeding: 5 or 10 l/d at 120 g of milk replacer powder per litre; and two MR with crude protein (CP) contents of 230 and 300 g CP / kg fresh powder. Animals were allocated so that treatments were balanced for birth weight, genetic merit of dam, sire, and sex. Live weight was recorded at weekly intervals, with linear measures recorded fortnightly throughout the pre-weaning phase of the study. Live weight and linear measures were recorded monthly post weaning. MR intakes were recorded daily on 5 days per week and calves had access to *ad libitum* concentrate from day 5. The data were analysed using repeated measures analysis of variance, fitting fixed effects for treatment, sex, age and their interactions, with birth weight as a covariate.

Results Over the period 0-28 days, calves on the high intake treatments gained significantly more live weight per day compared with the calves on the standard intake treatments resulting in calves being 6 kg heavier (P<0.001) by day 28 (Table 1). There was no difference in live weight gain between the 5 l/d and 10 l/d treatments during the period from 28 to 56 days. Calves on 10 l/d were 2 cm taller (P<0.01), 4 cm longer (P<0.001), and had 3 cm greater heart girth diameters (P<0.001) and higher body condition scores (P<0.01) compared with calves on 5 l/d by day 56. There was no significant difference in the live weight of calves fed 230 vs. the 300g CP/kg MR at day 28. However by day 56, calves fed the low protein MR were 3.65 kg (P<0.001) heavier compared with the calves fed the 300 g CP/kg MR.

Table 1 Milk replacer intakes, live weights and linear measurements for calves offered 5 versus 10 litres milk replacer per day and either a powder containing 230 or 300 g crude protein per kg fresh powder (There were no significant interactions between plane of nutrition and crude protein content of the MR)

	Milk Replacer Offered (l/d)				Crude Protein Content (CP) g CP/kg			
	5	10	s.e.d	sig	230	300	s.e.d	sig
Average Intakes day 5-56								
Milk Replacer (l/d)	4.7	8.0	0.14	***	6.5	6.2	0.14	**
Live weight (kg)								
Birth	44.4	43.7	0.89	NS	44.0	44.0	0.89	NS
Day 28	50.7	56.8	1.10	***	54.3	53.2	1.10	NS
Day 56	66.3	73.2	1.50	***	71.6	67.9	1.49	**
Day 180	168.3	174.1	5.77	NS	172.5	169.9	5.75	NS
Day 270	236.1	232.6	7.70	NS	238.2	230.6	7.71	NS
Linear Measures – day 56 (cm)								
Wither Height	82.3	84.3	0.73	**	83.7	82.9	0.72	NS
Body Length	87.9	91.3	1.03	***	90.8	88.1	1.03	**
Heart Girth	92.1	95.2	0.86	***	94.9	92.4	0.85	**
Body condition score	1.72	1.92	0.079	**	1.81	1.83	0.079	NS

* = P<0.05; ** = P<0.01; *** = P<0.001

Conclusion Calves fed higher levels of milk replacer grew significantly faster in the first 28 days of life but there was no difference at day 180 or 270. There was no benefit in calf performance from increasing the protein content of the milk replacer, lower growth rates were recorded for calves fed the high protein milk replacer.

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Effects of upland pastures sown with two contrasting *Lolium perenne* varieties on the performance of beef steers when compared to steers grazing permanent pastures

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Introduction Grazing experiments have shown that using a ryegrass (*Lolium perenne* L.) variety bred by conventional techniques for high water-soluble carbohydrate (WSC) concentrations can improve liveweight gain in pre-weaned lambs (Lee *et al*., 2001) and increase milk yields and reduce N excretion in dairy cows (Miller *et al*., 2001) compared to conventional ryegrass. The aim of this study was to determine the effects of using reseeded upland pastures, sown with either a ryegrass variety bred for elevated levels of WSC or a control ryegrass on the production performance of grazing steers when compared to steers grazing permanent ryegrass/white clover pastures.

Materials and methods Replicate 2 ha plots were used for each of the three forage treatments: a high water-soluble carbohydrate variety (AberDart) of perennial ryegrass pasture reseed, a control perennial ryegrass (Fennema) pasture reseed and a permanent ryegrass with white clover pasture. Plots were sown at a rate of 40 kg/ha for AberDart and Fennema, respectively, on 21st June 2001 at Bronydd Mawr Research centre (52º 15'N, 3º 38'W), an upland site at 310–363 m above sea level with a mean annual rainfall of 1500 mm. Plots were grazed at a stocking rate of 5 and 4 steers ha^{-1} in the first (2002) and second (2003) harvest year of the pasture reseeds (Year 1 and 2, respectively). In Year 1, the experiment ran from 1st May to 23rd August (total of 113 days) and in Year 2 from 30th April to 17th October (total of 170 days). Replicate forage samples were taken at the same time of day every seven days during the grazing period to determine WSC concentrations. In Years 1 and 2, 10 Spring-born (2001) Charolais cross steers (initial liveweight 341 s.e. 2.9 kg) and 8 Autumn-born Charolais cross steers (initial liveweight 253 s.e. 6.6 kg) were allocated, respectively, to each replicate plot on the basis of age, liveweight and body condition taken on two consecutive days 2 days prior to the start of the experiment. Animals were weighed at the same time of day at 21 day intervals. Linear regressions were performed on the liveweights of individual animals and the slope of the regressions (i.e. liveweight gain) were analysed by analysis of variance.

Results Mean forage WSC concentrations were 231, 205, 155 and 155, 133, 126 g/kgDM for AberDart, Fennema and permanent pasture during the experimental periods in Year 1 and 2, respectively. There was an significant effect of treatment on liveweight gain in both years (Table 1), with animals grazed on reseeded Fennema pastures growing at significantly lower rates than animals grazed on either reseeded AberDart or permanent pasture swards.

Table 1 Effect of treatment on liveweight gain (kg/d) of growing beef steers grazed on different pastures

Live weight gain	AberDart	Fennema	Permanent pasture	s.e.d.	Significance
Year 1	1.12^{a}	0.95^{b}	1.20^{a}	0.056	***
Year 2	1.11^{a}	0.83^{b}	1.02^{a}	0.089	***

***, $P < 0.001$; means with different superscripts within rows differ significantly

Conclusions Beef steers grazed on upland pastures reseeded with AberDart, a ryegrass variety that has been bred to express elevated WSC concentrations, grew as well as steers grazing permanent pastures in the first harvest year of pasture re-seeding and these effects continued in the subsequent year.

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Performance of Botswana composite breed and indigenous breeds under feedlot and grazing conditions

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Introduction The Botswana Composite Breed (BCB) was developed by Dept. of Agricultural Research to mitigate problems of small herds that could not sustain crossbreeding programs. The breed has 47.5% Sanga, 22.6% Zebu and 29.9% *Bos taurus* blood. Indigenous Tswana cattle are 40% of the national herd (Masilo and Podisi 2001), indicating an erosion of local genetic material. Tswana cattle are small framed and are prejudiced by the Botswana Meat Commission (BMC) weight-based pricing system in favour of large-framed cattle. Lack of carcass characterization of indigenous cattle contributes to the above situation. The aim of this study was to evaluate performance of BCB and other indigenous breeds under feedlot and grazing conditions in order to promote their attributes.

Materials and methods 128 steers of Brahman, Tswana, Tuli, Bonsmara, BCB and three Brahman-sired crosses were used in a study for 99 days. A randomized block design resulted in; Low Level Roughage (LLR; n=32; 302.2±5.7kg), Medium Level Roughage (MLR; n = 32; 301.4±5.7), High Level Roughage (HLR; n=32; 308.8±5.7kg) and Grazing Control (GC; n=32; 302.0±5.7kg). Animals were adapted by giving them HLR diet for 14 days, dosed for internal parasites and injected with vitamin ADE. A sample of 3 animals from each breed within the feedlot diets were confined individually for 7 days to measure feed intake and thereafter group-fed for 39 days. The cycle was repeated during the 99 days. Animals were weighed at day 38, 61 and 99. General Linear Model procedure was used to determine the effect of diet, breed and diet x breed interaction on all variables. Initial weight (LW0) was used as covariate for performance and carcass data but not for feed intake (FI) and efficiency coefficients.

Results and discussion Breed, diet and LW0 effected ($P<0.001$) live weight (LW), daily gain (ADG), cold dress mass (CDM), carcass shrinkage (CS) and revenue (Table 1). Brahman terminal crossbred of Tswana with South Devon (BR/SD/TSW) produced the heaviest live weight at day 99 (LW3) and the lowest live weights were from Brahman purebred steers. LW3 was significantly correlated ($r=0.62$; $P<0.001$) to LW0. The highest (14.5%) proportion of each of Tswana and BCB carcasses were classified as sound super (ss) grade. FI at day 99 was affected by breed and diet ($P<0.001$) (Table 1). There was no ($P>0.05$) breed x diet interaction for LW, ADG, CS, CDM, Revenue, FI and feed conversion efficiency (FCE). Diet did not affected ($P>0.05$) FCE at day 99. Brahman-sired steers had higher ADG and slaughter weights than Tuli- and Boran-sired steers (Franke 1997) whereas in the present study Brahman performed similarly to Tuli and Tswana. A higher proportion of carcasses that got ss grades were Tswana and BCB indicating a better carcasses quality. Crosses performed better than pure indigenous cattle and the Brahman in terms of live weight and revenue. This is because crosses are big-framed. The difference in revenue is also compounded by the BMC's weight-based pricing system, which prejudices small-framed indigenous cattle. Synthetic breeds (Bonsmara and BCB) ranked second to crosses. Crossbreds ate more. Synthetic breeds ate similarly to indigenous breeds but gained more and generated similar revenue to some crosses. Brahman and indigenous cattle were more efficient in feed utilization than exotic crossbreds.

Table 1 Effect of breed on LW, ADG, CS, CDM, FI and FCE

Breed	LW (kg)	ADG (kg/d)	CS (%)	CDM (kg)	Revenue (Pula)[1]	FI (kg)	FCE (feed/gain)
Brahman	365.7±7.9^{ef}	0.6±0.1^{d}	5.8±0.13^{d}	187.5±4.3^{f}	1239.06±43.2^{c}	9.9±0.36^{d}	4.7±2.1^{b}
Tswana	371.6±8.3^{ef}	0.7±0.1^{d}	5.8±0.13^{d}	187.9±4.5^{f}	1226.04±45.3^{c}	11.2±0.36^{c}	10.0±2.1^{a}
Tuli	384.5±7.5^{de}	0.8±0.1^{cd}	5.9±0.12^{d}	191.1±4.1^{ef}	1229.82±40.9^{c}	11.4±0.39^{c}	8.9±2.3^{ab}
Composite	398.7±7.9^{c}	1.0±0.1^{c}	6.2±0.13^{c}	201.2±4.3^{de}	1345.04±43.0^{b}	11.5±0.36^{c}	8.2±2.1^{ab}
Bonsmara	402.6±8.1^{cd}	1.0±0.1^{c}	6.7±0.13^{c}	207.0±4.4^{cd}	1357.71±44.0^{b}	11.6±0.39^{c}	9.1±2.3^{ab}
BR/CH/TSW	443.1±9.1^{ab}	1.4±0.1$^{a\,b}$	7.0±0.15^{b}	221.0±5.0$^{b\,c}$	1473.60±49.8^{ab}	13.6±0.39^{b}	10.8±2.3^{a}
BR/SD/TSW	459.0±10.3^{a}	1.6±0.1^{a}	7.7±0.17^{a}	247.4±5.6^{a}	1582.99±56.2^{a}	14.8±0.36^{a}	12.1±2.1^{a}
BR/SU/TSW	428.8±7.9^{b}	1.3±0.1^{b}	6.9±0.13^{b}	221.8±4.3^{b}	1462.12±43.39^{b}	12.8±0.39^{b}	10.1±2.3^{a}
Mean	406.8	1.0	6.4	208.1	1364.55	12.1	9.2
SL	***	***	***	***	***	***	NS

[1]One Pula = 0.125 Euro. NS = $P>0.05$, *** = $P<0.001$

Conclusion It is concluded that synthetic breeds may be ideal cattle for feedlotting under Botswana conditions. However, if the diets contain more roughage it would be advisable to use indigenous breeds.

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The study of replacing maize silage with triticale or barley whole crop silage on feeding the lactating cows

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Introduction Grass and forage maize are the most important fodder crops for feeding dairy cows. However, on drought prone sandy soils, and in years with insufficient rainfall the yield of maize is very low (7 to 8 tons DM/ha). In situations where water is a limiting factor for growing maize, triticale and barley may be an alternative fodder crop. Triticale grows mainly during the early spring when there usually is a precipitation surplus and so, water is not a limiting factor for growth. When triticale is harvested as triticale whole crop silage the DM yield ranges between 9 and 11 ton of dry matter per hectare. Therefore, under water limiting conditions it may be attractive to replace forage maize by triticale and barley whole crop silage. The objective of this study is to find the effects of replacing maize and barley silage by triticale whole crop silage on feed intake and milk production of lactating Holstein cows.

Materials and methods Whole crop triticale and whole crop barley were harvested, chopped and ensiled with urea (15 g/kg of DM). Holstein lactating cows (n=15, 37.1± 4.9 kg milk/d), were used in a complete randomized design for 6 weeks. Experimental diets consisted of (DM basis) 12% maize silage (MS) or triticale silage (TS) or barley silage (BS), 65% concentrate (23% barley, 19% maize, 15% soybean meal, 14% cottonseed, 12% wheat bran, 11% sugar beet pulp, 4% cottonseed meal, 0.7% sodium bicarbonate, 0.3% magnesium oxide, 0.2% dicalcium phosphate, 0.2% $caco_3$, , 1% mineral and vitamin premix), and 23% Lucerne hay. Samples of milk were collected at the end of each week. Milk samples were analysed for fat, protein and lactose by milko-tester (Foss electric, conveyor 4000). Daily dry matter intake was recorded. Data of milk production and milk composition of the first week of the experiment were used as covariate. Data were analyzed as repeated measures in time using the Mixed procedure of SAS (Version 8e, SAS Inst. Inc., Cary, NC). The statistical model was Y = covariate + treatment + cow (treatment) + lactation week + treatment by lactation week, where cow (treatment) was used to test the treatment effect.

Results Dry matter intake, milk production and milk composition are shown in Table 1. Dry matter intake was significantly ($P<0.05$) influenced by the treatments. Cows fed diet containing barley silage had higher feed intake than the cows of other groups. Milk yield was significantly higher in cows fed diet containing maize silage compared with the other treatments ($P<0.05$).

Table 1 Dry matter Intake, milk yield and milk compositions of lactating cows fed diets containing maize, triticale and barley silage

	Treatment effect*					Time effect	
Item	MS	TS	BS	s.e.m	*P*	s.e.m	*P*
Dry matter intake (kg/d)	19.5	16.7	22.7	0.90	0.01	0.88	0.23
Milk yield (kg/d)	32.0	27.2	28.8	0.64	0.01	1.58	0.48
Milk fat (%)	3.20	2.53	2.90	0.11	0.01	0.20	0.15
Milk protein (%)	3.00	2.90	3.00	0.05	0.39	0.01	0.19
Milk lactose (%)	4.70	4.30	4.70	0.09	0.03	0.10	0.94

*: when the difference between the treatments was more than 2 times of s.e.m it has been considered as significant ($P< 0.05$). MS: maize silage, TS: triticale silage and BS: barley silage

Conclusions Results of the present study showed there was no benefits in lactating cows when were fed with diet containing triticale silage. Cows fed diet with triticale silage had significantly low dry matter intake and milk yield than cows of the maize and barley silage treatments. When cows were fed by diet of barley silage, dry matter intake was 3 kg DM higher than cows fed diet of maize silage. However, milk yield of cows fed maize silage diet was 3.2 kg/d higher than cows fed diet containing barley silage.

Acknowledgement The authors wish to acknowledge for funding and technical supporting from Ferdowsi University of Mashad and Centre of Excellence in Animal Science.

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Monitoring the fate of untreated and microwave treated canola (oilseed rape) meal protein in the rumen using SDS-PAGE

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Introduction Canola meal (CM) proteins are extensively degraded in the rumen. Various physical and chemical treatments have been used to alter the rate of ruminal degradation of CM protein, thus decreasing rumen protein degradability and increasing the content of metabolizable protein. To our knowledge, little information is available concerning the effect of microwave treatment on the type of CM proteins that leaves the rumen undegraded. The main objective of our research was to evaluate the degradation of untreated and microwave treated CM proteins by using sodium dodecyl sulphate-polyacrylamide gel electrophoresis (SDS-PAGE).

Materials and Methods Three 450-kg Holstein steers fitted with rumen fistulas were used for *in situ* incubations. Ruminal disappearance of dry matter (DM) and crude protein (CP) from the untreated, 2, 4 and 6 min microwave treated CM at power of 800 W were measured at 0, 2, 4, 6, 8, 12, 24 and 48h. The exponential model of Ørskov and McDonald (1979) was used to estimate DM and CP degradation kinetic. Data were analyzed according to the GLM procedure of the SAS (1996). Twelve mg of well-ground dried untreated and microwave treated CM (and residues from in situ rumen incubation) were placed into 750µl SDS-PAGE sample buffer. After 30 min of thorough mixing, samples were immersed at 90˚C for 3 min, and then centrifuged at 10000g for 1 min. 30µl aliquot of each protein sample was then loaded into the sample well. Samples were fractionated by a SDS-PAGE discontinuous system as described by Laemmli (1970). Electrophoresis of proteins was performed on 15% resolving gels with a 3.75% acrylamide stacking gel. Protein fixation and staining were performed simultaneously using a solution of Coomassie brilliant blue. The sub-fractions of the gel were then monitored by densitometric scanning at 580 nm. Digestibility was measured *in vitro* method of Calsamiglia and Stern (1995).

Results and discussion From the SDS-PAGE pattern and densitometric scanning, rapeseed meal proteins are composed of napin and cruciferin accounting for 38 and 51 percent of the total protein, respectively. The molecular weight of 10.3 and 8.2 KDa for two subunits of napin and 31.2, 26.8, 21.1 and 20.5 KDa for four subunits of cruciferin were estimated. Napin sub-units of untreated, 2, 4 and 6 min microwave treated CM were disappeared at 0, 2, 6 and 8h incubation times, respectively. Microwave heating decreased disappearance of cruciferin sub-units. SDS-PAGE results indicated that two sub-units of cruciferin when untreated CM is fed to ruminants, make an appreciable contribution to metabolizable protein, but in microwave treated CM, two sub-units of napin and four sub-units of cruciferin are escaped to the small intestine. From *in situ* trial, ruminal protein degradation characteristics of untreated and microwave treated CM were significantly different ($p<0.05$). Microwave heating for 6-min decreased ERD of CP further than other treatments. The *in vitro* digestibility of the undegradable protein of 4-min microwave treated CM was higher than untreated, 2 and 6-min microwave treated CM.

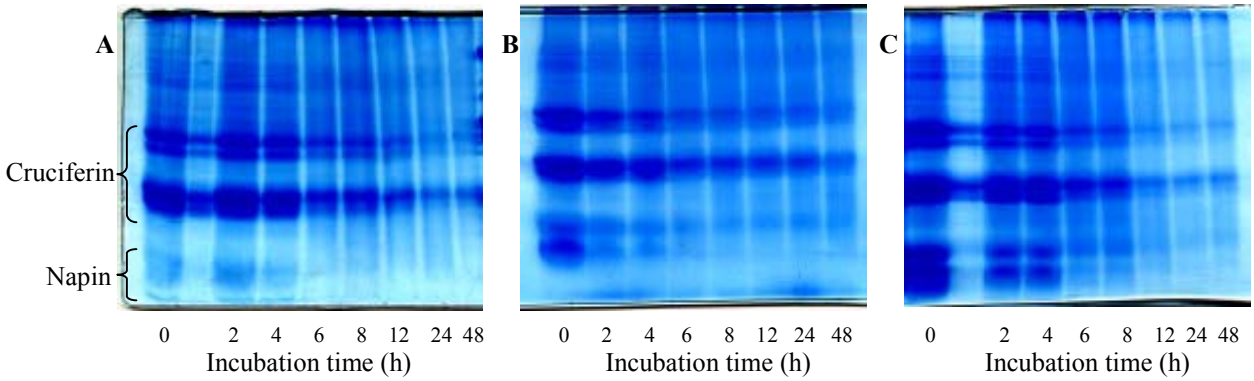

Figure 1: Slab gels of untreated (A), 4-min (B) and 6-min microwave treated canola meal (C).

Conclusion Canola meal proteins appeared to be effectively protected from ruminal degradation by a 4-min microwave treatment. Furthermore, SDS-PAGE results indicated that cruciferin in untreated, whereas napin and cruciferin in microwave treated canola meal make the bulk of ruminally undegraded protein.

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Changes in total and individual proteins during drying and ruminal fermentation of alfalfa

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Introduction Proteolysis within plant cells occurs during wilting and drying. Changes in plant proteins during those periods usually are monitored by measurement of total crude protein and non protein nitrogen. Alternatively, changes in concentrations of individual proteins can be measured. Plants are composed of an array of different proteins. Electrophoresis can be used to separate these proteins and has been used to study effects of wilting and ensiling on proteins of some forages (Grum *et al.,* 1991). Electrophoresis also has been used in the study of ruminal hydrolysis of oilseed meals proteins (Sadeghi *et al.,* 2004). Most of the experiments designed to use electrophoresis to study protein metabolism in forages and ruminants have been qualitative. The main objective of this study was to determine whether sodium dodecyl sulphate-polyacrylamide gel electrophoresis (SDS-PAGE) and densitometry could be used to monitor quantitatively the changes in alfalfa protein composition during wilting, drying and ruminal exposure.

Materials and methods Alfalfa (ALF) was grown in field plots, clipped by hand, divided into four portions, and allotted to one of four treatments: fresh, wilted, semi-dried and dried hay. Fresh forage was frozen (-20˚C) within 45 min of cutting. Wilting treatment consisted of storing samples (layers were approximately 7 cm thick) on a laboratory bench (20˚C) for 24 h. semi-hay and hay were made by drying the forage on a laboratory bench for about 90 and 120 h, respectively. Three 450-kg Holstein steers fitted with rumen fistulas were used for *in situ* incubations (AFRC, 1992). Ruminal disappearance of true protein from alfalfa hay was measured at 0, 6, 12, 24 and 48h. Finely ground (with liquid nitrogen) dried samples (20mg) of each treatment and also residues from in situ rumen incubation were placed into 750 µl SDS-PAGE sample buffers. After 30 min of thorough mixing, samples were immersed at 100˚C for 5 min, and then centrifuged at 10000g for 1 min. 50µl aliquot of each protein sample was then loaded into the sample well. Samples were fractionated by a SDS-PAGE discontinuous system as described by Laemmli (1970). Electrophoresis of proteins was performed on 12.5% resolving gels with a 3.75% acrylamide stacking gel. The sub-fractions of the gel were then monitored by densitometric scanning at 580 nm. The staining intensity of all bands of interest was summed and designated as total electrophoretically identified protein (TEIP).

Results and discussion Eight different proteins were separated from extracts of fresh ALF (Figure 1 and 2). Total ribulose 1,5-bisphosphate carboxylase oxygenase (RUBISCO, - 15 and 45kDa) comprised 51% of TEIP in the fresh sample, and the 45-kDa protein made up 12% of TEIP. No other protein comprised >9% of TEIP in fresh ALF. Wilting (Figure 1; B, C and D) had little effect on the composition or amount of protein in ALF and did not cause large differences in proteolysis among proteins. Only small amounts of RUBISCO (54 and 15 kDa) and carbonic anhydrase (30 kDa) were hydrolyzed during wilting. Further drying of ALF to semi-dried hay (Figure 1; E) and hay (Figure 1; F and G) reduced TEIP by about 55 and 85% compared with that for fresh ALF (Figure 1; A). Disappearance of individual proteins during hay making ranged from 75 to 100% of original proteins. SDS-PAGE results indicated that both subunits of RUBISCO (15 and 54 kDa) underwent extensive proteolysis during fermentation.

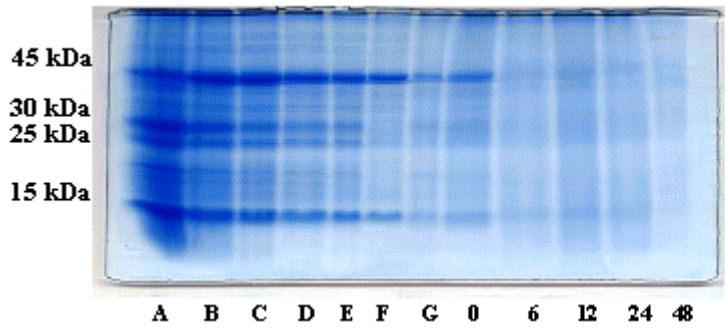

Figure 1 Slab gels of fresh (A), wilted (B, C & D), semi-dried hay (E), dried alfalfa hay (F and G) and *in situ* incubation time (0-48 h).

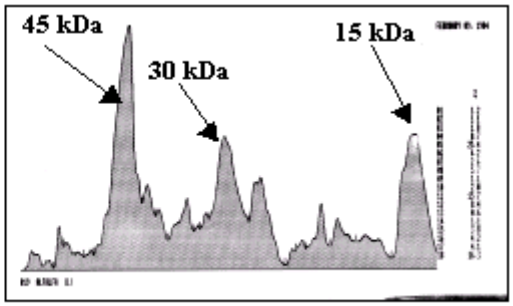

Figure 2 Densitometrical scanning of fresh alfalfa

Conclusion Results of this study indicated that SDS-PAGE technique not only can be used to predict ruminal protein degradation directly and accurately, but also to assess the type of proteins that will undergo degradation during preservation. Accounting for variation in the relative amounts of individual proteins may allow improved estimation of extent of proteolysis during the preservation process and during ruminal fermentation.

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Effects of micronisation on ruminal starch and protein degradation kinetics of corn grain

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Introduction Micronisation or infrared processing has been used as a thermal process of feedstuffs. In this technology, feeds are subjected to rapid surface and internal heating by the application of infrared light. This energy is absorbed by the product and causes constituent molecules to vibrate, resulting in rapid internal heating. A major advantage of micronisation over other heat treatment methods is the shorter heating time applied during processing. The effects of micronisation of cereals on starch structure and digestibility of starch and crude protein (CP) and performance of pigs has been investigated (Zarkadas and Wiseman, 2001). However, data on ruminal starch and protein degradability of micronised cereals, especially corn grain are limited. Furthermore, the effect of micronisation on the type of corn true protein escaping from the rumen is lacking. The objectives of this study were to determine the effects of micronising corn grain on ruminal kinetic parameters of dry matter (DM), CP and starch and to determine the types of corn true protein escaping from the rumen to small intestine by using SDS-PAGE.

Materials and methods Corn grain (moisture content, 20%) was micronised for 50s at 110˚C using a Micro Red 20 Microniser. Nylon bags of untreated and treated corn grain were suspended into the rumen of three Holstein steers from 0 to 48 h. The exponential model of Ørskov and McDonald (1979) was used to estimate DM, CP and starch degradation kinetics. Data were analyzed by a variance analysis GLM procedure of SAS (1996, SAS Institute, Cary, NC, USA) in a completely randomized design according to this model: $Y= \mu + Ti + Eij$, where μ is overall average, Ti is the treatment effect and Eij is the residual error. Finely ground dried (15 mg) of untreated and micronised corn grain was placed into 750-µl SDS-PAGE sample buffers. After 30 min of thorough mixing, samples were immersed at 90 ˚C for 3 min, and then centrifuged at 10000g for 1 min. 30µl aliquot of each protein sample was then loaded into the sample well. Samples were fractionated by a SDS-PAGE discontinuous system as described by Laemmli (1970). Electrophoresis of proteins was performed on 12.5% resolving gels with a 3.75% stacking gel. Protein fixation and staining were performed simultaneously using a solution of Coomassie brilliant blue. The sub-units of the gel were then monitored by densitometric scanning at 580 nm.

Results and discussion From *in sacco* trial, ruminal DM, CP and starch degradation parameters of untreated and treated corn grain were significantly different ($p<0.05$) (Table 1). The rapid internal heating affects corn grain protein matrix structure, causing to denature and also starch granules within a grain, causing them to swell, fracture and gelatinize. The heat treatment reduced *in sacco* ruminal degradability of corn protein by increasing the size of the slowly degradable protein fraction as well as reducing its ruminal degradation rate. The chief aim of increasing starch gelatinization is to increase ruminal starch fermentation. Electrophoretic and densitometric analysis of protein residues revealed that the prolamin fraction for untreated, in addition, albumins, globulins and glutelins for micronised corn was more resistant to ruminal degradation. Relative rates of degradation of zein and the fraction containing albumins, globulins, and glutelins were 0.029, 0.057 and 0.018, 0.041/h for untreated and micronised corn grain, respectively.

Table 1 DM, CP and starch degradation parameters of corn grain

	Degradation traits			ERD at out flow rate		
	a	b	c	0.02	0.05	0.08
Dry Matter	%	%	%/h	%	%	%
Untreated	16.4	81.3	5.1	74.6	57.2	47.9
Micronised	17.3	79.1	5.0	73.8	56.8	47.7
Crude protein						
Untreated	11.6[a]	85.7[b]	4.3	70.1[a]	51.2[a]	41.5[a]
Micronised	7.1[b]	88.2[a]	3.9	65.4[b]	45.7[b]	36.0[b]
Starch						
Untreated	20.1[b]	78.7[a]	6.5	80.4	64.6[b]	55.4[b]
Micronised	25.9[a]	73.4[b]	6.1	81.2	66.2[a]	57.6[a]

[a]immediately soluble fraction, [b]potentially degradable fraction.
[c]degradation rate, ERD: Effective rumen degradation. $p<0.05$

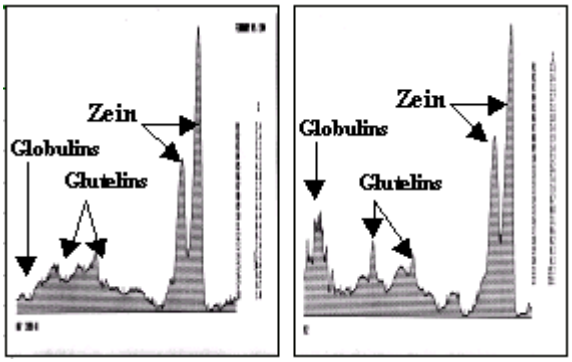

Figure 1 Densitometer scaning (48h) of untreated (Left) and micronised corn grain (Right)

Conclusion Corn proteins can be effectively protected from degradation in the rumen by micronisation. Furthermore, ruminal starch availability increased by this treatment. The bulk of the bag residual protein for untreated at 48-h incubation time was zein and for micronised corn grain were zein, glutelins and globulins.

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Plasma methionine and lysine concentrations of early lactating Holstein cows fed diet containing raw or roasted Iranian soybean variety

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Introduction Whole soybean has 19 percent ether extract and 42 percent CP and is used as a high energy-protein supplement for early lactation dairy cows, but the protein is highly degradable, so small amounts of amino acids can reach the small intestine to meet high amino acid requirements in early lactation. Therefore, various chemical and physical treatments have been suggested to decrease ruminal protein degradability. The practical use and application of any one method to lower ruminal feed degradability is dependent not only on its efficacy but also on its cost effectiveness, safety and ease of application. For these reasons, heat treatment is the most commonly used physical method. Energy expenditure and fixed costs are lower for roasting than for oven treatment, thereby warranting further research on this type of heat treatment (Plegge *et al.*, 1985). The purpose of this study was to determine how roasting of soybeans affect Met and Lys plasma levels (as the first limiting amino acids in milk yield) in early lactation cows.

Materials and methods Iranian variety of soybean was used in present study. The soybeans were fed into a turning cylindrical tunnel with a flame and blower at its end, so that they were exposed to burning air. The temperature of the soybeans exiting the roaster was 130 to 135 ºC. After that, they immediately placed in barrels, without cooling, and covered with canvas for about 45 minutes (steeping), then cooled. Fourteen Holstein dairy cows were used in this study (based on complete randomized design with 3 treatments). At the beginning of the trial the cows had a mean lactation stage 16.9 days (s.d. 6) and mean milk yield 33.2 Kg/d (s.d. 3.39). Three total mixed rations based on concentrate and forage (0.39:0.62 dry matter (DM) basis) were offered individually throughout the study to groups 1 to 3 and had the following composition: NE1 1.61 Mcal/Kg DM, CP 176 g/Kg DM, RUP 65.2 g/Kg DM, RDP 110.3 g/Kg DM, NDF 305 g/Kg DM, Ca 6 g/Kg DM, P 4.5g/Kg DM. Rations 1 to 3 were included roasted soybean, soybean meal and raw soybean, respectively. During last week of experiment (6^{th} week) blood samples were taken from vein tail vessel (before and 4h after feeding) then, Met and Lys plasma concentrations were analysed AccQ. Tag method with 717 HPLC. Data were analysed using general linear model procedure of SAS (SAS, 2000). Mean of treatments were compared by Duncan's method and reported as significant while $P<0.05$.

Results Chemical composition of the raw and roasted soybeans is shown in Table 1. Results in Table 2 showed that the plasma Met concentration at before feeding was not significantly different among treatments, but at 4 h after feeding the Met concentration was significantly ($P<0.05$) higher in cows fed the diet containing the roasted soybean than those fed diets containing the raw soybean or soybean meal.

Table 1 Chemical composition of soybeans
(The values in parenthesis are s.e.m.)

Item	Raw soybean	Roasted soybean
DM, g/Kg	920.0 (0.95)	970.0(0.90)
OM, g/Kg DM	945.0(1.22)	946.0(1.47)
N, g/KgDM	59.0(0.35)	60.9(0.40)
NPN[1],g/KgN	86.6(1.52)	26.7(1.27)
BSN[2],g/KgN	433.0(2.74)	88.9(2.61)
ADIN[3], g/KgN	105(2.62)	80(2.28)
EE[4], g/kgDM	175.2(1.5)	185.0(2.0)
NDF, g/KgDM	220.0(1.5)	168.0(2.0)
NFC[5], g/KgDM	181.0(0.80)	164.0(1.20)

[1] Non protein nitrogen; [2] Buffer soluble protein;
[3] Acid detergent insoluble protein; 4 Ether extract;
[5] Non fiber carbohydrate calculated as:
100-(CP+NDF+EE+Ash)

Table 2 Met and Lys Plasma concentrations (µmol/L)

	Ration			
Item	1	2	3	s.e.m
Met (0)[1]	5.63	3.12	3.35	0.746
Met (4)[2]	6.10[a]	5.92[a]	2.18[b]	0.940
Lys (0)	3.12	5.63	3.36	0.746
Lys (4)	15.59[a]	6.07[b]	6.76[b]	0.913

Means within rows with different superscripts differ
[1] Plant Met before feeding; [2] Plasma Met 4h after feeding

Conclusions The effect of roasting on decreasing the soluble nitrogen and protein degradability is proved in previous studies. The results of this study showed that roasting is an effective processing method for increasing the flow of amino acids to the small intestine in Holstein early lactation cows.

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Effect of a yeast culture (Yea-Sacc^{1026}) on the performance of cereal fed beef cattle

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Introduction The introduction of the Single Farm Payment support system sees a change from headage to area payments. The removal of the Beef Special Premium for steers is likely to see a move towards either 12-15 month intensive finishing systems or low input extensive grass based 24-30 month finishing systems. Late maturing breed type cattle reared on the latter system may however require a 2-3 month intensive finishing period to achieve adequate fat cover. With falling cereal prices there is increased interest in their use in beef cattle rations. Antibiotic based feed additives e.g., monensin sodium, have been successfully used for over 40 years to manipulate microbial activity and improve beef cattle performance. The use of monensin sodium will be banned from January 2006 and there is therefore a requirement to find alternative 'natural' products that can improve the efficiency of beef production with intensive cereal based rations. Yeast cultures are composed of yeast (*Saccharomyces cerevisiae*) and the medium on which it was grown. These products are dried in a manner which preserves the fermenting activity of the yeast. It is suggested that production responses associated with the use of live yeast culture supplements in ruminants may be related to their stimulatory effects on specific groups of micro-organisms in the rumen. The objective of this study was to determine the effect of feeding a live yeast culture (Yea-Sacc^{1026}) on the performance of cereal fed beef cattle.

Materials and Methods Thirty six Belgian Blue cross Holstein bull and heifer calves with a mean live weight of 284kg were randomly assigned in a 2 x 2 factorial designed experiment to either a control ration fed *ad libitum* or control including 3.75kg/t Yea- Sacc^{1026} Farm Pak to supply 7.5 x 10^7 cfu/kg of *Saccharomyces cerevisiae* (CBS 493.94). The control ration contained the following ingredients (g/kg): rolled barley 730, soyabean meal 100, molassed sugar beet pulp 100, molasses 50, mineral 20. The cattle were housed in straw bedded pens with straw also available *ad libitum* from racks. The bulls were selected for slaughter at MLC fat class 3 and heifers at fat class 4L. To allow for the analysis of carcase classification data, a numerical value was attributed to each class as follows: Conformation; -P=1, P+=2, -O=3. O+=4, R=5, -U=6, U+=7, E=8; Fat class; 1=7, 2=6, 3=5, 4L=4, 4H=3, 5L=2, 5H=1 The data was analysed using ANOVA. Carcase weight at the beginning of the trial was estimated by assuming a dressing proportion of 0.47 (Patterson *et al.,* 1995)

Results. The mean chemical composition of the cereal based concentrates was: DM 889 and 887g/kg; crude protein 154 and 153, ether extract 19 and 19, neutral detergent fibre 228 and 224, starch 408 and 416 and ash 69 and 70 g/kg DM for the control and Yea-Sacc^{1026} rations respectively. Data on animal performance and feed intakes are shown in tables 1 and 2. The bulls recorded significantly higher daily liveweight gains (DLWG), slaughter weights, carcase weights, killing out percentage and carcase grades compared to the heifers ($P<0.001$). Feeding Yea-Sacc^{1026} resulted in a significant increase in DLWG and reduction in the number of days to reach slaughter ($P<0.05$). There was a reduction in total feed intake with Yea-Sacc^{1026} with a marked improvement in feed conversion ratio (FCR).

Table 1 Animal Performance (kg)

	Yea-Sacc^{1026}	Control	s.e.d	Sign
Start wt	285.5	282.1	13.67	0.790
Slaughter wt	520.4	520.1	9.46	0.766
Days	169.3	190.3	9.66	0.042
DLWG	1.38	1.24	0.053	0.011
Carcase wt	290.2	291.3	5.95	0.559
Carcase DWG	0.92	0.82	0.039	0.030
KO %	55.8	55.8	0.51	0.618
Conformation	4.56	4.44	0.171	0.521
Fat score	4.72	4.78	0.186	0.768

Table 2 Feed intakes (kg/head)

	Yea-Sacc^{1026}	Control
Total Feed intake	1381	1662
FCR	5.87	6.98

Based on the prices prevailing at the time of the study, feeding Yea-Sacc^{1026} increased the gross margin by £29 per head (£127 versus £98) and reduced the cost per kg liveweight gain from 78p to 67p.

Conclusions The results indicate that feeding Yea-Sacc^{1026} to cereal fed beef cattle can raise the efficiency of production by increasing daily liveweight gain, reducing the number of days to reach slaughter condition and improving financial performance.

Biohydrogenation of linoleic acid and production of conjugated linoleic acids by fractions prepared from bovine rumen fluid

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Introduction Dietary conjugated linoleic acids (CLA) offer significant health benefits for man, and ruminant products are the major dietary sources (Bauman *et al*., 2001). The synthesis of CLA in the ruminant animal occurs either directly in the rumen or in the tissue from *trans*-vaccenic acid (TVA), formed primarily as intermediate products of ruminal biohydrogenation of linoleic acid (C18:2) to stearic acid (C18:0). Within the rumen, the pattern of biohydrogenation and the products formed appear to differ between the particle rich and the liquid fractions of the rumen (Singh and Hawke, 1979), with biohydrogenation occurring primarily on small particles. The aim of this study was to investigate whether the pattern of CLA and TVA formation differs in these fractions.

Materials and methods Whole rumen fluid was withdrawn two hours after feeding from four rumen cannulated Holstein-Friesian dairy cows that had been maintained on a mix of grass, maize and red clover silage for 12 weeks prior to sampling. The whole rumen fluid was mixed to give a representative sample and strained through a 100 μm^2 steel gauze to give strained rumen fluid (SRF) and a large particle fraction (LP). SRF was centrifuged at 1000×*g* for 5 mins to give both a small particle (SP) and particle free rumen fluid (PFRF) fraction. PFRF was centrifuged at 20,000×*g* for 20 mins to give a cell free rumen fluid (CFRF) fraction. Prior to use LP and SP where resuspended to their original concentration in CFRF. All manipulations were carried out under CO_2 at 39°C. Fractions were incubated with C18:2 in ethanol (final concentration 1 mg C18:2/ml, incubation volume 2.5 ml) at 39°C under CO_2. At 0, 3, and 9 h, 1.25 ml of 1 M phosphoric acid was added to duplicate tubes from each fraction. Fatty acids were extracted using $CHCl_3$: CH_3OH (2:1; v/v) with internal standard (100µl C21 in $CHCl_3$ [15mg/ml]). Fatty acids were converted to methyl esters using the bimethylation procedure described by Kramer and Zhou (2001) and analysed by gas liquid chromatography on a CP Select chemically bonded FAME column (100 m × 0.25 mm i.d., Varian Inc., California, USA) with split injection (1:30). Peaks were identified from standards and quantified using the internal standard. Variation from the duplicate analysis was used to compare the responses across the five rumen fractions.

Results Biohydrogenation, estimated as disappearance of C18:2 and the subsequent appearance of C18:0 between 0 and 9 h, was highest in SRF, followed by SP, PFRF and then LP (Figure 1). No production of C18:0 was apparent in incubations with CFRF. Accumulation of total CLA was high in incubations with SRF and LP and lower with SP. Little CLA accumulated in incubations with PFRF. Conversely, accumulation of TVA was highest in incubations with SP and PFRF and lower in incubations with SRF and LP (Figure 2).

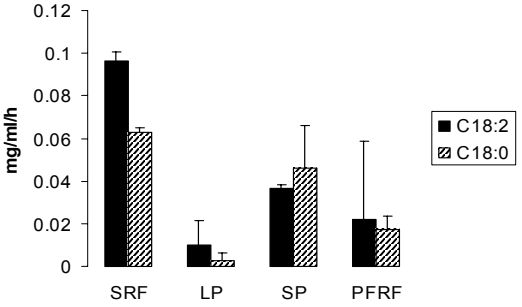

Figure 1 Disappearance of C18:2 and production of C18:0 by SRF, LP, SP and PFRF, over 9 h incubation (± SEM)

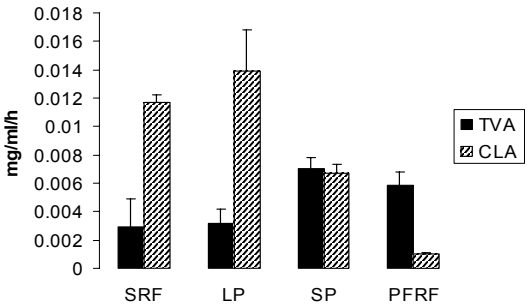

Figure 2 Appearance of TVA and CLA (all isomers) when SRF, LP, SP and PFRF were incubated with C18:2 for 9 h (± SEM)

Conclusions Biohydrogenation of C18:2 to C18:0 was higher in SP than LP ($P<0.05$). However, despite the relatively low rate of C18:2 hydrogenation in the LP fraction CLA production was high, with a substantial proportion of the C18:2 lost appearing as CLA. The SP fraction resulted in a greater formation of the end product C18:0 and the intermediate TVA and a lower proportion of CLA than the LP fraction ($P<0.05$). It is clear that the surfaces of particles are important sites for CLA and TVA production in the rumen and that the microbial populations involved in biohydrogenation on particle surfaces is worthy of further study.

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Effects of thermally activated natural zeolite on faecal consistency score and performance of Holstein calves from birth to 6-month of ages

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Introduction Natural Zeolite are characterized by framework of linked tetra hydration enclosing open cavities in the form of channels, and cages which are commonly occupied by water molecules and cations (Tomlinson, 1998). Various applications of natural and synthetic zeolites in animal nutrition, and in other uses to cope with environmental problems are widely known (Sadeghi *et al.,* 2004; Nikkhah and Sadeghi, 2004; Tomlinson, 1998). Heat processing changes the structure of this clay and makes it as a material with Cation Exchange and adsorption properties. To our knowledge, little information is available concerning the effect of thermally activated natural zeolite on plasma IgG1 concentration, and performance of Holstein calves from birth to 6-month ages. This study was conducted to determine the effect of T-zeolite on faecal score and performance of Holstein calves from birth to 6-month ages.

Materials and methods One calf growth trial was conducted using 30 newborn Holstein male calves (44 ± 3 kg) that were individually fed diets of colostrum (for 3 days), milk (4 d - 80 d) and then alfalfa hay and calf concentrate (81 d - 6 month ages). Calves were assigned randomly to one of five treatments, which consisted of control group: without T-zeolite; group 1) 5 g T-zeolite /kg DM; group 2) 10 g T-zeolite /kg DM; group 3) 15 g T-zeolite /kg DM and group 4) 20 g T-zeolite/kg DM. T-zeolite was added to colostrum and milk as above, but per day (i.e. 0, 5, 10, 15 and 20 g/calf/day). Weight data were collected every 7d until 1 month, then every 28-d before feeding, and intakes were recalculated based on current weights. Blood was collected by jugular vein into evacuated tubes containing EDTA at 24 h of age. Plasma was separated by centrifugation (3000×g for 15 min) and stored (–20 °C) prior to analysis for IgG1 concentration. Faecal consistency score were recorded twice daily for each calf until 4-week ages (Larson, 1977). Data were analyzed by Proc GLM in a completely randomized design using SAS (SAS, 1996, SAS Institute Inc., Cary, NC, USA) and appropriate covariance (birth body weight) as following model: $Y= \mu + Ti + B (Xi. - X..) + eij$.

Results and Discussion Plasma IgG1 concentration, urea nitrogen concentration, faecal score and body change weight of calves are shown in Table 1. Calves receiving 10 g T-zeolite had higher ($p<0.05$) plasma IgG1 than other treatments. This clay may be cause clearance of *E. Coli* from the intestinal tract, impaired colonization of the intestinal epithelium and so prevent immunoglobulin receptors capture. Calf faecal consistency scores were lower ($p<0.05$) for calves receiving 5 and 10 g T-zeolite/kg DM compared with other treatments. Average daily gain was not significantly different ($p>0.05$). Nearly in all periods, the highest daily gain was for group 2 and lowest one for control group.

Table 1 Effects of T-zeolite on plasma IgG1, faecal score and daily gain

	Treatment						
Item	control	T1	T2	T3	T4	Mean	SEM
Plasma IgG1 (g/L)	18.93^{c}	20.20^{b}	22.41^{a}	18.83^{c}	17.91^{c}	19.66	0.80
Average faecal score							
1st week	2.29^{a}	1.52^{bc}	1.24^{c}	1.89^{ab}	2.02^{ab}	1.78	0.40
2nd week	2.73^{a}	2.05^{b}	1.35^{c}	2.41^{ab}	2.82^{a}	2.24	0.53
3rd & 4th week	1.77^{a}	1.21^{b}	1.00^{b}	1.10^{b}	1.21^{b}	1.20	0.24
Daily gain/loss (kg/day)							
1st week	-0.11	0.03	0.17	-0.12	-0.12	-0.03	0.07
2nd week	0.05	0.32	0.29	-0.04	0.05	0.13	0.10
3rd week	0.25	0.34	0.34	0.29	0.29	0.30	0.08
4th week	0.35	0.43	0.41	0.41	0.41	0.40	0.09
2nd Month	0.53	0.52	0.54	0.52	0.53	0.52	0.03
3rd Month	0.63^{b}	0.64^{b}	0.66^{a}	0.64^{b}	0.63^{b}	0.64	0.10
4th Month	0.58	0.58	0.59	0.57	0.57	0.57	0.10
5th Month	0.59	0.61	0.60	0.61	0.59	0.60	0.10
6th Month	0.70	0.71	0.83	0.81	0.80	0.77	0.10

$^{a, b, c}$ Means in the same row followed by different superscripts differ at $p<0.05$

Conclusion Supplementation of Holstein calves (from birth to 6-month of ages) diet with 10-g/kg DM zeolite improved plasma IgG1 concentration and faecal consistency score, but its effect on daily gain was low. Zeolite in higher amounts (15 and 20 g/kg DM) had negative effect on faecal consistency score, immunoglobulin G1 absorption and daily gain.

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Effects of thermally activated sodium bentonite on ruminal degradation and intestinal digestibility of soya bean meal crude protein

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Introduction In ruminants, the protein value of a feedstuff is determined by the amount of amino acids from microbial protein and rumen undegraded dietary protein (UDP) absorbed in the small intestine. The requirement of UDP increases with the production level of the animal. This protein can be supplied by increasing the amount of dietary protein escaping degradation in the rumen. Various physical and chemical treatments have been used to alter the rate of ruminal degradation of soya bean meal (SBM) protein, thus increasing its post-ruminal availability. Recently Al-Asheh et al (2003) reported that thermally activated sodium bentonite (T-bentonite) has the potential to be used as a low cost sorbent since it is naturally available and has high surface area. We hypothesized that this clay can reduce degradation of SBM crude and true protein in the rumen. The main objectives of our research were to evaluate the degradation of untreated and T-bentonite treated SBM proteins by using SDS-PAGE and to determine effective rumen degradation (ERD) and intestinal digestibility of untreated and T-bentonite treated soya bean meal crude protein (CP).

Materials and methods Three 450-kg Holstein steers fitted with rumen fistulas were used for *in situ* incubations. Ruminal disappearance of DM and CP from the untreated and T-bentonite treated SBM (40g T-bentonite/Kg DM) was measured at 0, 2, 4, 6, 8, 12, 24 and 48 h. The exponential model of Ørskov and McDonald (1979) was used to estimate protein degradation kinetic. Data were analyzed according to the GLM procedure of the SAS (1996). Finely ground dried samples (20mg) of untreated and T-bentonite treated SBM and residues from rumen incubation were placed into 750µl SDS-PAGE sample buffer. After 30 min of thorough mixing, samples were immersed at 90 ˚C for 3 min, and centrifuged at 10000g for 1 min. 30µl aliquot of each protein sample was then loaded into the sample well. Samples were fractionated by a SDS-PAGE discontinuous system as described by Laemmli (1970). Electrophoresis of proteins was performed on 12% resolving gels with 3.75% acrylamide stacking gel. Protein fixation and staining were performed simultaneously using a solution of Coomassie brilliant blue. The subunits of the gel were monitored by densitometric scanning at 580 nm. CP digestibility was measured *in vitro* method of Calsamiglia and Stern (1995).

Results and discussion Ruminal DM and CP degradation characteristics of untreated and T-bentonite treated SBM were significantly different ($p<0.05$) (Table 1). The undegradable protein digestibility of treated SBM was similar to untreated SBM. From the SDS-PAGE pattern (Figure 1), conglycinin α and ά sub-units of untreated and T-bentonite treated SBM were deg raded completely within 4h and 12h respectively, whereas the β sub-unit of β-conglycinin as well as the basic and acidic polypeptide components of glycinin were more resistant to degradation. From densitometric scanning about 32 and 40 percent of the untreated and T-bentonite treated soya bean proteins incubated in the rumen were not degraded after 12-h incubation in the rumen, respectively.

Table 1 Ruminal protein degradation characteristics of untreated and T-bentonite treated soya bean meal

	Degradation traits			ERD*		
	a	b	c	0.02	0.05	0.08
Dry Matter	%	%	%/h	%	%	%
Untreated	25[a]	69	9.5	83[a]	71[a]	63[a]
T-bentonite	23[b]	70	9.0	80[b]	67[b]	59[b]
Crude protein						
Untreated	18[a]	80[b]	8.5[a]	82[a]	68[a]	59[a]
T-bentonite	12[b]	85[a]	7.8[b]	79[b]	63[b]	53[b]

a: immediately soluble fraction, b: potentially degradable fraction, c: degradation rate. Level of significance: $p<0.05$
*ERD: Effective rumen degradation at different outflow rate.

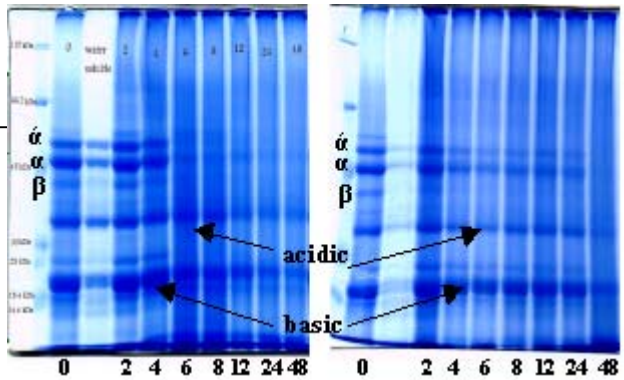

Figure 1 Slab gels of untreated (left) and T-bentonite treated SBM (right)

Conclusion *in situ* results indicated that T-bentonite could reduce ruminal protein degradation in the rumen. Further researches are needed regarding the mechanism of T-bentonite action on decreasing of protein degradation in the rumen and its effect on rumen microbes, especially protozoa population.

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The influence of dietary cation-anion difference on urine pH, feed intake and calcium and phosphor homeostasis in Holstein heifers

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Introduction In nutrition of dry cows use diets with low dietary cation-anion difference (DCAD) for preventing milk fever. Therefore, anionic salts are used for reduce DCAD of diet that are caused subacute metabolic acidosis and following stimulation of PTH and 1, 25(OH_2) D3 and result to calcium reabsorbing from gut and its transition from bone, so calcium concentration of blood is increased. Anionic salts caused increase calcium excretion of urine and decreasing pH. The objective of the present study was to evaluate the effect of diets with different DCAD on physiological characteristics of Holstein heifers.

Material and methods Lucerne (27% Dm) was harvested, chopped and mixed with 1/2% HCL then ensiled for 40 days. Treatments including: 1-base diet (barely silage, Lucerne hay + concentrate), 2-Lucerne hay sprayed with HCL (1.2%DM) and included in base diet instead of Lucerne hay, 3-base diet+ complex of anionic salts; consisted of $MgSO_4$, $MgCl_2$, $(NH4)_2SO_4$, NH4Cl,$CaSO_4$ and $CaCl_2$ (300g/head/d), 4-replasement of Lucerne hay with HCL treated Lucerne silage (1.2%DM). Sixteen heifers (12±3 month ago) were used in three groups (four heads per each treatment) in completely randomized design. DCAD of diets was for treatments 1,2,3,4 respectively, +215, +201, -81, +190meq/kgDM of feed. Heifers were fed for six days with basal diet containing 94.4% forage and 5.6% concentrate. Cows fed with experimental diets, two times per day for 21days. Feed intake measured daily. Samples of urine were taken two times during the experimental period. The samples were analysed for pH, Calcium and Phosphor of urine. Blood samples were taken via jugular vein two times at the middle and the last day of the experiment at 0.0 and 4 h after the morning feeding. Blood samples were analysed for minerals. Data were analysed using the GLM procedure of SAS.

Results Data of pH, Calcium and Phosphor of urine are shown in Table 1. Results of blood minerals and DMI are shown in Table 2. Effect of treatment on calcium and pH of urine in second sampling was significant ($p<0.05$). The effect of treatments on other minerals of urine was not significant ($p>0.05$).

Table 1 pH, Calcium and Phosphor concentration of Urine of heifers fed diets containing different DCAD

		Treatments					
Item	Sampling	T1	T2	T3	T4	SEM	*P-value*
pH	First	7.56	7.75	6.52	7.89	0.45	> 0.05
	Second	7.81	7.62	5.8	7.86	0.1	< 0.05
Ca (mg/dl)	First	3.2	3.6	11.7	2.39	4.73	> 0.05
	Second	1.33	1.57	20.27	2.69	1.12	< 0.05
P (mg/dl)	First	5.35	4.43	7.47	3.38	3.35	> 0.05
	Second	5.19	9.27	3.05	3.64	5.24	> 0.05

Table 2 Calcium and Phosphor concentration of blood and DMI heifers fed diets containing different DCAD

	Sampling	Treatments					
Item		T1	T2	T3	T4	SEM	*P-value*
Ca (mg/dl)	First	8.99	8.73	9.12	8.79	0.24	> 0.05
	Second	7.45	8.51	8.41	8.33	0.48	> 0.05
P (mg/dl)	First	6.36	7.98	7.33	7.83	0.57	> 0.05
	Second	8.01	7.08	7.31	7.03	0.6	> 0.05
DMI(Kg)		6.81	8.35	7.88	7.57	0.06	> 0.05

Conclusions The result of the present study showed that calcium of blood and urine were highest in heifers fed diet containing anionic salt and DMI in treatment 2 (Lucerne hay sprayed with HCL) than other treatment. Overall, suggested that diets containing anionic salt have a positive effect on minerals of blood and urine.

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Identification of the training, advisory and research requirements of milk producers in the South West of England

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Introduction In the UK increasing economic pressure on milk producers has highlighted the need to identify key areas to optimise farm efficiency and profitability**.** The areas of dairy herd production diseases are a major concern and improvements made in reducing the incidence of disease will improve animal welfare and reduce costs (Kossaibati, M. A. and Esslemont, R. J., 1997)
Therefore the aim this research was to identify the training, advisory and research requirements of milk producers in the SW of England.

Materials and methods This research was completed using a telephone survey of 72 dairy farmers from Cornwall, Devon and Dorset, which were selected at random from a dairy farmer co-operative database. The questionnaire had a total of forty questions designed to characterise management practices and herd performance and to identify training and advisory needs. A pilot survey was carried out on five farms in January 2003 to 'test' the questionnaire design and the main survey was completed during July 2003. The areas requested regarding training needs were 'unprompted' responses. Data was analysed using main component analysis in SPSS.

Results A total of 50 questionnaires were completed representing a response rate of 72%. The mean yield was 7000 l/cow and the majority of herds were 'all year' calving, 12% of farms specialising in milk production and 88% of farms had more than one main enterprise as shown in Figure 1. The training areas identified by farmers were, in order of priority; mastitis control, dairy herd nutrition, computer and software use, fertility, lameness / foot trimming and general administration. These are presented in Figure 2. Significantly more farmers requested training for mastitis control, dairy herd nutrition compared with computer and software use, fertility, lameness / foot trimming. Significantly less farmers requested general administration training compared with all the others areas.

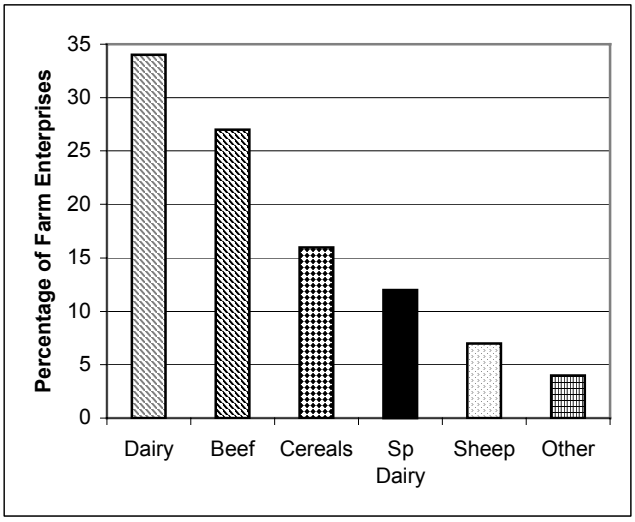

Figure1 Enterprises identified on farms in the South West of England

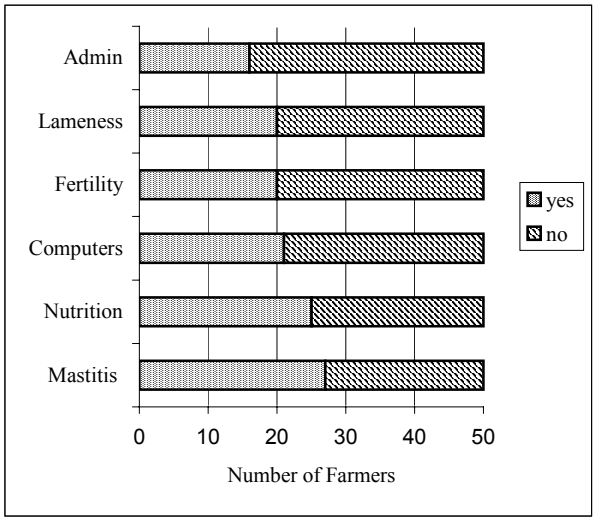

Figure 2 Training needs identified by farmers in the South West of England

Discussion Mastitis control was found the factor most frequently identified as a training and research requirement, followed by animal nutrition, computer and software use, fertility, lameness / foot trimming and general administration**.** Mastitis control provides the opportunity for participatory research to enable the farmer to more effectively control and prevent clinical mastitis thus reducing somatic cell counts. This has the opportunity to reduce antibiotic use and economic loss and increase milk price and farm profitability.

Conclusion These results highlight the opportunity for participatory research in the areas of dairy herd production and allows for the opportunity to improve economic loss and increase milk price and farm profitability.

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A comparison of the effectiveness of oxytetracycline or salt water in the management of digital dermatitis in dairy cattle

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Introduction Digital dermatitis is one of the main causes of lameness in dairy cattle, possibly accounting for 25% of the reported cases of lameness (Watson, 1999). With lameness being attributed to reduced milk yields and increased calving intervals there are considerable economic implications and effective treatment and prevention regimes are essential. Topical antibiotic treatment is the most common method of treating digital dermatitis in the UK although there is currently only one product licensed for use (Terramycin spray, Pfizer Animal Health) which contains oxytetracycline. Although effective, there can be various problems (e.g. antibiotic resistance) associated with using antibiotics for the management of digital dermatitis meaning that a suitable prevention regime that uses a non-antibiotic solution instead would be desirable. One possible alternative is sodium chloride solution (salt water) which is hypertonic and would therefore cause the bacterial cells to dehydrate, inhibiting cell growth and multiplication. This trial aimed to investigate the effect of topical application of either oxytetracycline or sodium chloride solution on the pre-washed rear feet of cows for the prevention/treatment of digital dermatitis in dairy cattle.

Materials and methods A pilot study investigated the prevalence and severity of digital dermatitis in the rear feet of sixty lactating dairy cows. It was found that approximately 50% of the cattle had lesions present of varying severity. These sixty cows were then split into three groups of twenty balanced by calving date. The cows were housed in cubicles throughout the trial and all cows had their rear feet pre-washed with water before any treatment was administered. The control group received no treatment. The antibiotic group were treated with oxytetracycline aerosol and the NaCl group with application of salt water (20% sodium chloride solution using a hand held spray gun). Both the antibiotic and NaCl groups had treatment applied three times a week for eight weeks. Lesions on the feet were scored on day 1, 14, 28 and 56 of the study and the score was based on lesion size, pain score when touched, appearance and lameness. Recordings were also taken to investigate how many cows that did not have dermatitis at the start of the trial contracted it throughout the study. Statistical analysis using Kruskal-Wallis and Chi-Squared tests on the data investigated the effects of different applications on the treatment and prevention of digital dermatitis.

Results There was no significant difference in lesion score (Figure 1) across the three groups on Day 1 of the trial. By Day 56 there was a significant difference $P<0.05$ between all three groups with the control group having the highest score and the antibiotic group the lowest. Lesion size, pain score, appearance and lameness were also analysed individually and all results followed the same pattern as the overall lesion score. Analysis on the number of new cases of digital dermatitis contracted during the trial period showed there was an association, $P<0.05$ between treatment method and incidence of digital dermatitis. Control group cows were found to have more chance of contracting digital dermatitis than cows receiving either antibiotic or NaCl treatments.

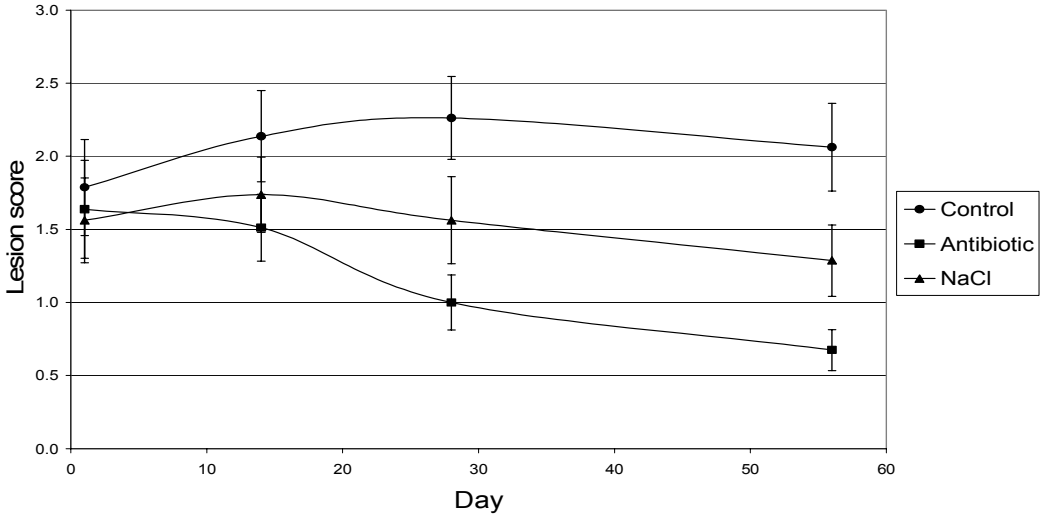

Figure 1 Effect of treatment on mean lesion score (±s.e.) over the trial

Conclusion Treatment with oxytetracycline significantly reduced lesion score compared to no treatment whilst salt water treatment prevented lesion score from increasing but did not reduce it. This would suggest that as a treatment for lesions, only oxytetracycline is effective. Salt water would provide a cost-effective alternative to antibiotic use on farms as a preventative measure against digital dermatitis.

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Hoof measurements and their relationship to lameness in first lactation heifers

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Introduction A significantly greater percentage of lesions on the claws of the outer hind foot has been recorded and this has been linked to the foot and leg conformation of the cow. Claw measurements were compared to survival rates and locomotion scores (Boelling and Pollot, 1998), but few experiments looked at changes during the lactation period (Offer *et al*., 2000) in heifers housed in straw yards and compared them to changes in lesion scores. The aim of this experiment was to compare measurements of the front and hind claws to the incidence of lameness and the formation of lesions in the sole horn during the pre- and postpartum period in first lactation heifers housed in straw yards.

Materials and methods The hoof angle, length of the front hoof wall, height of the heel, hoof growth and wear rates were measured on the right front and rear hooves of 20 heifers at two months before calving and at 50, 100 and 150 days after calving. At the same time the heifers had all claws assessed for sole ulcer and sole haemorrhage. Scores were calculated separately for the sole and white line areas. Locomotion score was scored weekly using a 5 points system. The heifers were kept at pasture and joined the lactating cow group one month before calving. After calving the heifers were kept in a straw yard in a separate group. All the parameters were compared by observation period, using ANOVA, general linear modelling command (Minitab 13.0). The comparison of means was done using the Tukey test. Correlation analysis between variables was done using Pearsons correlation. Regression analysis was performed to test the effect of days in the postpartum period on the locomotion score.

Results The mean measurements of hoof angle, length of the front wall, height of the side wall and height of the heel of the front and hind outer claws at 50, 100 and 150 days postpartum are presented in Table 1. Growth and wear rates did not differ between measurement periods. Mean growth rate was of 62.5 and 63.0 mm/month for front and hind claws. Mean wear rate was significantly greater ($P<0.05$) for hind claws (0.66 cm/month) when compared to front claws (0.50 cm/month). The front claws had significantly ($P<0.001$) higher height of the heel at all periods, significantly higher ($P<0.01$) hoof angle at day 50 postpartum and significantly ($P<0.05$) higher height of the side wall at day 150 postpartum when compared to hind claws. The locomotion score was found to increase significantly from day 7 up until day 120 of the postpartum period and subsequently decreased after day 150 postpartum (Loc. score = -8×10^{-5} days^2 + 0.0212 days + 0.9759, R^2adj. = 0.795, $P<0.001$). The mean total lesion score of the sole and white line areas was found to increase significantly ($p<0.001$) between the prepartum and day 50 and 100 of the postpartum period, decreasing from day 100 to 150 postpartum for the sole horn. The mean lesion scores of front and hind claws were significantly different ($p<0.001$), hind claws presenting always the greatest scores. Length of the hind claws at day 150 postpartum was significantly ($P<0.01$) and positively correlated to the lesion score of the white line area at the same period ($R^2 = 0.60$). Height of the side wall of the front claws at day 100 postpartum was significantly ($P<0.05$) and positively correlated to the locomotion score at the same period ($R^2 = 0.48$) and to the lesion score of the white line at 150 days postpartum ($R^2 = 0.51$). Height of the side wall of the hind claws at day 150 postpartum was significantly ($P<0.01$) and positively correlated to the lesion score of the white line at the same period ($R^2 = 0.56$) and to the locomotion score at day 189 postpartum ($R^2 = 0.52$). The height of the heel of the front claws at day 150 postpartum was significantly ($P<0.05$) and positively correlated to the locomotion score at the same period ($R^2 = 0.45$).

Table 1 Hoof measurements of the front and hind outer claws at 50, 100 and 150 days postpartum

Days postpartum	50	100	150	sem	P
Length front wall, front claw (cm)	8.05	7.83	8.04	0.125	NS
Length front wall, hind claw (cm)	7.89	7.87	7.89	0.142	NS
Height side wall, front claw (cm)	7.82	8.14	8.29	0.154	NS
Height side wall, hind claw (cm)	7.71	7.90	7.78	0.147	NS
Height heel, front claw (cm)	5.28^{b}	5.90^{a}	6.35^{a}	0.170	0.001
Height heel, hind claw (cm)	4.47^{b}	4.80^{ab}	4.82^{a}	0.111	0.05
Hoof angle, front claw (degrees)	48.84	50.94	51.82	0.885	NS
Hoof angle, hind claw (degrees)	46.63^{b}	48.05^{ab}	50.30^{a}	0.971	0.05

$^{a, b}$ – different letters in the same row indicate values that are statistically different, NS – not statistically significant

Conclusions The length of the dorsal border of the hind claws was related to a higher lesion score of the white line. The lesion score of the white line and the locomotion score were also positively correlated with the height of the heel and height of the side wall indicating that they were related to a general increase in hoof measurements. The increase in the length and height of the hooves during the post partum period may be related to smaller wear rates when animals are housed in a straw yard.

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Epidemiology of bovine and human tuberculosis in the Federal Capital Territory of Nigeria, Abuja

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Introduction Tuberculosis (TB) is a chronic debilitating disease of man and animals caused by members of the genus Mycobacterium. TB is a major health problem with 8-9 million new cases a year in the world and 3 million deaths (WHO, 2002), and the majority of these are in developing nations. Infection due to due to *M. bovis* was once a major problem in developed countries but following eradication programmes, the incidence reduced to the extent that some areas are now free of the disease (Caffery, 1994). However, the infection continues in developing countries due to lack of rigorous control measures. In Nigeria there have been limited studies to determine the prevalence/relationship between bovine and human TB especially with the eating culture of '*fura da nono' i.e.* unpasteurized milk. Abuja is the new capital of Nigeria with the population of 4 million continues to increase due to the influx of people from all states of the federation. The number of people diagnosed with TB is also on the increase. The semi forest vegetation of the Federal Capital Territory (FCT) also encourages migration of Fulani nomads in search of green area for their animals. The objective of this study was to determine the prevalence of bovine and human TB in the capital as well as to establish whether there is a link between animal and human TB.

Materials and methods For the study, sputum samples were collected from 500 patients suspected of having TB from 8 hospitals in Abuja. These patients are known to be herders and have milk from their cows as part of their main diet. Equally 150 bovine tissue samples were collected from suspected TB infected cattle slaughtered in abattoirs in the FCT. The samples were taken between 5.30-10.00am during meat inspection. Samples were collected from lesions seen on lungs, lymph nodes, liver and other visceral organs. Also 196 cows that have calved at least once, from 10 herds (where most of the patients tested come from), were screened for TB using the single intradermal comparative test (SCITT) with purified protein derivative antigen (PPD) of bovine and avian TB. (Veterinary Laboratory Agency, UK). Milk samples were collected from all positive reactors for culture using Lowenstein-Jensen (LJ) and staining using Zeil-Neilsen (ZN) and bleached-ZN stains for isolation and identification of the organism.

Results Of the 500 sputum samples collected, 142 (28.4%) were ZN and bleached ZN smear positive and 102 (20.4%) were positive on LJ. On the other hand out of the 150 bovine tissue samples collected, 44 (29%) were ZN and bleached ZN smear positive and 40 (26%) were positive on LJ. Out of the 196 cows tested with PPD, 20 (10%) were positive and the milk collected from the 20 gave, on ZN stain, 18 (9.1%) were ZN and bleached ZN stain positive while 15 (7.6%) were positive on LJ.

Table 1 Prevalence of human and bovine TB in FCT

Sample	No. Collected/tested	ZN +ve (% +ve)	LJ +ve/ (% +ve)
Sputum	500	142 (28.4%)	102 (20%)
Tissue	150	44 (29%)	40 (26%)
Milk	20	18 (9.1%	15 (7.6%)

Conclusions This result shows that there is high prevalence of both bovine and human TB amongst herders in the FCT and because they sell milk and other animal products to the population especially within the capital, there is every likely hood that many out there are infected. Also a link could be seen from the fact that over 20% of the herders reacted positive with 9% reactors within their herds. This demonstrated that there is every likelihood the farmers were infected from cows in their herds. As this is a preliminary work, further work is being undertaken to establish the link between the two using molecular techniques. This shows that an effective TB control in cattle must be taken seriously to achieve TB control in humans than just concentrating on immunization of children and the direct observation therapy (DOT) methods that is currently undertaken by the Nigerian Government.

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The effect of thermally activated natural zeolite on colostral IgGl, IgM and Aga absorption in newborn Holstein calves

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Introduction Neonatal calves are born with no immunoglobulins (Igs) in the blood stream and rely on Ig from colostrum through passive immunity transfer. Unfortunately, transfer of passive immunity to neonatal calves is too often inadequate, resulting in excessive rates of morbidity and mortality. Natural zeolite is characterized by framework of linked tetra hydration enclosing open cavities in the form of channels, and cages with ion exchanger and adsorption capacity. In literature, there were reported that thermally activated natural zeolite (T-zeolite) could increase colostral IgG absorption and decrease susceptibility of neonates to infections (Sadeghi *et al.,* 2004; Stojic *et al.,* 1995). To our knowledge, little information is available concerning the effect of thermally activated natural zeolite on colostral IgG1, IgM and IgA absorption in neonates. Our experiment was designed to investigate the effect of thermally activated natural zeolite on colostral IgG1, IgM and IgA absorption in newborn Holstein calves.

Materials and methods Fresh colostrum was collected from donor cows as they calved. When enough colostrum had been collected for an experiment it was thawed, pooled and refrozen in 1-L portions in sealed plastic bags. An aliquot was tested for IgG1, IgM and IgA concentration by single radial immunodiffusion (sRID kit; VMRD, inc. Pullman, WA). Thirty Holstein calves (15 male, 15 Female) were isolated immediately after birth and were fed, via nipple bottle, 2 Kg of colostrum containing 0 (control: T1), 0.5 (T2), 1.0 (T3), 1.5 (T4) and 2.0 (T5) g T-zeolite powder per Kg body weight per day. Blood was collected by jugular vein into evacuated tubes containing EDTA as soon as possible after birth and at 12, 24 and 36 h of age. Plasma was separated by centrifugation (3000g for 15 min) and stored (–20°C) prior to analysis for IgG1, IgM and IgA by single radial immunodiffusion. At 24h of age, calves were injected with approximately 2 ml of 1.5% Evans blue dye to estimate plasma volume (PV). Apparent efficiency of IgG, IgM and IgA (AEA) at 24h was calculated as plasma IgG, IgM or IgA (mg/ml) × PV (ml) ÷ IgG, IgM or IgA intake (mg) ×100. Data were analyzed by Proc GLM in a completely randomized design using SAS (SAS, 1996, SAS Institute Inc., Cary, NC, USA) and appropriate covariance as following model: $Y= \mu + Ti + B (Xi.-X..) + eij$.

Results and discussion Plasma IgG1, IgM and IgA are shown in Table 1. Mean of plasma IgG1, IgM and IgA concentration for all calves, immediately after birth, were lower than 1, 0.1 and 0.1 mg/ml respectively, which indicate that none of calves have consumed colostrum before blood collection. The means of plasma IgG1, IgM and IgA concentration were significantly ($p<0.05$) different among treatments. Calves receiving 1g T-zeolite /kg BW/day had higher plasma IgG1, IgM and IgA, and calves receiving 2 g T-zeolite/kg BW/day had lower plasma IgG1, IgM and IgA compared to control and other treatments. This clay may be cause clearance of *E. Coli* from the intestinal tract, impaired colonization of the intestinal epithelium and so prevent immunoglobulin receptors capture.

Table 1 Effect of T-zeolite on colostral IgG1, IgM and IgA absorption in newborn Holstein calves

Item	Treatment (g T-zeolite per Kg body weight per day)					Mean	SEM
	0	0.5	1.0	1.5	2.0		
Plasma IgG1 (mg/ml)							
12 h after birth	9.34^{b}	9.55^{b}	10.75^{a}	10.61^{a}	9.21^{b}	9.89	0.40
24 h	18.10^{bc}	18.22^{b}	20.95^{a}	18.31^{b}	17.32^{c}	18.58	0.71
36 h	14.38^{c}	15.45^{b}	16.92^{a}	15.30^{b}	14.10^{c}	15.23	0.47
AEA of IgG1 (%)	26.50^{c}	27.83^{c}	34.16^{a}	32.13^{b}	31.97^{c}	30.52	1.78
Plasma IgM (mg/ml)							
12 h after birth	0.59^{bc}	0.65^{ab}	0.71^{a}	0.54^{c}	0.58^{cd}	0.61	0.18
24 h	1.96^{c}	2.16^{b}	2.35^{a}	1.78^{d}	1.66^{d}	1.98	0.25
36 h	1.88^{a}	1.95^{a}	1.98^{a}	1.69^{b}	1.55^{b}	1.81	0.26
AEA of IgM (%)	43.55	42.43	51.81	49.26	45.64	46.54	7.12
Plasma IgA (mg/ml)							
12 h after birth	0.22	0.18	0.20	0.19	0.22	0.19	0.02
24 h	0.52^{ab}	0.49^{ab}	0.57^{a}	0.46^{b}	0.50^{ab}	0.50	0.07
36 h	0.38^{ab}	0.32^{ab}	0.39^{a}	0.31^{b}	0.36^{ab}	0.35	0.05
AEA of IgA (%)	22.93c	22.47^{c}	25.69^{b}	28.84^{a}	28.26^{a}	25.64	1.71

$^{a, b, c, d}$ Means in the same row followed by different superscripts differ at $p<0.05$

Conclusion Addition of T-zeolite (1 g/Kg BW/day) to colostrum could increase IgG1, IgM and IgA absorption in newborn Holstein calves. Zeolite had negative effect on Igs absorption in higher amount (1.5 and 2 g/kg BW/day).

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Responses of lactating dairy cows to sodium bicarbonate or sodium bentonite in low forage diet

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Introduction Dietary sodium bicarbonate or sodium bentonite has been used in lactating cow diets to aid ration adjustment. Addition of sodium bicarbonate increased intake and milk production for cows fed high concentrate diets in the first two months after parturition (Erdman et al., 1980). Addition of dietary buffers such as sodium bicarbonate and sodium bentonite increased molar percentage of acetate and reduced propionate in dairy cows. Milk fat percentage was increased by sodium bicarbonate in dairy cows when fed low roughage diets (Erdman, 1988). The objective of the present study was to investigate the effect of sodium bicarbonate or sodium bentonite in diets of high yielding dairy cows on milk yield, milk composition, and faecal pH.

Materials and methods Multiparous Holstein cows (n=14) averaging 595 kg BW (SD=21.4), 49 DIM (SD=6), and 33.7 kg/d of milk (SD=3.4) were randomly grouped into two groups of seven cows each. Cows were assigned to a completely randomized design employing two treatments for eight weeks. The cows were kept in tie stalls with individual feed bins in an animal house, which was well ventilated, and had continuous access to water. Basal diet contained (DM basis) approximately 13% maize silage, 22% Lucerne hay, and 55% concentrate (20% maize, 20% barley, 14% cottonseed, 13% soybean meal, 13% sugar beet pulp, 9% wheat bran, 6% fish meal, 4% cottonseed meal, 0.3% magnesium oxide, 0.2% dicalcium phosphate, 0.1% $CaCo_3$, 0.4% mineral and vitamin premix). Sodium bicarbonate (150g/cow/d) or sodium bentonite (350 g/cow/d) was top dressed on the basal ration as treatments. Experimental diets fed as complete mixed feeds twice daily to allow 5 to 10% feed refusals. Feed refusals were recorded once daily. Cows were milked three times daily at 0600, 1400 and 2200 h each day. Daily measurements included milk production and feed intake. Milk fat, protein and lactose (g/kg) were measured by Milko-Meter from morning, evening and night samples taken one day each week. Samples of faeces were collected from each cow on the two consecutive days at the last week of the experiment for determining the pH. All data were subjected to least squares ANOVA using the GLM procedure of SAS (Version 8e, SAS Inst. Inc., Cary, NC).

Results Feed intake, milk production, milk composition and faecal pH are presented in Table 1. Diet containing sodium bentonite resulted in non-significant 0.5 kg increase in daily milk production.

Table 1 Treatment effects on means for feed intake, milk production, milk composition and faecal pH

	Treatments			
Item	Sodium bentonite	sodium bicarbonate	s.e.m.	*P*
Feed intake, kg/d	23.2	23.4	1.20	0.60
Milk				
Yield, kg/d	31.0	30.5	1.10	0.18
Fat, g/kg	32.4	32.0	0.22	0.07
Protein, g/kg	29.9	30.0	0.16	0.32
Lactose, g/kg	40.6	40.4	0.30	0.07
Faecal pH	6.9	6.8	0.08	0.26

Conclusions The results of the present experiment demonstrated that diet with sodium bentonite had non-significant positive effect on high yielding dairy cow production. The addition of sodium bentonite to the low forage diet slightly enhanced milk yield and milk fat. Most experiments that have studied effects of buffers in early lactation have reported increases in fat corrected milk production (Erdman et al., 1980). Thus, benefits in higher peak milk production from high concentrate rations may be obtained while maintaining normal milk fat percentage if sodium bentonite or sodium bicarbonate are used. There was no significant effect of the buffers used in the present study on faecal pH. This is not surprising as a previous experiment (Erdman et al., 1980) with similar dietary concentration of sodium bicarbonate failed to alter faecal pH.

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Comparison of two models of phosphorus flows in calves infected with *Cooperia punctata*

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Introduction *Cooperia punctata* is the most prevalent parasitic intestinal nematode in Brazil and its site of fixation is duodenum and jejunum that are also the sites of greatest dietary phosphorus (P) absorption. Studies of phosphorus metabolism often involves balance trials and use of isotopes. When combined with mathematical modeling, calculation of flows between several pools becomes a possibility. The objective of the study on calves employing isotope and balance techniques was to apply and compare two models of P metabolism for resolving data generated by these techniques.

Materials and Methods Ten male three-month-old Holstein calves were housed in stalls (five animals per stall) without contact with parasites. After weaning, animals were fed hay (*Cynodon dactilon*) and a commercial concentrate mixture.Five calves received a single oral dose of 45000 *C. punctata* infective larvae, and five calves remained as non-infected control animals. All calves received a dose of 29.6 MBq/kgLW of ^{32}P via jugular vein, and blood samples, faeces and urine were collected at 24h intervals for 7 days. The animals were slaughtered in the animal house located at the Nutrition Laboratory, according to recommendations of the Radiological Protection Service and the Animal Experimentation Ethic Committee at CENA. Samples of tissues (liver, kidneys, heart, muscles and bone) were collected for determination of inorganic phosphorus and radioactivity. Two mathematical models were applied to analyze data. The model of Vitti *et al*. (2000) describes P circulation between four pools: gut, blood, bone and smooth tissues. The model of Fernández, (1995) describes P circulation between P pools in gut, blood and bone. Data were analysed statistically using ANOVA (SAS, 1999), considering a factorial design (2 models and 2 treatments). Comparison of means was carried out using Duncan test and significant variability of the data was determined at $P < 0.05$ level.

Results Mean phosphorus intake was 12.43g/animal /day and was considered adequated. Phosphorus flows for control and infected animals calculated using the model of Fernández (1995) and the model of Vitti *et al*. (2000) are shown in Table 1. There were no significant differences for the parameters studied ($P>0.05$) between control and infected animal for both models. The two models agreed on absorption rates from gut to blood and blood to gut. Phosphorus incorporation into bone was higher ($P<0.05$) in the Vitti model but P reabsorption was similar for the two models. P flows to and from tissues were higher in Vitti model, but the models gave an identical P retention in soft tissues (P>0.05) (3.46 and 4.45 g/day for Vitti and Fernández models).

Table 1 Flows calculated using the models of Fernández (1995) and Vitti *et al.* (2000) for infected calves with *Cooperia punctata* and control group (treatment means)

	Fernandez		Vitti	
Item	Control	Infected	Control	Infected
Model output (g P/day)				
Gut to blood	25.20	23.07	25.09	20.52
Blood to gut	13.13	14.19	13.13	11.51
Blood to bone	8.74	6.97	12.77	10.87
Bone to blood	2.49	3.52	3.36	2.68
Blood to tissue	1.35	0.91	2.08	1.57
Tissue to blood	0.28	0.22	0.56	0.49

Conclusions *Cooperia punctata* infection did not affect parameters of phosphorus metabolism at conditions of this study. The two models compared were similar in principal, although their aim and therefore calculations differed.

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Phosphorus kinetics in calves experimentally infected with *Cooperia punctata* evaluated by isotopic dilution

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Introduction *Cooperia punctata* is the most prevalent intestinal parasite in young bovines in Brazil (Lima, 1998). The site of fixation of *C. punctata* is the upper part of the small intestine (Bailey, 1949), also the site of dietary phosphorus (P) absorption (Schröder *et al.*, 1995), and the damage caused in the intestinal epithelium could interfere with P metabolism (Bown *et al.,* 1989). The aim of the present experiment was to evaluate the P kinetics by using ^{32}P isotopic dilution technique in calves submitted to single and trickle infection by *C. punctata.*

Materials and methods Separate groups of 10 Holstein male calves were used in each trial. In Trial I (single infection), five animals each received a single dose of 45,000 infective larvae (L3) and the other five remained as control animals. For the trial II (trickle infection) five animals were each inoculated with 5,000 L3 twice a week, for five weeks, and the other five animals remained as controls. For isotopic dilution assay (Vitti, 1989), each animal was intravenously injected with 29.6 MBq of a ^{32}P solution. Blood samples were taken each 24h for seven days. Faeces, urine, and tissues (liver, heart, kidneys, bones, muscles - taken during necropsy) samples were taken for analysis. Experimental measurements were analysed as a completely randomised design. A comparison of means between each treatment was carried out using the General Linear Models procedure (SAS, 1990), and compared by the Tukey test. Treatment means were assessed using the least significant difference method when overall treatment effects were $P < 0.05$.

Results At trial I there were significant differences ($P < 0.05$) regarding only to live weight variation, which was lower for the infected animals (means of 65.70 to 68.10 kg, compared to 63.30 to 70.30 kg from controls), and with no interference in the other parameters. At trial II, however, there were significant differences ($P < 0.05$) regarding to P intake, P absorption and P retention, showing a decrease for the infected animals, and weight loss for the same calves (means of 72.00 to 70.12 kg, compared to 76.60 to 84.47 kg from controls).

Table 1 Parameters relating to P metabolism in experimentally infected calves with *C. punctata*, and controls, Trial I and II – single and trickle infections'

	Trial I				Trial II			
Parameters	Infected	Control	s. e.	*P*	Infected	Control	s. e.	*P*
DM intake (kg/d)	2.30	2.30	0.000	0.31	1.67	2.16	0.006	0.01
P intake (g/d)	12.43	12.43	0.000	1.00	12.56	18.13	8.512	0.01
P excretion (g/d)	5.46	3.75	0.652	0.08	3.15	4.41	0.655	0.19
Endogenous P (g/d)	2.60	1.80	0.410	0.31	1.34	1.50	0.416	0.79
P absorption (g/d)	9.51	10.66	0.543	0.15	10.86	15.40	0.542	0.01
P absorption eficiency	0.76	0.85	0.042	0.22	0.86	0.85	0.038	0.84
P retention (g/d)	6.97	8.68	0.647	0.09	9.41	13.72	0.664	0.01
Plasma P (mg/dl)	6.18	7.80	0.502	0.05	7.74	7.39	0.309	0.40
Bioavailability	0.77	0.86	0.004	0.13	0.86	0.82	0.004	0.42

Conclusions Phosphorus metabolism in calves was not affected by the single infection with *C. punctata* in the dose of L3 used in this study. In this situation, only the weight gain was significantly affected. However, a trickle infection with the same parasite, in the dose used in this study, affected negatively the P kinetics, reduced DM and P intake and induced weight losses in the infected animals.

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Development of a low technology *in vitro* procedure using faecal liquor for the estimation of digestibility of feedstuffs for horses

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Introduction Currently, there is no specific *in vitro* technique for the estimation of digestibility of feedstuffs for horses. The most common technique used is based on the two stage method of Tilley and Terry (1963). As this technique aims to simulate the digestive processes of a ruminant, its suitability for application to the monogastric equines needs to be considered. This was one objective of the current study. The other objective was to develop a low tech faecal liquor procedure based on Omed *et al.* (1989) method to obviate the need for fistulated animals.

Materials and methods Four experiments were conducted: Experiment 1 followed the technique of Omed *et al.* (1989) using sheep faeces for the inoculum. Experiment 2 reversed the two stages of the standard faecal liquor technique, by first 'digesting' the sample with acid pepsin, followed by incubation with faecal liquor (derived from sheep faeces). Experiment 3 was as Experiment 1, but used horse faeces in place of sheep faeces. Experiment 4 was as experiment 2, but again using horse faeces. The sheep faeces collected came from fully-grown Welsh Mountain Ewes and the horse faeces came from an 8-year-old Thoroughbred gelding that was at grass but also fed on concentrates. Feedstuff samples of known in-vivo digestibility for equines were provided by Smolders & Hindle. Minitab (Version 14) was used to perform Analysis of Variance tests on the data.

Results The mean digestibility of the different feedstuffs, as determined by each experimental technique are shown in Table 1, along with the *in vivo* digestibilities values of the samples.

Table 1 Mean and SE of estimated in *vitro* DMD% from each experiment and in *vivo* DMD in horses

	Exp 1		Exp 2		Exp 3		Exp 4		*in vivo*
Sample	Mean	SE	Mean	SE	Mean	SE	Mean	SE	digestibility
1. Grass Hay	42.90	0.493	64.06	0.151	55.52	2.278	52.00	1.462	44.60
2. Grass Hay	48.76	0.784	75.40	1.680	67.72	0.575	60.93	0.591	53.60
3. Grass Hay	55.96	1.067	77.83	0.070	70.15	0.533	64.25	0.310	59.40
4 .Grass Hay	56.82	0.188	78.55	0.732	71.72	0.247	67.05	0.585	65.50
5 .Grass Seed Straw	60.83	0.335	82.47	0.296	76.68	0.205	73.58	0.696	69.80
6. Compound Feed	32.71	0.463	54.75	0.664	46.51	0.165	47.44	0.540	46.10
7. Compound Feed	28.95	0.337	50.86	0.095	44.70	0.475	38.31	0.431	32.40
8. Barley	61.90	0.638	65.39	0.483	76.41	0.269	73.79	0.457	72.20
9. Wheat	44.02	0.533	82.27	0.954	57.75	0.038	54.14	0.512	59.40
10. Wheat Meal	70.42	0.145	85.43	0.413	82.86	0.435	81.15	0.649	83.40
11. Wheat Bran	72.98	1.191	90.08	0.456	88.24	1.852	85.47	1.855	83.70
12. Fresh Grass	71.90	0.051	89.84	1.127	87.09	0.144	82.70	0.313	84.80
13. Lupin Seeds	58.58	0.890	79.58	0.662	73.58	0.354	72.78	0.526	66.10
14. Lucerne Meal	67.14	0.766	91.52	0.495	89.89	0.255	87.25	0.247	79.40

Experiment 1 provided estimates of digestibility which were not significantly different from the *in vivo* digestibility values. The faecal liquor technique has been established as a reasonable method for digestibility estimation and this result was, therefore, expected. Experiment 2 and Experiment 3 consistently yielded digestibility values which were significantly different from the *in vivo* digestibility values. They could not be used to predict the digestibility of the feedstuff with any confidence. By contrast, Experiment 4 provided as good an estimation of the digestibility values as did the traditional faecal liquor technique. The fact that Experiment 4 has yielded estimations of digestibility which are not significantly different from the true digestibility values suggests that reversing the faecal liquor technique – beginning with acid pepsin digestion – has yielded a substrate more similar to, and therefore suitable for, the micro-organisms of the equines' caecum. Compound feedstuffs consistently yielded low digestibility values, this may result from an increase in acidity reducing the activity of the caecal micro-organisms.

Conclusion This series of experiments has indicated the validity and potential utility of an adapted version of the faecal liquor technique to provide a reliable estimation of the digestibility of feedstuffs for equines. It is suggested that the technique is both more transparent and understandable, in the context of equines, than a technique based on simulating ruminant digestive processes. Furthermore, when dealing with equines it is probable that their faeces, rather than those of sheep, may be more readily available.

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Bioassay for measuring tannin effects based on gas production technique. 1. Binding compounds

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Introduction Anti nutritional factors in tropical legumes are very common and the chemical analysis for tannins has become an important tool to evaluate alternative ruminant feeds in the tropics. However, frequently results from tannin chemical analysis are not in agreement with biological response when animals are fed those feeds. There is a lack of information concerning the biological effects (activity or reactivity) of tannins on ruminants. Usually the effects of tannins are tested in vitro by adding compounds with capacity of biding tannins. The aim of this work was to compare two binding compounds to evaluate the effect of tannins of tanniniferous feeds for ruminants.

Material and methods The gas production technique was carried out according to Mauricio et al. (1999) using six substrata (feeds) in duplicate and repeated three times using sheep rumen liquor as inoculum. The gas production profile were obtained using the model proposed by France et al. (1993) to fit the results for 96h of incubation. The tested feeds were: aroeira (*Astronian urundeuva*), jurema preta (*Mimosa hostilis*), sorghum grain (*Sorghum bicolor*), Tifton-85 hay (*Cynodon* sp.) and two mixtures with 45% of sorghum leaves and 45% of concentrate (maize and soybean meal) plus 10% of either quebracho (*Schinopsis lorentzii*) extract or Acacia (*Acacia mollissima*) tannin extract. Two binding compounds (polyvinyl polypyrrolidone – PVPP and polyethylene glycol – PEG) were added to the substrate directly into the fermentation flasks (1 g of binding compound for each g of substratum). The binding potential was compared for the parameters of France et al. (1993) model and the increase of gas production using the binding compound was compared as well. Treatments (binding compounds) were compared by Tukey test (SAS, 2000).

Results The chemical composition of feeds used as substratum is presented on Table 1. Although the parameters for gas production profiles (A, b, c, L and T½) were not different between treatments ($P > 0.05$), the binding potential could be observed on the increase of gas released when those compounds were added (Table 2). PEG seemed to be more efficient to bind tannins than PVPP. The greatest increases were obtained in the first periods, and for long-term incubations differences were shorter.

Table 1 Chemical composition of feeds

feeds[†]	composition[‡]					
	CP	NDF	ADF	TP	TT	CT
A	113	436	287	207	190	11
B	161	587	475	144	122	55
C	103	604	126	15	12	27
D	74	803	461	6	3	0
E	155	543	257	138	130	35
F	149	603	271	130	126	62

[†]A: aroeira; B: jurema preta; C: sorghum, D: Tifton-85 hay; E: 45% sorghum leaves + 45% concentrate + 10% quebracho extract; F: 45% sorghum leaves + 45% concentrate + 10% *Acacia* extract.

[‡]CP: crude protein (g kg^{-1}); NDF: neutral-detergent fibre (g kg^{-1}); ADF: acid-detergent fibre (g kg^{-1}); TP: total phenolics (eq-g tannic acid kg^{-1}) TT: total tannins (eq-g tannic acid kg^{-1}); *CT*: condensed tannins (eq-g leucocyanidin kg^{-1})

Table 2 Parameters of gas production profile (A, b, c and L from France et al (1993) model) and increasing on gas production with PVPP or PEG as binding compound

parameters	treatments			S.E.M.
	control	PVPP	PEG	
A (ml g^{-1})	189.7 [b]	206.5 [a]	211.3 [a]	3.31
b (h^{-1})	0.0362 [b]	0.0409 [ab]	0.0422 [a]	0.00151
c (h^{-1})	-0.1092 [a]	-0.1302 [a]	-0.1226 [a]	0.00684
L (h)	2.46 [a]	2.69 [a]	2.33 [a]	0.162
T½ (h)	36.18 [a]	34.86 [a]	34.87 [a]	1.973
increase after				
12h (%)	-	25.6 [b]	49.0 [a]	4.66
24h (%)	-	21.8 [b]	34.5 [a]	2.19
36h (%)	-	19.7 [b]	28.4 [a]	1.87
48h (%)	-	17.9 [b]	24.3 [a]	1.74
72h (%)	-	15.4 [a]	19.3 [a]	1.53
96h (%)	-	14.0 [a]	16.4 [a]	1.35

[a-b]means followed by different letters, within row, are significantly different ($P < 0.05$)

Conclusion The complex formed by polyethylene glycol and tannins is more stable than polyvinyl polypyrrolidone and tannins. For bioassays using binding compounds to attenuate the effect of tannins, PEG is more effective than PVPP.

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Bioassay for measuring tannin effects based on gas production technique. 2. Dosage of polyethylene glycol

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Introduction Tannins are secondary compounds that can bind protein and other nutrients and reduce their availability to the animals. Polyethylene glycol (PEG) has a great affinity with tannins and when it is added to the feed it is bound to tannins and releases the protein and other nutrients. There is no information about the amount of PEG that is needed to obtain the maximum precipitation of tannin and the minimum tannin effect. Some assays are conduced using doses of PEG according to the tannin content, but the activity of tannins can vary and this imply that the tannin analysis has to be done prior. The aim of this work was to evaluate doses of polyethylene glycol to minimize the effect of tannins on rumen fermentation.

Material and methods The semi automated gas production technique (Mauricio et al., 1999) was carried out using six substrata (feeds) in duplicate and repeated three times using sheep rumen liquor as inoculum. The tested feeds were: aroeira (*Astronian urundeuva*), jurema preta (*Mimosa hostilis*), sorghum grain (*Sorghum bicolor*), Tifton-85 hay (*Cynodon* sp.) and two mixtures with 45% of sorghum leaves and 45% of concentrate (maize and soybean meal) plus 10% of either quebracho (*Schinopsis lorentzii*) extract or Acacia (*Acacia mollissima*) tannin extract. The five doses of PEG (treatments) used were 0 (*T0* – control), 500 (*T1*), 750 (*T2*), 1000 (*T3*) and 1250 (*T4*) mg per gram of DM and they were added to the substrate directly into the fermentation flasks. The fermentation was carried out until 96 h of incubation and data were fitted by the model proposed by France et al. (1993). Treatments were compared for the parameters of France et al. (1993) model and the increase of gas production using the different doses of PEG. Means of treatments were compared by Tukey test (SAS, 2000).

Results The chemical composition of tested feeds is presented on Table 1. Among the feeds are forages with practically no tannin (feed *D*) and various levels of tannins until feed *E* produced artificially by adding tannin extract. Addition of PEG (in any dose) resulted in a greater gas production compared to the control (*T0*) however treatments T1, T2, T3 and T4 did not present differences ($P > 0.05$) (Table 2). There was an interaction feed*treatment and this could be responsible for the high variation and the non-significance for the treatments. ($P < 0.01$). Although there were no differences, the increasing on gas production presented high correlations with doses of PEG ($r > 0.85$; $P < 0.01$) for all incubation times.

Table 1 Chemical composition of feeds

feeds†	composition‡					
	CP	NDF	ADF	TP	TT	CT
A	113	436	287	207	190	11
B	161	587	475	144	122	55
C	103	604	126	15	12	27
D	74	803	461	6	3	0
E	155	543	257	138	130	35
F	149	603	271	130	126	62

†A: aroeira; B: jurema preta; C: sorghum, D: Tifton-85 hay; E: 45% sorghum leaves + 45% concentrate + 10% quebracho extract; F: 45% sorghum leaves + 45% concentrate + 10% Acacia extract.

‡CP: crude protein (g kg^{-1}); NDF: neutral-detergent fibre (g kg^{-1}); ADF: acid-detergent fibre (g kg^{-1}); TP: total phenolics (eq-g tannic acid kg^{-1}) TT: total tannins (eq-g tannic acid kg^{-1}); CT: condensed tannins (eq-g leucocyanidin kg^{-1})

Table 2 Parameters of gas production profile from in vitro fermentation of taniniferous feeds treated with different doses of PEG

parameters†	PEG‡					S.E.M.
	T0	T1	T2	T3	T4	
A (ml g^{-1})	182^{b}	196^{a}	195^{a}	198^{a}	198^{a}	2.3
b (h^{-1})	0.030^{b}	0.039^{a}	0.040^{a}	0.039^{a}	0.039^{a}	0.0013
c (h^{-1})	-0.102^{a}	-0.124^{b}	-0.130^{b}	-0.119^{ab}	-0.118^{ab}	0.0061
L (h)	3.26^{a}	3.13^{a}	3.00^{a}	2.80^{a}	2.56^{a}	0.226
T½ (h)	44.85^{a}	37.92^{b}	35.25^{b}	35.63^{b}	35.83^{b}	1.122
increase after						
12h (%)	-	86.5^{a}	108.8^{a}	120.0^{a}	129.1^{a}	32.72
24h (%)	-	50.0^{a}	57.4^{a}	61.6^{a}	63.1^{a}	7.43
36h (%)	-	40.6^{a}	46.5^{a}	49.0^{a}	49.6^{a}	4.39
48h (%)	-	34.6^{a}	39.6^{a}	41.5^{a}	41.7^{a}	3.19
72h (%)	-	26.6^{a}	30.1^{a}	32.0^{a}	31.8^{a}	2.13
96h (%)	-	21.7^{a}	24.1^{a}	26.1^{a}	25.9^{a}	1.70

†parameters from the model of France et al. (1993)

‡T0 = 0 mg; T1 = 500 mg; T2 = 750 mg; T3 = 1000 mg and T4 = 1250 mg of PEG per gram of DM

$^{a-b}$means followed by different letters, within row, are significantly different ($P < 0.05$)

Conclusion All the doses tested produced a response to evaluate tannin effects but response was more evident for the dose of 1000 mg per gram of dry matter.

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Bioassay for measuring tannin effects based on gas production technique. 3. Curve of biological equivalence

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Introduction The chemical determination of tannins has become inefficient to predict the negative effects in nutritional parameters. Apparently, different tannins have distinct activity (or reactivity) resulting in anti nutritional effects. The objective of this work was to test three compounds to establish a curve of biological equivalent effect of tannins using the in vitro gas production technique.

Material and methods The semi automated gas production technique was carried out for 96 h of incubation to evaluate six feeds (with distinct composition – Table 1) regarding the tannin effect on rumen microbial activity. To establish the curve, three compounds were tested as standards for tannins: tannic acid (powder, P.A.), quebracho (*Schinopsis lorentzii*) extract (total tannins (TT) = 663.6 eq-g tannic acid (TA) kg^{-1} and condensed tannins (CT) = 171.8 eq-g leucyanidin (LC) kg^{-1}) and Acacia (*Acacia mollissima*) extract (TT = 638.6 eq-g TA kg^{-1} and CT = 159.7 eq-g LC kg^{-1}). To make the curve, five levels of each compound were added to 1g of a standard feed (Lucerne hay). Doses were 0, 40, 80, 120, 160 and 200 mg of tannic acid, 0, 100, 200, 300, 400 and 500 mg of quebracho extract, and 0, 100, 200, 300, 400 and 500 mg of Acacia extract. The gas production results were fitted by France et al. (1993) model. The percentage of gas produced in relation to the control (dose 0) was used to create a curve of effect of increasing levels of tannins. Curves were obtained by regression for 12, 24, 36, 48, 72 and 96h of incubation. Biological equivalent effect was compared to tannin composition by correlation.

Results Linear regressions were very reliable (R^2>0.90) for all times. In Table 2, the regressions after 24h of incubations are presented to illustrate. The curves of equivalence showed that tannins can have different capacities to produce biological effect. Feeds *A*, *B*, *C*, *D*, *E* and *F* presented TT content values of 190, 122, 12, 3, 130 and 126 eq-g TA kg^{-1}, respectively, but their tannins were equivalent to 159, 208, 81, 25, 88 and 84 eq-g TA kg^{-1} for tannic acid standard, 209, 291, 80, -12, 92 and 85 eq-g TA kg^{-1} for quebracho extract standard and 224, 300, 104, 18, 115 and 109 eq-g TA kg^{-1} for Acacia extract standard. The same occurred for CT, which chemical analysis results were 11, 55, 27, 0, 35 and 62 eq-g LC kg^{-1} and their biological equivalent were 54, 75, 21, -3, 24, and 22 eq-g LC kg^{-1} for quebracho extract standard and 56, 75, 26, 4, 29 and 27 eq-g LC kg^{-1} for Acacia extract standard, respectively for feeds A, B, C, D, E and F. In other words, feeds with lower tannin content can have higher biological effect or vice-versa, and this approach allowed visualizing that. Data predict from those curves were also correlated to chemical parameters. The correlation coefficients observed for total phenolics and biological equivalent of tannic acid, quebracho or Acacia extracts were higher than 0.70 (P<0.0001) and the same was observed for total tannins (r>0.65; P<0.0001) and condensed tannins (r>0.45; P<0.0051).

Table 1 Chemical composition of feeds

feeds	composition†					
	CP	NDF	ADF	TP	TT	CT
A	113	436	287	207	190	11
B	161	587	475	144	122	55
C	103	604	126	15	12	27
D	74	803	461	6	3	0
E	155	543	257	138	130	35
F	149	603	271	130	126	62

†CP: crude protein (g kg^{-1}); NDF: neutral-detergent fibre (g kg^{-1}); ADF: acid-detergent fibre (g kg^{-1}); TP: total phenolics (eq-g TA kg^{-1}) TT: total tannins (eq-g TA kg^{-1}); CT: condensed tannins (eq-g LC kg^{-1})

Table 2 Linear regression between level of tannins (total – TT – or condensed – CT, in eq-g kg^{-1}) and their biological effect (BE, in %) on gas production after 24h of incubation

standard	regression equation	
total tannins		
tannic acid	BE = -312.55 TT + 105.37	(R^2=0.94)
quebracho extract	BE = -188.52 TT + 95.17	(R^2=0.96)
Acacia extract	BE = -202.51 TT + 101.15	(R^2=0.99)
condensed tannins		
quebracho extract	BE = -728.20 CT + 95.17	(R^2=0.96)
Acacia extract	BE = -809.80 CT + 101.15	(R^2=0.99)

Conclusion Curves of biological equivalence can provide information about reactivity of tannins that, regarding practical aspects, are more significant than just chemical analysis.

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Tannin bioassay using semi-automated gas production technique

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Introduction Brazil has arid regions where livestock production is limited by forage source. However, some native herbaceous browses have a dry tolerance and had been used as animal feed. Some of those plants have anti nutritional compounds such as tannins that can interfere on intake and digestibility. Tannins have a high affinity to proteins and could make these molecules unavailable for animal. Compounds as polyethylene glycol (PEG) has been used on tannin studies, because it has more affinity with tannins than proteins. Based on that, it is possible to evaluate the nutritive potential of tanniniferous plants, using PEG in gas based techniques for assessing anti nutritional factors in tanniniferous plants for ruminants. The aim of this work was to investigate the effects of different treatments (oven-, shade- and sun-drying and treatment with urea) on phenolics compounds and on the biological activity of tannins using the in vitro gas method with the addition of polyethylene glycol (PEG).

Material and methods Six browse species with potential as forage were selected: Angico (Anadenanthera macrocarpa), Aroeira (*Astronian urundeuva*, Engl.), Feijão bravo (*Capparis flexuosa*, L.), Jurema preta (*Mimosa hostilis*, Benth), Malva branca (*Sida cordifolia*, L.) and Maniçoba (*Manihot pseudoglaziovii*). The samples were collected at 2m height or inferior and with 5mm or less of diameter. The collections were made in the dry (March) and the wet season (October) with three replicates for each substrate. Three drying treatments were tested: control, dried in air drying oven at 40^{o} C (Control) during 2 days, sun-driying (Sun) and shade-drying (Shade) during 3 days and urea treatment: plant material was sprayed with an aqueous solution of urea (4g urea in 10 ml water/100 g DM), and stored in sealed plastic boxes for 30 days at ambient temperature (25-27˚C). Total phenol (TP) was determined using Folin-Ciocalteu reagents, total tannins (TT) as the difference of phenolics before and after tannin removal using the insoluble polyvinyl polypyrrolidone (PVPP) and condensed tannins (CT) were analyzed as described by Makkar (2000). *In vitro* gas production assay was conducted according to Mauricio et al. (1999). Four sheep with rumen cannulas were used as inoculum donors. Inoculum was prepared with 50% liquid and 50% particulate ruminal matter (Bueno et al., 2000). About one gram of each sample was disposed in duplicate, with or without PEG (1:1). Gas production was recorded at 3, 6, 9, 12, 16 and 24 h., using a pressure transducer. Data were compared by Duncan test using SAS system (SAS, 2000).

Results Table 1 shows the gas production (GP) and percent increasing in GP from treated browses, after incubation with or without PEG for 24 h. A higher increase (%) in gas production with the addition of PEG for oven- (81.4), sun- (78.5) and shade-drying treatments (76.7) compared to urea treatment (10.9) indicates that urea treatment reduced the biological activity of tannins the most significantly ($P<0.05$). The percent increase in GP, after 24 h incubation, from the browses due to PEG varied between species ($P<0.05$) and values were 121, 104, 100, 24, 5 and 4 for Aroeira, Jurema, Angico, Maniçoba, Malva and Feijão, respectively. The increase in gas production at 24 h was positively correlated ($P<0.01$) with TP ($r^2 = 0.80$), TT ($r^2 = 0.81$) and CT ($r^2 = 0.66$). The high correlation of an increase in GP and TP and TT ($P<0.01$); $r^2 = 0.81$) suggests that these two parameters could also be taken as an index for the biological activity of tannins.

Table 1 Means of volume of gas production (ml/g DM) from browses treated in different ways, after incubation with (+) or without (-) PEG for 24 h

Treat.	*Oven-dried*			*Sun-dried*			*Shade-dried*			*Urea*			*means*
	+	-	%	+	-	%	+	-	%	+	-	%	*of%*
Plants	*PEG*	*PEG*	*increase*	*PEG*	*PEG*	*increase*	*PEG*	*PEG*	*increase*	*PEG*	*PEG*	*increase*	*increase*
Angico	66.9	29.8	124.0	61.3	27.0	128.1	62.5	27.8	125.0	26.6	22.0	21.2	99.6 [a]
Aroeira	62.5	27.0	140.1	63.4	30.1	114.0	63.6	30.3	116.4	51.7	30.5	69.8	120.7 [a]
Feijão	50.5	47.5	6.7	47.1	46.2	2.5	47.4	41.4	14.8	26.2	29.6	-8.3	3.9 [b]
Jurema	33.8	16.6	113.2	32.2	15.5	120.6	30.4	17.3	93.3	32.2	29.8	8.4	103.7 [a]
Malva	74.9	73.6	1.5	79.9	74.4	7.5	74.8	69.9	7.6	73.7	72.5	2.2	4.7 [b]
Maniçoba	92.1	83.2	12.2	85.9	71.2	20.8	74.3	51.9	47.0	55.9	50.8	9.8	23.6 [b]
means			81.4 [A]			78.5 [A]			76.7 [A]			10.9 [B]	

SEM for percentage of increase: 6.60 (for treatments) and 8.86 (for plants); [A,B] means with different superscripts, within rows, are different (Duncan test, $P<0.05$); [a,b] means with different superscripts, within column, are different (Duncan test, $P<0.05$)

Conclusions The study showed that tannins had negative effect on *in vitro* rumen fermentation and PEG could show this effect. Urea treatment was the most effective treatment on decreasing tannin concentration in browses.

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A methodology for the rapid assessment of forage tree defaunating capacity

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Introduction It is known that some forage trees have potential defaunating capacity, as rumen protozoa population is reduced when ruminant are feed with them (Odenyo *et al*., 1997[a],b). The effect has been attributed to saponins (Diaz *et al.*, 1992) and tannins (Odenyo *et al.*, 1997a,b). It is also known that PEG binds to tannins and has been used to reduce the deleterious effect found in animals feed tanniferous trees (Makkar *et al.*, 1998). However, to our knowledge it has not been studied if using PEG to increase digestibility will, on the other hand, affect the defaunating capacity of the tree. The objective of the present study was to develop a simple technique to screen forage trees for defaunation capacity and to assess if PEG could be used to overcome this effect.

Material and methods The batch culture system described by Ojimoto and Imai (1981) was used. The culture was grown in 50 ml capped tubes. To feed the protozoa a dry Taiwan grass (*P. purpureum*) and starch (5% v/v) mixture was used as recommended. Rumen liquor was obtained from two cannulated cows and placed in laboratory funnels to allow the protozoos to accumulate at the bottom where they were collected. Two ml of the protozoos collected were inoculated to the tubes and incubated at 39 ^{o}C with and without 0.25g PEG. Plant extract (supernatant) was obtained using 10g DM which was placed in a beaker containing 80 ml on the culture media, agitated for 30 min and then centrifugated for 5 min. After the 0h sample was taken (6ml) the culture was additioned with the plant extract or media (5ml), protozoa feed (0.5ml) and PEG or media (0.5ml) every 24h up to 72h. Protozoa were fixed with MFS and identify under microscope. Each treatment had four replicates. Protozoa counts+1 were $\log_{10}$ transformed before statistical analysis. The effect of diet (sorghum-grass vs *C. calothysus*), hour (0, 24, 48 ,72) and PEG (with vs without) were assessed using ANOVA followed by a post test using the Bonferroni methods to asses the differences with GraphPad Prism 4 (Motulsky, 2003).

Results Table 1 present the chemical composition of the feeds. No tannins were detected in the grass and grain used as protozoa feed. On the other hand, *C. calothyrsus* had considerable amounts of tannins.

Table 1 Chemical composition of the material use in the defaunation study

Especie	DM	CP	NDF	ADF	Ash	TP	CT
Calliandra calothyrsus	38.26	15.15	38.12	21.06	4.96	4.11	22.36
Panicum maximum	19.14	14.76	63.26	36.32	9.24	0	0
Sorgum bicolor (grain)	88.20	9.97	ND	ND	1.51	0	0

ND: No determined, TP total polyphenol, CT condensed tannins

PEG had no effect on the survival of protozoa after 72h (preliminary observations showed no effect after 96h) and shows that PEG can be used as part of the culture media for rumen protozoos (Table 2). Addition of PEG significantly reduced the defaunating effect of *C. calothyrsus*. When PEG was not used it was clearly observed a reduction in protozoa number above after 24h and no protozoa was found after 48h. However, when PEG was additioned the protozoa number remained at similar levels to those obtained in the control tubes.

Table 2 Number of protozoa (log 10) remaining on vitro culture when incubated with and without PEG

	Control		C. calothyrsus	
Hour	- PEG	+ PEG	- PEG	+ PEG
0	4.087a	4.093a	4.078a	4.090[a]
24	3.993[a]	4.123a	1.767b	4.219[a]
48	3.929[a]	3.852a	0c	3.784[a]
72	3.911a	3.925[a]	0c	3.761[a]
Overall SEM		0.265		
W/wo PEG Mean	3.98a	3.99a	1.46b	3.96[a]
SEM		0.132		

Values in the same row with different literal differ at P<0.0001

Conclusion A quick, cheap and sensitive method to screen defaunating capacity of forage tree was developed. PEG can be used in the culture media to assess the defaunating capacity of tannins.

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Tropical forage trees with potential defaunating capacity

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Introduction Rumen protozoa population is reduced when ruminant are feed with foliage from some tropical trees an effect attributed to both saponins (Diaz *et al.*, 1992) and tannins (Odenyo *et al.*, 1997a). As PEG binds to tannins, it has been used to reduce its deleterious effect in animals feed tanniferous trees (Makkar *et al.*, 1998). In a companion summary (Monforte *et al.,* 2005) we showed that using PEG the defaunating capacity of a tanniferous tree is reduced. The objective of the present study was to assess if adding PEG to a protozoa culture will help to separate the tannin and saponin effect upon the protozoa population.

Material and methods The batch culture system described by Ojimoto and Imai (1981) was used. The culture was grown in 50 ml capped tubes. To feed the protozoa a dry Taiwan grass (*P. purpureum*) and starch (5% v/v) mixture was used as recommended. Rumen liquor was obtained from two cannulated cows and placed in laboratory funnels to allow the protozoos to accumulate at the bottom where they were collected. Two ml of the protozoos collected were inoculated to the tubes and incubated at 39 ^{o}C with and without 0.25g PEG. Plant extract (supernatant) was obtained using 10g DM (see plant species in table 1) which was placed in a beaker containing 80 ml on the culture media, agitated for 30 min and then centrifugated for 5 min. After the 0h sample was taken (6ml) the culture was additioned with the plant extract or media (5ml), protozoa feed (0.5ml) and PEG or media (0.5ml) every 24h up to 72h. Blood red cell hemolysis was used to assess saponin activity (Segal *et al*., 1966). Protozoa were fixed with MFS and identify under microscope. Each treatment had four replicates. Protozoa counts+1 were log_{10} transformed before statistical analysis. The effect of diet, hour (0, 24, 48, 72) and PEG (with vs without) were assessed using the ANOV followed by a post test using the Bonferroni methods to asses the differences GraphPad Prism 4 (Motulsky, 2003).

Table 1 Chemical composition (% DM) of the forages

	DM	CP	NDF	ADF	CT	Hem
Enterolobium cyclocarpum	36.7	15.7	50.4	30.7	3.79	100
Lysiloma latisiliquum	45.1	13.2	46.2	25.5	10.38	0
Acacia angustissima	48.9	19.1	28.3	16.6	13.06	86
Acacia farnesiana	45.2	16.7	35.9	19.1	33.50	0
Panicum maximum	19.1	14.8	63.3	36.3	0.00	0
Sorgum bicolor (grain)	88.2	9.97	ND	ND	0.00	0

ND: not determined, CTcondensed tannins, Hem. % hemolysis

Results The addition of PEG only reduced the defaunating capacity of extract from forages which tested negative to saponin-hemolysis test. Batch cultures of both plants (*E. cyclocarpum* and *A. angustissima*) which were positive to saponins had no protozoa population after 24 and 48h (Table 2).

Conclusion Addition of PEG to a protozoa batch culture can be used to differentiate the tannin and saponin effect of forage tree extract upon the rumen protozoa population.

Table 2 Protozoa counts in an *in vitro* culture

	Hour	Log_{10}	
		-PEG	+PEG
A. angustissima	0	4.196 [a]	4.167 [a]
	24	3.574 [a]	3.698 [a]
	48	0.000 [a]	0.000 [a]
	72	0.000 [a]	0.000 [a]
A. farnesiana	0	4.147 [a]	4.157 [a]
	24	3.533 [a]	3.799 [a]
	48	0.000 [c]	1.615 [b]
	72	0.000 [c]	1.747 [b]
E. cyclocarpum	0	4.212 [a]	4.186 [a]
	24	0.000 [b]	0.000 [b]
	48	0.000 [c]	0.000 [c]
	72	0.000 [c]	0.000 [c]
L. latisiliquum	0	4.161 [a]	4.148 [a]
	24	0.000 [b]	4.098 [a]
	48	0.000 [c]	3.841 [a]
	72	0.000 [c]	3.962 [a]
Control	0	4.104 [a]	4.105 [a]
	24	3.993 [a]	4.122 [a]
	48	3.929 [a]	3.852 [a]
	72	3.911 [a]	3.925 [a]
SEM		0.1886	

Values with different letter in the same Time measurement period are different at $p<0.05$

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Tropical forage trees with low potential defaunating capacity

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Introduction Forage trees are commonly use for livestock feeding in the tropics. It is known that some species can affect the rumen protozoa population (Odenyo *et al.,* 1997). However, little is known about the potential effect upon rumen protozoa of several species which are also use as feed in tropical systems. The objective of the experiment was to assess the defaunating capacity of forage trees. In companion reports (Monforte *et al.*, 2005) we reported plants with a potential defaunating effect as evaluated under an in vitro batch culture system (Sandoval *et al*., 2005). Here we present those plants which did not have or had low effect on protozoa population in an *in vitro* culture.

Material and methods An adaptation of the batch culture system described by Ojimoto and Imai (1981) was used. Plant extracts from ten forage trees were evaluated (Table 1). *P. maximum* and sorghum grain mixture was used as protozoa feed and as control. The experimental conditions are described in the companion summary (Monforte *et al.,* 205). Pa

Table 1 Chemical composition (%DM) of the forage trees evaluated

	CP	NDF	ADF	CT
Erytrina standleyana	11.8	38.8	27.9	0.0
Gliricidia sepium	20.8	32.7	21.1	0.0
Piscidia piscipula	14.1	41.1	25.7	5.4
Leucaena leucocephala	26.6	40.2	21.5	3.7
Erytrina indica	21.3	41.5	29.4	0.0
Vitex gaumeri	11.2	51.5	40.2	0.0
Guazuma ulmifolia	15.0	47.6	29.8	7.8
Bursera simaruba	11.4	38.0	26.4	10.1
Gliricidia maculata	21.5	33.8	21.6	0.0
Acacia gaumeri	16.1	39.2	18.4	2.3
Panicum maximum	14.8	63.3	36.3	0.0
Sorgum bicolor (grain)	9.97	ND	ND	0.0

ND. No determined, CT. condensed tannins

Results Except for *G. ulmifolia* and *B. simaruba* all plants had low tannin content (Table 1). In both plants, also a low anti protozoa activity was detected (Table 2). *A. gaumeri*, *G. sepium* and *V. gaumeri* also did show a low anti protozoal activiy after 48h. In all cases, addition of PEG did not overcomed this effect indicating that tannins were not associated with this effect. As saponins were also not detected in this samples, it might be possible that, other chemical factors might be associated with this effect, or, it might be an effect of the batch culture system. Further, research will be needed to screen for potential defaunating chemical compounds in order to clarify this point. However, as its effect was low after 72h it is likely that under feeding conditions (*in vivo*) the potential impact of this compound are of minor relevance.

Conclusion Several forage trees containing condensed tannins did not showed effect on rumen protozoa under an *in vitro* culture system. Defaunating capacity might be related with tannin biological activity.

Table 2 Protozoa counts in an *in vitro* culture

	Hour	Total	
		-PEG	+PEG
A. gaumeri	0	4.20 ^{ab}	4.16 ^{ab}
	24	4.07 ^{ab}	3.95 ^{ab}
	48	3.90 ^{bc}	3.75 ^{bc}
	72	3.98 ^{ab}	3.90 ^{bc}
*B. simaruba**	0	4.14 ^{ab}	4.13 ^{ab}
	24	4.12 ^{ab}	4.11 ^{ab}
	48	3.94 ^{ab}	3.84 ^{ab}
	72	3.89 ^{bc}	3.92 ^{ab}
E. standleyana	0	4.13 ^{ab}	4.06 ^{ab}
	24	4.13 ^{ab}	4.12 ^{ab}
	48	4.03 ^{ab}	3.98 ^{ab}
	72	4.05 ^{ab}	4.08 ^{ab}
E. indica	0	4.13 ^{ab}	4.14 ^{ab}
	24	4.09 ^{ab}	4.09 ^{ab}
	48	4.10 ^{ab}	4.04 ^{ab}
	72	4.10 ^{ab}	4.06 ^{ab}
G. maculata	0	4.10 ^{ab}	4.01 ^{ab}
	24	4.08 ^{ab}	4.17 ^{ab}
	48	4.01 ^{ab}	3.93 ^{ab}
	72	3.80 ^{bc}	4.08 ^{ab}
G. sepium	0	4.14 ^{a}	4.08 ^{a}
	24	4.12 ^{a}	4.13 ^{ab}
	48	3.86 ^{bc}	3.80 ^{bc}
	72	3.77 ^{bc}	3.67 ^{bc}
L. leucocephala	0	4.10 ^{ab}	4.22 ^{ab}
	24	4.17 ^{ab}	4.10 ^{ab}
	48	4.12 ^{ab}	4.00 ^{ab}
	72	4.01 ^{ab}	3.97 ^{ab}
P. piscipula	0	4.08 ^{ab}	4.07 ^{ab}
	24	4.29 ^{a}	4.10 ^{ab}
	48	4.14 ^{ab}	4.00 ^{ab}
	72	4.11 ^{ab}	3.97 ^{ab}
G. ulmifolia	0	4.11 ^{ab}	4.19 ^{ab}
	24	4.04 ^{ab}	4.12 ^{ab}
	48	3.91 ^{ab}	3.89 ^{bc}
	72	3.76 ^{bc}	3.80 ^{bc}
V. gaumeri	0	4.15 ^{ab}	4.23 ^{ab}
	24	4.04 ^{ab}	4.12 ^{ab}
	48	3.84 ^{bc}	3.92 ^{b}
	72	3.72 ^{bc}	3.78 ^{bc}
Control	0	4.10 ^{ab}	4.10 ^{ab}
	24	3.99 ^{ab}	4.12 ^{ab}
	48	3.93 ^{ab}	3.85 ^{bc}
	72	3.91 ^{b}	3.92 ^{ab}
SEM		0.189	

Values with different literal differ at P 0.05

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Determination apparent digestibility pomegranate seed using *in vivo* method

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Introduction Pomegranate by-products (peel and seed) contain about 40-45 percent of the fruit's weight, but little information is available on their nutritive value. Chemical analysis of the pomegranate seed (PS) show that it contains average of 10-12 percent of crude protein. PS also contain a little amount of tannin (about 2.7 percent). Since feed accounts for 75-85% of the total costs of meet production and the use of them in feeding ruminant may decrease the cost of feeding. The objective of this experiment was also to determine nutrients digestibility of PS.

Materials and methods In order to determine the apparent digestibility of PS (in vivo) 16 Baloochi rams were used in a completely randomized design with 4 replicates in each of 4 treatments. The animals were allocated to individual metabolic cages with four diets including (1) 100% alfalfa hay as a based diet, (2) 75% alfalfa + 25% PS, (3) 50% alfalfa + 50% PS and (4) 25% alfalfa + 75% PS. A three-period feeding schedule was used consisting adaptation (10 day), preliminary (21day) and restricted intake period (10 day) which total feces was weighed and sampled daily. Nutrients digestibility of PS were calculated by difference method. Samples of feed and faeces were analysed for chemical composition (AOAC 1990). Data were analysed using the GLM procedure of SAS (1997).

Results The results indicated that amount of dry matter, organic matter, crude protein, crude fiber, ether extract, nitrogen free extract (NFE) and total extractable tannins (TET) of PS were 948 , 968 , 114 , 390 , 10 , 455 (g /kg DM) and 35.3 (mg/g) respectively. The data indicate that increasing the percentage of PS from 25 to 75 resulted a significant decrease ($p<0.05$) of nutrients digestibility (Table 1), however, there was not significant difference between nutrient digestibility of levels 25, 50 and 75% of PS (Table 2).

Table 1 Digestibility of diets contains different levels of alfalfa and pomegranate seed (g kg^{-1} DM)

	Diets				SEM	P-Value
Alfalfa %	100	75	50	25		
PS %	0	25	50	75		
Dry matter	594^{a}	563^{a}	518^{b}	477^{c}	11.90	0.0001
Organic matter	607^{a}	571^{a}	525^{b}	480^{c}	12.32	.00001
Crude protein	706^{a}	681^{ab}	657^{b}	665^{b}	10.54	0.0308
Crude fiber	421^{a}	364^{a}	298^{b}	279^{b}	19.74	0.0010
NFE	718^{a}	698^{a}	670^{a}	605^{b}	15.37	0.0012
TDN	557^{a}	534^{ab}	504^{b}	464^{c}	11.56	0.0007

means on the same row with different superscripts significantly differ ($p<0.05$)

Table 2 Digestibility of pomegranate seed calculated by difference method (g kg^{-1} DM)

	Diets			SEM	P-Value
Alfalfa %	75	50	25		
PS %	25	50	75		
Dry matter	437	457	449	11.91	0.518
Organic matter	430	462	448	13.72	0.324
Crude protein	614	614	646	19.75	0.462
Crude fiber	230	202	213	41.11	0.892
NFE	612	631	601	19.17	0.564
TDN	437	476	464	14.17	0.227

Conclusions The results of this experience demonstrate the potential of PS can be used in animal nutrition. Also indicated that inclusion of PS up to 25% of the diet has no negative effect on the nutrients intake and digestibility.

Acknowledgement This study was a cooperation between Mazandaran University and Agricultural and Natural Resources Research Center of Khorasan Province, Mashhad.

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In vitro gas production of pomegranate peel treated with urea, with and without PVP

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Introduction Pomegranate by-products (peel and seed) contain about 40-45 percent of the fruit's weight. The rind of the fruit (peel),when dried, is brown outside, yellow inside, hard, dry, brittle, in irregular fragments, inodorous, and with a very astringent, somewhat bitter taste. Analysis of pomegranate peel (PP) is shown that it contains 18.8 percent of tannin, 17.1 of mucilage, 10.8 of extractive matter, 30 of lignin, a trace of resin, and 29.9 of moisture. However, little information is available on PP nutritive value for ruminants. It is poor in protein and rich in tannins. Tannins components of the peel prevents its optimal use. The objective of this experiment was to evaluate the effect of different levels of urea (U) on in vitro gas production with and without added polyvinylpolypyrrolidone (PVP) to ensiled pomegranate peel (EPP).

Materials and methods In the experiment 4 levels of urea (0, 2.5, 5 and 7.5% of dry matter) were added to PP (6 replicates per treatment) and ensiled for two periods of 30 and 60 days. Total extractable phenol (TEPH) and total extractable tannins (TET) were determined according to Julkunen-Tiitto (1985) and Makkar (1992). For the in vitro gas production, rumen liquor was obtained from 3 fistulated cows fed with alfalfa hay twice a day. Buffer solutions and rumen liquor-buffer (1:2) prepared as described by Menke and Steingass (1988). About 220 ± 5 mg of air-dried milled (1.0 mm) sample was weighed into calibrated glass syringes (100 ml) without PVP or with 300 mg dry weight of PVP (4 replicates with or without PVP). The syringes were warmed (40˚C) before the injection of 30 ± 1.0 ml of rumen-buffer mixture into each syringe, followed by incubation in a incubator (39 ± 0.1˚C). Gas production was recorded at 2, 4, 8, 12, 24, 48 and 96 hr. Gas production data were analysed in a randomized complete block design using the GLM procedure of SAS. The results from gas volume recording were fitted to the exponential equation of the form $p=a+b\ (1-e^{-ct})$, where p represents gas production at time t, a+b the potential gas production, and c the rate constant. Effect of PVP on gas production was assessed with a "t" test.

Table 1 CP , TET and NFC of **PP ensiled** with urea

	Urea levels				SEM	P-Value
	0%	2.5%	5%	7.5%		
CP(g/kg DM)	41 ^{d}	120 ^{c}	178 ^{b}	230 ^{a}	1.38	0.0001
TET (mg/g)	206 ^{a}	177 ^{b}	169 ^{c}	170 ^{c}	2.37	0.0001
NFC(g/kg DM)	670	610	560	520		

NFC: Non – fiber carbohydrate
means on the same row with different superscripts significantly differ($p<0.05$)

Results In vitro gas production after 24 and 48 h was higher for EPP treated with 0% urea and lower for EPP treated with 7.5% urea. There was a negative correlation between the CP content of EPP and in vitro gas production at 24 and 48 h incubation. Also non –fiber carbohydrate (NFC) level was positively correlated with gas production potential. Against the previous studies, in this study, the relationship between the tannins content and volume of gas production was not negative.

Table 2 Gas production (ml /200 mg^{-1} DM) from pomegranate peel with or without PVP after 24 or 48 h incubation

Treatment	Incubation time (h)		Gas production constants			RSD	Incubation time (h)		Gas production constants			RSD
	24	48	a	B	c		24	48	a	b	c	
	Without PVP						With PVP					
PP + 0% U	40.37^{a}	45.20^{a}	8.39	37.89	0.08	0.335	43.23^{a}	50.29^{a}	9.65	43.09	0.07	0.872
PP + 2.5% U	35.41^{b}	40.25^{b}	7.85	33.83	0.07	0.43	36.41^{b}	43.70^{b}	9.66	37.62	0.05	0.753
PP + 5% U	32.80^{c}	37.64^{c}	6.50	32.75	0.07	0.55	34.55^{c}	42.21^{b}	7.66	39.14	0.05	1.00
PP + 7.5% U	30.21^{d}	34.91^{d}	6.24	30.26	0.07	0.38	31.95^{d}	39.24^{c}	6.53	38.66	0.05	1.12
SEM	0.659	0.672					0.534	0.537				

means on the same column with different superscripts significantly differ ($p<0.05$), RSD: residual standard deviation

Conclusions Based on these results, the addition of urea and then storage decreased tannins content. It seemed that there is a positive relationship between the tannins content and volume of the gas produced which was against the previous studies may be relates to the fact that different sources of tannins have different natures and different biological responses. However, this study shows that tannins have negative effect on in vitro rumen fermentation and PVP could show this effect.

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The degradation of *Rhinanthus minor* (yellow rattle) *in vitro*

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Introduction *Rhinanthus minor* is a facultative hemiparasitic plant of the *Scrophulariaceae* family native to the British Isles. It is typically found in meadows associated with a high floristic diversity, but it can also be found in pasture, where it is susceptible to heavy grazing. Containing the iridoid glycoside rhinanthin ($C_{29}H_{52}O_{20}$), *R. minor* is strongly suspected of being poisonous, but it is not clear how harmful this is to livestock (Long 1924). Through parasitism, particularly of the grasses, *R. minor* is also associated with a loss of grazing. Consequently, the presence of *R. minor* in a sward is often viewed negatively. However, through reductions in productivity of grasses, *R. minor* may have a role in the restoration of species-rich grasslands. As a result, the probability of cattle consuming *R. minor* might be expected to increase. This paper aims to evaluate the degradation of *R. minor* and discusses the implications of *R. minor* inclusion in the diet.

Materials and methods Samples of hay (consisting of mainly *Lolium perenne*) and *R. minor* were dried, milled to pass a 2mm screen and mixed to give five levels of inclusion. (Table 1). The roots and a portion of stem were removed from *R. minor* to provide a sample similar to that which grazing cattle may consume. Fermentation and degradation characteristics of the combinations were examined using the *in vitro* Reading Pressure Technique (Mauricio *et al*., 1999). Four replicates of 1 g (+/-10mg) substrate per flask and 90ml buffer were prepared. Flasks were sealed and stored overnight (16 h at 20°C), then raised to 39°C prior to inoculation. Rumen fluid obtained pre-feeding was strained through a double layer of muslin and 10 ml added to each flask. Headspace gas pressure measurements were taken up to 48 h post inoculation. Fermentation residues were recovered after 48 hours incubation by filtering the flask contents through tared Gooch sintered glass crucibles (porosity 1) under a light vacuum. *In vitro* dry matter degradation (*i*DMD) was then calculated. Predicted *i*DMD values for R25, R50 and R75 were generated using weighted values obtained from the randomised pairing of R0 and R100 observed *i*DMD values. One-tailed t-tests were used to identify significances of difference between observed and predicted *i*DMD values as affected by the *R. minor* content of the substrate mix.

Table 1 Sample composition

Sample	Hay (mg g^{-1})	*R. minor* (mg g^{-1})
R0	1000	0
R25	750	250
R50	500	500
R75	250	750
R100	0	1000

Figure 1 Gas production kinetics

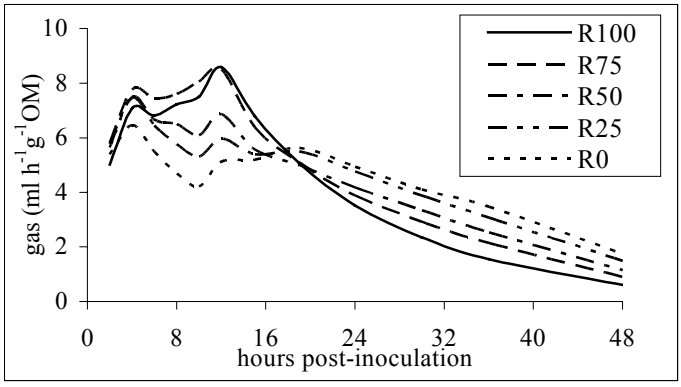

Table 2 Mean predicted and observed *i*DMD values

Sample	observed *i*DMD g g^{-1}	predicted *i*DMD g g^{-1}	*P* <
R0	0.610	-	-
R25	0.603	0.592	n.s.
R50	0.598	0.573	0.01
R75	0.576	0.555	0.05
R100	0.537	-	-

Results Rates of gas production for combinations of hay and *R. Minor* are shown in Fig 1. Highest initial rates of fermentation were observed with those combinations containing the greatest proportion of *R. minor* and are associated with the microbial fermentation of cell contents, whilst later onset of gas production represents the fermentation of the cell wall. Hay is known to ferment relatively slowly due to its higher fibre content, thus showing the ability of this method to describe fermentation. Degradation of hay was found to be greater than that of rattle when offered alone, although the actual *i*DMD values are significantly ($P<0.01$ and $P<0.05$) higher than the predicted results at R50 and R75 levels of inclusion in the diet (Table 2).

At inclusions of *R. minor* greater than 50%, the mean observed *i*DMD values decreased. This may indicate that levels of inclusion of *R. minor* above 50% may be toxic to the mixed rumen microflora. Biomass can contribute up to 42.8% when sown at 1000 seeds m^{-2} into a newly established *Lolium perenne* sward (Westbury & Dunnett *unpublished*), therefore, it is unlikely that distribution of *R.minor* at this level will have a detrimental effect on mixed rumen microflora. However, *R. minor* is typically observed in transient patches within swards, forming dense populations and problems may occur with grazing of these areas. There could also be potential difficulties should *R. minor* from localised areas be included in hay destined for ruminant feed.

Conclusions *R. minor* appeared to enhance the degradation at 48 hours of the diets examined, to a greater extent than expected, indicating a possible interaction between the two substrates. It is unclear why this may have occurred, one possibility being that the nutrients contributed by *R. minor* enhanced growth of certain species of micro-organisms.

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Persistency of the effect of *Lactuca sativa* and *Urtica dioica* on *in vitro* acidosis

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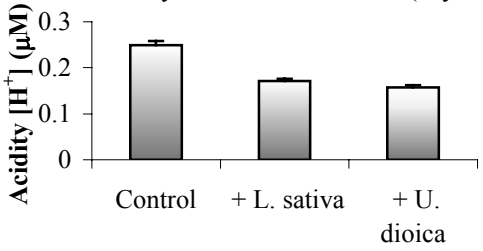
Introduction As part of the EU Framework 5 project "Rumen-Up", plants were screened for their effect on the *in vitro* fermentation medium pH. Common lettuce (*Lactuca sativa*) and stinging nettle (*Urtica dioica*) were identified as having a positive effect, maintaining a higher pH when fermented with wheat over 48 hours. It was considered that the rumen microflora may adapt to the inclusion of either plant in the diet, leading to negation of the effect, and therefore reducing the opportunities for use as a supplement to prevent acidosis. This study was designed to investigate the persistency of the anti-acidosis effect using the Rumen Simulation Technique (RUSITEC), together with batch *in vitro* fermentation using inoculum harvested from RUSITEC.

Materials and methods RUSITEC was set up following the procedure of Czerkawski & Breckenridge (1977), using the same rumen fluid inoculum as Kliem *et al*., (2005), with three control vessels and two vessels each for *L. sativa* and *U. dioica*. The feed bags contained either 30:70 rolled wheat:maize silage (control), or 27:63:10 rolled wheat:maize silage:test plant. The feeding level was 12 g DM/d increasing to 15 g DM/d after 3 days. Artificial saliva was infused at 650 ml/d to produce a turnover of 70%. After 3 days liquor from similar vessels was mixed and redistributed to ensure even fermentation across like vessels. Vessel fluid pH was measured twice daily. After 7 days fluid from vessels was harvested and bulked by treatment. The substrates for batch fermentation were prepared by mixing either *L. sativa* or *U. dioica* (dried at 65°C, ground to <2mm) with ground wheat at 100 mg/g DM level. Into 125 ml fermentation flasks 1 g (+/- 10 mg) substrate was weighed (4 replicates) and 80 ml reduced medium (50% strength of Goering & Van Soest (1970) medium, to permit acid conditions) added. 20 ml fluid from the control vessels was used to inoculate flasks containing wheat only and wheat plus each plant. The test plant vessel fluid was used to inoculate flasks containing wheat only and wheat plus the respective test plant. pH was measured at 1, 24 and 48 h and values converted into hydrogen ion concentration ($[H^+]$) and were averaged. Student's *t*-test was used to analyse the results statistically.

Figure 1 Mean acidity in RUSITEC vessels (days 4-7)



Results Within RUSITEC vessels, the mean acidity for control vessels was significantly higher than that of vessels with *L. sativa* or *U. dioica* ($P < 0.05$, Fig. 1). Figs. 2 and 3 show the effect on acidity of inoculation with each RUSITEC fluid treatment to the different substrates - (a) control fluid + wheat, (b) control fluid + wheat and test plant at 100 mg/g DM, (c) Test plant fluid + wheat, (d) test plant fluid + wheat and test plant at 100 mg/g DM.

Figure 2 Control and *L. sativa* RUSITEC fluid as an inoculum for *in vitro* batch fermentation; effects on acidity

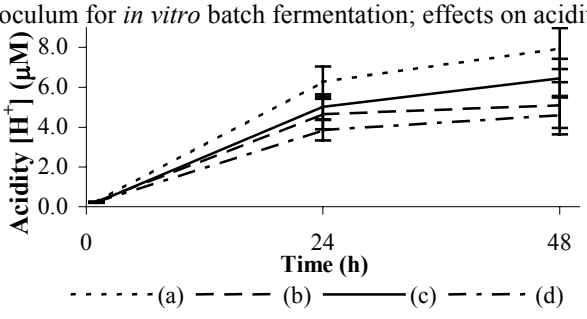
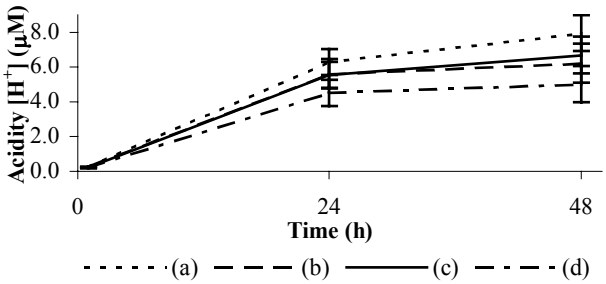


Figure 3 Control and *U. dioica* RUSITEC fluid as an inoculum for *in vitro* batch fermentation; effects on acidity



A significant difference was found between acidity at 24 h for control fluid + wheat substrate, and *L. sativa* fluid + *L. sativa* substrate ($P < 0.05$), and also between control fluid + wheat substrates, and both plant fluids + plant substrates at 48 h ($P < 0.1$). Inoculum that had been incubated in the presence of either *L. sativa* or *U. dioica* for 7 days maintained a higher pH than the controls of the batch fermentation vessels at both 24 and 48 h. When including either plant in the substrate, the effect is further enhanced so that at 48 h the acidity of the *L. sativa* fermentation flasks was found to be 42 % lower than that of the controls. Likewise the 48 h acidity of the *U. dioica* fermentation flasks was 37 % lower than that of the controls.

Conclusions The results confirm the effect that *L. sativa* and *U. dioica* have on limiting the level of acidity *in vitro*. Both *L. sativa* and *U. dioica* exerted an effect over the micro-organisms present in RUSITEC so that the population was altered and no adaptation occurred even after 7 days exposure. The acidity of batch fermentation flasks was maintained at lower levels using a plant-exposed inoculum compared to a control inoculum. Including both plants in the substrate caused an additive effect so that after 48 h these flasks were almost half the acidity of the control flasks.

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The effect of *Lactuca sativa* and *Urtica dioica* on *in vitro* acidosis

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Introduction As part of "Rumen-Up", an EU Framework 5 project, a total of 500 plants and plant extracts were screened *in vitro* for their effect on general rumen fermentation parameters, in particular their ability to influence microbial protein production, protozoal numbers, methane production, bloat and acidosis. Many of the plants investigated were found to have potentially beneficial effects with respect to ruminant production. The activities of 25 plants were patented, including two that The University of Reading identified as maintaining a significantly higher fermentation medium pH - common lettuce (*Lactuca sativa*) and stinging nettle (*Urtica dioica*) with the aim that these plants (or their derivatives) would be incorporated as feed supplements to reduce the incidence of rumen acidosis. The results reported here are from an *in vitro* dose titration study conducted to identify possible dietary inclusion levels prior to conducting a large-scale animal production study.

Materials and methods *L. sativa* and *U. dioica* were dried (65°C) and ground to <2mm. The substrates were prepared by mixing these with ground wheat at four levels (10, 20, 50 and 100 mg/g DM). One g (+/- 10 mg) substrate was weighed into 125 ml fermentation flasks (10 replicates) and 90 ml reduced medium (50% strength of the medium of Goering & Van Soest, [1970], to allow acid conditions) added. This was inoculated with 10 ml prepared rumen fluid obtained from two rumen-fistulated cows offered a high concentrate diet and the flasks incubated at 39°C for 48 hours. Positive controls (wheat only) were also included. The fermentation pH was measured at 1, 24 and 48 h and the values converted into hydrogen ion concentration ($[H^+]$) and the mean for each treatment calculated. Student's *t*-test was used to analyse the data statistically.

Results The effects of both plants on *in vitro* acidity is shown in Figs. 1 and 2 – *a:* wheat only, *b:* wheat + plant (10 mg/g DM), *c:* wheat + plant (20 mg/g DM), *d:* wheat + plant (50 mg/g DM), *e:* wheat + plant (100 mg/g DM).

Figure 1 Effect of *L. sativa* on *in vitro* acidity over 48 h

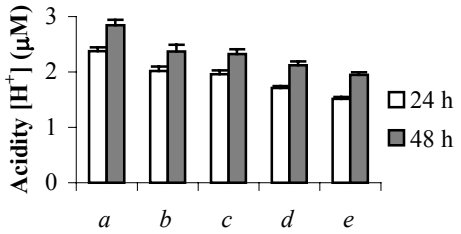
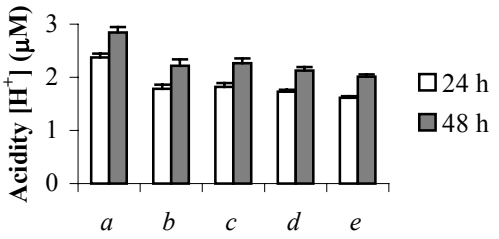
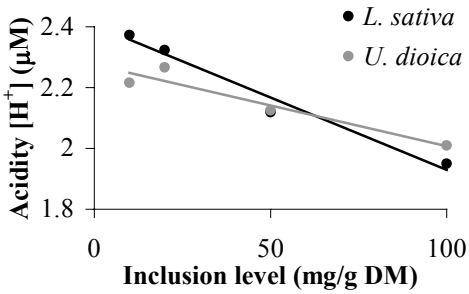


Figure 2 Effect of *U. dioica* on *in vitro* acidity over 48 h



At 24 and 48 h a significant difference between the wheat only and wheat + *L. sativa* at all levels of inclusion was observed ($P < 0.05$), and also between the 20mg/g v. 50 mg/g, and 50 mg/g v. 100 mg/g levels of inclusion at 24 h ($P < 0.05$). At 24 and 48 h there was also a significant difference between wheat only and wheat + *U. dioica* at all levels of inclusion ($P < 0.05$), and also between the 20mg/g v. 50 mg/g, and 50 mg/g v. 100 mg/g levels of inclusion at 24 h ($P < 0.05$). These differences were not due to the fact that the supplements were less fermentable as earlier studies had shown that *L. sativa* and *U. dioica* did not significantly reduce either dry matter degradability or fermentation efficiency when included at the 100 mg/g DM level (unpublished).

Figure 3 Dose titration response at 48 h



A marked dose titration effect was noted with either *L. sativa* or *U. dioica*, whereby an increase in inclusion level of both plants in the substrate resulted in lower acidity at both 24 and 48 h (Fig. 3). R^2 values for the dose response for *L. sativa* and *U. dioica* were 0.97 and 0.91 respectively. At 48 h the acidity value for wheat only was 2.8 µM H^+. Inclusion of both plants at 10 mg/g DM caused the acidity to be 16 and 21 % lower that wheat only for *U. dioica* and *L. sativa,* respectively. Inclusion of both at 100 mg/g DM caused the acidity to be 30 % lower for both plants when compared to wheat only.

Conclusions These results identified that both *L. sativa* and *U. dioica* have the ability to maintain a significantly elevated *in vitro* fermentation medium pH. This is further confirmed by evidence of a dose titration effect, the most potent inclusion level for both being 100 mg/g DM, although the lowest inclusion level (10 mg/g DM) caused the acidity to be around 20 % lower than when using wheat only. These results were repeatable over time. Further work is needed to identify the active agent(s) of both plants, but the inclusion of either one in ruminant diets as a supplement may provide a possible solution to preventing the occurrence of acidosis, perhaps by preventing the growth of the sub-populations of bacteria that predominate during acidosis.

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Effects on animal performance of summer grazing of *Molinia* dominant semi-natural rough grazing by cattle and sheep

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Introduction The Less Favoured Areas (LFAs), which occupy almost half of the agricultural land in the UK, can be divided into two categories: rough grazing (semi-natural) and grassland (improved permanent pasture and temporary grass). Although rough grazing accounts for two-thirds of the land, it contributes only 15% to total output. However, it is this category that requires more sympathetic grazing management if its environmental value is to be maintained or enhanced. While some information exists on the impact of grazing by cattle on semi-natural vegetation communities such as *Molinia caerulea* (Grant *et al*., 1996) there is a lack of information on the effects that grazing with cattle or sheep over the summer months might have on animal performance. The underlying hypothesis for this experiment was that grazing in summer would have beneficial effects on animal performance through changes in the short term in the structure of the vegetation, and in the long term through changes in both structure and species composition.

Materials and methods The experiment began in 2001 and was conducted on an area of rank *Molinia*-dominant semi-natural rough grazing (SNRG) which had been not been grazed for approximately 10 years. Three summer treatments were compared: 1) no grazing, 2) grazing by sheep and 3) grazing by cattle. There were two replicates of each treatment, with individual plots 2 ha in size. Each of the cattle plots were grazed by 4 animals, i.e. at a stocking rate equivalent to 0.30 Livestock Unit/ha/annum, which was anticipated would achieve an utilisation rate of *Molinia* of 50%. The sheep plots were stocked at a comparable level, equating to 16 ewes per plot. The plots were grazed for approximately nine weeks from early July (Year 1) and mid-June (Years 2 and 3). The cattle used were yearling Welsh Black heifers, and the sheep were dry Welsh Mountain ewes (Years 1 and 3) or Welsh Mountain hoggs (Year 2). Winter grazing was by sheep only, and was carried out at a stocking density of 8 sheep per plot, equating to 0.15 LU/ha/annum, with all plots grazed by Welsh Mountain ewe lambs. The winter grazing period began at the beginning of November and lasted until weather conditions dictated the animals be removed from the exposed experimental site. This resulted in the plots being grazed for 63 d, 29 d and 39 d in Years 1, 2 and 3 respectively. The empty live weight of all cattle and sheep grazing the plots were measured at the beginning and end of each grazing period, and liveweight change across the grazing period calculated. Data analysis was carried out using ANOVA, with individual animals as experimental units and replicate as a blocking factor.

Results The liveweight gains recorded for the cattle during the first two years of grazing were poor (Table 1), but by the third year the growth rates had improved. The response of the sheep grazing in summer was more variable, but they always gained at least 20 g/d.

Table 1 Liveweight change during summer grazing (g/d)

	Year 1	Year 2	Year 3	s.e.d.	Sign.
Cattle	-83[a]	84[a]	456[b]	71.1	***
Sheep	45[a]	68[b]	21[c]	8.0	***

There was a trend for previous summer grazing treatment to have affected the performance of the sheep with subsequently grazed the area in winter in Years 1 and 2, but it was not until the third year of grazing that this was significant (Table 2). Animals which grazed plots which had been ungrazed during the previous summer suffered significantly greater weight loss.

Table 2 Liveweight change of ewe lambs during winter grazing (g/d)

	Summer grazing treatment				
	None	Cattle	Sheep	s.e.d.	Sign.
Year 1	-34	-26	-13	8.4	NS
Year 2	-17	14	20	16.6	NS
Year 3	-54[a]	-26[b]	-29[b]	11.8	*

Conclusions
The results indicate that liveweight gain can be compromised if growing cattle graze SNRG, and that careful consideration should be given to stock type when contemplating using cattle as management tools in the hills. Summer grazing was found to improve the performance of sheep grazing the plots during subsequent winter months.

Acknowledgements
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The relationship between grazing animals and a Biodiversity Action Plan species, *Spiranthes romanzoffiana*, Irish Lady's-tresses orchid, in the West of Scotland

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Introduction *Spiranthes romanzoffiana* (Orchidaceae: specialist orchid form of mycorrhiza present) flowers in July and August. Plants also occur above ground in the non-flowering state but are hard to detect. Established plants can spend up to 6 years in the underground (U: sometimes called dormant) phase; Dr J. Robarts, personal communication. Both vegetative (V) and flowering (F) plants produce lateral buds which appear above ground in summer or early autumn. Current data indicate that it is in decline in Britain and Ireland, (UK Biodiversity Action Group, 1999). However numbers detected in study populations have increased over the 2 or 3 year periods of investigation, (Gulliver, Gulliver and Sydes, 2003). Most sites in Scotland are grazed by sheep and/or cattle. Plants are also grazed by wild vertebrates and by invertebrates, especially slugs. Plants are often defoliated by domestic stock. Stock modify sites by dung production. Their trampling activities can damage individual plants, can tear open swards and can create small to medium scale bare patches (especially in damp ground). Each of these activities may have some negative and some positive elements. For example, defoliation results in a loss of tissue; but, on balance, *S. romanzoffiana* with its second source of organic carbon, may be less disadvantaged than potential competitors. The objective was to investigate survival over a 4-year period at a heavily grazed and at a lightly grazed site.

Materials and methods During the period 1999-2001 permanent markers were placed by all plants observed over a minimum of 3 visits per year at 2 sites. This set of 18 plants at the heavily grazed site (KC) and 37 plants at the lightly grazed site (LF) was then monitored between 2001 and 2004. Visits were made 3 times a year except 2002 (1 visit); only late July/early August data are presented herein. Frequently at site LF a few plants detected in May or June were not detected in late July/early August, e.g. 2 in 2004. These were assumed to have been totally grazed by slugs or by stock. The grazing unit containing KC is very approx. 50 ha and LF 3 ha. The unit containing KC typically has 200 sheep and 15 cows. At LF the balance of sheep and cattle, numbers, and length of grazing period are extremely variable; and gates to other fields sometimes open, sometimes shut. All plants including bud-only plants present were counted as in Gulliver, Gulliver and Sydes, (2003). These are a) the newly generated second member of a pair of twin lateral buds on a plant (F or V) above ground in summer, b) buds newly appearing above ground with no F or V plants present, often having spent the previous 12 months (at least) in the U state c) buds where there was above ground tissue in May/June but not in late July/early August. They are in the next growing year to the F and V plants present. Vegetation height i.e. height to the point where the sward thins out markedly, was measured in mms at the position of each plant (U, V, or F).

Results The number of plants in the monitored set recorded at the heavily grazed site (KC) in the years 2001, 2002, 2003, 2004 and was relatively stable, as it was at the lightly grazed site (LF), Table 1.

Table 1 Number of plants at a heavily grazed site (KC; monitored set, n = 18) and at a relatively lightly grazed site (LF; monitored set, n = 37), and vegetation height recorded on a single summer visit

Site	2001	2002	2003	2004	2001	2002	2003	2004
	Total plants: Single visit (Bud only in brackets)				Number of Inflorescences			
KC	16 (1)	11 (0)	14 (0)	14 (0)	9[a]	1[a]	1[a]	2[a]
LF	26 (1)	22 (2)	17 (2)	23 (1)	8	2 [+1[b]]	1	2 [+5[b]]
	Median Vegetation height (mm)				Vegetation height (mm): range of values			
KC	20	25	30	20	20-30	20-30	25-30	15-25
LF	100	80	70	70	70-110	50-140	30-100	40-130

Notes: [a] always grazed by August at KC, 6 grazed by 29 July in 2001: [b] in addition to those in the monitored set.

Conclusions This 4-year set of results shows that the 2 study populations of *S. romanzoffiana* can persist when subject to a heavy or a light grazing regime. Trends over a longer period of time and at a greater variety of soil conditions and vegetational structures remain to be investigated. It is important to determine the full range of positive and negative attributes of stock presence. For example it has been postulated that detached fragments of roots of some species of orchid may survive and develop into whole plants (Rasmussen, 1995). Trampling may cause root fragmentation.

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Long-term effects of extensification of sheep grazing management on botanical diversity and sheep production in upland grassland

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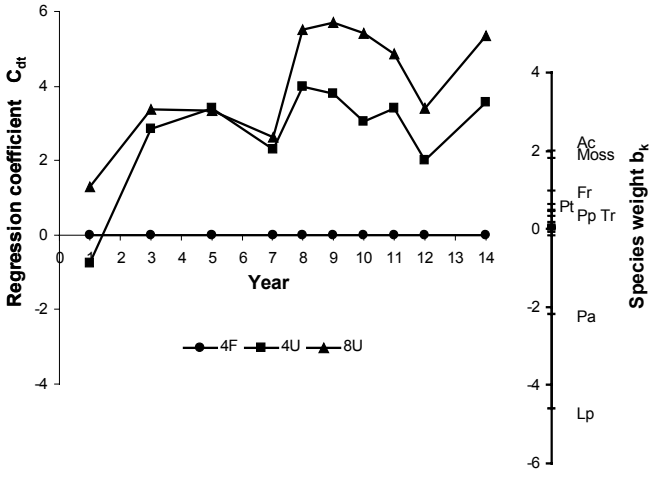
Introduction Sheep systems on upland permanent pastures sown with *Lolium perenne/Trifolium repens*, have typically been relatively intensively managed, relying on inorganic fertilizers to maintain or increase animal output. However changes in the Common Agricultural Policy have resulted in the development of agri-environment schemes to deliver environmental goals from grasslands. These schemes encourage more extensive grazing systems, and change the emphasis from animal output to issues such as increasing biodiversity. Lower stocking densities provide increased opportunities for diet selection, the development of a heterogeneous habitat and associated changes in species composition. However, will more extensive management increase botanical diversity in upland sown swards? The experiment reported here describes the effect of more extensive management combining cessation of fertilizer and lower grazing intensity on vegetation change, stocking density and lamb output over 14 years.

Materials and methods An experiment was set up in 1990 on sown *L. perenne*/*T. repens* swards at three upland sites to compare vegetation changes and animal output under intensive and extensive management (Marriott *et al.*, 2002). In this paper, the intensive treatment (4F) and two extensive grazing treatments (4U and 8U) at one site are compared. The site was in south east Scotland at Sourhope Research Station (2º 14' W 55º29' N, 367 m a.s.l.), on a freely draining brown forest soil. All swards were grazed by Scottish Blackface ewes, with their single lambs from May until weaning in mid-August. Treatment 4F was maintained at a sward height of 4 cm from April until mid-November and was fertilized (150 kg ha^{-1} N and 20 kg ha^{-1} each of P_2O_5 and K_2O each year).The extensively managed treatments were maintained at two sward heights, 4 cm (4U) or 8 cm (8U), and received no fertilizer. Height treatments were maintained by adjusting ewe numbers in response to weekly measurements of sward surface height. The plots were approximately 0.45 ha, and each treatment was replicated twice in a randomised block design. Vegetation composition was measured at 18 permanent locations per plot, using an inclined point quadrat and a 0.5 x 0.5 m grid quadrat. Ordination of species was done using Principal Response Curves (PRC) to show the effects of the extensive treatments over time relative to treatment 4F at the community level. The statistical significance of the PRC axes was tested using Monte Carlo permutation tests. The associated species weights showed the changes in abundance of individual species relative to treatment 4F. The number of species, number of ewe grazing days per year and mean live weight of lambs at weaning were analysed by analysis of variance.

Results The number of plant species did not change over time and was similar in all treatments (13.8, 15.6 and 16.3 species in treatments 4F, 4U and 8U respectively, s.e.d. 1.8). Only PRC axis 1 was significant ($p<0.01$), and it explained 75% of the captured treatment variance. Changes over time in species composition in treatments 4U and 8U were small, and the treatments behaved similarly over time in relation to 4F (Figure 1). Under more extensive management *L. perenne* (Lp) and *Poa annua* (Pa) decreased over time whereas *Agrostis capillaris* (Ac), Moss, *P. trivialis* (Pt), *P. pratensis* (Pp) and *T. repens* (Tr) increased. The number of ewe grazing days per year on treatments 4U and 8U were 0.65 and 0.40 respectively of those on treatment 4F ($p<0.01$), and the difference between treatments did not increase over time. Compared with treatment 4F, live weight of individual lambs at weaning was similar in treatment 4U and 0.14 higher ($p<0.05$) in treatment 8U. Total output of lamb averaged 505 kg ha^{-1} per year (s.e. 28.8) from 1990 to 2000 on treatment 4F, with treatment 4U producing 0.77 and treatment 8U producing 0.57 of this amount ($p<0.001$). Both individual performance and lamb output per ha in treatments 4U and 8U showed no decline relative to treatment 4F over time.

Figure 1 PRC axis 1 scores show botanical changes over time under extensive compared with intensive management



Conclusions The small changes in species composition over 14 years show that it may be difficult to achieve increases in botanical diversity in such upland sheep systems simply by removing fertilizer and reducing grazing intensity. The most likely reason for this is the lack of seed sources of new plant species in sown grasslands. The presence of a diverse range of vegetation types within the local area could improve on the colonization by new plant species. Otherwise, reseeding with desired species may be necessary. The lower levels of sheep production arising from a change to extensive management were sustained over the 14 years of the study.

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Short-term impact of sheep and cattle grazing on upland wet heath vegetation

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Introduction The UK Biodiversity Action Plan identifies upland heath and blanket bog as priorities for conservation. Heavy grazing by livestock has damaged these habitats in many parts of the UK. Agri-environment schemes have partly addressed the problem by encouraging farmers to reduce sheep stocking levels on degraded moorland. This can prevent further loss of dwarf shrub cover, but the increased biomass of moorland grasses can inhibit regeneration of dwarf shrubs and other desirable species. The objectives of this system-scale study are to assess the impact on plant species composition and animal performance, of sheep-only and mixed grazing regimes with both cattle and sheep on degraded wet heath vegetation. It is being carried out as part of a wider project to determine environmentally sustainable and economically viable grazing systems for heather moorland.

Materials and methods The study is on 103 ha of degraded M15 *Scirpus cespitosus – Erica tetralix* (Rodwell, 1991) wet heath in Northumberland, UK. Prior to the study, two halves of the area had been grazed by Scottish Blackface sheep at 1.5 and 0.66 ewes/ha respectively since 1995, with 25% reduction from November to March and all ewes removed for three weeks during tupping and lambing. These grazing regimes had resulted in high biomass of *Molinia caerulea* (Adamson *et al*., 2002). In 2003, each half was further divided giving a total of four paddocks, each approximately 25 ha. The previous sheep grazing regimes were continued and Continental cross dry suckler cows introduced to two paddocks at 0.75 cows/ha from 10 June – 13 August. This gave four grazing regimes, which were sheep at 1.5 and 0.66 ewes/ha, with and without cows. Vegetation data were recorded in late summer 2001 and 2003 in 198 1 m^2 fixed quadrats located on a grid across the site. In each quadrat, top cover of plant species was recorded from a grid of 100 points at 10 cm spacing. Species data from 2001 were subjected to fuzzy clustering (Equiha, 1990) to differentiate vegetation types. Change in percentage cover in each paddock was analysed by paired *t*-tests. Liveweight and condition score measurements were made of cows at the beginning and end of the grazing period and of ewes and lambs throughout the year. Livestock data were analysed using the REML procedure in Genstat 5.

Results Six vegetation types were present and characterised by, respectively *Calluna vulgaris*, *Calluna vulgaris – Molinia caerulea* mosaic, *Molinia caerulea*, *Nardus stricta*, *Carex nigra* and *Juncus effusus – J. acutiflorus*. In the *Molinia* and *Calluna – Molinia* vegetation types, the cover of *Molinia* decreased in both paddocks with cows (Table 1). There was a corresponding increase in bare peat and cover of mosses and plant litter exposed by the removal of *Molinia* biomass. Without cows, *Molinia* cover increased at the lower sheep stocking rate but no change was detected in the paddock with higher sheep stocking rate. No change in *Calluna* cover was detected apart from a decrease probably attributable to earlier heather beetle attack in one paddock. Cows gained 42-67 kg in liveweight and 0.09 - 0.22 units in body condition score, more than sufficient to replenish body reserves lost during the previous lactation. The presence of cows had no significant effect on sheep performance overall or lamb growth rate up to weaning (193 and 191 g/day liveweight gain respectively with and without cows; SED 6.0, p>0.05). Individual ewe and lamb performances were better at 0.66/ha than 1.5/ha but output of weaned lamb per ha was 65% greater at the higher stocking rate due to increased lamb numbers per ha.

Table 1 Mean percentage cover of *Molinia caerulea* in two vegetation types under different grazing regimes.

Vegetation type	*Molinia caerulea*					*Molinia caerulea – Calluna vulgaris*				
Stocking rate/ha	*n*	2001	2003	SED		*n*	2001	2003	SED	
0.66 ewes	9	59.9	74.6	3.94	**	11	42.8	56.2	4.73	*
0.66 ewes + 0.75 cows (summer)	16	58.6	31.1	4.67	***	6	46.5	24.2	5.76	*
1.5 ewes	14	62.4	54.9	5.37		14	34.1	40.2	3.55	
1.5 ewes + 0.75 cows (summer)	11	72.1	26.6	3.64	***	7	36.6	17.3	5.55	*

* p<0.05, **p<0.01, ***p<0.001.

Conclusions Cows selectively grazed *Molinia*, enhancing opportunities for regeneration of dwarf shrubs and other species. Wet heath vegetation is unlikely to be restored by grazing with sheep alone. The mixed grazing regimes applied here were economically viable in the first year and have potential for aiding restoration of wet heath vegetation. Longer term effects will continue to be assessed.

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The manipulation of vegetation field and field margin vegetation structure in intensively managed UK cattle grazed pasture systems: Implications for invertebrate biodiversity

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Introduction Changing management in UK lowland pasture systems has lead to larger fertiliser inputs, increased intensity and frequency of cutting and a movement towards silage rather than hay based systems. This has lead to changes in both floral diversity and the seasonal characteristics of sward architectural complexity, which include the loss of key vegetation structures at critical times of the year, e.g. seed heads. This has had large impacts on invertebrate communities in pasture systems and is thought to be the cause of large-scale declines in both the abundances and diversity of invertebrates (Duffey *et al*., 1974). This decline in invertebrate abundance has also been linked to a concomitant decline in farmland bird populations reliant on invertebrates as a food sources (Vickery *et al*., 2001). By manipulating cattle grazing, cutting and fertiliser regimes in intensively managed pasture systems the role of vegetation structure for a variety of invertebrate communities has been investigated.

Materials and methods Two ongoing experiments funded through DEFRA research projects were used. Experiment I used a replicated block design in four intensively managed cattle farms in Somerset and Devon to create seven treatments of increasing architectural complexity, ranging from Treatment 1 with two annual silage cuts, NPK fertiliser and aftermath cattle grazing, to the structurally complex Treatment 7 which remained unmanaged. Experiment II looked at within-field vegetation structure using a replicated block design to manipulate sward architecture with three grazing regimes of moderate and lenient grazing by Charolais steers, and lenient grazing by Red Devon steers. Vegetation structure was measured using drop discs and categorised in Experiment II into structurally distinct classes using K-means cluster analyses (Fig. 1). Within both experiments suction sampling was used to collect beetles (Coleoptera) and leaf hoppers (Auchenorhyncha). Statistical analysis used generalised linear and generalised linear mixed models to compare treatment and architecture effects of invertebrate abundance, and redundancy analysis to investigate community level responses. Both experiments were performed in 2003.

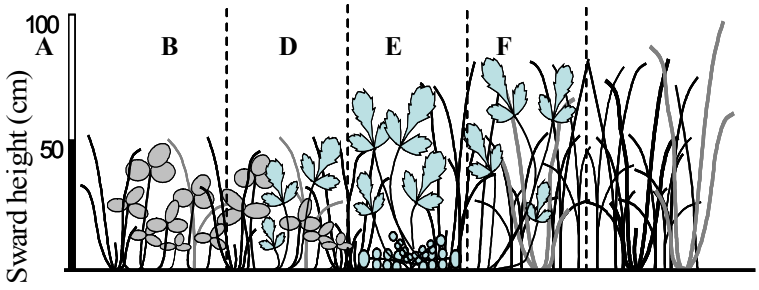

Figure 1 Five main sward structural classes: A=short sward dominated by *Trifolium repens*; B=short sward with *T. repens* and *Ranunculus repens*; D=intermediate sward with *R. repens* and *Cardamine pratensis*; E=intermediate sward dominated by *R. repens*; F=tall sward dominated by grasses, low forb cover.

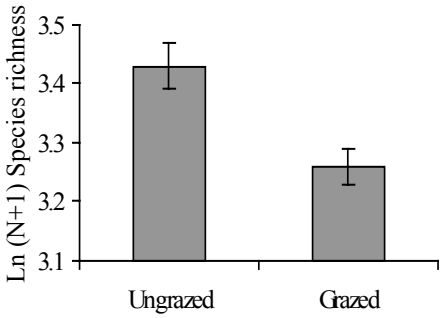

Figure 2 Effect of grazing on beetle species richness

Results In Experiment I sward architectural complexity was positively correlated with overall beetle abundance ($F_{1,76.4}$ =5.21, p=0.03), as well as influencing beetle community structure (RDA: F=2.71, p<0.01). Proportions of flower/seed feeding beetles were also higher in the more structurally complex treatments ($F_{6,74.3}$=11.77, p<0.001). Lower beetle species richness was found in grazed treatments ($F_{1,74.8}$=18.01, p<0.01) (Fig.2). In Experiment II different classes of vegetation architecture supported different abundance of both leaf hoppers ($F_{18,96.7}$=2.26, p<0.01) and beetles ($F_{18,97.0}$=2.36, p<0.01). Beetles were associated with intermediate canopy heights, whilst leaf hoppers predominated in much higher vegetation.

Conclusions The results demonstrate that management practices influencing vegetation structure both within the field and in its margins can be used to increase the abundance and alter the community structure of invertebrates. The effects of sward architecture were complex and were often dependent on life history characteristic of the different taxa. There is, however, a strong indication that relatively small changes in management could produce benefits in terms of enhancing invertebrate biodiversity, as well as increasing their abundance as a resource for secondary consumers such as birds. The results of these studies will feed back into the development of DEFRA agri-environmental scheme prescriptions.

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Could social and economic side-effects undermine nature conservation? - An investigation into the socio-economic impact of conservation grazing regimes in Cumbria

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Introduction English Nature has negotiated substantial stocking reductions (up to 60%) on a number of upland Sites of Special Scientific Interest in Cumbria with the objective of restoring their vegetation quality. Because concerns were raised about possible socio-economic effects of these conservation regimes English Nature asked stakeholders to set out their concerns. Consultants were then requested to review and assess these for English Nature action. This paper summarises specific aspects of the conclusions of this research and the conclusions of a workshop to whom the report was presented.

Method Consultants identified 5 key issues out of the original 20 generic representations. These were investigated by case studies of a total of 53 farms in 3 areas. 6 topics were used as the basis for a guided questionnaire for farmers in these areas and in an email survey of other stakeholders. The questionnaire covered the financial performance of farms, labour use, prices of stock, farm management including hefting and animal welfare, attitudes of stakeholders to Conservation Grazing regimes and attitudes to English Nature agreements. (These topics corresponded to the five key issues with a further subdivision of the issue of stakeholder attitudes) Consultants' conclusions were based on their analysis of consultees' perceptions rather than hard data. Results and recommendations to English Nature on how to deal with possible adverse impacts were presented to a meeting of farmers and commoners, scientific researchers and staff from statutory agencies. Workshop groups considered Economic Impacts (EI) and Sheep Management (SM) impacts and reported back to a plenary discussion. Further meetings are planned to progress issues and will be reported within the conference poster.

Results The study identified a number of important issues (within the six topics) which it was felt could not be addressed in the context of independent study and required, instead, a collaborative programme of adaptive management. In particular, Workshop groups gave great weight to the fact that that the consultants' report was based on comparative perceptions of farmers rather than real data. This factor contributed to the different weight given by Workshop groups on the following issues. The consultants reported a lack of evidence of adverse financial performance and higher labour costs in conservation grazing agreements with English Nature. However the EI Workshop group considered that real income data was inadequately dealt with when identifying integrated solutions to the problems of sustainable management of hill farm systems. They identified the need for baseline data, whole farm schemes with an environmental component, good communication and collaboration by agencies running such schemes, infrastructure support for niche marketing of environmentally friendly produce, a need for both agencies and farmers to upskill and for a support system to help local integrated initiatives. The consultants identified shepherding difficulties as an issue for conservation management. They found animal welfare benefits. The SM Workshop group and later plenary discussion expressed views that conservation agreements exacerbated or arguably led to hefting break down and animal welfare costs.. The group identified the need for measures to encourage shepherding practices and group actions by farmers. Some participants expressed doubts concerning the need for the level of stock reductions. The group identified the value of farmer/scientist cooperation in refining methods of setting grazing prescriptions and a research need to investigate sheep behaviour in hefts. Dialogue to identify indicators of site vulnerability and/or desired land management outcome was advocated as was research into the motivation and attitudes of farmers to inform the design of programmes.

Conclusion The Report and the Workshops on its findings identified areas where improved communication and collaboration would increase understanding. They also recommended that there was need for future research on base line data, sheep hefting behaviour and farmer attitudes. These issues will be pursued in partnership with the International Centre for the Uplands- Cumbria at further meetings.

Stocking levels in lowland grasslands managed for wildlife conservation

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Introduction Appropriate grazing management is essential to help maintain the wildlife conservation and biodiversity value of most semi-natural grasslands. Stocking requirements are influenced both by the specific sward requirements of the site and by factors such as climate, location, topography and soil wetness. A study, funded by the Countryside Council for Wales, English Nature, Scottish Natural Heritage and the Environment and Heritage Service for Northern Ireland, aimed to provide conservation site managers and agri-environment project officers with updated guidance on stocking levels. Current grazing prescriptions from all UK agri-environment schemes were also reviewed.

Methods Stocking information and other site and management data were acquired by questionnaire from a wide range of nature conservation sites in the UK (66 sites, providing a total of 108 discrete grazing units). Five lowland grassland Biodiversity Action Plan priority habitats (UK Biodiversity Steering Group, 1995) were targeted: coastal and floodplain grazing marsh (CFGM), lowland calcareous grassland (LCG), lowland dry acid grassland (LDAG), lowland meadow (grazed only) (LM) and purple moor-grass and rush pastures (PMGRP). Information was also gained from a sample of six fairly species-rich semi-improved grasslands (SRSIG). Predictive modelling, using multiple linear regression and Restricted Estimated Maximum Likelihood, was carried out to identify the influence of climatic and other site-based variables on the stocking level (SL) applied within each habitat to achieve desired biodiversity targets. SLs were measured as livestock units (LU) per hectare, with an adult dairy cow, for example, equivalent to 0.7 to 1.1 LU depending on breed size, and an adult ewe ranging from 0.08 to 0.15 LU. SLs were expressed either as LU/ha. i.e. averaged over a period or as that present at a given time, or as LU days/ha, i.e. the daily stocking rate multiplied by the number of grazing days.

Results Habitats differed both in annual total SL, and in the seasonal pattern of grazing (Figure 1). Seasonal patterns were much more marked in wetter habitats (i.e. CFGM and PMGRP) than in drier habitats (LCG and LDAG). In CFGM habitats, SLs were positively related to easterly location ($p<0.05$), but since coastal sites in the sample were predominantly located to the east of the UK, SLs were higher at coastal than floodplain sites. SLs in LM habitats were positively related to March-October rainfall ($p<0.001$) and negatively related to temperature ($p<0.01$). Stocking requirements were higher at sites grazed predominantly by cattle compared to sheep, both within LCG habitats ($p<0.001$) and overall ($p<0.05$). PMGRP and LM sites were grazed largely by cattle. Equines were more often used in LM sites than in other habitats. LCG sites were evenly divided between those grazed mainly by cattle and those grazed by sheep or by both sheep and cattle. LDAG and SRSIG sites were mainly grazed by sheep.

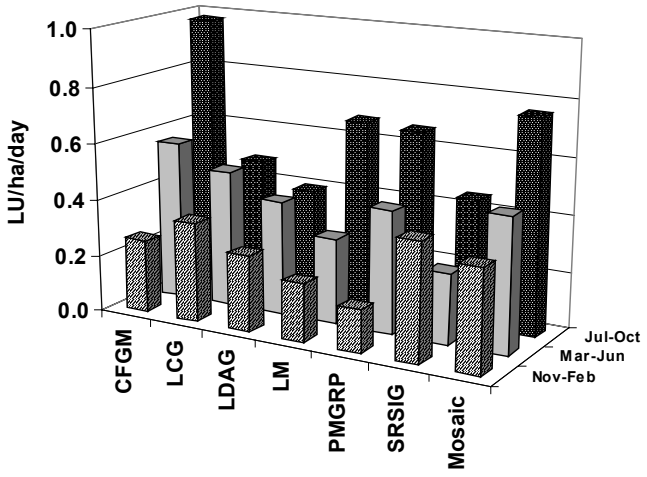

Figure 1 Mean stocking rates applied during three periods within seven habitat types, averaged over the period in each case ('Mosaic' = sites where no one habitat type predominates, see text for details of the other habitats)

Conclusions Insufficient stocking information was obtained for SRSIG and LDAG to produce reliable guidelines. In CFGM habitats, daily levels of < *c.* 20 LU/ha may be needed in summer where no grazing is allowed during the preceding winter and spring, < 5.0 when grazed only from April to October, and <2.0 LU/ha when grazed all year round. Annual totals range from 140 LU days/ha on floodplain to 230 LU days/ha on coastal sites. Management records showed relatively low year-to-year variation in annual stocking rate for CFGM habitats (e.g. ±5% of the site mean averaged over all years, exceptionally up to ±20%). By contrast, requirements for LCG habitats are much lower. Daily levels range between <1 and about 4 LU/ha, depending upon specific site requirements. On dry sites, and where winter grazing by sheep predominates, annual stocking levels may be about 47 LU days/ha, but can be 215-220 LU days/ha at more productive sites, typically grazed by cattle. Year-to-year variation in annual stocking requirements, as indicated by management records, may be ±20-25%, exceptionally up to ±40%. Setting stocking rates at any site requires careful consideration of the productivity and composition of the vegetation present, and regular monitoring is desirable to ensure that the biodiversity objective is being achieved.

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Short-term impact of grazing prescriptions on cattle performance

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Introduction Livestock farming is a traditional and important contributor to the rural economy in the hills and uplands of the UK. However, significant areas of the uplands have seen a decline in the condition of heath and mire habitats and the loss of dwarf shrubs as a result of over-grazing. Attempts to halt the decline and improve the condition of upland heath and mire habitats have been undertaken by the introduction of agri-environment schemes. In the main, such schemes rely on the reduction of sheep numbers. However, recent Defra funded research (LS1508) has indicated that this can result in dominance by competitive and/or unpalatable species such as purple moor-grass (*Molinia caerulea*) or mat-grass (*Nardus stricta*), leading in time to a reduction in the physical and financial performance of the flock. The objective of this study is to assess the impact of cattle grazing on *Nardus stricta* dominated pasture on sheep and cattle performance. It is being carried out as part of a wider project to determine environmentally sustainable and economically viable grazing systems for heather moorland.

Materials and methods This study is on 72 ha of predominately *Nardus stricta* pasture at ADAS Pwllpeiran in West Wales, UK. Prior to this study the area had been grazed by Welsh Mountain ewes and lambs at a stocking rate of either 1.5 sheep per ha or 1.0 sheep per ha. In this study the area has been split into four treatments randomised over the area. In treatment 1 the stocking rate is 1.5 sheep per ha for 10 months of the year, treatment 2 is 1.0 sheep per ha for 10 months of the year, treatment 3 is as treatment 1 + 0.5 cattle per ha for two months in summer and treatment four is 0.5 cattle per ha for two months in summer only. Grazing regimes in all four treatments began in the summer of 2003. Welsh Black cattle were weighed onto and from the treatment plots in summer 2003 and summer 2004 and liveweight changes calculated. Differences in liveweight due to treatment and year were analysed using ANOVA. Liveweight and body condition scores were recorded for sheep at the start of grazing, tupping, pregnancy scanning, shearing and weaning. Changes in liveweight were calculated for two periods; start of grazing to tupping and tupping to weaning. Differences in liveweight changes due to treatment were analysed using ANOVA.

Results There were no significant differences in daily liveweight changes of cattle between the two treatments but there was a significant difference in cattle daily liveweight changes in treatment 3 between years. Cattle grazing treatment 3 in summer 2003 had significantly higher daily liveweight changes than cattle grazing treatment 3 in summer 2004. From the commencement of the grazing prescriptions in summer 2003 through to tupping (2003) there were no significant differences in daily liveweight changes in sheep between treatments. However between tupping (2003) and weaning (2004) sheep grazing treatment 2 had significantly greater daily liveweight losses than sheep grazing either treatment 1 or treatment 3.

Table 1 Daily liveweight changes in cattle grazing *Nardus stricta* dominated pasture at two different grazing prescriptions for two grazing seasons

	Treatment 3 (mixed grazing)		Treatment 4 (cattle only)		SED	Significance
	Summer 2003	Summer 2004	Summer 2003	Summer 2004		
Daily liveweight change (kg/day)	0.588[a]	0.295[b]	0.453[ab]	0.425[ab]	0.116	*

Values not sharing common superscripts differ significantly (P<0.05)

Table 2 Daily liveweight changes in sheep grazing *Nardus stricta* dominated pasture at three different grazing prescriptions

Daily liveweight change (kg/day)	Treatment 1 (1.5 sheep per ha)	Treatment 2 (1.0 sheep per ha)	Treatment 3 (mixed grazing)	SED	Significance
Start to tupping	-0.045	-0.040	-0.0497	0.0049	NS
Tupping to Weaning	-0.008[a]	-0.025[b]	-0.010[a]	0.0064	*

Values not sharing common superscripts differ significantly (P<0.05)

Conclusions In the initial year, introduction of cattle in addition to sheep had no effect on sheep performance and allowed an acceptable cow performance due to the availability of rank, unutilised vegetation. In the second year, such vegetation was no longer available and cattle performance was reduced. Further work is on going, but these initial results could have significant implications for future grazing strategies aimed at managing semi-natural vegetation in the hills and uplands.

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LS1508 – Economic impact of heather conservation in Environmentally Sensitive Areas

The Grazing Animals Project (GAP); enhancing the effectiveness of conservation grazing through a partnership approach

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The Grazing Animals Project (GAP) is a partnership between most of the major conservation organisations, governmental as well as non-governmental, working alongside key groups from the livestock sector. Its main aim is to promote and facilitate effective and sustainable livestock grazing systems that will directly benefit wildlife and landscape conservation.

One of GAP's main roles is to enhance the effectiveness and sustainability of conservation grazing wherever this is being undertaken within the UK. GAP has developed an entirely new approach to delivery of conservation grazing known as Local Grazing Schemes (Grayson 2002). These focus on making the delivery of conservation grazing within a specific geographic area more sustainable and more effective by co-ordinating and integrating the actions of a number of local stakeholders. There are currently around 40 of these LGSs throughout the UK, all of them based on active collaboration between partners from both conservation and livestock sectors, who have been brought together by a collective recognition of the benefits of working jointly to build systems that are effective, viable and sustainable.

Some of the current LGS projects have secured outside funding to appoint full time staff whose main remit is to pro-actively improve links between the managers of conservation sites and their local farming community. These Project Officers have proved very successful in identifying owners of suitable livestock and motivating them to provide a conservation grazing facility for nature reserves in their area. Occasionally, a particularly enthusiastic grazier will completely redesign their farming operation around these new opportunities, developing a fully integrated grazing system dedicated to nature conservation.

A key function for many of these LGSs is to secure added value for the products that their livestock generate. The story of how these animals are benefiting local wildlife and the landscape it inhabits is one that frequently appeals to people living in or visiting the area. This message can be used to good effect when marketing the meat or other livestock produce and thus secure premium prices that will help to support the graziers. Such marketing initiatives need to be developed in a co-ordinated way, supported by the combined efforts of all participating organisations, many of who have strong membership bases that will already be sympathetic to a conservation message.

GAP is itself membership-based, and acts as an information provider to around one thousand individuals and groups, all of whom receive the quarterly newsletter, GAP News. This provides a very effective network within which to circulate ideas, information and insights concerning conservation grazing matters. With representatives from research and advisory bodies sitting on its advisory panel, GAP is well placed to act as a conduit for passing research results and policy developments out to people working at a practical level.

Concerns about welfare have always been high on GAP's agenda because of specific challenges to animal health and safety that are inherent in grazing unimproved, semi-natural habitats. GAP employs a number of measures to ensure that conservation graziers and site managers are made fully aware of these risks and are kept informed about appropriate ways of reducing them to acceptable levels. It has published 'A Guide to Animal Welfare in Nature Conservation Grazing' (Tolhurst 2001) to inform and direct the managers of animals in these situations. Specialist courses have been developed to provide accredited training for site managers and their volunteers who need to supervise the health and welfare of grazing animals satisfactorily. These are now being rolled out on a UK-wide basis.

GAP also produces other publications that address specific topics where lack of information had previously been hindering conservation grazing, such as choice of grazing animals (Tolhurst & Oates 2001), and the marketing of their produce (Boothman & Grayson 2003). All of these are now available on GAP's website (www.grazinganimalsproject.org), which also provides specialist forums through which members can discuss topical issues and raise practical questions.

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Grassland arthropod species richness in a conventional suckler beef production system and one compatible with the Irish agri-environment scheme (REPS)

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Introduction Grassland management practices, such as grazing, strongly affects the biodiversity of grassland arthropods; increasing grazing intensity causes a general decline in species richness (Morris, 2000). One of the aims of the Rural Environment Protection Scheme (REPS) is to conserve and enhance biodiversity within Irish agricultural land (Feehan *et al*., 2002). In order to determine the effectiveness of this aspect of REPS, one must compare the relative biodiversity of grassland under REPS with that of conventionally managed grassland. Aiming to determine whether species richness was higher in REPS-compatible compared with a standard system of management, we measured the species richness of grassland arthropods within two contrasting grassland treatments within an experimental study of suckler beef production.

Materials and methods Grassland arthropods were sampled from the Systems of Suckler Beef Production experiment at Teagasc Grange, County Meath. The experiment compared 2 treatments: standard system (0.65ha/cow unit, 225kg N/ha); and REPS-compatible (0.82ha/cow unit, 88kg N/ha). The experiment involved 4 blocks, each containing one replicate of both treatments. The individual replicates were sub-divided into 3 grazing paddocks, grazed in a fixed sequence within each treatment and between blocks, with 2 blocks being grazed concurrently. Insects were sampled in Aug 2003 using a Vortis suction sampler. One sample, consisting of 10 randomly placed sub-samples of 10s duration, was taken/paddock, giving 3 nested samples/replicate. Depending on the taxon, 5 groups of arthropods were identified to species, morphospecies, genus or family. The 5 groups were Araneae (species); Coleoptera (species); Diptera (family); Hemiptera (species and morphospecies); parasitic Hymenoptera (genus).

Results The number of species, or equivalent, recorded for the 5 arthropod groups were: Araneae 7; Coleoptera 43; Diptera 23; Hemiptera 17; parasitic Hymenoptera 43. Treatment comparisons were carried out using the log transformed (ln+1) number of species/grazing paddock, which was incorporated into a nested analysis of variance. There were no significant differences between blocks or treatments for Coleoptera, Diptera or Hymenoptera. Block was not significant for Araneae and Hemiptera, respectively ($F_{3,4} = 0.42$ & $F_{3,4} = 0.85$), but the REPS-compatible treatment had significantly more species than the standard system ($F_{4,16} = 3.17$ $p < 0.05$ & $F_{4,16} = 4.84$; $p<0.01$, respectively). Figure 1 shows the mean number of species/grazing paddock for each treatment.

Conclusions Although these grasslands had relatively low species richness of arthropods, significant treatment effects were found. The species richness of both Araneae and Hemiptera, but not the three other arthropod groups, was significantly higher in REPS-compatible than in conventionally managed grassland. This provides evidence that REPS-can fulfil, at least partially, its aim of maintaining and enhancing biodiversity. The differences between the arthropod groups may reflect contrasting mobility and relationships with vegetation structure. Araneae and Hemiptera would appear to be suitable groups for studying the effect of grassland management on arthropod biodiversity.

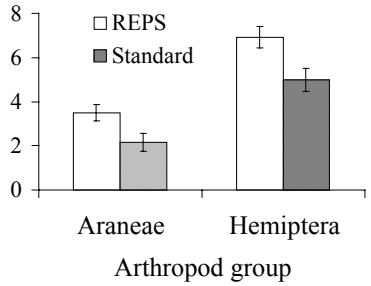

Figure 1 Species richness of Araneae and Hemiptera

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Developments in genetic evaluation: from test days to genomics

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Introduction Genetic evaluations have come a long way during the past decades, where the development and implementation of Best Linear Unbiased Prediction (BLUP) was undoubtedly the most notable achievement. The most important advances during the past 10 years were probably the direct use of test-day data in the BLUP model, ie. test-day models, the correction for heterogeneous within herd variances, multiple across country genetic evaluations (MACE), and the inclusion of more and more functional, and often difficult, traits in the evaluations. This paper will review the developments in test-day models, and the future of the genetic evaluations field, namely the inclusion of genomic information in the evaluations.

Test-day models The extension of lactation models to test-day models implied that the EBV for a lactation curve needed to be estimated instead of a EBV for total lactation production. The main competing methodologies to do this were: i) the random regression models, usually fitting polynomials or Wilmink curves (Ptak and Schaeffer, 1993); ii) splines (White and Brotherstone, 1997); and iii) character process models (Jaffrezic and Pletcher, 2000), which aim at fitting the (co)variances between the test-days instead of the curves. The random regression models are most often used in practise, mainly because they are easiest to fit in the BLUP framework. They however often provide a poor fit of the (co)variance structure of the test-days, mainly at the beginning and ends of the lactations. The latter is because the polynomial curves are highly flexible and extend over the entire lactation, ie. improving their fit in the middle of the lactation makes them vary widely at the end of the lactation, where there are few data points to keep the estimates within reasonable bounds (Pool and Meuwissen, 2000). Spline-curves, which are much more local, provide a solution to this problem of the polynomial curves, but more curves need to be fitted, ie. the number of equations often becomes too large. Character process models provide a much better fit of the (co)variance matrix, but this (co)variance matrix is often full rank and thus leads to too many equations in a BLUP model. More research is needed to avoid the anomalies at the end of the lactation curves that occur when fitting polynomials, either by the fitting of splines, character process, or other models.

Inclusion of genomic information The new challenge in the field will clearly be the inclusion of genomic information in the genetic evaluations. The simplest situation is that of a genetic test for a gene. In this case, the genotype may be fitted as a fixed effect, and its estimate added to the breeding value of animals. Fernando and Grossman (1989) also showed how the information of a molecular marker linked to a QTL could be implemented into the BLUP-EBVs, ie. how the relationship matrix at the QTL position given the marker information, **G**, could be calculated. A number of challenges remain however: i) the number equations increases with 2 per animal per QTL, which may soon lead to computational problems; ii) most animals will have missing marker genotypes, which complicates the estimation of **G**; iii) the inverse of **G** is needed in the BLUP equations. Problems i) and ii) may be solved by only including the genotyped animals in the equations and using the information of the remaining animals in the form of DYDs or YDs. This is not an ideal solution, because not all effects are estimated simultaneously, ie. pre-estimates for the DYD or YDs are used. Fernando and Grossman already showed how to solve Problem iii), but if MCMC techniques are used to properly account for the missing marker information (problem ii), **G** is estimated and not $\mathbf{G}^{-1}$, and direct inversion may be computationally hard. Meuwissen et al. showed how the information of a genome wide dense marker map could be used in the estimation of EBVs. Here, small marker haplotypes were used to identify chromosomal segments, and next the effects of these segments were either estimated by BLUP or Bayesian methods, where prior information was carefully used. An EBV of an animal is estimated by summing the estimates of all the segments, which were identified by marker genotyping. It may be noted that this estimation does not involve the relationship matrix, which has been key to all the BLUP evaluations up till now. The accuracy of these genomic EBVs was high, up till 0.84, for animals without performance nor progeny information. This genomic selection is most useful in the absence of performance information, e.g. when selecting embryos, or for traits that are not recorded in practice.

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Testing quantitative genetic selection theory with the mouse: A review

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Introduction The theory of quantitative genetics is used to predict certain outcomes in a dynamic population undergoing selection. The goal of this review is to demonstrate the value of the mouse as a model to test quantitative genetic selection theory.

Predicted and realized heritabilities Heritablity estimates in a base population are used to predict selection response. How good is this prediction? Sheridan (1988) reported discrepancies between predicted and realized heritabilities in selection experiments with laboratory and farm animals. An updated summary of single-trait selection experiments for different traits in mice indicates good agreement between predicted and realized heritabilities ($r = 0.81$, $P < 0.01$), with no suggestion of upward or downward bias in the base estimates (Eisen, 2005).

Predicted and realized genetic correlations How well do base estimates of genetic correlations predict correlated responses in single-trait selection studies? Ideally, a realized genetic correlation should be based on selection for a different trait in each of two replicated lines. However, few paired single-trait selection experiments have been reported. Summarizing those mouse studies that have been published (Eisen, 2005), the agreement between predicted and realized genetic correlations is good ($r= 0.82$, $P < 0.05$).

Replication in selection experiments When estimated by ordinary least squares, standard errors of realized heritabilities and genetic correlations are biased downward due to genetic drift effects (Hill, 1972). The theory was verified in a replicated divergent selection experiment for 6-wk body weight (Falconer, 1973). Results also showed the value of replication in assessing asymmetric and correlated responses.

Response to antagonistic index selection Antagonistic index selection is defined as simultaneous selection for two traits that are in the direction opposite to the sign of the genetic correlation between them. A survey of these index selection studies with mice, including restricted and desired gains indices, indicates that often the observed responses in the individual traits are less than expected. This outcome suggests the need to frequently re-estimate genetic parameters when conducting antagonistic index selection.

Long-term selection Most long-term selection studies with mice have been for either litter size, a lowly heritable trait, or adult body weight, a moderately heritable trait. Selection plateaus for litter size were primarily associated with segregation of undesirable recessives at low frequency. In contrast, the basis for the selection limit for body weight was exhaustion of additive genetic variance and poor reproductive performance.

Testing validity of the infinitesimal model The infinitesimal model assumes that traits are controlled by an infinite number of unlinked additive loci each with small effect, and gene frequencies are assumed to be unchanged by directional selection (Bulmer, 1971). A review of several studies of selection experiments using restricted maximum likelihood methods indicates failure of the assumptions of the infinitesimal model in some cases.

Conclusions A survey of selection experiments in mice for growth, body composition and reproductive traits shows reasonably good agreement between predicted and realized genetic parameters. Use of the mouse in selection experiments has confirmed the importance of replication to account for genetic drift effects and to test for asymmetry of response and correlated responses. In contrast to single-trait selection experiments with mice, antagonistic selection index studies often have failed to agree with predicted responses. In general, the results of long-term selection studies with mice verify the theory of selection limits, in that total response is increased with greater effective population size. More research is needed to determine the causes and consequences for failure of the animal model to hold in the analysis of several long-term selection studies. The mouse has proven to be and will continue to be a valuable model for testing selection theory applicable to animal breeding.

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The genetic analysis of growth and body composition in the mouse as a livestock model

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Introduction The similarities between the mouse and farm livestock at the genetic and functional level make it a useful model for farm livestock breeding and indeed for human genetic research, taking the opportunities presented by its short generation interval, the development of inbred lines, and the ability to do gene knock-outs. Genetic similarities apply both at the molecular level, in gene structure and sequence, and at the quantitative level, for example genetic parameters of growth. We discuss here what can be learnt about the action and interaction of genes that influence traits of growth and body composition and contribute to genetic changes in them from work on the mouse, concentrating particularly on candidate genes and experiments conducted in our laboratory. As a resource we have developed highly divergent selection lines for growth, body composition and food intake, brought together lines of mice selected for growth from around the world, and inbred them both for stability and to facilitate their use for molecular genetic analysis. These lines differ greatly as a consequence of selection not only in growth and degree of fatness, but also in efficiency, as assessed by food intake corrected for body weight.

Contributions to selection response Classical selection theory is based on the unrealistic infinitesimal model of many unlinked genes each of small additive effect. However analysis of log transformed data from,20 generations of high-low selection for fat content, assessed by gonadal fat pad weight/body weight, that produced about four fold divergence between replicated high and low lines showed an almost perfect fit to infinitesimal model expectations. Such analyses can mask, however, responses due to constituent genes with large effect; for example, analysis of an F2 cross of the lines revealed a QTL contributing almost 20% of the variance. The infinitesimal model can be used to predict responses to artificial selection spanning many generations in farm livestock because it is robust rather than true.

Contribution of candidate genes Selected lines for growth traits provide a model to check the role of candidate genes and the pathways by which they operate using introgression of mutant or null alleles by repeated backcrossing into both high and low lines: a line x allele interaction implies a role of the pathway involved in the selection response. Our findings have been consistent: the deficient allele has a major effect on performance in both high and low lines, but a similar one in both (expressed, if necessary, on the appropriate scale). Thus introgression of the GH deficient *lit* gene into large and small lines reduced absolute body weight more in the large line, but the proportional effect, almost 60% at 98d of age, was similar in both. Similar results have been obtained by introgression of deficient leptin structural or receptor genes into fat and lean lines. From this we conclude that the large selection responses have not been contributed by alleles at these major loci or indeed at other genes in close by pathways.

Major genes discovered in mice The mouse has been important in elucidating major genes in livestock. For example leptin, important in fat deposition and food intake, was first discovered in mice and the leptin structural genes and leptin receptor genes were first cloned in the mouse using the *ob* and *db* mutants, respectively. The double muscling gene in cattle was identified after a knockout of the myostatin gene in the mouse led to large increases in muscularity. A mouse mutant (*compact*) was also found to be the same locus. Much work has been undertaken to map quantitative trait loci (QTL) affecting traits of growth and obesity, and substantial numbers have been reported. The interest here is not in marker assisted selection, as in livestock, but in trying to identify the subsequent genetic lesion, albeit a long task. An X-chromosome effect on body size in our lines, accounting for 20% of high-low line divergence, has been located to a region of under 2 cM and the gene will soon be identified. This is a gene which produces a normal, albeit larger phenotype, and so is a model locus for studies of control of growth.

Introgression of candidate and major genes In the absence of epistatic interactions, a gene having a large effect in one population would have the same effect in another. We have used the largest body weight line, DUH, as a recipient in such experiments using marker assisted introgression to introduce the gene but not the background. In DUH the *compact* myostatin gene showed a substantial effect on muscle development, but in contrast to the line in which it was discovered, had no growth enhancing effect and also reduced viability. Initial crosses between DUH and the line carrying the high X chromosome QTL indicated that DUH had a low X, and that about 9g increase in body weight would be obtained at the level of the F1 (the test is to compare male and female offspring in reciprocal crosses). Yet when the X-QTL was backcrossed into DUH, the effect was small, and barely significant: much less than 9g, let alone the same proportional effect on the high background. Both these experiments indicate that effects of marker assisted introgression of genes or QTL of large effect for growth traits into extreme lines are not predictable.

The mouse as a model for understanding the regulation of body composition

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Body composition of animals and man is generally assumed to be a regulated phenomenon. Understanding the factors that are involved in such regulation is important in at least two different contexts. The obesity epidemic sweeping across developed nations has been described by the WHO as the greatest health threat facing Western societies. Understanding the underlying physiological factors that lead sectors of the population to fail in their attempts to regulate body mass and composition are of key importance in the drive to develop pharmaceutical remedies for this serious condition. A knock on effect for the agricultural sector however is the consumer demand for leaner animal products. This places a premium on understanding how body composition is regulated in livestock. Moreover the financial rewards for improving the energetic efficiency of production provide an additional incentive for understanding the details of energy regulation that underlie control of body composition. While direct genetic and physiological studies of livestock are feasible the mouse provides a convenient model animal that can inform our understanding of the conserved physiological mechanisms in both man and other animals. The key advantages of using the mouse in this context are that its small size and short breeding cycle enable experiments to be performed rapidly. Measuring physiological components of energy balance in mice is easily performed. In addition the mouse genome has been sequenced and the tools for performing large scale gene expression studies are already commercially available, opening up the capacity to perform integrative physiological studies form the level of the genome to the whole animal. Several genetic models of mice are known which have monogenic forms of extreme obesity. The best known of these is the ob/ob mouse, which is deficient in production of the adipokine leptin. However, many other single gene mutants are known which generate similar effects. Dissecting the loci of such effects has enabled us to construct a working model of how adiposity is signalled in the brain via the melanocortin system and how feedback loops including this system may contribute to regulation of energy balance. While some individuals have been identified that have similar genetic disruptions these are very rare, and it is clear that variation in human and livestock body composition generally reflects polygenic effects. More useful models may therefore be mice that have been selected for many generations for traits that impact on their body composition. The short generation time of the mouse has been extremely useful in the generation of such lines. My own group has been collaborating with the University of Edinburgh where such long-term selection experiment was initiated in the 1970s. We have in particular been quantifying the energy balance of mice long term selected for fat and lean body composition. We first showed that these polygenic effects do not seem to include polymorphisms within the leptin signalling system. By comparing total energy intake, with measures of resting energy expenditure the contribution of different energy compartments to energy balance can be assessed. These studies indicated that the major difference in energy regulation between the lines is that the lean line diverts substantially more energy into activity than the fat line. Direct measures of activity have been made to confirm this effect with mixed results. Using passive infrared detection devices the converse result is found – that the lean mice are less active, but using running wheels the logged activity matches the measured energy balance. These data indicate that the factors influencing energy balance reflect complex polygenic effects that reach far outside the leptin signalling system. The mouse is an ideal tool to explore these effects with implications for both the livestock industry and the obesity epidemic.

Reaping the benefits of an equine genome map

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Genetics has not been a usual academic pursuit in the study of horses. Nutrition, exercise physiology and veterinary topics related to infectious diseases or mechanical defects are more traditional scientific pursuits. Genetics has been left to the realm of horse breeders. Indeed, horse breeders are historically credited with being the leading practitioners of the art and certainly have the longest pedigree records including the Weatherby Studbook and the oral tradition of Arabian horse breeding.

On the other hand, modern animal breeder need not yield ground in the area of genetics to horse breeders. Rightfully, our quantitative geneticists can point to the remarkable genetic gains and genetic predictions that have been made with Dairy cattle and since the 1940s,... without benefit of molecular biology!

Today transportation and power are mechanized and this role for the horse has been eliminated in almost all agricultural societies. However, in these same societies the horse industry plays a large role in sports and recreation. This is the reason why nutrition, exercise physiology and veterinary medicine remain strong areas of equine research in our agricultural institutions. If we improve the efficiency of equine reproduction, health of our horses and efficacy of our management systems, we will make money and create jobs. Agriculture is economics.

Genetics of pig health and immunity

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Introduction Infectious diseases have great impact on the margin per pig sold and the animal's welfare. The common veterinary approach to illness is to deal with the pathogen and ideally eliminate the pathogen from the herd. This approach reduces the probability of an outbreak, but increases the consequences of an outbreak, should it occur. A complicating matter is that an increasing number of parasites and pathogens have become resistant to antibiotics or anthelmintics. The objective of this paper is to draw attention to the pig's ability to deal effectively with pathogens after natural exposure, with particular emphasis on genetic improvement. The terms used in this paper are defined as in Knap and Bishop (2000).

Resistance to infectious disease Whether exposure of a pig to a pathogen leads to infection or infection leads to disease symptoms depends among other things on the pig's genetic potential, previous infections and whether it is supported or counteracted in dealing with the pathogen. Improving resistance to infectious disease requires therefore a three-way approach: improve living conditions of the pig, use active and passive immunization and apply breeding measures (Visscher *et al.,* 2002). The ultimate goal is not to improve resistance to infection, but to reduce the incidence of disease.

Direct genetic selection Direct genetic selection requires a sufficient incidence of all infectious diseases that are commonly present and damaging in commercial pig herds. Candidate breeding stock itself is usually reared on sites with a relatively high health status, so disease records from these sites are of limited value. The alternative is the use of information of relatives on representative farms with a Combined Crossbred and Purebred Selection approach. There are several drawbacks to this approach. Variation in exposure prior to entering the finisher facilities may well mask genetic variation. Furthermore, a large number of relatives and herds is generally needed, which effectively means field data recording on commercial herds. In the study of Ten Napel *et al.* (2005), it was found that the quality of field data was limited, with a substantial number of animals with disease symptoms apparently not recorded, despite existing disease recording protocols. Problems are limited resources for recording if suddenly a large number of pigs is affected (e.g. outbreak of respiratory disease), difficulty to observe subclinical infections and problems to link a disease symptom to an individual pig (e.g. diarrhoea). Ideally, one would like the time to the start of the disease, the duration of presence of symptoms and the need for intervention (i.e. treatment to kill the pathogen).

Indirect genetic selection The problems listed above for direct genetic selection make one look seriously for alternatives. To be useful for indirect genetic selection, marker traits need to be heritable, genetically correlated to disease, cheap and easy to measure and must not require exposure to a pathogen. Visscher *et al.* (2002) conclude "Therefore in the short term, the development of immunological markers appears the most promising, but in the longer term these may be partly replaced by genetic markers". There are many studies showing genetic variation in traits of the innate and specific immune system, especially in antibody response. The problem, however, is that we do not know how to select for the various components of the immune system to guarantee resistance to a specific disease or to diseases in general. Niewold *et al.* (2005) collected a total of 103 traits from various parts of the immune system on 202 young AI boars, before and 7 and 21 days after vaccination for Aujesky's disease, and related these traits to disease records of their progeny on commercial herds. Overall, the linear association between immune traits and disease incidence was not very strong. They found that naïve traits (measured before vaccination) were stronger linearly associated with disease incidence than response traits (d 7 and 21) and concluded that effective resistance to diseases in this study requires a good balance between the Th1 and Th2 response. Kitano (2004) reviewed biological robustness mechanisms and his paper demonstrates the highly complex and interactive nature of these mechanisms and their robustness to manipulation. Perhaps our approach to linearly change components of the immune system in an attempt to achieve better immuno-competence is inherently flawed.

Discussion An effective immune response consists of the right type and the right magnitude of the response. My conclusion from the above is that genetic selection for the right type of response can only be done through elimination of animals with an incompetent immune system, which would require exposure to relevant pathogens. Mounting a response of the right magnitude may be more a problem of resource allocation.

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Livestock production post CAP reform: Implications for the environment

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We now live in a Decoupled world. The direct support measures paid to farmers as part of the CAP Pillar 1 agricultural support, which paid them according to the number of livestock held or areas of crops grown, have been replaced by a Single Farm Payment (SFP). In the UK as a whole, these direct subsidy payments represented 77% of Total Income from Farming (TIFF) in 2004 and a large proportion of farmers would derive negative net farm incomes in the absence of them. In particular, livestock farmers appear to depend crucially on direct subsidies such as Suckler Cow Premium, Sheep Annual Premium and Beef Special Premium. The latest average position for LFA grazing livestock producers is that 188% of NFI is derived from subsidies and for lowland livestock producers the situation is even worse, at 259%. This suggests that if these subsidies were removed, Net farm Income would be negative and the business would be unsustainable.
What it also suggests is that on current market price alone, our livestock producers cannot survive. As total subsidies to production fall away in future years, farmers have four options:

- Reduce costs;
- Attain better prices;
- Stop farming;
- Do something new.

The signals being sent to farmers now are, however, extraordinary. They are effectively being given income support payments to allow them to continue to lose money in livestock farming if they so wish: to fund a bad habit. However, these support payments will not last forever and for a new generation of farmers to survive, they need to unlock themselves from the economically non-viable enterprises they are in, do something new or get out.

The early indications are that farmers are doing very little to change. If you want a prediction about how farming will look in three of four years time, the answer will probably be much the same as it is now, although farm incomes will continue to decline as more and more of the SFP is withdrawn to rural development. Farmers are still able to hide behind the blanket of the SFP. Looking further ahead, perhaps fifteen or twenty years, the situation could change dramatically. At the moment, looking at the total income from farming figures, only about 23% of farms are profitable without subsidy. The remaining 77% need to take action and in the longer term will not be able to hide.

However, the key to what many livestock farmers can do is to start to recognise that they no longer primarily produce food. The animals they produce are a means to an environmental end. Public goods such as attractive landscapes or clean water are legitimate goods and services to spend public money on, because the public expresses a willingness to pay. The protection of beef and sheep farmers for the sake of producing unprofitable beef and sheep is increasingly something that the public is not willing to pay for.

So what can we expect in terms of the types of livestock that will be wanted by the UK's livestock farmers of the future? In cases where farmers are able to cut costs and/or gain a price premium for a niche or quality product, carcass quality, efficient feeding and high growth will be sought, but there are few of these producers about at the moment. For those seeking to promote the environment and who are able to adjust properly to a norm of producing environmental goods and services, they will want easy-care systems and it may even be that mortality rates of progeny are less of an issue as offspring rearing simply becomes valuable for replacements in the land management flock or herd and a headache to market. Both sets of producers will, however, be looking to reduce labour costs and both will need to comply with increasing animal welfare regulation.

The impacts for the environment arising as a result of the signals being sent to livestock producers through CAP reform are potentially threatening. All environmental measures directed at farmers are essentially voluntary and largely only brokered on the knowledge that farmers cannot do without the money. As new farming generations emerge, new scenarios about how the environment might be affected need to be thought about. This paper tries to throw some light on those scenarios and outline what livestock research can offer to help deliver sustainable outcomes. In particular, the paper focuses on what the author sees as the increasing dichotomy of livestock producers – those who will be able to chase the market and break free from the shackles of subsidy and who at the same time will be decreasingly concerned about securing environmental subsidies, and those who can only survive by gaining from the public willingness to pay for environmental goods and services and who will be increasingly audited to make sure they produce the environment the public wants.

Impact of grazing management on botanical diversity of grasslands

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Grazing is a natural process affecting the composition and structure of plant communities and is widely considered to be an essential nature conservation tool. However, our understanding of the interrelations between grazing by large herbivores and biodiversity is relatively poor. Nature conservation imperatives, to control succession, for example, mean that practice has moved ahead of the science knowledge base on grazing. This gap now needs to be bridged. Improving our understanding of and ability to predict consequences of manipulating grazing pressure, duration, type and/or mix of large herbivore on biodiversity outcomes are particular issues that we are addressing.

Species-rich neutral grassland is a scarce resource in the UK (Jefferson and Robertson, 1996) and there is a pressing need to define what constitutes a sustainable grazing pressure for biodiversity maintenance. Using continuous grazing with cattle to maintain different grazing pressures on species-rich neutral grassland we examined the effects on botanical diversity, vegetation structure, invertebrate responses, and cattle growth rates over five years. Plant species diversity was not significantly affected by the different treatments in five years. Significant effects on vegetation structure emerged. The cover of *Poaceae* increased ($P < 0.001$) under the more lenient grazing pressures. *Fabaceae* abundance increased ($P < 0.001$) under the most intensive treatment. *Fabaceae* cover was also enhanced (P 0.036) in short sward patches that remained short throughout the grazing season in the lenient treatment. Stability of short sward patches was relatively high (Kappa-Index 0.6) under the lenient grazing pressure compared with the more intensive grazing treatments. The cover of *Cirsium* species increased (P 0.001) across all grazing treatments, but no treatment effects were observed. Studies by CABI Bioscience have shown that *Heteroptera* (true bug) abundance increased (P 0.05) with decreasing grazing pressure. Abundance of foraging bumblebees the density of spiders also increased ($P <$ 0.001) with decreased grazing pressure, reflecting enhanced nectar and pollen resources and vegetation structural complexity/stability, respectively. Cattle growth rates equivalent to commercial levels were achieved under moderate – lenient grazing pressures on the species-rich grassland. These results indicate that biodiversity can be enhanced on species-rich grassland, at least in the short term, under moderate to lenient grazing pressures while also achieving high cattle growth rates and predictable agronomic output. The challenge now is how to optimise the value of such grassland within farmed landscapes to enhance and maintain populations of specialist grassland fauna.

Semi-improved species-poor grassland represents a major habitat in the UK. We are examining the extent to which biodiversity can be enhanced on such grassland by manipulating grazing pressure and type of livestock. We are examining effects on faunal abundance and diversity of grazing with cattle at either moderate or lenient grazing pressures and, in the latter, using a commercial or traditional breed. De Vries *et al.* (2005) have shown that species richness and abundance of butterflies were enhanced (P 0.005 and < 0.007, respectively) by the low grazing pressure compared to the moderate pressure. Studies by CAER (Reading University) have shown that different patch types created by the grazing animal have important influences on invertebrate assemblages. Increased leaf hopper (*Auchenorrhyncha*) abundance was associated with taller patches and *Coleoptera* abundance was influenced by certain patch types. This study has highlighted the need to gain greater understanding of influences of plant structural patchiness on faunal biodiversity and population stability at a range of scales: from plant, patch, community to landscape. This study provided some indications of a breed effect on vegetation structure, but we could not be certain that observed breed effects had not been confounded by other factors such as different previous environmental conditions influencing the grazing behaviour of the cattle. We have just started to examine these issues in a separate project.

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How does the nature of forages and pasture diversity influence the sensory quality of dairy livestock products?

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Introduction The characteristics of dairy products depend on both the processing technology and the chemical and microbiological characteristics of milk. The milk properties depend themselves on a number of production factors linked to animals (genetic and physiology) or feeding. Some of these factors, the way animal are fed in particular, are increasingly becoming the focus of consumers' concern. In particular, grass-based diets are sensitive because grass carries a positive image that can be attractive to some, because it may confer special nutritional characteristics to the products and also because grass feeding is part of the basic link between products and their original land which is important in the case of labelled products (Protected Denomination of Origin [PDO]). The aim of this text is to take stock of the recent studies (Coulon *et al.,* 2004), which have studied the effect of grass on the sensory qualities of cheeses and butter. Other dimensions of quality, i.e., health and nutrition, are not investigated.

Impact of feeding on the sensory quality of dairy products Feeding dairy cows or goats with corn silage by comparison with hay or grass silage leads to whiter, firmer and generally less appreciated butters or cheeses mainly because of their less developed flavour. Concerning the issue of the conservation of grass in the form of silage, recent results evidenced that when silage quality is good, the sensory properties of milk or cheeses issued from silage are very similar to those of milks or cheeses issued from hay, except colour, yellower with grass silage. Nevertheless, the effect of silage may vary according to the cheese type; in a recent trial grass silage induced wider sensory differences on Cantal-type cheeses than on Saint-Nectaire-type ones. Additionally, major differences in sensory characteristics were observed between milk, butter or cheeses coming from cows fed diets based on preserved grass or pasture. Saint-Nectaire cheeses made with pasture milk were yellower, with a less firm texture, stronger taste and less piquant, less sour and less fruity flavour than those made with winter milk. Butter was also yellower, softer and has a more grassy flavour when the cows were fed with a grass-based diet (pasture or silage) than when they are given concentrate and maize. Additionally, some recent experiments showed a significant effect of grass botanical composition on cheese texture and flavour, whatever the grass is grazed or preserved as hay. The differences may be important in particular when grass is grazed. The sensory characteristics of the cheeses coming from the highest and/or more diversified meadows vary widely from their counterparts coming from lowland or monospecific meadow. The latter are generally more cohesive, elastic and ductile with a less diversified aroma.

Origin of the sensory differences A number of cheese sensory features or characteristics may be due to certain milk components, directly linked to feeding and to forage in particular. Such is the case of carotene which contributes to the yellow coloration of dairy products. Its content in dairy products depends of the forage's one. Another direct origin of the sensory differences involves the effect of terpenes; these plant-specific molecules abound in certain species, dicotyledons in particular, and are found in milk fat and cheese in much larger quantities when the cows eat dicotyledon-rich swards, which generally characterise highlands. However, it does not seems -except in some extreme Mediterranean conditions where swards are particularly rich in aromatic plants- that the modification of their concentration in milk or cheese would suffice to exert a direct effect on milk or cheese. The effect of the type of feeding can also be an indirect one. Some of the differences noted between cheeses according to the botanical composition of the grass may be related to the wide variability of milk plasmin concentration from one situation to the other. The increase in milk of this proteolytic enzyme coming from blood could be related to an increase in the cell permeability of the mammary tissue under the effect of specific species intake (*Ranunculaceae*) that are only present in certain grasslands. Milk fat composition (length of the carbon chain and degree of unsaturation), highly dependent on animal feeding conditions, may also be at the origin of butter and cheese texture and/or flavour differences. Butter is all the more spreadable as linoleic content is higher and palmitic acid concentration is lower. Also, some fatty acids may be degraded by microbial enzymes during cheese maturation, to produce compounds that are responsible for cheese aroma. Lastly, it cannot be ruled out that the type of forage modifies the microbial ecosystem or its activity in milk and cheese.

Conclusions These various results show that the characteristics of forage used by animals may modify the sensory features of dairy products. The effect of the diets result from the presence in the raw material of specific molecules directly induced by feeding (carotenes, terpenes) or produced by the animal under the effect of specific diets (plasmin, fatty acids). Apart from their sensory interest, some of these molecules can still be used as feed tracers and/or confer specific nutritional properties upon dairy products. Those results also evidence the existence of a link between natural environment and product characteristics. In view of these results, it appears that maintaining forage biodiversity (green or conserved) is crucial for dairy products to best reflect the typicity and diversity of their territory of origin.

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BSAS Ethical Policy

The British Society of Animal Science (BSAS) does not publish work that it views as having resulted in unnecessary pain, distress or other forms of suffering to experimental animals. Any experimental work published by BSAS must have been conducted in accordance with relevant national legislation and recommendations relating to the use of animals for experimental purposes. The 'BSAS Ethical guidelines for research in animal science' is also available on the BSAS members website. For further information, contact the BSAS secretariat.

British Society of Animal Science
Ethical guidelines for research in animal science

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1. Introduction

Animal science research is important in relation to our understanding of animals, their function and performance, and their relationships with their social and physical environments. Animal science research covers a wide range of disciplines and so can lead to the use of a variety of experimental techniques on animals for many different purposes. This has the potential to lead to a multitude of diverse ethical issues. Members of the British Society of Animal Science and authors of papers submitted to the Society for publication come from countries around the world and therefore are subject to differences in legislative requirements and recommendations regarding animal experimentation. These legal requirements, along with the ethical implications of the research must be fully considered ***before*** any experimental work is undertaken.

The British Society of Animal Science has formulated the following set of ethical guidelines for animal experimentation which should be used alongside legislation that applies in the country of study and institutional ethical review procedures.

These guidelines are based around the principle of assessing the cost of experiments in the form of 'harms' to the animals involved and the potential benefits that might be realised from the research. They discuss ways of reducing costs (harms) to experimental animals but also of how to maximise the benefits of animal science research if it is undertaken.

2. Justification of research – Cost/Benefit analysis

Research has the potential to generate conflict between the researcher achieving objectives and the wellbeing of the animals involved. The justification for undertaking the research must be based on a systematic assessment before starting.

Any animal science research undertaken should have realistic and achievable aims of increasing our knowledge of the species of interest in relation to our understanding of its functioning, performance, health or welfare. These outcomes can be regarded as examples of 'benefits' of the research. However animals may suffer as a result of the experimental procedure itself and also as a consequence of sub-optimal housing or husbandry conditions. The 'cost' to animals can be defined as any harm in the form of pain, distress or other forms of suffering that an animal experiences at any stage of its life as a consequence of the research. The researcher must fully consider the likelihood of causing harm to the animals involved and decide whether the benefits are sufficient to justify the suffering. Formalisation of this cost/benefit analysis of research programmes can be conducted (see Mellor and Reid, 1994). By considering the costs to the experimental animals as well as the likely benefits of research, the researcher, if requested to, should be able to justify his/her use of experimental animals both to peers and in the public arena.

3. Ethical Review and Legislation

Before commencing a programme of research involving the use of animals, a researcher should:

• Be up to date with relevant literature in that area to avoid needless duplication of experimental work and the potential suffering of experimental animals.

• Discuss the potential use of the experimental animals with peers as this may identify areas of ethical concern that the researcher has not considered.

• Consider all available options to replace use of animals with other techniques that will allow the scientific objectives to be met

• Be able to justify the use of animals based on a cost/benefit analysis as discussed in section 2.

• Have obtained relevant authorisation at both local, and where applicable national levels as appropriate in the country of study. Even where experimental procedures are unlikely to cause pain, distress or other forms of suffering, and for example do not require national approval, it is recommended that local authorisation (from the organisation the researcher is representing and the place where the animals will be used) is gained before the commencement of the experiment.

• Consider and comply with local, national and international legislation relating to the acquisition, transport, housing and husbandry of animals (e.g. on the farm, or in the laboratory). This legislation will cover, for example, maximum journey times, minimum space requirements and group sizes, weaning ages and euthanasia techniques. Researchers should consider this legislation as being the standards that are used in applied situations and bear in mind that these are only minimum standards and can be improved upon. If any legislation relating to the keeping of animals will be contravened as a part of the experimental study then relevant national and local authorisation must be gained *before* the commencement of the study.

• Be up to date with scientific literature and guidelines relating to the keeping of animals, and incorporate this within their study to ensure the use of appropriate species-specific housing and management practices as recommended at the time of study.

• Particularly when planning to work under commercial conditions, give consideration to factors that may be outside of the researcher's control and which may lead to situations in which there might be additional potential for animal suffering, as well as potential infringements of legislation. Discuss the ethical and experimental implications of the occurrence of these undesirable events.

Any researcher submitting a paper to the journal, a summary or award application to the society may be asked to justify their use of experimental animals and describe the ethical evaluation that the study has gone through.

4. Considerations of the 3Rs (Refinement, Reduction and Replacement)

4.1 Refinement

Refinement deals with improving the welfare and reducing any pain, suffering and distress that may be experienced by *each* individual experimental animal at any stage of its life.

- *Species*

The species chosen for the experimental study should be the one most suited to realising the aims of the study. Choosing a species that is inappropriate will invalidate the study and is therefore ethically and scientifically unacceptable. Avoid choosing a species based on their *apparent* poorer perception of pain. This assumption may be misguided. Sheep, for example, like other prey species have evolved to instinctively and adaptively show little response to pain even though they may be suffering. Also avoid using species based on their *apparent* reduced capacity to suffer or be distressed. For example, although birds and fish do not show behavioural expressions similar to mammals in distressing situations, it should not be assumed that they are not suffering. Behavioural studies have shown that these animals too can perceive aversive stimuli and will act in a way to avoid further exposure to such negative experiences. Detailed knowledge of the species to be used is therefore a prerequisite.

- *Housing and management*

Housing and management of animals must comply with legislation relating to the keeping of animals in the country of study. When studying animals in extensive systems, guidelines and legislation relating to the supervision of the health and welfare of the animals must be adhered to. The impact of housing and management on the experimental animals should be considered even if this is not part of the experimental manipulation involved. Researchers should not only consider the minimum standards set out in legislation but also should refer to more recent literature and consider improvements to the housing and management of their experimental animals.

The natural behaviour and social structure of the study species should be considered and if possible be provided for in the experimental housing. For example, factors that should be considered are space allowance, group size and structure, frequency of cleaning and the quality and complexity of the environment. Environmental enrichment is encouraged. Unsuitable housing environments may cause behavioural and physiological aberrations in animals, and may impact upon the potential validity and applicability of any experimental results.

- *Personnel*

It is imperative that people working with experimental animals are fully trained in animal care, the experimental procedures to be used and understand the needs of the species they are caring for. This includes the ability to observe and assess when an animal may be in pain or distress, and the knowledge to then implement relevant measures to alleviate this suffering as quickly and as far as is possible. They should be fully aware of the legislation relevant to the keeping of animals and the use of animals in experimentation that applies to the study. The researcher should ensure that all personnel are responsible, confident in their ability and have the relevant experience to take on their specific duties within the study.

- *Routine practices*

Certain standard practices are undertaken, especially on farms and in laboratories, which may have the potential to cause a degree of animal suffering. For example, identification of animals, mutilations such as tail docking, teeth-clipping and beak-trimming, early weaning and castration. The researcher should consider whether these practices are a necessary part of the research and thus whether these practices could be omitted from the study. If for example identification of individual animals is required then the least invasive method possible should be chosen. Non-invasive methods (e.g. pen marking) should be considered particularly if the duration of the study is short. Invasive methods such as ear-tags and wing-tags may be used, however identification by mutilation such as ear notching and toe amputation requires special justification. If any mutilation or other routine invasive practice is carried out as part of an experiment then appropriate sedatives, anaesthetics and analgesics should be considered.

- *Experimental procedures*

i) Infection

While the ultimate aim is most likely the prevention or curing of disease, animal health research often requires studies of infected animals. If possible, researchers should consider working with naturally occurring diseased animals and try to alleviate disease as opposed to inducing the disease in otherwise healthy animals. If deliberate infection of animals is required for the purposes of the research project then the duration and intensity of the diseased period should be minimised with appropriate procedures in place to intervene at pre-determined humane end-points.

ii) Nutritional restriction

Restricting nutrition below maintenance requirements in growing animals should be avoided where possible. If exceptions are justified in specific cases, the severity and duration of restriction should be minimised. In reproductive animals, loss of bodyweight and condition can occur during periods such as lactation. Such reproductive animals should not be allowed to lose significantly more bodyweight or condition than would normally be expected. Where protein and energy restriction is required bulky diets should be used where possible so as to alleviate some of the suffering due to hunger.

iii) Selective breeding and genetic modification

Experiments that involve selective breeding or direct genetic modification that are likely to affect the animal's integrity or lead to pain, suffering or an increased mortality rate require special justification in terms of benefit to the wider animal and human population.

iv) Physiological sampling

Researchers should consider the collection of physiological samples which are non-invasive (e.g. faeces, urine, saliva, hair). If invasive sampling is required any pain or suffering should be minimised. When repeated blood sampling is required the researcher should consider the implantation of indwelling catheters (using appropriate anaesthetics and analgesics). Researchers should ensure the total blood volume to be taken will not cause suffering and must consider the replacement of fluids. Appropriate anaesthetics and analgesics should be used where skin or other invasive tissue samples are required.

v) Deprivation

Resource (food, social contact, space and water) deprivation is used in animal science research and has the potential to cause animal suffering therefore the severity and duration of deprivation should be minimised. Food, in particular, may be withdrawn to motivate animals to perform certain tasks. In such studies, researchers should consider the possibility of giving positive food rewards (desirable foods) for performance of tasks thereby removing the need for food deprivation and a source of potential suffering.

vi) Aversive Stimuli

Some animal science studies employ the use of aversive stimuli (e.g. fear-inducing stimuli). Positive stimuli should always be considered as the primary method of choice as an alternative and consideration should also be given to whether a stimulus associated with a non-aversive cue can be used instead. Aversive stimuli should be avoided as far as is possible, but where it is used, the duration and severity of the stimuli should be reduced as much as possible

vii) Aggression

When studying aggressive behaviour the researcher must seriously consider the methodology to be used. If encounters between animals are occurring as part of farm practice then these encounters should be used where possible. If staged encounters are necessary strict guidelines relating to intervention should be developed and all personnel involved should be aware of these. The experiment should preferably be stopped at the first sign of aggression, but if the experimental protocol requires that the subordinate animal be subjected to the aggressor for a specified amount of time then adequate physical protection (e.g. cage) for the subordinate should be provided.

viii) Surgery

Where surgical procedures are undertaken appropriate levels of anaesthesia must be used. Researchers should ensure that the experimental animals are properly anaesthetised by a trained and responsible person. The surgical procedures should be carried out by a trained and competent person. Researchers should consider the use of general anaesthesia if there is any doubt over the efficacy of local anaesthesia. Pre- and post-operative close observation and care of experimental animals should always be employed; appropriate sedation, analgesic, antibiotic and anti-inflammatory treatments should be used.

ix) Previous experience of animals

The experiences animals have throughout their lives can affect the way they respond to challenges (which could impinge upon the applicability of experimental results). Therefore, where possible, all animals on an experiment should have a similar life history with respect to factors such as parental care, social and physical environment and nutrition. Wherever possible animals should be trained in advance to reduce the fear associated with procedures (e.g. regular considerate handling and familiarity with experimental situations).

x) Humane end-points

End-points for all experimental procedures should be determined before the commencement of the study and refined as appropriate as the study progresses. Death due to an experimental procedure is an unacceptable end-point. All personnel involved in carrying out the procedures should be fully aware of the humane end-points and be confident in carrying them out. Researchers should reassure more junior personnel that their informed judgement and decisions will be respected.

xi) Disposal of animals

Experimental animals can sometimes be re-used for other experimental work, however it should be ensured that any individual animal does not experience repeated stressful or painful procedures. Legislation relating to re-use of experimental animals must be adhered to. Experimental farm animals can often be returned to farm stock, however the

effect of the experimental procedures and the change of environment (physical and social) on the welfare of the animal should be considered fully.

If an animal has to be euthanased it is vital that this is done using the most humane method and it is recommended that a veterinarian be consulted. Experimental animals will sometimes be disposed of by standard practice (e.g. at a slaughterhouse) and so the researcher should consider the implications of this for the experimental animal. The animal should be confirmed dead before being discarded. For further details on methods of euthanasia see AVMA (2001) or Animals (Scientific Procedures) Act 1986 Guidance on Schedule 1 methods of killing.

4.2 Reduction

Reduction relates to the scientific, moral and legal requirement to expose as few animals to pain, suffering and distress as possible. Researchers should calculate how few animals are required to ensure they are able to obtain meaningful results. Where statistical significant differences are sought, power analysis can be used whereby known estimates/measures of:

1) the level of variability in the variable being measured
2) the level of difference expected between the treatments
3) the desired power of the overall comparison,

are used to define the sample size required

In some circumstances where the level of variability is unknown, or the expected difference between treatments is uncertain, estimates based on similar data sets within published literature can be utilised. Power calculations are also important to ensure that sample sizes in experiments are not too small to give statistically significant results, as this also represents wastage of animals and potential unnecessary suffering. A statistician with expertise in experimental design should always be consulted before carrying out any experimental work.

To ensure that researchers have complied with the requirement to consider reduction, the Editors of Animal Science and other BSAS referees may require justification and details of sample size estimates and power analyses where they have particular concerns.

4.3 Replacement

Replacement call for a researcher, where possible, to replace or avoid the use of living animals altogether with some other means of reaching the same experimental objective. In every instance, non-animal methods of investigation should be sought. Using living animals should not be the default action.

The types of substitution that can achieve replacement are diverse and include, for example:

- Statistical modelling on the basis of previously recorded data
- The use of previously recorded video-tapes in the case of an ethological/behavioural study
- *In vitro* techniques

5. Other considerations

In addition to the 3 R's (Refinement, Reduction and Replacement) there are some other considerations to be made when using experimental animals:

Source and transport of animals

It should be ensured that experimental animals are acquired from a reputable source following all legal requirements and, where relevant, international transport guidelines. Adequate transport facilities and personnel should be provided to transport experimental animals to and from the place of study with minimum distress.

6. Increasing the benefits

It is important to have realistic and achievable experimental aims. This can be facilitated by ensuring that the number and species of animals, experimental design and statistical tests are appropriate to test the hypothesis. This is aided, as mentioned above, by being aware of previous research to avoid duplication and any methodology that has been unsuccessful. Irrespective of the outcome of the study, the researcher has an ethical obligation to communicate the results accurately. For example, if the methodology the researcher used is unsuccessful then it is important that other

researchers in the field are informed to avoid using the methodology at the cost of the potential suffering of more experimental animals.

It is important to consider the significance of the aims of the study. Applied studies usually have a directly applicable aim, however more fundamental studies can also provide beneficial information which can subsequently assist more applied studies.

7. BSAS contact and sources of information

Potential authors and applicants for scholarships should consult the Senior Editor of Animal Science or the Chair of the BSAS Technical and Ethical Committee if they have any queries relating to the ethical suitability of their research. Contact can be made via the BSAS secretariat:

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9. Useful References

Web Resources

American Psychological Association (APA) "Guidelines for Ethical Conduct in the Care and Use of Animals". (http://www.apa.org/science/anguide.html)

Association for the Study of Animal Behaviour (ASAB) "Guidelines for the treatment of animals in behavioural research and teaching". *Animal Behaviour* **61:** 271-275.
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Other references

The 'British Veterinary Association (Animal Welfare Foundation) / Fund for the Replacement of Animals in Medical Experiments/ Royal Society for the Prevention of Cruelty to Animals / Universities Federation for Animals Welfare' - **Joint Working Group on Refinement** has also published the following guidance papers:

- Removal of blood from laboratory mammals and birds -*Laboratory Animals* (1993) 27, 1-22
- Refinements in rabbit husbandry -*Laboratory Animals* (1993) 27, 301-329
- Refinements in mouse husbandry -*Laboratory Animals* (1998) 32, 233-259
- Refining procedures for the administration of substances -*Laboratory Animals* (2001) 35, 1-42
- Refinements in husbandry and procedures for laboratory birds -*Laboratory Animals* (2001) 35 Supplement 1, 1-163
- Reduction and refinement in the generation, management and care of genetically modified mice -*Laboratory Animals* (2003) 37
- Refinements in telemetry procedures -*Laboratory Animals* (in press)
- Husbandry refinements for rats, mice, dogs and non-human primates used in telemetry procedures -*Laboratory Animals* (in press)

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