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Welcome

The British Society of Animal Science (BSAS) aims to provide an opportunity for those with an interest in animals and animal science to exchange views, ideas and information. It is an energetic and active society with members from countries throughout the world. Today, as ever, the Society is the natural connecting point for all of those with an interest in animal science and related sectors. Its membership is drawn from research, education, advisory work, commerce and practical animal keeping.

BSAS organises major scientific and specialist conferences on key issues facing the science related to animals.

The 2022 annual conference addresses the true 'Role of Animals in Human and Planetary Health'. Debating the role that animals play on the wider stage of dietary, environmental and mental health.

If you would like to join or receive further information about the British Society of Animal Science please contact:

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Proceedings of the British Society of Animal Science Annual Conference 2022

1. Livestock Science Matters for Human and Planetary Health

J. Fitzpatrick

Scottish Government, UK

The COVID-19 pandemic has created a new conversation among scientists, policy makers, politicians and the public. It has also emphasised the role of science and innovation in addressing global challenges. The COVID-19 response has seen innovation in vaccine technology, rapid diagnostics and new means of preventing disease transmission, including interventions, legislation and human behaviour. Success has been a result of an integrated, multi-disciplinary, and funded approach, focussed on populations of people. Infectious disease has been a major focus of livestock scientists over many decades and longer, and novel vaccines, diagnostic testing and disease control programmes, including nutrition, management and breeding have been successfully developed and applied to herds, flocks and populations of animals. This has underpinned much success in preventing, reducing and controlling disease which has resulted in i) improved animal health and welfare, ii) better biological efficiency and reduced waste, thus contributing to Net Zero initiatives, and iii) food security while maximising sustainable agriculture globally - a “win-win-win” for livestock science. Scientific evidence for many approaches to controlling disease is currently available and the focus must now be on knowledge exchange and uptake of existing technologies, essential for impact globally. There is however, the need for much more to be done - reducing the risk of emerging, zoonotic, and food-borne pathogens, developing alternatives to anti-microbial drugs and chemicals, and preventing disease in both intensive and extensive farming systems of the future, in both developed and developing countries. Animal scientists have a key role in providing new research outputs across many disciplines, not only for the scientific community itself, but to provide evidence for policy makers, politicians and society generally. This will be essential if we are to continue to improve the lives of animals while also increasing understanding of the role of animals in human and planetary health.

2. It is not as simple as just eating less meat: how healthy and environmentally sustainable are the alternatives?

J. Macdiarmid

University of Aberdeen, Scotland

The consumption of meat and dairy is at the center of most debates about sustainable diets because of the high environmental impact of livestock production. In the Climate Change Committee Sixth Carbon Budget report (2020) one of the actions proposed to put the UK on a pathway to achieve Net Zero by 2050 is to reduce consumption of meat and dairy by 20% by 2030, raising to 35% cut in meat by 2050. Eating less meat, especially red and processed meat, can also have health benefits, such as lowering the risk of some non-communicable diseases. However, these health and environmental benefits need to be assessed in the context of the foods that are replacing meat and the overall composition of the whole diet. Plant-based foods and meals cover a very wide spectrum in terms of healthiness, and while many of the alternatives are healthy increasingly there is a greater availability of highly processed products. Much of the research around meat reduction has focused on finding protein replacements, which have included pulses, insects and cultured meat. However, the emphasis on protein, both in research and the food industry, has had the unintended consequence of some people believing that reducing their meat consumption could lead to a protein deficient diet. This is not the case as the majority of people in high income countries eat more protein than they require, regardless of whether they eat meat or not. From a nutritional perspective, greater attention is needed on micronutrients to avoid a diet with an inadequate quantity of micronutrients. Meat and dairy are good sources of micronutrients, such as iron, zinc, calcium and iodine, and the bioavailability of some of these is higher in meat than plants. In this presentation I will explore some of the nutritional, environmental and social implications of switching to a more plant-rich diet.

3. Animal source foods in sustainable and healthy diets

F. Leroy

Vrije Universiteit Brussel, Brussels, Belgium

Over the last decade in particular, the position of animal source foods in food systems has become increasingly controversial. While being a fundamental component of traditional diets worldwide and providing important essential (and conditionally essential) nutrients, especially in vulnerable populations,

they have also been linked to chronic disease and environmental harm. Agricultural and health policies are affected by this evolution at the regional, national, and international level, which will obviously have an important impact on future systems. Both the effects on human and planetary health are, however, highly contextual. Regrettably, this is often not how the subject is approached in a policy environment that is mostly top-down oriented. What should be considered is the quality and robustness of the evidence (related to uncertainty, missing data, bias, confounding, etc.), the heterogeneity of the data due to the vast differences between and within the various food categories, the differences in production methods (with respect to environmental impact) and in metabolic responses between individuals (with respect to human health), the role of lifestyles and the degree of wholesomeness of the background diet, the need to factor in nutrition when performing environmental assessment, the potential trade-offs that may result from drastic dietary change, etc. Unfortunately, these elements are often neglected or minimized, which leads to reductionist approaches that may severely affect the desired outcomes of policy change. Although it needs to be acknowledged that animal agriculture faces serious challenges, the focus on an artificial animal/plant binary is particularly unhelpful and often comes with strong moral overtones. Instead, the best of both animal and plant production needs to be stimulated and carefully integrated, based on the most robust evidence, while damaging practices on both sides of the said binary need to be minimized.

4. How much Meat and Dairy is Good for Us? The Importance of Transparent Evidence-Based Health Metrics

A. Stanton

Devenish Nutrition & Royal College of Surgeons in Ireland, Ireland

Animal-Sourced Foods are nutrient-rich foods. They contribute many key nutrients to the human diet. In addition to being a source of high-biological value protein, many essential health promoting micronutrients (vitamins A, riboflavin, niacin, B6, B12 and D, calcium, iron, zinc, iodine and selenium, and long-chain omega-3 polyunsaturated fatty acids), are either most efficiently, or only, included in the human diet, through moderate consumption of animal-sourced foods. Dietary excesses do lead to chronic diseases such as cancers, heart attacks and strokes. However excessive calorie and salt intakes are the leading dietary causes of such diseases globally. By contrast, the possible deleterious effects associated with red meat intake are very small, and are only evident with red meat consumption in excess of 500g weekly. The majority of the world's population are not eating enough dairy foods - protection against colon cancer, heart attacks, strokes and total mortality increases with consumption of up to 3 portions a day of milk, yoghurt, butter or cheese. Hence, it is of considerable concern that the recently published, very influential, Global Burden of Disease (GBD) 2019 estimates of disease burdens attributable to dietary risk factors appears to omit the protective effects of meat and dairy against nutritional deficiencies, and the cardiovascular protection provided by dairy foods from their estimates. Furthermore, by assuming that the optimal intake of red meat is zero, risks for moderate red meat consumption appear to be either created or considerably inflated. The GBD 2019 analysis only provides a paucity of evidence regarding the scientific basis for their estimates - no peer-reviewed publications of their updated or new systematic reviews are included nor referenced. The WHO definition of a healthy diet is that it "helps to protect against malnutrition in all its forms, as well as against chronic non-communicable diseases." There is overwhelming scientific evidence that consumption of meat and dairy, in appropriate evidence-based quantities, should continue to be included in national and international guidelines for a healthy, balanced diet.

5. How Companion Animals Impact our Mental Health

N.R. Gee

School of Medicine, Virginia Commonwealth University, Richmond, Virgina, USA

Humans and animals have led a shared existence for thousands of years, and through the ages we have come to find ways to coexist to the benefit of both species, though most of those benefits have accrued to humans. This presentation will describe how the bond humans share with companion animals may impact our mental health and wellbeing, while also considering the needs of the animals. We will examine the state of the science from the perspectives of pet ownership (does owning a pet contribution to mental health?), and animal interaction (does interacting with someone else's pet contribute to mental health?). We examine these perspectives across the developmental lifespan, starting with children, and considering topics such as how animals may help children develop reading or social skills, reduce stress, or enhance standard treatments for Autism Spectrum Disorders or Attention Deficit Hyperactivity Disorder. Then we will turn our attention to adults and explore ways that animals may be involved in crisis intervention or help ameliorate symptoms of Post-Traumatic Stress Disorder, anxiety, depression, or other serious mental illness. For older adults we will examine the role of companion animals in the treatment of dementia, geriatric depression, or other aging related concerns such as staying active and maintaining mobility and reducing loneliness. Finally, we will take a look at a few specific applications of animal interactions, such as hospital visitation programs and psychotherapy, that have shown promising results in contributing to mental health or in the treatment of mental illness. Throughout this presentation, the importance of the animals, their welfare and quality of life, will be stressed. Additionally, the quality of the evidence accumulated will be considered, with the preponderance of high-quality evidence coming from animal interaction studies rather than pet ownership studies. Carefully consideration of both types of evidence gives us good reason to conclude that under the right circumstances, companion animals are beneficial to human mental health and wellbeing.

6. Future-proofing sustainable animal production systems with feeding technologies

S. Salami

Alltech, UK

The global demand for animal protein is expected to increase substantially over the coming decades, due to a simultaneous rise in population, urbanization, and household income. However, the livestock industry must meet the growing demand for animal-sourced foods while confronting several

environmental, economic, and social sustainability challenges. The future viability of the livestock industry would depend on how the sector leverages technology and innovation to tackle these unprecedented sustainability challenges. Historically, innovative feeding technologies (such as slow-release urea, antioxidants, mycotoxin binders, enzymes, organic trace minerals, prebiotics, and probiotics) have been developed in animal nutrition with the primary objectives of improving the productivity and profitability of animal production. However, the positive impacts of feeding technologies transcend these primary benefits and can be a crucial part of the solutions for sustainable animal production. In perspective, feeding technologies can deliver multiple sustainability benefits including the mitigation of greenhouse gas emissions and nutrient pollutions (particularly nitrogen and phosphorus), lower land use and water footprint, improved protein production efficiency, reduction of food loss and waste, lower trace mineral excretion, and reduction of antibiotic use. International guidelines such as the "FAO Environmental Performance of Feed Additives in Livestock Supply Chain" have provided robust guidance on how to quantify the impact of using feeding technologies to reduce the impact of livestock products on the environment. Further exploitation of advances in data mining and predictive analytics would provide tremendous opportunity in capturing the sustainability benefits of feeding technologies in animal production systems. This presentation would elucidate the combined use of meta-analysis and life-cycle assessment to substantiate how the effect of feeding technologies in improving production efficiency can be translated to lower environmental impacts and other sustainability credentials in monogastric (poultry and swine) and ruminant (dairy and beef cattle) production. The application of precision and data-driven tools in livestock systems is crucial to provide robust science-based evidence that could enable developing sustainability claims for the use of feeding technologies in the animal food chain. Finally, further perspectives would be highlighted on the implication of feeding technologies for the green labelling of animal feed and animal-sourced foods.

7. Assessing the enteric methane emissions from beef cattle fed silage from different pasture types during the winter housing period

P. Meo-Filho [a,*], M. Jordana Rivero [a], J. Evans [b], T. Misselbrook [a]

[a] Rothamsted Research - North Wyke, Okehampton, Devon, UK
[b] Rothamsted Research - Harpenden, Harpenden, West Common, UK

* Corresponding author. T.Q. Nguyen.

Application: Reduce enteric methane emission (EME) yield (gCH_4/ kg of live weight gain) feeding beef cattle with silages produced in different types of pasture.
Introduction: The methane produced by ruminants, remains a significant source of greenhouses gases from agriculture in the UK, accounting for 60.3% of emissions in this sector (DEFRA, 2021). Dietary modification is linked to changes in the rumen fermentation pattern and is an effective way of methane abatement (Haque, 2018). This justifies the comparison of EME from cattle fed with silage produced in different types of pasture. Since this food is used on a large scale to feed these animals in the UK every year. Therefore, this study aimed to test the hypothesis that cattle fed with silage harvested from different pasture types differ in the amounts of EME produced.
Material and methods: Beef cattle (Stabilizer cross and purebred, Charolais cross and Limousine cross), steers (n = 89) and heifers (n = 88) with live weight (LW) of 327.6 ± 57.1 kg, were evaluated during two housing seasons (2016-2017 and 2017-2018) from November to April, at the Rothamsted Research North Wyke Farm Platform (NWFP, UK). The treatments corresponded to three diets types, composed of a small amount of concentrate and mostly of silage harvested from three different pastures: G-WC, comprised of 70% of perennial ryegrass (cv. AberMagic), and 30% of white clover (Trifolium repens L.); PP, permanent pasture dominated by PRG (Lolium perenne L.) and Agrostis stolonifera L.; and G, monoculture of perennial ryegrass (cv. AberMagic) the latter two received 160-200 kg N/ha/year. Cattle were weighed every 30 days and the EME was determined by the GreenFeed automated system. Statistical analysis (GenStat®) included treatment effects (silage type), period (year), and the interaction treatments × period as fixed effects, breed and sex were included as a random effect in the model. The treatment effect was considered significant at $P < 0.05$. Mean separation was performed with the F-test.
Results: No differences were observed ($P > 0.05$) between treatments regarding the EME, 174.4, 170.7 and 170.0 g CH_4/day, or per kg LW, 0.48, 0.47 and 0.47 g CH_4/kg LW, for G, G-WC and PP, respectively. However, when the EME was expressed in relation to the average daily gain (ADG), the treatment G showed higher ($P < 0.05$) EME compared to the G-WC and PP treatments, 269.9, 247.7 and 235.4 g CH_4/ kg ADG. The inverse effect ($P < 0.05$) was observed for the variable ADG, 0.67, 0.71 and 0.74, respectively.
Conclusion: Despite the difference in botanical composition of the pastures, their silage showed no effect on the EME of beef cattle over winter. However, our findings suggest that EME may differ by being diluted in animals with higher ADG. BEIS (2021), Haque (2018).

Acknowledgement: The work was funded by Soil to Nutrition programme (BBS/E/C/000I0320) using the NWFP (BBS/E/C/000J0100), both of which are funded by BBSRC.

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8. Artificial neural network model for prediction of manure nitrogen excretion from lactating dairy cows

X. Chen [a,b,*], H. Zheng [b], H. Wang [b], T. Yan [a]

[a] Agri-Food Biosciences Institute, Hillsborough, Down, UK
[b] Ulster University, Belfast, Antrim, UK

* Corresponding author. X. Chen.

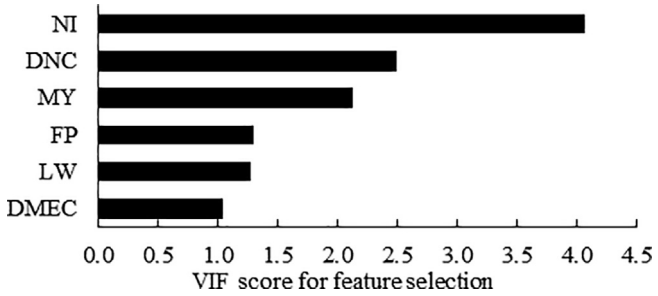

Figure 1. The variance inflation factors (VIF) score of features selected.

Table 1
Predictive performance of ANN models for prediction of manure N excretion of lactating dairy cows.

Primary predictors	Features	R^2	RMSE[1]	RMSE[1] (% of mean observed MN)
NI	NI + LW + MY + FP + DNC + DMEC	0.83	32.1 ± 1.68	10.9 ± 0.44
LW and MY	LW + MY + DNC + CDMI + DMEC	0.79	35.2 ± 1.08	12.1 ± 0.47

[1] RMSE = root mean square error (obtained by 10-fold cross validation), mean ± standard deviation.

Application: The artificial neural network (ANN) can be used to develop robust models for prediction of manure nitrogen (MN) excretion in lactating dairy cows.

Introduction: The comparative advantage of the ANN over most statistical models can be attributed to its capability to handle non-linear and complex datasets and to explore interaction effects among input variables (White, 1990). A previous paper indicated that the ANN performed better than the multiple linear regression for prediction of MN excretion of lactating dairy cows (Chen et al., 2022). Hence, the objective of the present study was to evaluate if the ANN approach could be used to develop accurate prediction models for MN excretion of modern dairy cows.

Materials and methods: Data used were collated from 43 total diet digestibility studies with 951 lactating dairy cows undertaken at Agri-Food and Biosciences Institute in Northern Ireland between 1990 and 2015. The ANN was fitted using R package neuralnet. Multilayer perceptron networks trained with backpropagation learning algorithms were used and consisted of an input layer, hidden layer(s) and an output layer. The input variables were obtained using a hybrid knowledge-based and data driven approach and the neuron in output layer represents MN. The ANN models were trained based on the selection of training algorithms and learning parameters including the number of hidden layer(s), number of neurons in hidden layer(s), error function, and activation function etc. The optimized number of hidden layer(s), number of neuron(s) in the hidden layer(s), learning algorithms and other learning parameters were obtained on the basis of prediction performance measured as root mean square error (RMSE) with 10-fold cross validation and then the best topology/architecture was finalized.

Results: The features selected were N intake (NI), diet N concentration (DNC), milk yield (MY), forage proportion (FP), live weight (LW) and diet metabolizable energy concentration (DMEC) (Figure 1). Two ANN prediction models were developed using either NI or LW and MY as primary predictors as NI data are not always available especially in commercial farms. The ANN model based on NI had 2 hidden layers with 3 neurons in the first layer, and 6 in the second layer. The input layer consists of NI, DNC, MY, FP, LW and DMEC. The ANN model based on LW and MY had 2 hidden layers – the first layer with 4, and the second layer with 2 neurons. The two ANN models showed good predictive performance and the corresponding RMSE (% as mean actual MN) values 10.9% and 12.1%, respectively (Table 1).

Conclusion: Two ANN models using either N intake or live weight and milk yield as primary explanatory variables provide a novel and useful tool for prediction and mitigation of manure N excretion of dairy cows.

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9. Improving the sustainability of silage

D. Davies [a,*], K.L. Cocq [b]

[a] Silage Solutions, Scotland
[b] Harper Adams University, UK

* Corresponding author. D. Davies

Silage is the most important source of forage used for dairy cow feeding in commercial production systems globally. In the UK, data suggests that greater than 85% of milk produced is from cows consuming silage rather than grazed grass. Therefore, it is crucial that the impact of silage within ruminant production life cycles is the focus of attention, both in research and practice. The study of silage production is a multi-disciplinary science where plant breeding, agronomy, microbiology, biochemistry and animal nutrition can all have a bearing on end quality and subsequently impact on animal health and environmental factors. Often, advice on silage production is given from one expert's view-point without examining the whole

system. The presentation will focus on important contributing factors that underpin GHG emissions in livestock and silage production. Covering a number of key elements and a critical examination of the following:

(i) Nutritional needs of livestock and efficiency of silage utilization by the rumen microbiota and N and C use.
(ii) Dry matter losses. It is estimated that on the average farm between 20-25% of the DM of harvested forage is lost prior to being consumed by a ruminant. Examining the direct and indirect impact of dry matter losses on GHG emissions will be a key focus. Two key areas for attention on this will be losses occurring during silage fermentation and storage versus losses occurring during feed-out. The silage additive trade is predominantly focused on aerobic stability and many of the current silage inoculants enhance the inefficiencies occurring during the silage preservation phase which are likely to result in poorer rumen fermentation and feed utilization thus increasing the impact on GHG emissions.

The presentation will aim to interrogate these interactions, highlight areas of concern and direct future research and advice. Data presented will be wide ranging, from detailed science, based on both farm collected data and theoretical data gained over the last 50 years about the microbiology of silage and the rumen. The overall aim of the presentation is not only to highlight targets for future research but also to provoke thoughtful debate about what is the best advice for the future of ruminant agriculture and its impact on the planet.

10. Microbial Proliferation of hay produced using three different dehydrating techniques during storage period

I.A. Ewetola [a,*], A.A. Amisu [b], J.A. Olanite [c]

[a] Department of Animal Nutrition and Forage Science, Michael Okpara University of Agriculture, Umudike, Abia, Nigeria
[b] Department of Pasture and Range Management, Federal University of Agriculture, Abeokuta, Ogun, Nigeria
[c] Department of Pasture and Range Management, Federal University of Agriculture, Abeokuta, Ogun, Nigeria

* Corresponding author. I.A. Ewetola.

Application: Microbial growth on hay during storage period influenced by both fertilizer type and dry technique.
Introduction: Moisture re-absorption at early period of storage is linked to improper drying of harvested forage materials during hay production. Oxidation of non-structural carbohydrate in moist hay has been a primary factor responsible for microbial respiration, which causes substantially increased temperature in the hay mass (Shan et al., 2012). To maintain good quality of hay during storage, harvested forage materials should be cured without rainfall or with reasonably low relative humidity to less than 20% moisture content. Nutrient losses from hay associated with moulding and spoiling may occur if the moisture content exceeded this limit. Abundant growth of mould and thermophilic actinomycetes in stored hay results in nutrients loss which consequently affects hay quality and this can be hazardous for the producer who inhales these contaminants when the mouldy hay is fed in closed barns (Duchaine, 1995). Therefore, the study was conducted to evaluate microbial characteristics of hay produced using different drying techniques sampled during storage period in Abeokuta derived savanna zone, Nigeria.
Materials and methods: The experiment was a 4 × 2 × 3 factorial arrangements laid out in a Completely randomised design containing four fertilizer types (NPK, Poultry manure, Aleshinloye Organo mineral, Zero fertilizer i.e control) and two grass species (*Panicum maximum* var. Ntchisi and *Andropogon tectorum*) and three drying techniques (Solar, Oven and Conventional). Eight weeks after cut back, forage samples were harvested to make hay using the three drying techniques. Hays were stored for a period of three months, and samples were taken at an interval of six weeks for 90 days storage period to determine microbial growth. The data collected were subjected to one-way analysis of variance (ANOVA) using SAS 2009 R package and the significant means were separated using Duncan's Multiple Test range (Duncan, 1955).
Results: The results showed that the mean values of Total Bacterial Counts (TBC) were significantly affected by both fertilizer types and drying techniques at 12 weeks storage period. Oven dried hay produced the lowest TBC (0.27 CFU/ml). Hay from poultry manure fertilized grasses recorded the least TBC mean value (0.26 CFU/ml) at 12 weeks storage period Duchaineet al. (1995), Duncan (1955), Shanet al. (2012).

Table 1
Effects of fertilizer types on Total Bacterial Counts (TBC) (CFU/ML) of differently dried hay from *P. maximum and A. tectorum* samplings at intervals of six weeks during storage period.

Factors	Sampling Periods (weeks) 0	6	12
Grass species			
A. tectorum	1.32	8.03	0.31
P. maximum	1.31	8.12	0.30
SEM	0.02	0.67	0.01
Fertilizer type			
Control	1.35	7.56	0.33[a]
AOM	1.34	6.17	0.31[ab]
NPK	1.25	8.44	0.33[a]
PM	1.32	10.17	0.26[b]
SEM	0.03	0.88	0.02
Drying technique			
Conventional	1.31	7.61	0.33[a]
Oven	1.33	7.83	0.27[b]
Solar	1.31	8.75	0.33[a]
SEM	0.02	0.82	0.02

SEM = Standard error mean, TBC = total bacterial count.
AOM = Aleshinloye organo-mineral fertilizer
PM = Poultry manureNPK = N.P.K. 20:10:10
[a,b] means in the same column with different superscripts are significantly ($P < 0.05$) different.

Conclusion: The study therefore concluded that oven dried *P. maximum* fertilized hay had good durability. However, microbial population generally declined as the storage exceeded 6 weeks.

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11. Reproductive characteristics, haematological, and serum biochemical indices of West African Dwarf Does fed Neem Leaf Meal

M. Babatunde *, O. Adewumi, O. Adelusi, R. Aderinboye, R. Obembe

Federal University of Agriculture, Abeokuta, Ogun State, Nigeria

* Corresponding author. M. Babatunde.

Application: 5 g/kg of Neem leaf meal (Azadirachta indica) could be included in the diets of pregnant does without adverse effect on kids, and internal physiology.

Introduction: The heavy demand for cereal grains by humans and animals has given rise to the high costs of livestock feeds. The neem plant can adapt to intense drought seasons, poor soils (Ogbuewu et al., 2011), and contribute considerably towards assuaging the nutritional inadequacies of ruminants throughout the dry season. Leaf meals derived from leguminous plants can enhance animal performance (Esonu et al., 2002; Nworgu and Fapohunda, 2002) and blood parameters. The study evaluated the reproductive characteristics, haematological, and serum biochemical indices of West African Dwarf (WAD) Does fed Neem Leaf Meal.

Materials and methods: Three inclusion levels (0 g/ kg, 2.5 g/ kg, and 5 g/ kg) of ground air-dried leaves of neem (Azadirachta indica) were added to a formulated diet to replace wheat offal. The 12 WAD does were divided into three treatments and four does per treatment in a completely randomized design. The experiment lasted for 166 days. Gestation lengths, litter sizes, birth weight were estimated to highlight the reproductive performance of does. Litter size was determined by counting the number of kids per doe, and their individual birth weights were measured using a sensitive weighing scale. Blood samples were collected from the does only at the end of the experiment via the jugular vein using a 10ml hypodermic syringe. 5ml of the blood was infused into collection bottles containing Ethylene Di-amine Tetra118 acetic acid (EDTA) for serum and the remaining 5ml into collection bottles without anti-coagulants for plasma and taken to the laboratory for analysis. Blood parameters namely PCV and RBC were determined following the procedure outlined by (Shah and Altindag, 2004). Haemoglobin concentration was obtained by using Van Slyke apparatus and applying Hufner's factor (1.36ml oxygen per 1g of Hb) for its calculation. White blood cell (WBC) count was also determined. Data were analysed using one-way analysis of variance with means separated at $P < 0.05$ (Duncan's multiple range test) using SPSS 23 software.

Results: The effect of inclusion of neem leaf meal on reproductive characteristics of West African Dwarf does is presented in Table 1 and the parameters were not significantly ($P > 0.05$) different. The effect of inclusion of neem leaf meal on haematological and serum biochemical indices of West African Dwarf does is presented in Table 2 and the parameters were not significantly ($P > 0.05$) different.

Table 1
Reproductive characteristics of West African Dwarf does fed different levels of Neem Leaf Meal.

	Treatment				
Parameters	0	2.5	5.0	SEM	P-VALUE
Mated does	4	4	4	0.00	0.00
Number of does that kidded	3	3	3	1.31	1.00
Gestation length (days)	151	152	152	1.30	1.00
Total number of kids	4	5	4	0.30	0.89
Live birth weights (kg)	1.01	1.14	1.08	0.18	0.94

0 g/kg = 0 g/kg NLM + concentrate; 2.5 g/kg = 2.5 g/kg neem leaf meal (NLM) + concentrate; 5.0 g/kg = 5 g/k neem leaf meal (NLM) + concentrate, SEM = Standard error of means.

Table 2
Haematological and serum biochemical indices of West African Dwarf (WAD) Does fed Neem Lea Meal.

	TREATMENT					
Parameter	NormalValue	0	2.5	5.0	SEM	P-VALUE
Haemoglobin (g/dL)	8-12	9.20	8.90	10.33	0.40	0.34
PCV (%)	22-38	27.00	26.25	32.75	1.39	0.11
RBC ($x10^{12}$/L)	8-18	14.45	13.98	16.73	0.61	0.14
WBC ($x10^{9}$/L)	5-12	11.00	11.23	11.45	0.48	0.94
Total Protein (g/dL)	6.4-9.0	8.30	8.13	7.68	0.19	0.45
Albumin (g/dL)	2.7-7.0	5.00	4.73	4.18	0.18	0.18
Globulin (g/dL)	2.7-5.7	3.30	3.40	3.50	0.11	0.81

0 g/kg = 0 g/kg NLM + concentrate; 2.5 g/kg = 2.5 g/kg neem leaf meal (NLM) + concentrate; 5.0 g/kg = 5 g/k neem leaf meal (NLM) + concentrate, SEM = Standard error of means.

Conclusion: The result suggested that 5 g/ kg dietary inclusion of neem leaf meal could be added in the diets of pregnant does without adverse effect on kids, and internal physiology.

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12. A comparison of baseline values of Fatty Acid profiles in milk fat of Cattle, Buffalo and Goat

U.G.V.S.S. Kumara [a,*], M.W.D.C. Weerathunga [a], C.M. Keerthirathne [b], W.M.P.B. Weerasinghe [a]

[a] Veterinary Research Institute, Peradeniya, Sri Lanka
[b] Artificial Insemination Centre, Polonnaruwa, Sri Lanka

* Corresponding author. U.G.V.S.S. Kumara.

Application: Current findings established Fatty Acids (FAs) profiles of cattle, buffaloes and goats for the first time in Sri Lanka. Furthermore, it has shown that buffalo milk fat contained more beneficial FAs such as cis and trans conjugated linoleic acids (CLAs) compared to other species.
Introduction: Milk greatly contributes to human daily intake of fat (Timon et al., 2020). Composition of FAs are mainly classified into two groups; saturated fatty acids (SFAs) and unsaturated fatty acids (USFAs) and also to short chain (SCFAs), medium chain (MCFAs) or long chain (LCFAs). Predominant CLAs in ruminant fat are cis-9, trans-11-CLA and trans-10, cis-12-CLA and they exhibit immune stimulatory, antihypertensive, anti-carcinogenic, and anti-atherogenic properties. The objectives of the current study were to establish and analyze the baseline FAs profiles in milk fat of three ruminant species; cattle, buffalo and goat in Sri Lanka with special emphasis on the beneficial FAs.
Materials and methods: Sixty-six milk samples of cows (n = 33), buffaloes (n = 15), and goats (n = 18) were collected from commercial scale dairy farms representing all agro-ecological zones in the country and stored at -20 ^{o}C until FAs analysis. Milk fat was extracted and methylated according to the method by Teng et al. (2017). Then FAs methyl esters were separated in gas chromatography using a CP-SIL 88 fused silica capillary column and FAs profile of each sample was determined. Data was analyzed using MINITAB (16thversion) as one-way ANOVA.
Results: The content of MCFAs in goat milk fat was higher ($P < 0.05$) than that of cattle and buffalo (Table 1). However, the content of LCFAs in cattle milk fat was higher than buffalo and goat milk fat. Goat milk fat contained the highest level of C4:0 (1.97g/100g ± 0.11) and MCFAs (15.11g/100g ± 1.31) and the lowest level of LCFAs (47.6g/100g ± 3.2). Buffalo milk fat had lowest MCFAs (7.01g/100g ± 0.74) and the highest level of cis-9, trans-11 and trans-10, cis-12-CLAs (0.65g/100g ± 0.10 and 1.34g/100g ± 0.17 respectively).
Conclusion: It can be concluded that milk fat of cattle contained more LCFA, buffalo had more cis-9, trans-11 and trans-10, cis-12-CLAs and goat milk fat contained more C4:0 FA and MCFA. Therefore, consumption of buffalo milk may increase the intake of beneficial FAs such as cis and trans CLAs.

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Table 1
Milk fatty acid composition (g/100 g of total fatty acids) in milk fat of cattle, buffaloes and goats.

Fatty acid	Cattle	Buffalo	Goat	P-value
C4:0	1.75 ± 0.06^{a}	1.35 ± 0.15^{b}	1.97 ± 0.11 ^{a}	0.004
C6:0	1.24 ± 0.26^{b}	3.35 ± 0.16 ^{a}	2.55 ± 0.09^{a}	0.000
C8:0	1.11 ± 0.08^{b}	0.54 ± 0.07^{c}	2.05 ± 0.20^{a}	0.000
C10:0	2.77 ± 0.27^{b}	1.07 ± 0.14^{c}	7.43 ± 0.72^{a}	0.000
C12:0	4.11 ± 0.30^{a}	2.41 ± 0.43^{b}	4 ± 0.68^{ab}	0.054
MCFA	9.11 ± 0.60^{b}	7.01 ± 0.74^{b}	15.11 ± 1.31^{a}	0.000
C14:0	10.73 ± 0.39^{a}	10.32 ± 0.64^{a}	9.47 ± 0.99^{a}	0.370
C14:1	1.67 ± 0.09^{a}	1.78 ± 0.36^{a}	1.35 ± 0.11^{a}	0.18
C15:0	1.45 ± 0.09^{a}	1.65 ± 0.16^{a}	0.93 ± 0.04^{b}	0.001
C16:0	30.9 ± 0.58^{a}	32.6 ± 1.26^{a}	29.02 ± 1.32^{a}	0.111
C16:1	1.46 ± 0.22^{a}	0.61 ± 0.04^{a}	0.38 ± 0.04^{a}	0.025
C18:0	2.13 ± 0.12^{a}	0.98 ± 0.26^{b}	0.48 ± 0.11^{b}	0.000
C18:1(trans)	13.13 ± 0.80^{a}	1.1 ± 0.11^{b}	0.5 ± 0.14^{b}	0.000
C18:1(Cis)	0.9 ± 0.08^{c}	8.32 ± 0.70^{a}	6.6 ± 0.60^{b}	0.000
C18:2	2.51 ± 0.26^{a}	3.1 ± 0.43^{a}	2.44 ± 0.34^{a}	0.509
C18:3	0.72 ± 0.06^{b}	1.42 ± 0.21^{a}	1.09 ± 0.20^{ab}	0.002
LCFA	66.72 ± 1.25^{a}	57.45 ± 5.05^{b}	47.6 ± 3.20^{b}	0.000
CLA(9,11)	0.44 ± 0.08^{a}	0.65 ± 0.10^{a}	0.56 ± 0.15^{a}	0.474
CLA(10,12)	0.70 ± 0.09^{b}	1.34 ± 0.17^{a}	0.73 ± 0.10^{b}	0.005

Values are expressed as means ± SE with the same letter are not significantly different at the 0.05 probability level.

Table 1
Effect of supplementing brown seaweed and seaweed derived extracts on OMD, total gas and CH_4 production parameters using the RUSITEC system.

	CO	SW A	EX F	EX I	SW K	SEM	P-value
OMD	70.12[ab]	67.91[ab]	66.81[a]	72.44[b]	68.35[ab]	1.415	0.0285
Total gas (L/day)	2.18	2.10	2.06	1.88	1.76	0.168	0.2398
Methane parameters							
CH_4 mmol/day	13.53[a]	13.04[ab]	10.37[ab]	12.14[ab]	9.79[b]	1.526	0.0345
CH_4 mmol/g DOM	0.93	0.88	0.75	0.77	0.61	0.103	0.0806
CH_4 % [1]	14.95[a]	14.73[a]	11.73[b]	15.24[a]	13.74[a]	0.773	<.0001
CH_4 (L/day)	0.33[a]	0.31[ab]	0.25[ab]	0.29[ab]	0.23[b]	0.037	0.0345

CO = negative control. SW A = Seaweed A. EX F = Extract F. EX I = Extract I. SW K = Seaweed K.
[a,b] Means within a row with different superscripts differ ($P \leq 0.05$)
[1] CH_4% calculated as proportion of total gas production

13. In vitro effects of brown seaweeds and brown seaweed derived extracts on methanogenesis and organic matter digestibility using the rumen simulation technique (RUSITEC)

E. Roskam [a,*], S. Kirwan [a], D. Kenny [a], M. Hayes [b], S. Waters [a]

[a] Teagasc Grange, Dusany, Meath, Ireland
[b] Teagasc Food Research Centre, Ashtown, Dublin, Ireland

* Corresponding author. E. Roskam.

Application: Enteric methane production from ruminants represents a major environmental concern. Red seaweeds have shown to reduce CH_4 *in vitro* and *in vivo* (Kinley et al., 2016), realising the anti-methanogenic properties of more inexpensive and accessible indigenous seaweeds would be a more sustainable methane mitigation option. In this study, extract F was a promising candidate for methane reduction in the RUSITEC system.
Introduction: Agriculture accounts for 21% of total global greenhouse gas (GHG) emissions, methane (CH_4) being the dominant emitter. Approximately 60% of Irish emissions are derived from enteric CH_4 emissions. Ireland has committed to reduce GHG emissions by 40% by 2030 compared to 2005 levels. Brown seaweeds contain the polyphenols, phlorotannins (PTs), which act on rumen cellulolytic bacteria which can have anti-methanogenic properties (Abbott et al., 2020). The objective of this study was to evaluate the effects of brown seaweeds and brown seaweed derived extracts on methanogenesis and digestibility in vitro using the RUSITEC system.
Materials and methods: The experiment was conducted using three RUSITEC systems (8 vessels/system) previously described by Kirwan et al. (2018). Treatments included: Control (CO - no seaweed inclusion), two brown seaweeds (SW K, SW A), and two brown extracts (EX F, EX I), all supplemented at 40 g kg^{-1} dry matter (DM). The in vitro basal diet consisted of grass silage:concentrates 50:50 on a DM basis. Rumen inoculum was sourced from four rumen-cannulated Aberdeen Angus steers on a total mixed ration diet. The study lasted for 21 days; 14 day adaptation period followed by a 7 day measurement period where total gas and methane percentage was measured. Data were analysed using the Mixed procedure in SAS 9.4. Statistically significant differences were considered when $P < 0.05$, while $P < 0.1$ was considered as a tendency towards significance.
Results: There was a significant difference observed between EX F and EX I ($P < 0.05$) for organic matter digestibility (OMD), however relative to the control there was no difference (Table 1). Total gas (L/d) showed no significant difference between treatments. SW K was the only treatment to reduce CH_4 (L/d), CH_4 mmol/day and CH_4 mmol/g DOM relative to the control ($P < 0.1$). Inclusion of Ex F reduced CH_4 % relative to all other treatments ($P < 0.05$).
Conclusion: Supplementation with SW K resulted in a 28% reduction in CH_4 (L/d) and CH_4 mmol/day, and resulted in a tendency to reduce CH_4 mmol/g DOM by 34% relative to control. Supplementation with Ex F reduced CH_4 % by 22%, however there was a slight decline in OMD when compared with EX I (-8%).

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14. Strategies to reach zero carbon beef and sheep production on Welsh farms

L. McNicol [a,*], A.P. Williams [a], D. Styles [b], R.M. Rees [c], D. Chadwick [a]

[a] School of Natural Sciences, Bangor University, Bangor, Gwynedd, UK
[b] School of Engineering, University of Limerick, Limerick, Ireland
[c] Scotland's Rural College (SRUC), Edinburgh, UK

* Corresponding author. L. McNicol.

Application: Understanding baseline farm greenhouse gas emissions and how they may be mitigated requires a validated, standardised carbon accounting tool. This work demonstrates the extent to which efficiency measures can reduce emissions, and the degree of afforestation needed to enhance sequestration to off-set remaining emissions, enabling farms to reach net zero.

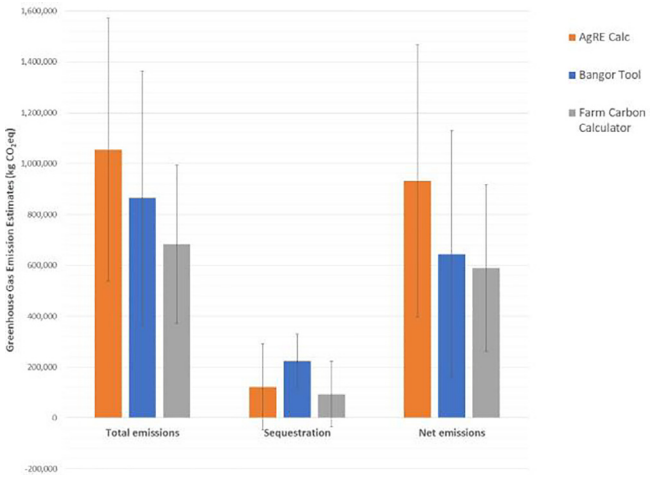

Figure 1. Mean emission estimates ± standard deviations (n = 20) for each total emissions, sequestration, and net emission estimate from AgRE Calc, the Bangor Tool and the Farm

Introduction: The Climate Change Committee has recommended a 64% reduction in greenhouse gas emissions from the agriculture and land-use sector to meet the 2050 net zero target in the UK. However, it is still unclear what these changes will look like at a farm level. The aims of this study are: i) to assess the effects of carbon calculator choice on baseline carbon footprints of Welsh beef and sheep farms, and ii) to investigate strategies for these farms to reduce emissions and increase sequestration to achieve net zero. The study will define net zero typologies and assess their effect on production.
Material and methods: Carbon footprints were calculated for 20 Welsh beef and sheep farms using three carbon accounting tools: Bangor University's Carbon Footprinting Tool, AgRE Calc, and the Farm Carbon Calculator. Tools were compared based on their input requirements, emission estimates and sensitivity to mitigation options. A hybrid model including emission estimates from AgRE Calc and sequestration calculations from the Bangor Tool were then chosen to calculate baseline emissions. Mitigation scenarios for each farm were created. Mitigation measures and abatement potentials were sourced from the most recent Marginal Abatement Cost Curve. The reduction in emissions achieved and area of woodland needed for offsetting to reach net zero were noted and the effect on production assessed.
Results: Carbon accounting tools have notable differences in emissions estimates (Figure 1) and therefore footprints from different tools are not directly comparable. The application of mitigation measures was projected to reduce emissions by an average of around 30% across all farms. After implementing these measures, the area of farm needed for woodland to off-set (via sequestration) remaining emissions ranged from 15-50%. Therefore, at present, achieving net zero would have a significant effect on production through the reduction in livestock numbers required to 'free' land for offsetting purposes.
Conclusion: Urgent action must be taken to improve livestock farming's contribution to the net zero target due to its critical role in Welsh society and economy. Calculating carbon footprints of farms is a key first step, but a standardised carbon accounting tool is required to understand both baseline farm emissions and the impacts of mitigation measures. However, mitigation measures alone will not sufficiently reduce emissions, therefore enhancing sequestration through afforestation will be needed. The subsequent impacts of this on production capacity will need to be considered.

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15. Development of young horses until one year of age when the dam was exposed to blue monochromatic light directed at one eye during pregnancy

A. Lutzer [a,*], C. Nagel [b], J. Aurich [c], B. Murphy [d], C Aurich [a]

[a] Centre for Artificial Insemination and Embryo Transfer, Vetmeduni Vienna, Vienna, Austria
[b] Graf Lehndorff Institute for Equine Science, Vetmeduni Vienna, Neustadt (Dosse), Germany
[c] Obstetrics, Gynaecology and Andrology, Vetmeduni Vienna, Vienna, Austria
[d] School of Agriculture and Food Science, University College Dublin, Dublin, Ireland

* Corresponding author. A. Lutzer.

Application: There are no detrimental effects of blue LED light treatment of pregnant mares with regard to the size or health status of their offspring. This is of importance because foal size has been associated with the horse's later performance potential in racing and equestrian sports.
Introduction: In horses, light programmes transmitted via blue LED light directed at one eye with head-worn individual light masks (Equilume, Kildare, Ireland) are equally effective to stabling mares under light with regard to advancing the breeding season (Murphy et al., 2014). When the treatment was applied to pregnant mares from the mid of December, it shortened gestation length and resulted in the birth of foals with lower wither heights, similar weight and reduced hair length compared to controls (Lutzer et al., 2022). The treatment can only be recommended when foals develop normally and do not differ in size from control foals when they are sold at yearling sales or selected as future sport horses.
Materials and methods: We have analysed postnatal development of foals born to either blue LED light-treated (n = 20) or control mares (n = 20). Weight was measured with an electronic horse scale and height at withers, chest circumference, distance from fetlock to carpal joint, distance from

carpal joint to elbow and cannon bone circumference were determined on days 1, 6, 15, 30 and at 2, 4, 6, 8, 10 and 12 months, respectively. Length of the guard hair was measured on the same days. Heart rate and the heart rate variability parameter RMSSD (root mean square of successive beat-to-beat differences) were recorded (Polar V800, Polar, Kempele, Finland). Statistical comparisons were made by one-way analysis of variance using a general linear model (GLM) for repeated measures with time (age) as within subject factor and mare treatment (blue LED light and control) as between subject factor (IBM SPSS 26). Results are given as mean ± SEM.

Results: Foals were born between February and May with a gestation length of 333 ± 5 and 338 ± 8 days in blue LED light and control pregnancies, respectively ($P < 0.05$). Heart rate ($P < 0.001$) and HRV ($P = 0.002$) increased until 6 days of age but never differed between groups. At birth, the guard hair was shorter in foals born to treated mares ($P < 0.001$) but no differences between groups in hair coat length were observed beyond the age of two months. At birth and 6 days thereafter, wither height ($P < 0.01$) and elbow to carpus distance ($P < 0.05$) of control foals were higher than in foals born to blue LED light-treated mares. Height differences decreased over time and were no longer evident when foals were 10 and 12 months old (e.g. at 12 months wither height was 147 ± 1 and 148 ± 1 cm in blue light treated and control foals, respectively).

Conclusion: Blue LED light treatment of pregnant mares is without detrimental effects on postnatal foal growth and development.

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16. The effect of buffering systems on post-thaw characteristics of equine spermatozoa

F. Couldwell

School of Animal, Rural and Environmental Sciences, Brackenhurst Campus, NottinghamTrent University, Southwell, Nottinghamshire, UK

Application: No differences between conventional and alternative buffering systems were indicated in the post-thaw analysis of viability and motility of equine spermatozoa.

Introduction: The use of frozen semen is widespread due to its suitability for worldwide distribution (Crespilho et al., 2013). To limit cold shock damage to cells during freezing, an extender is used. Changes in pH occur during freezing, to resist these changes buffering agents are integral in extenders (Rasul et al., 2000). EDTA-Trisodium citrate buffers are used, due to the chelating agents and ability to prevent DNA degradation. This study was designed to compare post-thaw viability and motility characteristics between conventional buffering agents (EDTA-Trisodium citrate/INRA96®) and an alternative (ACES) to identify a suitable buffering system for equine spermatozoa.

Materials and methods: Three buffers were prepared: EDTA-Trisodium, ACES andINRA96® (IMV-Technologies, France). To these the following were added to prepare the extenders: egg yolk (20% v/v), α lactose monohydrate (5.5% w/v), glucose (1.5% w/v), N,N-Dimethylformamide (3% v/v), lincomycin-spectinomycin (150/300μg), penicillin (500IU), streptomycin (500μg). One ejaculate, from four stallions, was collected. Raw semen was diluted 1:1 in INRA96® and centrifuged on a density gradient medium at 1,000 X g for 20 minutes. The cell band was aspirated, and the sample split into three aliquots. The samples were resuspended with the extender treatments. Semen was loaded in 0.25ml straws, sealed (IMV-Technologies, France) and cooled to 5˚C for 25 minutes. Freezing was performed using a programmable freezing unit (Minitube, Germany). Straws were stored in liquid nitrogen and thawed in a water bath at 37˚C immediately before post thaw assessment. Viability was determined using the NucleoCounter® NC-100™ (ChemoMetec, Denmark) and was defined as the percentage of cells with membranes impermeable to propidium iodide. Total motility (%) and progressive motility (%) was determined using CASA (Hamilton Thorn motility analyser IVOS). Results are presented as mean ± SEM. Data for each variable were analysed by analysis of variance (ANOVA).

Results: No modification of extender was superior to another ($P > 0.05$). No significant differences ($P > 0.05$) were observed in viability, total motility, or progressive motility of spermatozoa between the extenders (Table 1).

Conclusions: Though differences were observed between individual stallion samples, no buffering system provided a significantly better means of cryoprotection. It can be concluded that, though buffering systems are integral to maintaining cell quality during cryopreservation, other components within the extender are of greater consequence. One such component, being egg yolk. The role of low-density lipoproteins, found in egg yolk, for protection of spermatozoa remains unclear. Optimisation of chemically formulated liposomes rather than those of animal origin would prove advantageous to freezing extender development.

Acknowledgement: The present study was supported by Stallion AI Services Ltd.

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Table 1
Concentration (x10^6 spermatozoa/ml) of viable, motile (Mot) and progressive (Prog) stallion sperm in extenders containing EDTA-Trisodium, ACES or INRA as the buffer (n = 4 ejaculates)

Buffer	Viability	Mot	Prog
EDTA-Trisodium	87.3 ± 13.89	96.35 ± 7.66	73.32 ± 8.69
ACES	84.9 ± 2.39	92.9 ± 10.92	77.17 ± 9.14
INRA	86.3 ± 13.58	87.62 ± 11.99	70.15 ± 11.18

17. New frontiers in Equine Reproduction- ART on the main stage

N. Lewis

University College Dublin, Ireland

Horses are one of the few species, beside humans, in which assisted reproductive technology (ART) has important clinical applications. In recent years interest in the use of ARTs such as ovum pick-up (OPU) and intracytoplasmic sperm injection (ICSI) has rapidly increased worldwide with more than 3000 procedures now being carried out annually in Europe alone. While there is established clinical success with the technology, there remains many unanswered questions that could improve the process and potentially maximise the health of the resulting offspring. The use of OPU/ICSI was first driven by breeders wanting to produce offspring from subfertile mares that repeatedly failed to produce embryos from conventional embryo transfer (ET) and/or from stallions with low fertility. Due to increased efficiency of the technology breeders are now using it to maximise mare genetics and access sought after stallions with limited availability of frozen semen. The first step in the process is Ovum pick up (OPU). OPU involves trans-vaginal aspiration of all visible follicles on the ovary. OPU can be performed throughout the year and then retrieved immature oocytes are shipped overnight to an ICSI laboratory. On arrival at the ICSI laboratory the oocytes are placed in maturation media for approximately 26-30 hours to promote resumption of meiosis. Approximately 60% of immature oocytes will reach Metaphase II and be suitable for sperm injection. A small section of a frozen semen straw from the chosen stallion is then thawed and semen is prepared for ICSI in order to select the most viable sperm cell. The injected oocytes are then allowed to develop in an incubator for 6-9 days until they reach the blastocyst stage. The blastocyst rate per injected oocyte is approx. 20% but can range from 0-100%. At this point they are either frozen or transferred fresh to a recipient mare. Approximately 75% of OPU sessions will result in production of at least 1 embryo, with the average number of embryos produced being 1.7-2. Transfer of ICSI embryos results in similar pregnancy rates to those for fresh embryos flushed from a mare (approx. 70%), however, there is a slightly higher embryo loss rate so the actual live foal rate per embryo transferred is closer to 50%. Assisted reproduction technologies aim to mimic the periconceptual environment. As such, it is important to make sure they are optimised to the best of our knowledge. In the horse, there is a paucity of species-specific optimisation of the in vitro embryo production (IVEP) process. It is clear that good blastocyst rates and foal production can occur under the current conditions and anecdotal evidence exists of excellent performance in the resulting adult horses. This indicates that the equine oocyte and embryo are able to adapt to culture conditions. However, as is becoming clear in other species, this adaptation can occur at the detriment of long-term health outcomes. These are indices which have not yet been examined for foals produced by equine ART and is an area of interest to the research group in UCD.

18. The impact of trainer curiosity on equine training method choice, learning theory awareness, and equine welfare

L. Harris [a,b,c]

[a] University Centre Sparsholt, Winchester, Hampshire, UK
[b] University Centre Reaseheath, Nantwich, Cheshire, UK
[c] Hartpury University, Hartpury, Gloucester, UK

Application: If horse trainers become more curious when exploring training method options, trainers could choose methods focusing on ethical horse training. Implementation of ethical learning theory approaches could aid in reducing the risk of horse wastage due to behavioural issues (Brown and Connor, 2017, Warren-Smith and McGreevy, 2008).
Introduction: Previous research has highlighted gaps in equine industry knowledge of learning theory (LT) (Warren-Smith and McGreevy, 2008, Brown and Connor, 2017). Greater curiosity may lead to people choosing training methods more focused on improving animal welfare and a greater understanding of learning processes. This study aimed to investigate the importance of human curiosity and training method choice reasoning on the understanding of LT.
Materials and methods: Respondents (n = 70) completed an online survey collecting information on equestrian training method use and LT knowledge. The target demographic included individuals who have ridden or worked with horses and all who submitted a response were included in the final data analysis. Respondents self-rated their awareness of LT on a Likert scale (1 no knowledge, 10 full knowledge), answered multiple choice LT terminology and multiple-choice training scenario questions. Statistical tests included Chi-squared for Association and General Linear Models (GLM). Level of curiosity and training method choice reasoning was measured. The curiosity level was categorised by the amount of training techniques used as identified by the respondent when asked, using a list of options that they could select multiple answers from, which methods they use e.g., 1 method given – not curious, 2 methods given – somewhat curious, 3 or more methods given– curious (Categories 1,2,3,4). Training method reasoning was categorised based on whether their explanation for method use was associated with 1 of 3 categories (1-always have used method, 2-for improving performance, 3-for improving horse welfare).
Results: A significant association was observed between level of curiosity and training method choice reasoning ($P = 0.013$). When level of curiosity rose, training method choice reasoning was directed to improving horse welfare. Respondents whose reasoning for method was 'always have done', recorded lower LT awareness ratings and scenario scores than respondents who chose methods based on improving horse performance or welfare ($T = -2.37$, $P = 0.021$; $T = -2.52$, $P = 0.014$).
Conclusion: Educational interventions could increase awareness by utilizing level of curiosity and promote ethical training methods, positively impacting equine welfare. Survey use and data analysis methods used provide certain limitations to the interpretation of the results including potential respondent bias by those with a behaviour interest, and a less accurate data analysis approach for categorical data. A change in analysis approach and consideration of survey limitations could be undertaken in future research developments.

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19. Altrenogest treatment reduces the stress response in young mares during their initial equestrian training

M. Kaps [a,*], A. Lutzer [a], M. Wulf [b], C. Nagel [b], J. Aurich [c], C. Aurich [a]

[a] Artificial Insemination and Embryo Transfer, Department for Small Animals and Horses, Vienna, Austria
[b] Graf Lehndorff Institute for Equine Science, Neustadt (Dosse), Germany
[c] Gynecology, Obstetrics and Andrology, Department for Small Animals and Horses, Vienna, Austria

* Corresponding author. M. Kaps.

Application: The results provide evidence that treatment with the progestin altrenogest reduces the stress response of female horses during initial equestrian training.
Introduction: Progestogens and their metabolites induce sedative-like effects in males and females of different species (Majewska et al., 1986). This was also associated with improved performance of animals in different behavioural tests (Martínez-Mota et al., 1999). In female horses, continuous treatment with the progestin altrenogest is often used to inhibit oestrus and associated problems with regard to their performance. The question arises if positive behavioural effects are just the result of suppressed estrous behaviour or if there is an additional sedative-like effect being beneficial to the horses' performance. We therefore investigated if altrenogest treatment reduces the stress response of young female horses during their initial equestrian training.
Materials and methods: Three-year-old warmblood mares (n = 11) were randomly assigned to treatment with altrenogest (group ALT; 0.044 mg/ kg once daily; n = 6) or sunflower oil (group control 10ml once daily; n = 5) for a duration of 12 weeks from the beginning of their initial equestrian training. Bodyweight and body condition score (BCS) were assessed before the start of training and at 4 week-intervals thereafter. At predefined steps of the training programme, the physiological stress parameters salivary cortisol concentration, heart rate and the heart rate variability parameter RMSSD (Root Mean Sum of Squared Distance) were determined (from 30 min before to 120 min after training at 15 min intervals). A trainer blinded to treatment scored the horses' performance in each training unit from 1 = very good to 6 = insufficient. Statistical analysis was done by analysis of variance (general linear model for repeated measures).
Results: Body weight of horses decreased after the initial start of training and then increased again, but this increase was greater in ALT mares than in controls (time × treatment $P < 0.05$). BCS decreased in both groups, stayed at a lower level in control mares but increased again in ALT mares (time × treatment $P < 0.05$). During all training units, an increase in salivary cortisol concentration and heart rate and a decrease in RMSSD was determined ($P < 0.001$). There was an interaction between training unit, time and treatment group ($P < 0.001$) with a lower increase of salivary cortisol in ALT mares in all training units assessed (e.g. first riding, at 15 min after start of the training ALT 4.0 ± 0.7, control 10.1 ± 2.7 ng/ml). Performance scores did not differ between groups (range ALT 1 to 3, CON 1 to 5, n.s.).
Conclusions: ALT treatment reduced the stress response of three-year-old mares to initial equestrian training. Because stress-induced avoidance reactions could be reduced, positive effects on performance are suggested during stressful events. This may be of relevance with regard to FEI (Federation equestre international) regulations because altrenogest treatment is permitted for mares but not for male horses. For individual mares highly susceptible to stress, altrenogest treatment might be a valuable tool to improve animal welfare conditions.

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20. Vehicles have got faster but the horse has stayed at the same speed – attitudes to road safety by equestrians

D. Pollard [a,*], T. Furtado [b]

[a] The British Horse Society, Kenilworth, Warwickshire, UK
[b] University of Liverpool, Neston, Cheshire, UK

* Corresponding author. D. Pollard.

Application: Equestrians felt particularly vulnerable on roads, mainly due to the behaviour of other road users and the infrastructure of the road network. Changes to road user behaviour and creating a more inclusive transport system would reduce perceived and actual risk but requires collaboration between road safety stakeholders, local authorities and government.
Introduction: Road use by UK's equestrians is common, however, over 70% report having had a near-miss in the previous year while over 6% report sustaining injury (Pollard and Grewar, 2020, Pollard and Furtado, 2021, Trump and Parkin, 2020). The aim of this study was to collect qualitative data from equestrians throughout the UK regarding attitudes to road safety, experiences while using roads with their horses and opinions on how road safety could be improved.
Materials and methods: Equestrians were recruited to 12 regional focus groups and 9 semi-structured interviews, held virtually between December 2020 and April 2021, conducted by the lead author. All conversations were recorded (with consent), transcribed and anonymised. Analysis was conducted using inductive thematic analysis, with constant comparison between the two authors to ensure consistency of coding approach.

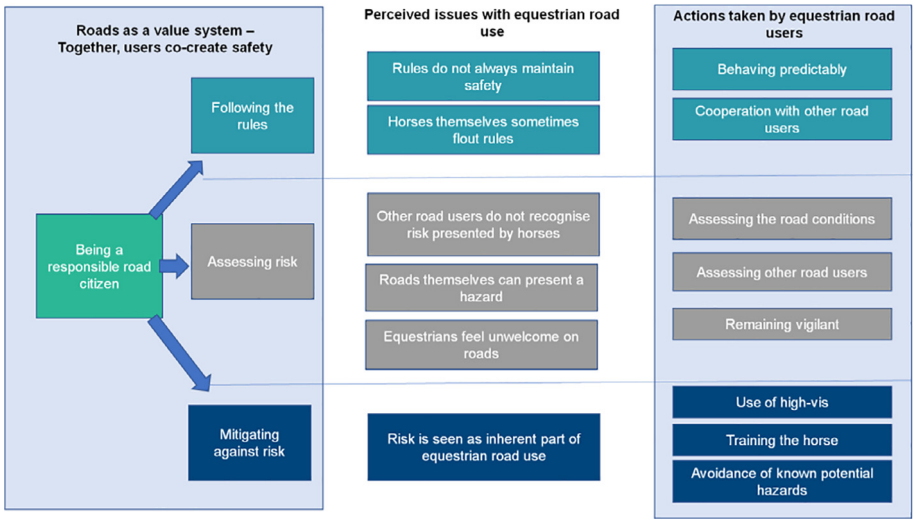

Figure 1. A conceptual framework of the themes developed from qualitative analysis of equestrian road safety focus group and interview narratives.

Results: A total of 71 equestrians participated; 62 in the focus groups and nine in the interviews. Participant ages ranged between 18 and 74 years, with most (52.2%, n = 37) being between 45 - 64 years. Most were female (90.1%, n = 64/71) with more than 30 years of equestrian experience (59.2%, n = 42). A conceptual framework of the themes developed is presented in Figure 1. The main themes highlighted that road use relies on a culture of shared responsibility, yet equestrians felt at risk despite promoting use of responsible behaviours. Horses were perceived as liminal road users (e.g. are often unfamiliar to others and do not follow man-made rules), leading to the need for extensive and personalised risk mitigation and changing the status quo (e.g. a more inclusive road network, behaviour change and incident reporting).
Conclusions: Equestrians felt strongly that road safety was a shared responsibility between all road users but due to a general lack of awareness and recognition of horses as living road users they felt particularly vulnerable and roads became dangerous places. This was exacerbated by a transport system that was not perceived to place the safety of equestrians at a high priority. Creating a safer and more inclusive road network and improving enforcement of road safety legislation would create a safer environment for all road users, but particularly the vulnerable ones.
Acknowledgement: The Department for Transport for funding. Colleagues at the British Horse Society for support and all the equestrians that contributed.

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21. Equine Behavioral Neuroscience: research goals for the next decade and beyond

A. Hemmings

Royal Agricultural University, UK

In order for the horse to behave appropriately within a dynamic environment, information is gathered from sensory receptors, and is conveyed via the peripheral nervous system to the brain. Following a process of cognition influenced by experience and innate genetic programming, a corresponding motor response ensues. Given the requirement for domestic horses to assimilate taught associations and respond correctly to cues, an understanding of cognitive neuroscience will no doubt bolster progressive training strategies. However, despite this putative linkage between brain function and training, few studies have sought to investigate the neural underpin of equine behavioural processes. As such, the primary aim of this paper is to firstly summarise the current state of knowledge, and then, using data from better studied species, recommend future research goals. Given the logistical and ethical dimensions of direct measurements of brain function, most equine studies have traditionally focussed on quantification of centrally released neurotransmitters in the peripheral bloodstream. Such endeavours are characterised by lack of repeatability and vagaries of interpretation. More recently, behavioural probes using cognitive testing approaches to analyse basal ganglia function have yielded higher quality data. Furthermore, other indicators such as spontaneous eye blink rate could provide non-invasive measures of behaviourally important neurotransmitters, like dopamine for instance. Finally, with an eye towards research horizons, genetic tests of brain function contain vast potential. For example, using genetic material extracted from hair, we are on the verge of predicting learning potential, food intake, stress susceptibility and aggressive tendencies. When interpreted carefully, this information could be used to direct breeding strategies, or to screen young stock such that bespoke management and training programmes can be implemented from an early age.

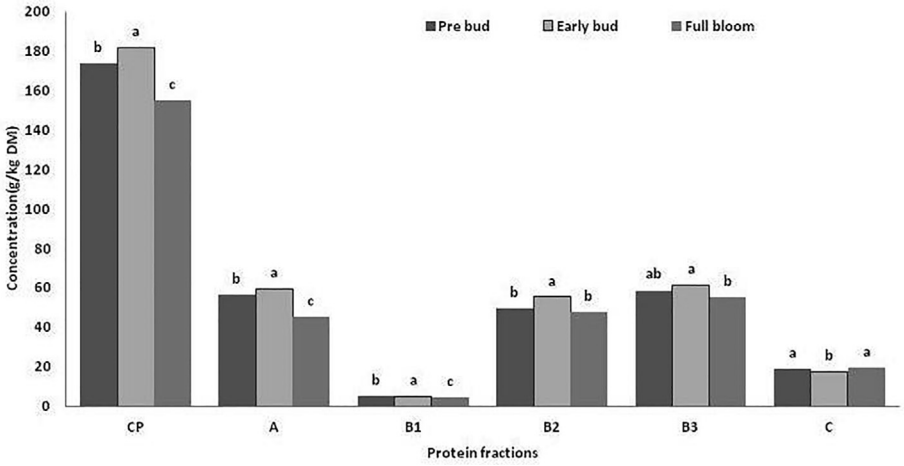

Figure 1. Effect of stage of growth on the protein fractions (g/ kg DM) of soybean herbage.

22. Protein fraction of soybean herbage as influenced by the stage of growth

P. Dele [a,*], B. Akinyemi [a], O. Omikunle [a], F. Enwete [a], O. Aiyesa [a], O. Awoola [a], C. Anotaenwere [a], T. Amole [b], A. Jolaosho [a], Arigbede [a]

[a] Federal University of Agriculture, Abeokuta, Abeokuta, Ogun State, Nigeria
[b] International Livestock Research Institute, Ibadan, OYO, Nigeria

* Corresponding author. P. Dele.

Application: Harvesting soybean herbage at the early bud stage of growth gives the highest yield of protein.
Introduction: Forage legumes are known to be a good source of quality feed for ruminant animals especially for their high crude protein content. The inclusion of legumes in the diets of ruminant either in their fresh or conserved forms have been attested to promote high productivity (Dele et al., 2019). The stages of growth have been known to affect the quality of the legumes. Therefore, this study is aimed to evaluate the protein fractions as influenced by the stage of growth of soybean herbage.
Materials and methods: This experiment was carried out at the Pasture Farm Units, Federal University of Agriculture, Abeokuta and laboratory of International Livestock Research Institute, Ibadan, Nigeria. The experiment was a randomized complete block design with three treatments based on growth stages (pre bud; early bud and full bloom) and was replicated four times. The seed of soybean (TGx 1951-3F) was sown in July 2020, and herbage harvested at 10 cm above ground at each respective stage of growth. The harvested samples were weighed, oven-dried at 60°C for 48 hours and milled. The samples were scanned with NIRS for the crude protein content using the equation for the feed sample analysis based on the mixed feed global calibration model using the software package (Win ISI II FOSS, Denmark, Model NIRS™ 5000) calibrated against convectional wet laboratory analysis. The protein fractions are the nonprotein nitrogen (fraction A), true protein rapidly degraded in the rumen (fraction B1), true protein degraded in the rumen at a moderate rate (fraction B2), true protein associated with the cell wall and slowly degraded in the rumen (fraction B3) and insoluble protein (fraction C) were determined according to Licitra et al. (1996). The statistical evaluation was done by the analysis of variance (ANOVA) and means separated by Tukey HSD at 0.05 probability level using SAS® 9.0 version and visualized using Microsoft Excel.
Results: The crude protein content was significantly ($P < 0.05$) affected with the herbage harvested at the early bud stage of growth being higher than others. All the protein fractions were significantly ($P < 0.05$) influenced by the stage of growth. There was higher content across the protein fractions for the soybean harvested at the early bud stage except for the fraction C where the early bud values were significantly lower.
Conclusion: The protein fractions of the soybean were found to be influenced by the Stage of growth and suggesting that harvesting at early bud is recommended.

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23. Dissolution kinetics of zinc, copper, and manganese sources in rumen fluid

V. Kromm [a,*], A. Hanreich [b], A. Romeo [a]

[a] Animine, Meythet, France
[b] Biopract GmbH, Berlin, Germany

* Corresponding author. V. Kromm.

Application: Compounds of essential trace minerals (zinc, copper, and manganese) have distinct dissolution kinetics which may lead to different interactions with other nutrients after solubilization in the rumen fluid. Their bio-accessibility for microorganisms is consequently variable.

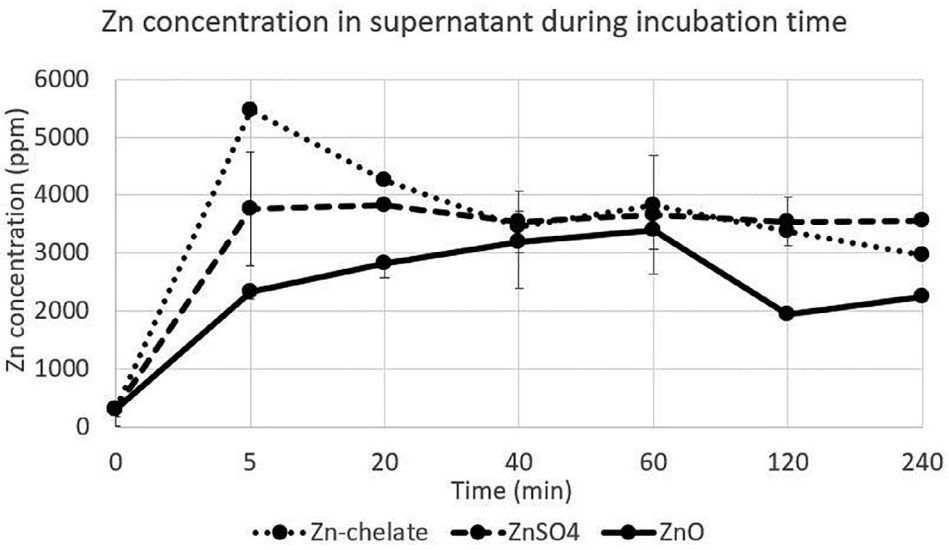

Figure 1. Dissolution kinetics of Zn sources in rumen fluid.

Introduction: Distinct trace mineral sources have different physicochemical properties and different solubility values. Those differences will potentially impact on their absorption and interaction in the rumen. However, their behaviour in water cannot mimic the mechanisms observed in vivo, in the rumen fluid. The objective of this study was to measure the dissolution kinetics of zinc, copper, and manganese from different sources in rumen fluid, before their absorption by microorganisms.
Materials and methods: The rumen fluid was sampled from fistulated sheep before morning feeding. It was centrifuged at 7 000 g for 15 minutes in order to remove microorganisms. Zinc (Zn), copper (Cu), and manganese (Mn) were added to the rumen fluid in separated tubes for each tested source: chelates of amino acids, oxides (ZnO HiZox® for zinc, Cu_2O CoRouge® for copper, MnO ManGrin® for manganese), and sulfates, with a final concentration of 30 mg/L in rumen fluid incubations. All tubes were incubated for 4 hat 39°C under stirring. For the analyses of mineral concentrations in supernatant, two aliquots of 200 mL were used (repeated sampling), with samples taken 5, 20, 40, 60, 120, and 240 minutes after set-up. Samples were centrifuged at 10, 000 g for 15 minutes and frozen. For the analyses of mineral concentrations in solid phase, one aliquot per tube was sampled 240 minutes after set-up. Samples were centrifuged at 10, 000 g for 15 minutes, then the pellet was collected in water and dried for 48 h at 105°C. The mass of the dried pellet was determined. In supernatant and in pellet, minerals concentrations were analysed by ICP-OES in an external lab.
Results: Variation between the replicate samples were in an acceptable range. For zinc, chelate source dissolved faster than sulfate and oxide (Figure 1). In the solid fraction, 82% (zinc sulfate) and 95% (zinc oxide) of zinc remained undissolved. For copper, chelate and sulfate sources were dissolved after 5 minutes and the concentration remained stable until 240 minutes. Cu_2O showed a different pattern and dissolved steadily over time. After 240 minutes, 14% (chelate), 44% (Cu_2O), and 53% (sulfate) of copper remained in the solid phase. For manganese, the three sources showed different patterns. Concentration of soluble manganese from chelate decreased over time, and of sulfate it increased. The MnO source did not seem to dissolve over the incubation time of four hours. It was shown that 36% (sulfate), 55% (chelate), and 90% (oxide) of manganese remained undissolved or matrix-bound in the pellet.
Conclusions: Data collected showed differences in overall dissolution of the products in rumen fluid. Dissolution kinetics and proportion of undissolved product differ within the minerals and also between sources, which may lead to different mode of actions into the rumen.

24. Nutrient composition and in vitro degradability of fungal treated crop residues for their use in ruminant diets

O.J. Idowu [a,*], O.O. Adelusi [b], R.O. Tanimowo [a], S.O. Rafiu [a], T.A. Babatunde [a], B.A. Adeoye [a], V.O.A. Ojo [a]

[a] Department of Pasture and Range Management, College of Animal Science and Livestock Production, Federal University of Agriculture, Abeokuta (FUNAAB), Abeokuta, Ogun, Nigeria
[b] Department of Animal Nutrition, College of Animal Science and Livestock Production, Federal University of Agriculture, Abeokuta (FUNAAB), Abeokuta, Ogun, Nigeria

* Corresponding author. O.J. Idowu.

Application: A promising approach for provision of high nutritive quality feed for sustained ruminant production during the dry season is the use of aerobic fungi degraded crop residues.
Introduction: In tropical regions during the dry season, crop residues seems to be one of the most abundant ruminant feed. However its low nutritive quality makes it unable to meet the nutrient requirements for ruminant production and performance. To improve their quality, the use of aerobic white rot fungi looks promising. The fungi degrade lignocellulose by opening up internal forage structure for breakdown by rumen microbes thus increasing feed utilisation for improved ruminant production (Mahesh and Mohini, 2013). This experiment determined the ability of three aerobic fungi to improve the in vitro degradability of selected crop residues for their use in ruminant diet.
Materials and methods: Three aerobic fungi (Pleurotus ostreatus, Pleurotus florida, and Pleurotus sajor-caju) were purchased from Forestry Research Institute of Nigeria (FRIN) and were inoculated on cowpea chaff, millet chaff, groundnut haulm, and maize Stover. About 10g of each residue was

Table 1
The forage and fungal effects on the crop residues chemical composition and IVGP.

	Chemical composition (g / kg DM)				IVGP (ml / g DM)		
Forages	DM	Ash	CP	NDF	24h	48h	72h
Groundnut haulm	899.09^{c}	130.59^{a}	117.64^{a}	700.96^{c}	50.02^{b}	78.74^{b}	92.91^{b}
Cowpea chaff	902.01^{bc}	92.65^{c}	67.27^{b}	718.37^{b}	68.24^{a}	109.40^{a}	133.28^{a}
Maize Stover	938.46^{a}	72.69^{a}	32.66^{c}	717.66^{b}	15.65^{d}	43.36^{d}	68.69^{c}
Millet chaff	905.22^{b}	98.82^{b}	27.14^{d}	764.81^{a}	31.50^{c}	64.02^{c}	92.98^{b}
SEM	7.32	6.38	9.74	8.7	8.2	9.77	9.39
P-value <	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Fungi							
Intact	909.16^{c}	85.52^{d}	50.90^{b}	753.48^{a}	57.34^{a}	97.86^{a}	106.89^{a}
Control	904.56^{c}	87.27^{d}	54.77^{b}	746.34^{b}	57.52^{a}	83.11^{b}	87.98^{b}
P. ostreatus	914.13^{b}	106.97^{b}	68.32^{a}	711.60^{c}	42.74^{b}	78.51^{b}	108.76^{a}
P. florida	920.37^{a}	102.63^{c}	65.29^{a}	713.75^{c}	20.09^{c}	52.34^{c}	86.46^{b}
P. sajor-caju	907.76^{c}	111.03^{a}	66.62^{a}	702.09^{d}	29.05^{c}	57.57^{c}	94.73^{b}
SEM	8.19	7.14	10.89	9.73	9.17	10.92	10.5
P-value <	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

weighed individually into 250 ml conical flask, soaked for 24 hours, drained, autoclaved, and inoculated with the spawn (2% w/w) at room temperature for 20 days. Control flasks were provided (i.e. autoclaved residues without fungi (control) and un-autoclaved residues (intact)). After inoculation the flasks and its content were dried at 60°C and milled sub-samples were taken for chemical analyses and in vitro gas production (IVGP). The data were then statistically analysed using two way analysis of variance in Minitab16 software and means were separated using Tukey's post hoc test.
Results: The fungus significantly ($P < 0.001$) decreased the Dry matter-DM, Neutral detergent fibre-NDF and increased the ash and Crude protein-CP contents of the residues. Cowpea chaff showed better degradability when treated with P.ostreatus.
Conclusion: *P. ostreatus* improved the nutritional quality of the residues especially cowpea chaff, and such improved feeds in ruminant diets is expected to produce better ruminants' performance and production through increased intake and digestibility.

Acknowledgement: Federal University of Agriculture, Abeokuta, Nigeria for facility used.

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25. Nutrient Composition and in vitro degradability of fungal degraded grasses for their use in ruminant diets

O.J. Idowu [a,*], T.O. Wusu [a], S.S. Oke [a], O.E. Fagbemi [a], E.I. Kehinde [a], R.O. Tanimowo [a], O.O. Adelusi [b]

[a] Department of Pasture and Range Management, College of Animal Science and Livestock Production, Federal University of Agriculture, Abeokuta (FUNAAB), Abeokuta, Ogun, Nigeria
[b] Department of Animal Nutrition, College of Animal Science and Livestock Production, Federal University of Agriculture, Abeokuta (FUNAAB), Abeokuta, Ogun, Nigeria

* Corresponding author. O.J. Idowu.

Application: The use of aerobic fungi degraded grass is a possible way of obtaining improved feed for ruminants dry season feeding.
Introduction: During the dry season in most tropical countries, most herbaceous forages do not persist due to the harshness of weather. However some grasses do persist due to their inherent quality but they are of low nutritive quality and unable to meet ruminants' nutrient requirements needed for

Table 1
The forage and fungal effects on the grasses chemical composition and in vitro gas production.

	Chemical composition (g / kg DM)				IVGP (ml / g DM)		
Forages	DM	Ash	CP	NDF	24h	48h	72h
B. decumbens	948.36^{a}	100.22^{b}	101.77^{a}	701.10^{d}	15.12^{c}	41.02^{b}	62.86^{ab}
P. purpureum	895.86^{c}	112.81^{a}	65.59^{b}	725.74^{c}	30.71^{a}	48.39^{a}	58.45^{b}
P. maximum var. ntchisi	926.23^{b}	98.36^{b}	24.43^{d}	770.27^{b}	23.23^{b}	50.85^{a}	68.81^{a}
P.maximum var. local	948.13^{a}	62.92^{c}	30.21^{c}	803.28^{a}	6.20^{d}	17.70^{c}	32.21^{c}
SEM	5.99	5.93	8.99	11.12	3.62	5.12	5.07
P-value <	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Fungi							
Intact	933.96^{a}	77.93^{d}	38.96^{c}	769.23^{a}	31.72^{a}	53.27^{a}	56.16^{abc}
Control	929.35^{bc}	83.63^{c}	45.40^{b}	763.48^{b}	20.03^{b}	43.45^{b}	52.70^{bc}
P. ostreatus	925.53^{c}	100.46^{b}	61.89^{a}	731.98^{e}	12.08^{c}	32.29^{c}	62.27^{a}
P. florida	926.94^{c}	101.73^{ab}	64.17^{a}	748.96^{c}	12.42^{c}	27.60^{c}	48.53^{c}
P. sajor-caju	932.46^{ab}	104.14^{a}	67.08^{a}	736.83^{d}	17.83^{b}	40.84^{b}	58.25^{ab}
SEM	6.71	6.63	10.06	12.43	4.05	5.73	5.66
P-value <	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

production and performance. To utilise them in animal feeding they require a nutrient upgrade and the use of aerobic fungi have been found capable of achieving such (Sindhu et al., 2016). The fungi acts by degrading the structural carbohydrate, thus improving palatability, intake and digestibility needed for better feed utilization. This experiment investigated the influence of three aerobic fungi on the in vitro degradability of selected grasses for their use in ruminant diet.

Material and methods: Four grasses (Brachiaria decumbens-BD, Pennisetum purpureum-PP, and two Panicum maximum varieties (ntchisii-PMN and local-PM)) were harvested in the dry season for upgrade by three aerobic fungi (Pleurotus ostreatus, Pleurotus florida, and Pleurotus sajor-caju) respectively. Approximately 10g of each chopped grass was weighed into 250 ml conical flask, soaked, drained, autoclaved, and inoculated with the spawn (2% w/w) at room temperature for 20 days. This was done alongside flasks containing each autoclaved grass without fungi (control) and un-autoclaved grass (intact). After the designated day, each flask with its content was dried at 60°C, milled and sub-samples taken for chemical analyses and in vitro gas production (IVGP). Data collected were statistically analysed using General Linear Model in Minitab16 software and means were separated using Tukey's post hoc test.

Results: The fungi reduced the Neutral detergent fibre-NDF and increased the crude protein-CP and ash contents of the grasses respectively as well as increased their degradability with P. ostreatus performing better on PMN.

Conclusion: Most of the fungi improved the grasses nutritive quality with the exception of P. florida. P. ostreatus producing better upgrade than others.

Acknowledgement: Federal University of Agriculture, Abeokuta, Nigeria for facility used.

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26. Inclusion of Bullock leaves decreased the in vitro total gas and methane production of cassava-rich diet

O.O. Adelusi *, S.R.Y. Aderinboye, S.T. Adedara, B. Okunade, C.F.I. Onwuka

Federal University of Agriculture, Abeokuta, Ogun, Nigeria

* Corresponding author. O.O. Adelusi.

Application: Air-dried leaves of Bullock (*Parquetina nigrescens*) exhibited properties to mitigate methanogenesis. The volume of methane and total gas reduced with increasing level of inclusion.

Introduction: Adapting to climate change effects that has resulted in ruminants subsisting on poor quality forage necessitated the use of crop residues in formulating diets to enhance animal performance during periods of prolonged dry season. Cassava peels and leaves, often discarded as waste, represents a large and available residue base being maximised as such. Parquetina nigrescens contain phytochemicals such as alkaloids, flavonoids, saponins, tannins and anthraquinones (Grace et al., 2017), which can serve as a dietary strategy for methane mitigation by affecting rumen fermentation and manipulating rumen activities. Thus, the study evaluated the in vitro total gas and methane production of cassava-rich diet incubated with varying levels of Bullock leaves.

Materials and methods: Six inclusion levels (0 g/ kg, 5 g/ kg, 10 g/ kg, 15 g/ kg, 20 g/ kg and 25 g/ kg) of ground air-dried leaves of Bullock (Parquetina nigrescens) were added to a formulated diet rich in cassava peel (50%) and leaves (25%). The experiment was set out as a completely randomized design with six treatments. The in vitro gas production technique employed was that described by Menke and Steingass (1988). A 200mg sample of diet substrate weighed into a fibre bag was replicated eight times (n = 8) for each treatment and were placed into 60ml calibrated syringes. Twenty millilitre of the buffered inoculum was then added to each syringe containing the ground samples and were then positioned in an incubator kept at 39°C. Blank syringes containing 20ml of the buffered inoculums only was included as control. Gas volume was recorded following; 0,

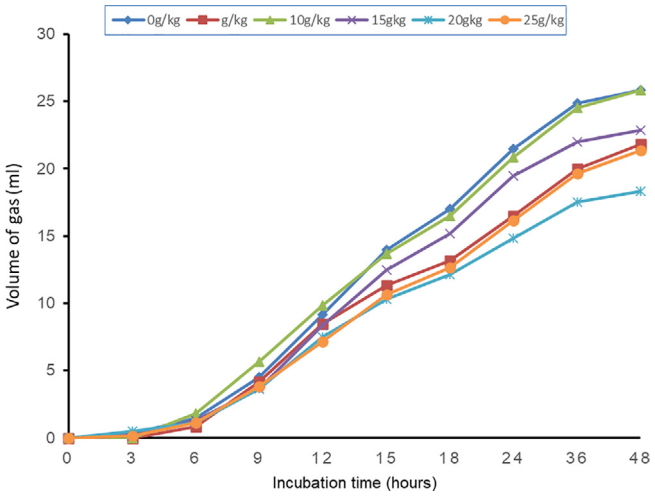

Figure 1. Effect of varying levels of Bullock leaves on total gas production.

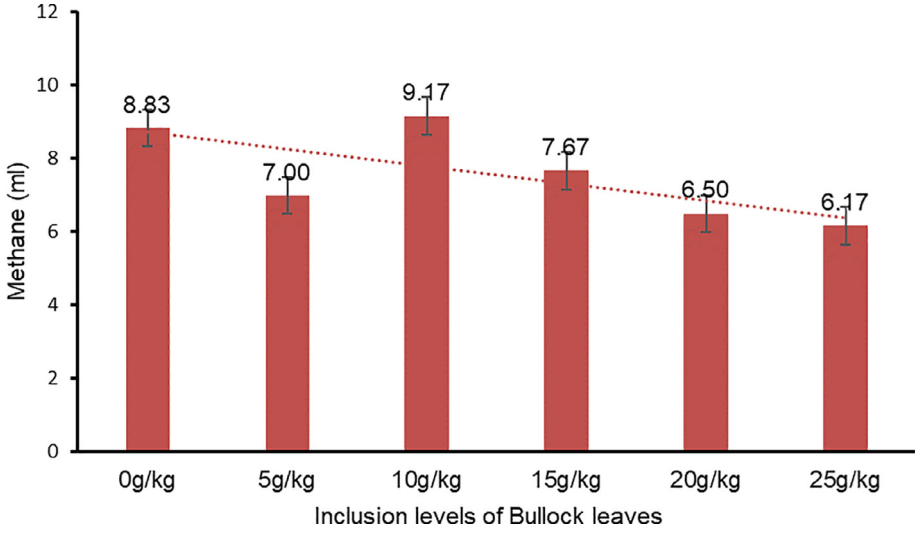

Figure 2. Effect of varying levels of Bullock leaves on methane production.

4, 8, 12, 16, 20, 24 and 48 hours of incubation and methane (CH_4) gas was determined by introducing 4ml of NaOH into the gas syringes. Data obtained were assessed for normal distribution and then subjected to one-way analysis of variance with significant means separated at $P < 0.05$ (Duncan's multiple range test) using the SPSS 23 software.

Results: Figure 1 showed that as the inclusion of Bullock leaves increased, the total gas volume reduced, with the lowest ($P < 0.05$) gas production value obtained at 20 g/ kg. The effect of inclusion of Bullock leaves on methane gas is presented in Figure 2. It shows a continuous reduction in methane as the inclusion of leaves increased. The lowest ($P < 0.05$) value of 6.17 ml was obtained at 25 g/kg Bullock.

Conclusion: Air-dried leaves of Parquetina nigrescens exhibited properties to mitigate methanogenesis among all treatments and have a prospect for future use to reduce ruminal gas production, improve energy and nutrient utilization. Inclusion of levels up 25 g/ kg level is recommended for ruminant diets.

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27. *In vitro* anthelmintic activity of Tropical almond specie plant parts used by Agropastoralists for treating intestinal worms in Cattle

I. Busari [a,*], K. Soetan [b], O. Aiyelaagbe [c], O. Babayemi [a]

[a] Department of Animal Science, University of Ibadan, Ibadan, Nigeria
[b] Department of Veterinary Physiology and Biochemistry, University of Ibadan, Ibadan, Nigeria
[c] Department of Chemistry, University of Ibadan, Ibadan, Nigeria

* Corresponding author. I. Busari.

Application: Botanical plants extracts could be used in place of conventional anthelmintic drugs. The leaf, bark, and root extracts of Tropical almond specie (Terminalia glaucescens) showed high activity against Haemonchosis in cattle. The plant extract is safe for use. It supports biodiversity, sustainability, and particularly ecological system.

Introduction: Endoparasite challenge is a major cause of economic loss in ruminant production. Ethnoveterinary Plants (EvPs) have been used by agropastoralists to control the effect of endoparasites in place of conventional anthelmintics which is expensive, and because of resistance to some of these drugs by pathogens (Busari et al., 2021). Botanical plant extracts have been used in treating Haemonchosis in cattle (Busari et al., 2021). However, information on the use of EvPs as anthelmintic has not been well documented. Hence, in vitro anthelmintic activity of Tropical almond specie plant parts used by agropastoralists was investigated.

Materials and methods: A structured questionnaire ($n = 50$) were administered to agropastoralists to elicit information on the use of EvPs for controlling helminthiasis in cattle. The EvPs used by agropastoralists were collected and identified at the Herbarium of Department of Botany, University of Ibadan. The EvPs were screened and the least utilised by the agropastoralists was selected. The parts were separately pulverised and cold-macerated with methanol to obtain crude extracts. The extracts were quantitatively (μg/mL) analysed for phytochemical constituents using standard procedure. Extracts of the plant leaf, bark and root were assayed for anthelmintic activity on Haemonchus contortus at various concentrations (μg/mL): 100.00, 50.00, 25.00, 12.50, 6.25 at 48-, 96-, and 144-hours using egg hatch inhibition technique. Experimental design was completely randomised in a $3 \times 3 \times 5$ factorial arrangement. Data were analysed using descriptive statistics and ANOVA at 0.05.

Results: Occurrence of helminthiasis during raining season was reported by 72% respondents, while 84% used EvPs in treating ruminants. Among 28 EvPs identified, Tropical almond specie was the least utilised by the agropastoralists. Tropical almond specie leaf contained 0.43 ± 0.02 (tannins), 0.10 ± 0.02 (alkaloids), 2.02 ± 0.17 (phenols), 0.35 ± 0.01 (flavonoids) and 1.32 ± 0.22 saponins. Egg-hatch of Haemonchus contortus was

significantly inhibited by bark extract (73.28 ± 2.04) compared to 63.53 ± 1.67 and 44.79 ± 1.21 for leaf and root, respectively. The extracts of Tropical almond specie at 100.00μg/mL, 50.00μg/mL and 25.00μg/mL exhibited significantly higher egg-hatch (75.73 ± 4.87, 70.32 ± 2.46 and 69.49 ± 3.91) compared to 55.08 ± 1.67 and 32.05 ± 2.41 for 12.50μg/mL and 6.25μg/mL, respectively. Percentage egg-hatch inhibition (70.38 ± 1.52) at 144hrs was significantly higher than 58.02 ± 4.65 and 53.21 ± 3.11 at 96hrs and 48hrs, respectively.
Conclusion: A 100.00 μg/mL concentration of Tropical almond specie bark extract had anthelmintic effect on Haemonchus contortus at 144hrs post-administration and is recommended for treating Helminthiasis in cattle. Further study should be done on the in vivo activity of the plant.

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28. The Role of Grasslands to deliver Biodiversity and Protect Soils in Sustainable Agri-food Production

C. Marley

IBERS, Aberystwyth University, United Kingdom

Grasslands cover approximately 25% of the terrestrial Earth surface (3.5 billion ha). Their role is multifunctional, providing both primary feed for forage-based livestock systems, whilst also providing additional ecosystem services, including storing carbon reserves, water management and biodiversity. Current livestock systems occupy about one third of available agricultural lands globally and contribute 40% of global agricultural output value. Globally, livestock production systems provide one third of the protein consumed by humans, with projected increasing demands for animal products due to population growth and increasing consumption per capita. Balancing increasing livestock production against increasing consumer demands to understand the impact of livestock products on the environment requires rapid scientific innovation as we strive to achieve the UK's ambition of net zero carbon by 2050. Grasslands containing diverse forages have the potential to improve agricultural productivity and increase biodiversity. To address the need for net zero agri-food systems, research will be presented on how different forages can help to deliver biodiversity and to protect soils in sustainable net-zero agri-food production systems.

29. Monitoring insect biodiversity on livestock farms using advanced sound analysis

C. Woodward

AgriSound, UK

The UK is one of the least biodiverse countries in Europe as a result of intense urbanisation, agricultural intensification and mass industrialization over the past few centuries. The introduction of the new Defra Environment and Land Management Scheme (ELMS) aims in part to address the biodiversity crisis in the UK within farming systems and will begin to incentivise farmers for taking action to reverse the decline of pollinators, birds and other wildlife. However, targeting interventions to the areas of greatest need remains challenging. Currently, farmers rely on manual assessments of biodiversity which are subjective and prone to errors under poor weather conditions. Whilst several camera-based trap systems exist for monitoring birds and large animals, very few are capable of monitoring insects and most come with high capital costs due to the need for high grade cameras and require power or high-speed internet connections. AgriSound has developed a pioneering low-cost automated monitoring device that uses bioacoustics to listen out for the sounds of pollinators as an alternative to vision-based techniques. Data is relayed back to a simple web app to help farmers to target interventions to pollinator deficit areas. For livestock farmers, information can be used to measure the impact of existing efforts to protect biodiversity e.g. maintaining hedgerows, to identifying areas that could benefit from the introduction of new biodiversity-enhancing measures e.g. planting or establishment of wildflowers in non-productive areas or creation of new bee habitats. Discussions with livestock farmers has shown that farmers know they have a key role to play in protecting biodiversity. Preventing overgrazing, protecting field margins, maintaining hedgerows and using pollen and nectar rich cover crops where possible are all simple measures that can be taken by farmers and quantified to help encourage local pollinator communities to recover. In return, increasing pollinators helps improve to local ecosystems and improves land value and by extension rural communities. AgriSound is working with farmers to monitor the impact of changing farm management practices and intends to share learnings annually via a 'State of the Nation's Pollinators' report.

30. Apparent nutrient digestibility of broiler chickens fed diets supplemented with probiotics

K.E. Akande *, O.J. Alabi, I.T. Adigun

Department of Animal Production, Federal University of Technology, Minna, Niger State, Nigeria

* Corresponding author. K.E. Akande.

Application: Probiotics may be capable of serving as a potential feed supplement for improving nutrient digestibility in broiler chickens, thereby leading to better nutrient utilization and general well-being of birds without residual effect in the meat.
Introduction: Probiotics have been reported to play significant roles in nutrient digestibility and utilization in poultry production (Jha et al., 2020). It also supports a healthy digestive system, thereby stimulating the general performance and health of animals. He et al. (2019) reported improvement in the apparent total tract digestibility of dry matter, organic matter, crude protein and gross energy of broilers fed probiotics. However, there are limited studies on the effect of the use of *Lactobacillus fermentum* as a probiotic (a prominent gram-positive bacteria). Therefore, this research aims to justify the utilization of *Lactobacillus fermentum* probiotics in enhancing the digestibility of nutrients in broilers.

Table 1
Apparent nutrient digestibility of broilers fed diets supplemented with probiotics.

Parameters	$LF_{0.00}$	$LF_{.1.25}$	$LF_{.2.25}$	$LF_{3.75}$	$LF_{5.00}$	SEM	P-value
Dry matter	98.06[a]	98.00[ab]	96.99[b]	96.77[c]	96.75[d]	0.166	0.001
Crude protein	99.17[a]	99.13[ab]	98.27[b]	97.71[d]	97.88[c]	0.171	0.001
Crude fibre	99.07[a]	98.87[b]	98.88[ab]	98.91[ab]	96.85[c]	0.229	0.010
Ether extract	99.15[c]	99.62[a]	99.62[a]	98.78[d]	99.18[d]	0.099	0.001
Ash	95.07[c]	96.78[a]	95.71[b]	94.96[d]	92.65[e]	0.366	0.001
Nitrogen free extract	98.06[a]	97.53[b]	96.06[e]	96.08[d]	97.04[c]	0.217	0.001

Means in the same row with different superscripts are significantly different ($P < 0.05$).

Materials and methods: This experiment was conducted at the Poultry Unit of the Federal University of Technology Minna, Niger State, Nigeria. One hundred Cobb 500 broiler chicks were used for the study, birds were weighed and assigned randomly to five treatments in a completely randomized design. The experiment was approved and followed the standard ethics of the Animal Production Department of the University. The probiotics used contained 10 CFU/g of *Lactobacillus fermentum*. Treatment 1 (control, $LF_{0.00}$) had no probiotics, while treatments 2, 3, 4, 5 were diets supplemented with 1.25, 2.50, 3.75 and 5.00g of probiotics per 1 kg of feed and were tagged $LF_{1.25,}$ $LF_{2.50,}$ $LF_{3.75\ and}$ $LF_{5.00}$, respectively. The birds were raised on deep litter. Iso-caloric and iso-nitrogenous diets were formulated for the broilers. Feed and water were provided ad libitum. Broilers were weighed weekly and feed intake was measured daily. An apparent nutrient digestibility study was conducted. The difference in the feed nutrients and the excreted nutrients were expressed in percentage to obtain the apparent digestibility coefficient of the feed. The content of dry matter, crude protein, ether extract, crude fibre, ash and nitrogen free extract of the feed and faeces were determined. All data were subjected to One-Way Analysis of Variance (ANOVA) and significant treatment means where it occurred were separated by Duncan multiple range test using (SPSS, 2017) version 16.0.
Results: All parameters measured showed ($P < 0.05$) significant differences (Table 1). Control birds had the highest ($P < 0.05$) nitrogen free extract digestibility. Treatments 2 and 3 had similar ether extract digestibility which was significantly higher than the control. However, Treatment 2 had better ash digestibility when compared with the other treatments. The dry matter and crude protein digestibility for Treatment 2 and Treatment 1 (control) were similar.
Conclusion: Birds on probiotics of 1.25g/ kg of feed (Treatment 2) compared favourably with the control and did better than most of the other probiotics treatments. Probiotics of 1.25g/ kg of feed could be included in diets of broilers to stimulate better digestibility of ash and ether extract. Further research may employ the use of other types of probiotics at lower levels in the diets of broilers.

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31. Productive performance response of broiler chickens to water supplementation with sweet orange peel powder in a hot humid environment

B. Majekodunmi *, M. Abioja, E. Adekunle, S.M. Logunleko, J. Daramola

Department of Animal Physiology, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria

* Corresponding author. B. Majekodunmi.

Table 1
Live weight, Feed intake and feed conversion ratio of broiler chickens given water supplemented with sweet orange peel powder in the tropics.

Treatments	Week 3	Week 4	Week 5	Week 6	Week 7	Final weight (g)
		Live weight (g)				
Control	581.5	953.7	1301.2	1574.3	1838.4[b]	1838.4[b]
2g SOPP	605.4	970.0	1316.2	1634.3	1879.2[ab]	1879.2[ab]
4g SOPP	603.3	993.3	1297.9	1646.3	1960.6[ab]	1960.6[ab]
6g SOPP	633.3	1033.3	1375.0	1791.1	2164.6[a]	2164.6[a]
SEM	13.34	18.06	23.43	42.67	53.07	53.07
P-value	0.657	0.488	0.688	0.359	0.001	0.001
		Feed intake (g)				
Control	506.48	696.56	822.69	941.20	797.69	
2g SOPP	502.08	624.58	872.08	849.77	762.73	
4g SOPP	497.08	677.92	913.33	886.25	861.81	
6g SOPP	529.17	710.42	860.42	1004.29	810.42	
SEM	11.56	22.47	24.24	25.68	23.29	
P-value	0.822	0.615	0.683	0.147	0.569	
		FCR				Average FCR
Control	1.65	1.87	2.39	3.60	3.02	2.40[a]
2g SOPP	1.59	1.71	2.52	2.67	3.12	2.26[ab]
4g SOPP	1.58	1.73	3.09	2.64	2.75	2.30[ab]
6g SOPP	1.62	1.77	2.52	2.64	2.40	2.11[b]
SEM	0.03	0.04	0.12	0.22	0.04	0.04
P-value	0.929	0.714	0.187	0.372	0.369	0.001

SEM = Standard error of mean.
[a,b] Means in the same column with different superscripts are significantly different ($P < 0.05$).

Application: The use of sweet orange peel as natural antioxidants in the mitigation of heat stress comes with little or no cost as it is an agricultural waste that is readily available. Its utilization will be beneficial to the farmers and rid the environment of orange peels.
Introduction: Heat stress is a major concern to poultry farmers in the tropics. Nutritional intervention especially via water represents a practical and cost-effective strategy of heat stress mitigation (Majekodunmi et al., 2021). Live weight (LW), feed intake (FI) and feed conversion ratio (FCR) are productive and economic parameters of birds negatively affected in the tropics. Sweet orange peel is an agricultural waste rich in phenolic compounds, carotenoids and ascorbic acid (Osarumwense et al., 2013). This study investigated the effect of supplementing drinking water with sweet orange peel powder (SOPP) on the LW, FI and FCR of broiler chickens reared in a hot humid environment.
Materials and methods: Day-old Ross broiler chickens (n = 96) were randomly allotted into four treatment groups in a seven-week experiment: T1-without SOPP (control), T2- 2g SOPP, T3-4g SOPP and T4-6g SOPP per litre of water. Each treatment had three replicates of eight birds in a completely randomized design. Starter and finisher diets formulated according to National Research Council (NRC) (1994) recommendations were provided. Freshly prepared water according to the treatment groups was provided daily in a drinker from day 15 to day 49 of the experiment. Live weight and FI were monitored on a weekly basis while FCR was calculated. The study was conducted in accordance with the University's ethical guidelines.
Results: Live weights were comparable ($P > 0.05$) among the treatments across the weeks except at week seven. Birds on 6g SOPP had significantly ($P < 0.05$) higher LW (2164.6g) compared with birds in the control group (1838.4g). The FI and FCR showed no significant ($P > 0.05$) variation among the treatments across the weeks. However, birds on 6g SOPP had a significantly ($P < 0.05$) lower average FCR of 2.11 compared with 2.40 recorded for birds in the control group. Significant increase in the final LW and better FCR at the later end of this study could be attributed to the cumulative effect of the antioxidant property of SOPP in ameliorating the negative effect of heat stress in the broiler birds.
Conclusion: Inclusion of sweet orange peel powder in drinking water resulted in a better productive performance in relation to the final live weight and average FCR of broiler chickens in this study.

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32. Effect of dietary vitamin D3 and UVB light on growth performance and corticosterone levels of broilers challenged with stress

A. Ogbonna [a,b,*], A. Chaudhry [a], L. Asher [a]

[a] Agriculture building, School of Natural and Environmental Sciences, Newcastle University, Newcastle Upon Tyne, UK
[b] Department of Animal Production and Livestock management, College of Animal Science and Animal Production, Michael Okpara University of Agriculture, Umudike, Abia, Nigeria

* Corresponding author. A. Ogbonna.

Application: Isolation increased corticosterone levels while dietary vitamin D3 improved broiler performance.
Introduction: Within commercial intensive poultry production, chickens, are vulnerable to environmental and management-associated stressors such as handling, social disruption, unfamiliar sounds, feed and water restriction (Zulkifli, 2013), leading to reduced performance. Vitamin D3 is required for optimal performance and can be produced in the skin through ultraviolet-B (UVB) irradiation or absorbed from the diet (Edwards, 2003). The objective of this study was to determine the effects of dietary vitamin D3 and UVB light on growth performance (GP) and stress on the serum corticosterone (CORT) levels of broilers challenged with social isolation stress.

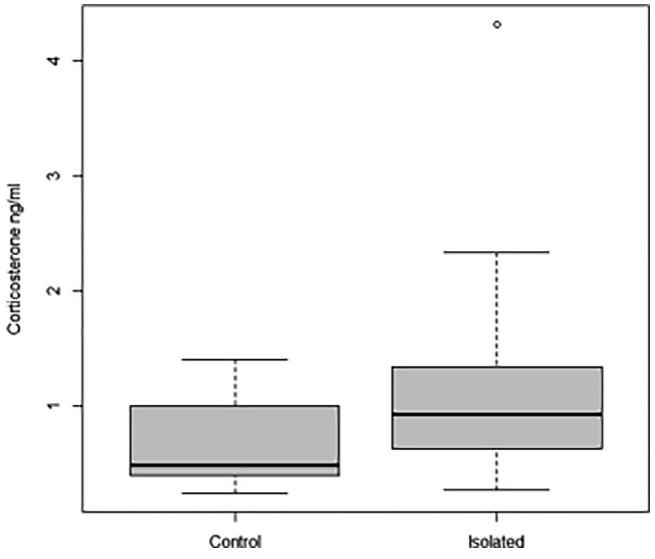

Figure 1. Effect of isolation on serum corticosterone levels of broiler chickens.

Table 1
Effect of dietary vitD3 (HD) and UVB light on GP of broilers challenged with stress.

Treatment	HD	UVB	SEM	P-value	Non-isolated	Isolated	SEM	P-value
BWG (g)	2831	2472	53.9	0.00	2621	2681	53.9	0.44
FI (g)	4090	3690	86.6	0.00	3882	3900	86.6	0.88
FCR (g:g)	1.44	1.50	0.02	0.04	1.48	1.46	0.02	0.42

SEM: Standard error of mean; BWG: bodyweight gain; FI: feed intake; FCR: feed conversion ratio.

Materials and methods: All procedures were conducted after obtaining approval from the Animal Welfare and Ethical Review Body (AWERB ID: 806), Newcastle University. One day old Ross 308 broiler chicks (n = 192) were weighed and allocated to a dietary vitamin D3 (control) at 4000 IU/ kg (HD) or a UVB light to evaluate GP (BWG: bodyweight gain; FI: feed intake; FCR: feed conversion ratio) and CORT levels (n = 32) of broilers. Each treatment had 8 replicate pens, each containing 6 broilers, in a 2 × 2 factorial design. Broilers were divided into non-isolated (control) and isolated groups; the isolated broilers were subjected to regular sessions of isolation by putting in a plastic/storage box for 15-minutes daily for 3 days/week for 2 weeks starting from day 10 (90 minutes total isolation) with inter isolation intervals of 48 hours. They had vocal contact but no physical contact with other birds under isolation. Thus, exposing them to a combination of capture, handling, isolation and no access to feed and water. UVB lamps with wavelength: 280-315 nm, intensity; 28.12 μW/cm^2 hung 50 cm above the substrate were used with the lighting schedule of 23L:1D (1-7 days) and 18L:6D (8 to 42 days) in all the treatment groups but were filtered to remove UVB in HD group. GP was analysed using the analysis of variance of SAS 9.4 software while CORT levels were compared using Wilcoxon rank-sum test (W) on the non-isolated and isolated birds only.
Results: Corticosterone levels were affected (W = 71.5, P = 0.035) by isolation (Figure 1). There were no (P > 0.05) interactive effects on performance but dietary vitD3 (HD) resulted in significantly (P < 0.05) better performance than the UVB treatment while isolation had no effect (P > 0.05) on the performance of broilers (Table 1).
Conclusion: Dietary vitD3 possesses beneficial effects to support the performance of broilers despite physiological challenges showing its potential to support health.

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33. Carcass characteristics of broiler chickens fed diets containing graded levels of fermented castor oil seed meal (Ricinus communis, L) supplemented with methionine

A. Adeniran [a,*], D. Kareem [a,b], A. Amos [a], O. Olukomaiya [a], N. Sakomura [b], O. Idowu [a]

[a] Federal University of Agriculture Abeokuta, Abeokuta, Ogun State, Nigeria
[b] São Paulo State University, Jaboticabal, São Paulo, Brazil

* Corresponding author. A. Adeniran.

Application: Fermented castor oil seed meal can be included in diet of broiler chickens up to 150 g/ kg as replacement for conventional oil seeds as protein source.
Introduction: Castor oil seed (Ricinus communis Linn.) has potential as animal feed because of its high crude protein and energy comparable to the conventional ones such as soybean but limited due to potent anti-nutritional factors such as ricin and allergens (Audi et al., 2005). Methionine has been reported to overcome in some cases, the dietary effects of some anti-nutrients by metabolic detoxification (Edoh et al., 2019). Consequent to increasing investigations of alternative feedstuffs and scanty reports on the use of fermented castor oil seed meal (FCSM) as dietary protein source

Table 1
Effect of interaction of varying dietary levels of FCSM and methionine supplementation on carcass characteristics of broiler chickens.

Methionine types	+DL-methionine				+Herbal methionine					
Levels of FCSM (g/kg)	0	50	100	150	0	50	100	150	SEM	P-value
Final weight (g)	2659.70^{a}	2368.70^{b}	2140.00^{d}	2100.00^{d}	2660.30^{a}	2471.30^{b}	2312.00^{bc}	2203.30^{cd}	52.53	0.01
Dressed weight (g)	1975.32^{a}	1753.91^{ab}	1573.90^{b}	1578.30^{b}	1779.00^{ab}	1779.00^{ab}	1784.00^{ab}	1698.02^{ab}	16.69	0.00
Thigh (%)	10.67	10.93	10.63	10.73	9.50	12.67	11.33	12.00	1.10	0.28
Breast (%)	19.77	19.67	16.10	20.56	17.34	19.97	20.01	20.14	1.72	0.58
Back (%)	16.21	16.67	16.00	18.22	15.00	18.77	19.25	17.21	1.84	0.31
Drumsticks (%)	10.63	10.12	10.33	10.31	9.33	12.23	14.09	10.52	1.50	0.24
Neck (%)	3.73	3.50	4.43	4.00	3.67	3.33	3.67	3.37	0.48	0.17
Wings (%)	7.87^{a}	7.17^{ab}	7.25^{ab}	5.42^{b}	6.00^{ab}	7.67^{a}	7.00^{b}	7.33^{a}	0.57	0.05
Heart (%)	0.60	0.43	0.51	0.66	0.60	0.49	0.51	0.58	0.10	0.15
Kidney (%)	0.40^{ab}	0.51^{a}	0.39^{ab}	0.44^{ab}	0.37^{ab}	0.32^{ab}	0.29^{b}	0.37^{ab}	0.06	0.02
Lungs (%)	0.55^{ab}	0.57^{a}	0.52^{abc}	0.38^{bc}	0.51^{abc}	0.40^{abc}	0.35^{c}	0.42^{abc}	0.06	0.01
Liver (%)	2.04^{ab}	2.19^{ab}	2.17^{ab}	2.42^{ab}	2.01^{b}	2.04^{ab}	2.51^{a}	2.44^{ab}	0.14	0.00
Gizzard (%)	1.87^{b}	2.35^{a}	2.02^{ab}	2.10^{ab}	2.17^{ab}	2.20^{ab}	2.35^{a}	2.02^{ab}	0.12	0.00

Mean values in the same row having different superscripts are significantly (P < 0.05) different.

in poultry nutrition, this study was conducted to evaluate the carcass characteristics of broiler chickens fed diets containing graded levels of FCSM supplemented with methionine.

Materials and methods: The castor oil seeds were soaked in fresh water for six days in an air tight container, the fermented seeds were rinsed, sieved and sun dried before incorporation into the formulated isocaloric and isonitrogenous experimental diets to replace soybean meal at graded levels. 320 day-old Anak broiler chicks were randomly allotted into eight groups with four replicates of 10 birds each. The experiment was laid in a 4 × 2 factorial arrangement consisting of 4 FCSM inclusion levels (0, 50, 100 and 150 g/kg) and 2 methionine sources (DL and herbal methionine) included at 2 g/kg to have eight experimental diets. At the end of the experiment, four birds weighing close to average weight of the birds from each replicate were selected for carcass analysis. Data obtained were subjected to Analysis of Variance according to the general linear model procedure of SAS statistical software package. Means were separated using Duncan's Multiple Range Test at 5% level of significance.

Results and discussion: Birds fed 0 g/kg FCSM based diet supplemented with either DL-methionine or herbal methionine had the highest final weight. The cut-up parts of economic importance were not affected by dietary levels of FCSM and methionine supplementation except the wings. Birds fed 0, 50 and 100 g/kg FCSM based diet supplemented with DL-methionine recorded comparably high wing. The increased weight of internal organs observed as levels of FCSM increased from 0-150 g/kg could be due to increased metabolic activities of these organs.

Conclusion: FCSM can be included in the diets of broiler chickens up to 150 g/kg, although it caused a decrease in the carcass weights as the inclusion levels increased.

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34. Egg laying qualities of Japanese quails fed yam peel meal based diets with enzyme cocktail + yeast supplementation

P. Aguihe [a,*], A. Kehinde [b], D. Joshua [c], I Ilaboya [d], K. Samuel [e], O. Odu [f]

[a] Department of Animal Production Technology, Federal College of Wildlife Management, New Bussa, Niger, Nigeria
[b] Department of Wildlife, Forestry Research Institute of Nigeria, Ibadan, Oyo, Nigeria
[c] Department of Basic Science, Federal College of Wildlife Management, New Bussa, Niger, Nigeria
[d] Department of Animal Production Technology, Edo State College of Education, Iguoriakhi, Edo, Nigeria
[e] Bamidele Olumilua University of Education, Science and Technology, Ikere-Ekiti, Ekiti, Nigeria
[f] Department of Animal Science, University of Ibadan, Ibadan, Oyo, Nigeria

* Corresponding author. P. Aguihe.

Application: Inclusion of yam peel meal could successfully replace maize up to 75% with mutl-enzyme and yeast supplementation in laying Japanese quail diets without any detrimental impact on productive and egg quality performance.

Introduction: The inadequate supply of traditional feed ingredients has been considered a major challenge facing the growth of the poultry industry, especially in many developing countries, triggering the search for other viable alternative feed resources to provide the bird's required nutrients (Adeola and Olukosi, 2008). Thus, research interest in optimizing the use of fairly inexpensive and readily accessible agro by-products, such as yam peel in poultry rations would help to mitigate the exorbitant prices resulting from high demand for conventional feedstuffs such as maize and soybean due to strong rivalry between humans, livestock and industries for their use. Supplementation of enzyme complex and yeast has been shown to improve the efficiency of utilization of poor quality or highly fibrous feed stuffs in poultry production (Attia et al., 2020). Therefore, the objective of this study was to investigate the effects of dietary combination of enzyme cocktail and yeast supplementation in yam peel meal (YPM) based diets of laying Japanese quails on growth and egg quality parameters.

Materials and methods: A total of 240, seven-weeks old quails were distributed in a completely randomized design with four dietary treatments and five replicates of 12 quails each. Diet 1 served as the control diet without YPM while diet 2, 3 and 4 contained 25, 50 and 75% YPM with enzyme cocktail + yeast supplementation, respectively. The dietary treatments were formulated to contain minimum of 2,900 kcal kg^{-1} ME, 20% CP, 3.60% Ca, 0.44% available phosphorus, 1.10% Lys and 0.80% Met + Cys levels. The enzyme cocktail + yeast used in this study which came as a commercial

Table 1
Egg laying qualities of quails fed yam peel based diets with enzyme complex + yeast supplementation.

Parameters	Diet 1 (0% YPM)	Diet 2 (25% YPM)	Diet 3 (50% YPM)	Diet 4 (75% YPM)	SEM	P-values
Average feed intake (g day^{-1})	32.27	32.21	32.39	31.98	1.75	0.183
Average weight gain (g day-1)	24.23^{ab}	23.40^{b}	24.98^{ab}	27.98^{a}	1.83	0.035
Hen day production (%)	83.15	80.20	88.25	88.76	4.09	0.234
Egg mass (g day^{-1})	7.65^{b}	7.47^{b}	8.15^{a}	8.29^{a}	0.03	0.002
Feed conversion ratio (g g^{-1})	4.22^{a}	4.31^{a}	3.97^{b}	3.85^{b}	0.65	0.002
Egg weight (g)	9.20	9.32	9.23	9.34	0.11	0.702
Egg shell weight (g)	1.25^{a}	1.15^{b}	1.24^{a}	1.29^{a}	0.03	0.001
Albumen weight (mm)	4.23	3.84	4.29	4.03	0.14	0.097
Egg shell thickness (mm)	0.31^{a}	0.22^{b}	0.28^{ab}	0.33^{a}	0.03	0.023
Albumen Height (mm)	0.44	0.51	0.56	0.53	0.66	0.080
Yolk weight (mm)	2.97	2.97	3.04	3.18	0.05	0.129
Yolk height (mm)	0.59	0.23	0.69	0.73	0.44	0.148
Haugh Unit (%)	59.66	60.21	60.75	60.31	6.34	0.235

product (Maxigrain®) was a microbial preparation originated from the bacteria Asperigillus oryzae and each gram contained mixture of phytase (2500 FTU), cellulase (10,000 IU), β-glucanase (200 IU), xylanase (10,000 IU) and yeast (Saccharomyces cerevisiae, $1x10^9$ cfu). Data collected on laying performance and egg quality attributes were processed based on a completely randomized design with the aid of general linear model procedure of SAS software.

Results: Feed intake and hen day production were not affected ($P < 0.05$) by dietary treatments; however, Maxigrain® supplementation improved ($P < 0.05$) weight gain, egg mass and feed conversion per egg as YPM increased in the diet up to 75% level (Table 1). Increasing levels of YPM with MXG® supplementation did not show any effect ($P > 0.05$) on internal and external egg quality attributes except for eggshell weight and thickness which was higher ($P < 0.05$) in quails fed 75% YPM diet.

Conclusion: Therefore, laying Japanese quails could tolerate 75% replacement level of yam peel meal for maize with dietary enzyme cocktail + yeast supplementation without any adverse effect on laying performance and egg quality attributes.

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35. Effects of in ovo and early post hatch feeding of honey solution on ileal histomorphometry of turkey poults

R. Adejumo *, A. Agboola, B. Omidiwura, E. Iyayi

University of Ibadan, Ibadan, Oyo, Nigeria

* Corresponding author. R. Adejumo.

Application: Honey solution up to 1%, fed in ovo and early post hatch, enhanced utilisation of nutrients in turkey poults.

Introduction: Embryonic mortality occurs in turkeys due to fast depletion of stored glycogen during the last phase of incubation. This forces the muscle protein of the growing embryo into gluconeogenesis which could lead to poor tissue formation, poor quality hatchlings and increased early poult mortality {11.4% annually} (Muhammad et al., 2010). In ovo feeding involves the administration of exogenous critical nutrients by the last phase of incubation into the amnion of developing chick embryos. Honey, which is rich in sugars and other essential nutrients (Agbaje et al., 2006; Obun et al., 2008), is a potential carbohydrate source for growing turkey embryo. Therefore, in order to augment the inherent nutrient in the amniotic fluid, this study was designed to evaluate the effects of in ovo and early post hatch feeding of honey on ileal histomorphometric measurements in turkey poults.

Materials and methods: Three hundred viable 21-day incubated turkey eggs of comparable weight were allotted into 6 treatments containing 5 replicates of 10 eggs each in a completely randomised design. The in ovo feeding procedure was carried out on day 24 of incubation at a reputable hatchery in Ibadan, Nigeria. In ovo and post hatch treatments were: Uninjected control (no egg drilling, no injection)/Water, Drilled uninjected (egg drilled, no injection)/Water, 5% Glucose (G)/1% Honey (H), 5% Glucose/5% Glucose, 1% Honey/5% Glucose and 1% Honey/1% Honey respectively. After hatching, poults were transferred within 24-hour hatching window, weighed, tagged and allocated to pens within their respective treatments (commercial turkey mash) in a study that lasted 4 weeks. On day 28, two poults were sacrificed, dissected and ileum harvested for ileal histomorphological measurements (Iji et al., 2001). This study complied with the University of Ibadan ethics requirements for animal care and handling. Data were analysed using descriptive statistics and ANOVA (SAS, 2013) and means were separated using Duncan's Multiple Range Test at significant level of $P = 0.05$.

Results: The effect of in ovo and early post hatch feeding of honey solution on ileal histomorphometry of turkey poults is presented in Table 1. In ovo injected eggs and poults on glucose and honey solutions had the highest villi compared to the uninjected diets except for 5%G in ovo + 5%G post hatch and 1%H in ovo + 5%G post hatch that were similar to the uninjected. Both in ovo and post hatch treatments had no significant effect on the crypt depth and villus width of the turkey poults. Ileal villus height to crypt depth ratio of poults on 1%H in ovo + 1%H post hatch was significantly higher ($P < 0.05$) than 1%H in ovo + 5%G post hatch and uninjected/water diet. Highest ($P < 0.05$) epithelial height was recorded in 1%H/1%H compared to the other diets.

Conclusion: *In ovo* and early post hatch feeding of 1% honey solution enhanced tissue development and improved nutrient utilisation in turkey poults.

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Table 1
Effect of in ovo and early post hatch feeding of honey on ileal histomorphometry of turkey poults (day 28).

In ovo/Post hatch Treatment	Uninjected/Water	Drilled/Water	5%G/1%H	5%G/5%G	1%H/5%G	1%H/1%H	SEM	P-value
Villus height (μm)	255.95^{b}	260.21^{b}	357.05^{a}	299.44^{ab}	298.59^{ab}	354.90^{a}	17.96	0.007
Crypt depth (μm)	38.48	39.16	48.56	42.24	50.21	36.00	2.35	0.167
Villus height/crypt depth	6.47^{b}	7.88^{ab}	7.91^{ab}	7.91^{ab}	6.13^{b}	9.96^{a}	0.55	0.008
Villus width (μm)	60.37	60.67	52.76	57.07	64.75	60.96	1.66	0.105
Epithelial height (μm)	25.91^{c}	26.18^{c}	32.36^{bc}	29.19^{bc}	35.98^{b}	296.89^{a}	44.52	0.000

^{a,b,c} Means on the same row with different superscripts are significantly different ($P < 0.05$). SEM = Standard Error of Mean. G - Glucose, H - Honey.

36. Performance of dairy cows offered either zero-grazed grass or ensiled grass prepared from the same sward

A. Lavery, C. Ferris *

AFBI, Hillsborough, Down, UK

* Corresponding author. C. Ferris.

Application: Offering cows grass silage, rather than the same herbage zero-grazed, resulted in a reduction in cow performance.
Introduction: Zero-grazing normally involves harvesting and offering fresh grass daily. However, zero-grazing can be labour intensive, and it can be challenging to ensure a consistent supply of grass at the optimum growth stage. Some of these challenges might be overcome by ensiling grass at the same growth stage as herbage which is used for zero-grazing. The current study examined offering either zero-grazed fresh grass, or grass silage prepared from the same sward at a similar time, on cow performance over a single season.
Materials and methods: This two-treatment experiment (Zero-grazing [ZG] and Silage [SIL]) involved 36 mid lactation dairy cows. Fresh grass was harvested daily using a zero-grazing harvester, and offered to ZG cows for a 12-week period commencing 16 June. During this period the same sward was harvested once weekly, and ensiled in round bales (mean pre and post-harvest herbage mass, across both treatments, 3880 and 1530 kg DM/ha). Following a five-week ensilage period, the silage was offered to cows on SIL for a 12-week period, commencing 21 July. The two treatment groups were balanced for lactation number, pre-experimental milk yield, milk composition, and live-weight at the time each started the experiment. All cows were offered 8.0 kg concentrate per day. Cow performance data was analysed by repeated measures analysis using a residual maximum likelihood (REML) model using Genstat.
Results: Silage ME was on average 0.3 MJ higher than grass ME (11.3 and 11.0 MJ/ kg DM, respectively). Average forage DMI and total DMI over the experimental period was higher for cows on ZG ($P < 0.001$: Table 1), while there was a significant treatment × week interactions ($P < 0.001$) for these parameters, with SIL decreasing from week 8 to 12 of the experiment compared to ZG. Cows on ZG had a higher milk yield, milk protein concentration, and fat plus protein yield ($P < 0.001$) than cows on SIL. There were significant treatment × week interaction for each of these milk production parameters. Milk fat concentration was unaffected by treatment ($P > 0.05$). Milk of cows on ZG had higher concentrations of total monounsaturated fatty acids (MUFA, $P < 0.001$), total polyunsaturated fatty acids (PUFA, $P < 0.001$), compared to SIL, while the reverse was true for total Saturated fatty acid (SFA) concentrations. Treatment had no effect on mean BW (mean 629 kg) and BCS (mean 2.3) of cows over the experimental period.
Conclusion: Cows offered grass silage had a lower DMI, milk yield and milk protein content than those offered zero-grazed grass harvested from the same sward, at the same time. This effect was particularly evident later in the growing season. These results suggest that daily harvesting of grass using a zero grazer cannot be replaced by offering the same grass following ensiling, without loss of performance.

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Table 1
Effect on dairy cow performance of offering fresh zero-grazed grass (ZG) or grass silage produced from the same sward (SIL) over a 12-week experimental period.

	Treatment			P-value		
	ZG	SIL	SED	Treatment	Week	Treatment × Week
Forage DMI (kg/d)	15.1	12.7	0.29	<0.001	<0.001	<0.001
Total DMI (kg/d)	22.2	19.7	0.35	<0.001	<0.001	<0.001
Milk yield (kg/d)	27.1	25.1	0.55	<0.001	<0.001	<0.001
Fat (g/ kg)	45.0	44.7	1.01	0.447	0.014	<0.001
Protein (g/ kg)	37.2	34.5	0.52	<0.001	<0.001	<0.001
Fat + protein yield (kg/d)	2.23	1.96	0.052	<0.001	<0.001	<0.001
Milk FA concentrations (g/100 g total FA identified)						
Total Saturated	67.88	73.08	0.851	<0.001	<0.001	<0.001
Total MUFA	25.32	21.87	0.652	<0.001	0.060	0.003
Total PUFA	2.75	2.14	0.098	<0.001	<0.001	<0.001

DMI, dry matter intake; FA, fatty acids; MUFA; monounsaturated fatty acids; PUFA, poly-unsaturated fatty acids.

37. Effect of grazing and feeding management on organic milk mineral concentrations

S. Stergiadis [a,*], N. Qin [a], G.Faludi [a,b], S. Beauclercq [a], J. Pitt [a], N. Desnica [c], A. Pétursdóttir [c], E.E. Newton [a], An. Angelidis [a], I. Givens [a], D.J. Humphries [a], H. Gunnlaugsdóttir [c,d], D.T Juniper [a]

[a] University of Reading, Reading, UK
[b] Szent Istvan University, Keszthely, Hungary
[c] Matis, Reykjavik, Iceland
[d] Orkídea, Selfoss, Iceland

* Corresponding author. S. Stergiadis.

Application: Total forage intake, but also non-Holstein breeds, in organic herds were positively correlated with milk Ca, Mg, Na and P and negatively correlated with Cu, Al, and Fe; however, organic milk from different grazing management systems had similar milk mineral concentrations.
Introduction: Milk is major source of essential macrominerals (Ca, Mg, P, and K) and trace elements (I, Se, Zn) for human health (NDNS, 2018). Pasture intake may increase milk Ca, P and K, but decrease I and Zn, concentrations (Qin et al., 2021), while pasture composition, plant maturity, and animal/environmental factors also have an effect (Alothman et al., 2019). This study aimed to assess (i) the milk mineral concentrations in organic herds with different pasture intakes, and (ii) the relative impact of individual feeds.

Table 1
Effect of grazing management on mineral concentrations of organic milk.

Macrominerals	HP	SP	LP	SEM	P-value	Essential trace elements	HP	SP	LP	SEM	P-value
Ca (mg/ kg milk)	1066[a]	1058[a]	1021[b]	9.8	0.008	Cu (µg/ kg milk)	51.7	51.2	55.8	3.72	0.198
K (mg/ kg milk)	1369	1387	1378	14.3	0.857	Fe (mg/ kg milk)	0.44	0.68	0.95	0.168	0.185
Mg (mg/ kg milk)	96.7	95.0	92.8	1.02	0.069	I (µg/ kg milk)	395	342	301	33.1	0.782
Na (mg/ kg milk)	360	347	332	6.0	0.066	Mn (µg/ kg milk)	30.2	28.8	28.4	2.49	0.804
P (mg/ kg milk)	817	811	794	8.9	0.246	Mo (µg/ kg milk)	75.5	72.4	73.3	4.12	0.995
Non-essential trace elements	HP	SP	LP	SEM	P-value	Zn (mg/ kg milk)	4.78	4.25	4.50	0.238	0.255
Al (mg/ kg milk)	0.24	0.31	0.39	0.075	0.421						
Sn (µg/ kg milk)	4.05[a]	2.40[b]	1.72[b]	0.625	0.016						

HP, high pasture intake; SP, standard pasture intake; LP, outdoors with low/limited pasture intake. Significant differences were declared at $P < 0.05$. Means with a different lower-case letter are significantly different according to Fisher's least significant difference test ($P < 0.05$).

Materials and methods: Bulk milk samples (n = 283) were collected over a 12-month period from 24 organic dairy farms, and corresponding animal diet and breeding data via online questionnaire. Farms were allocated into three groups (n = 8) representing contrasting grazing management between April-September: high pasture intake (HP; 68% DMI (42-84% DMI)), standard pasture intake (SP; 47% DMI (45-63% DMI)), and outdoors with low/limited pasture intake (LP; 26% DMI (17-33% DMI)). Milk mineral concentrations were determined using ICP-MS. Milk mineral concentrations (log(x + 1) transformed) were analysed by linear mixed effects models using pasture intake (HP, SP, LP), month (12 months), and their interaction as fixed factors. Farm ID was used as a random factor. A multivariate redundancy analysis (RDA) assessed the relative impact of feeds and breed on milk mineral concentrations.
Results: Milk from LP farms had significantly less Ca (-44.3 mg/ kg and -36.5 mg/ kg, respectively) and Sn (-2.3 ug/ kg and -0.7 ug/ kg, respectively) than HP and SP farms (Table 1). The RDA indicated that non-Holstein breeds (P = 0.002) and total forage intakes (P = 0.002) were positively correlated with Ca, Mg, Na and P, and negatively correlated with Cu, Al, and Fe; while the opposite correlations were observed for maize silage intakes (P = 0.032).
Conclusions: Although cow diet, which affects mineral intakes, and breed, which may affect mineral utilisation, had significant correlations with milk mineral concentrations, the overall effect of grazing management was marginal; meaning that typical grazing and feeding management variations within the organic dairy system may not be contrasting enough to affect milk mineral concentrations Alothman et al. (2019), National Diet and Nutrition Survey (2014), Qin et al. (2021).

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38. Low protein diets do not negatively impact on dairy cow performance in early lactation

A. Lavery [a,*], A. Craig [a], A. Gordon [b], C. Ferris [a]

[a] AFBI, Hillsborough, Co. Down, UK
[b] AFBI, Belfast, Co. Down, UK

* Corresponding author. A. Lavery.

Application: Provided diets are carefully formulated, dairy farmers can reduce the level of crude protein in the diets of high-yielding dairy cows without negative impact on performance.
Introduction: Reducing crude protein (CP) levels in dairy cow diets can lower feed costs, and reduce nitrogen excretion. The latter contributes to reductions in gaseous emissions of ammonia and nitrous oxide, and reduces the risk of aquatic eutrophication by nitrates (Lavery and Ferris, 2021). However, previous research at AFBI (Law et al., 2009) found milk production was reduced when total diet CP content was 14.4%. The current study examined the effect of diet CP level on cow performance and nitrogen use efficiency (NUE) in early lactation.
Materials and methods: A continuous design study using 90 Holstein dairy cows (24 primiparous) investigated the effect of three total diet CP levels: 15%, 16% or 17%. Cows were enrolled at calving and remained on treatments until day 180 of lactation. Treatment groups were balanced for parity, Predicted Transmitting Ability (PTA) milk yield, PTA milk fat and protein yield, and previous lactation 305d milk yield, and milk fat and protein content. A common silage (dry matter (DM), 351g/ kg; CP, 135g/ kg DM; metabolisable energy, 11.6 MJ/ kg DM) was offered to all treatments throughout the study, with iso-energetic concentrates formulated to achieve the desired total diet CP content. Silage and concentrates were offered in the form of a TMR (50:50 DM basis) with straw included in the mix at 0.3 kg/cow/day. Rations were offered via electronic feed boxes mounted on weight scales (Bio-control, Norway), enabling individual cow intakes to be recorded daily. Blood samples were taken at weeks 2,6,8,10,14 and 18 post-calving. Treatment effects on DM intake (DMI), milk yield and composition, body weight (BW), body condition (BCS) and blood metabolites were examined.

Table 1
Effect of total diet crude protein content on performance of early lactation dairy cows.

	15%	16%	17%	SED	P-Value Treatment (T)	Week (W)	(T × W)
Total DMI (kg/d)	23.2	23.3	23.8	0.29	0.082	<0.001	0.862
Milk yield (kg/d)	35.7	37.1	36.3	0.97	0.536	<0.001	0.995
Fat (g/ kg)	44.9	44.6	44.7	0.47	0.746	<0.001	0.593
Protein (g/ kg)	34.4	34.8	34.9	0.13	0.240	<0.001	<0.001
Fat plus protein yield (kg/d)	2.82	2.92	2.89	0.05	0.108	<0.001	0.479
Milk urea nitrogen (mg/ kg)	97a	115b	134c	1.8	<0.001	<0.001	0.094
Body weight (kg)	632	636	651	10.2	0.201	<0.001	0.929
Body condition	2.4a	2.4a	2.5b	0.04	0.021	0.003	0.705
Serum urea (g/L)	1.9a	2.4b	3.0c	0.08	<0.001	<0.001	0.160
Serum total protein (g/L)	50.2a	50.8a	53.7b	1.46	0.020	<0.001	0.773
Serum NEFA (meq/L)	0.26	0.25	0.25	0.017	0.446	<0.001	0.568
NUE	0.34b	0.34b	0.31a	0.004	<0.001	<0.001	0.659

DMI; dry matter intake, NEFA; non-esterified fatty acids, NUE; nitrogen use efficiency.

Mean weekly data were analysed using REML, with cow as the experimental unit and week as the repeated measure (GenStat 20th edition, VSN International Ltd).

Results: Diet CP level had no significant effect on total DMI, milk yield, milk fat and protein content and milk fat plus protein yield (Table 1). Milk urea nitrogen increased as diet CP level increased ($P < 0.001$). Cow BW was unaffected by treatment, but cows offered the 17% CP diet had a higher BCS. While serum non-esterified fatty acids were unaffected by treatment, serum urea and total protein content were higher with the 17% CP treatment than the 15% CP treatment. Nitrogen use efficiency (milk N as a proportion of total N intake) was lowest with the 17% CP treatment.

Conclusion: A reduction in total diet CP from 17% to 15% improved NUE, with no negative effect on the DMI or milk production performance of early lactation dairy cows.

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39. Effect of essential oils and biotin on feed intake, milk yield, feed efficiency and methane emissions from lactating dairy cattle

J. Margerison

University of Nottingham, Nottingham, Nottinghamshire, UK

Application: Essential oils (EE) pre parturition and EE + biotin (B) pre and post parturition lowered methane emissions (CH_4) per day and per kg EC milk, while increasing milk protein, energy corrected (EC) milk, milk fat and solids yields per day and per kg DMI, which would make these mitigation approaches more financially viable for farmers.

Introduction: Livestock farming sectors contribute 14.5% to the global greenhouse gas (GHG) emissions (Gerber et al., 2013) of which enteric CH_4 emitted by ruminant livestock is the greatest (17%) source of global anthropogenic CH_4 emissions (Knapp et al., 2014). Emissions of GHG are expected

Table 1
Milk yield, DMI and methane (CH_4) emissions (SE) from lactating dairy cows offered essential oils (EE) without and with biotin (+ B).

	None:None	None:EE	EE + B:EE + B	P-value
EC milk yield, kg/d [1]	38.6 (0.99) [b]	41.9 (1.05) [a]	42.3 (1.09) [a]	0.015
Milk fat, g/ kg	40.8 (0.70)	41.3 (0.73)	40.8 (0.76)	0.934
Milk protein, g/ kg	31.7 (0.27)	31.5 (0.27)	31.6 (0.30)	0.825
Milk lactose, g/ kg	46.5 (0.132) [b]	47.2 (0.143) [a]	47.0 (0.145) [a]	0.003
Milk fat, kg/d	1.54 (0.040) [b]	1.68 (0.012) [a]	1.69 (0.044) [a]	0.015
Milk protein, kg/d	1.20 (0.022) [b]	1.28 (0.024) [a, b]	1.31 (0.025) [a]	0.004
Milk solids, kg/d	2.74 (0.059) [b]	2.96 (0.063) [a]	3.00 (0.066) [a]	0.006
Milk urea,	22.8 (0.41)	23.8 (0.44)	23.0 (0.45)	0.157
Mean DMI, kg/d	19.8 (0.33)	19.8 (0.35)	19.3 (0.35)	0.437
kg EC yield / kg DMI [1]	1.95 (0.045) [b]	2.12 (0.050) [a, b]	2.19 (0.051) [a]	0.002
kg milk protein/ kg DMI	0.06 (0.001) [b]	0.07 (0.001) [a]	0.07 (0.001) [a]	<0.001
Methane (CH_4) output, g/d	336.7 (1.62) [a]	328.8 (1.71) [b]	327.7 (1.79) [b]	<0.001
CH_4 / kg EC yield, g [1]	8.7 (0.28) [a]	7.9 (0.30) [b]	7.8 (0.32) [b]	<0.001
CH_4 / kg milk protein, g	281 (6.5) [a]	257 (6.9) [b]	250 (7.3) [b]	<0.001

[a,b] - Means in rows that do not share a letter differ significantly 1 – Energy corrected yield.

to increase by 35% until 2050, especially in developing countries due to increased demands of meat and dairy products (Patra, 2014). Developing natural products, such as vitamins, EE, seaweed and yeast that lower GHG emissions from ruminants are essential. This study assessed the dietary effect of EE and B on individual animal CH_4 emissions (by NIR at milking), milk yield and feed efficiency.

Materials and methods: 45 Holstein dairy cattle were selected at random, 21 d prior to parturition, and allocated according to parity, previous and/or predicted milk yield, pre-partum body condition and live weight to one of three blocks, such that each block of animals were similar for these factors, and offered one of three iso-nitrogenous and energetic diet combinations between 21 d pre-partum and 68 d postpartum (pp): Nothing added pre and pp (None:None); addition of essential oils (EE) postpartum (pp) (None:EE); EE plus 20 (± 2) mg/d B (+B) pre and pp (EE+B:EE+B). Normally distributed individually measured milk yield and composition, DMI, methane, feed efficiency, rumen fluid pH, rumen fluid and plasma metabolite concentrations were assessed using Minitab (17.0) ANOVA GLM orthogonal comparison using diet as fixed and animal as a random effects in the model. Differences between means were assessed using Tukey' test, applying a confidence interval of 0.95 and differences between means were reported in the text at a P-value < 0.05.

Results: Milk (EC), milk fat and solids yield, EC yield and protein yield per kg DMI was greater, while daily methane emissions, CH_4 per kg EC milk and milk protein yield was lower from cows offered EE pp and EE+B pre and pp Gerber (2013)

Conclusions: EE+B prior to and pp and EE pp were successful in lowering daily CH_4 emissions and kg EC milk and protein yield, while increasing (EC), milk fat and solids yield, feed efficiency / kg EC yield and protein yield.

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40. Response of the rumen microbial community to a short-term feed restriction and re-feeding period in high yielding dairy cows

C. Johnson [a,*], T. Snelling [a], J. Huntington [a], J. Taylor-Pickard [b], H. Warren [b], L Sinclair [a]

[a] Harper Adams University, Newport, UK
[b] Alltech, Stamford, UK

* Corresponding author. C. Johnson.

Application: Short term periods of feed restriction should be avoided due to longer term changes to the rumen microbiome, though supplementation of yeast during feed restriction promotes fibrolytic bacteria which may enhance feed use efficiency.

Introduction: Short-term feed restriction occurs on over 33% of dairy farms in the UK (Tayyab et al., 2018), due to insufficient or restricted access to feed. Upon re-feeding cows can overeat, increasing risk of subacute ruminal acidosis, potentially compromising the rumen microbiome. The objective was to determine the effect on the rumen microbiome following short-term feed restriction and re-feeding in high yielding dairy cows supplemented either with or without a live yeast.

Materials and methods: Four Holstein-Friesian dairy cows fitted with rumen cannulas were used in a 2 x 2 Latin square designed study, with four periods each lasting 35 days. All cows were fed a mixed ration with forage to concentrate ratio of 60:40 (DM basis). Diets were supplemented with 1 g/cow/day of a live yeast (Yea-Sacc®, Alltech Inc., USA). Baseline measurements of the rumen microbiome were taken on day 30, by sampling rumen fluid and digesta via the rumen cannula at 0600, 1200, and 1800 h. On day 31 cows were restricted to 75% of previously recorded intake inducing a period of feed deprivation. On day 32 feed was reintroduced at 125% of previously recorded intake (recovery day 1), and additional rumen

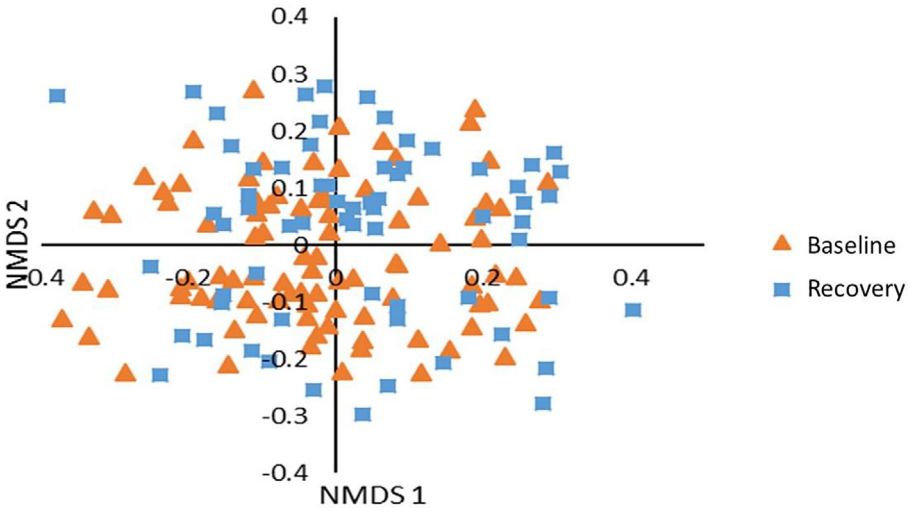

Figure 1. NMDS plot (Stress value 0.22763) for feed restriction period ($P < 0.001$).

samples collected. The DNA extraction was conducted using the bead beating protocol based on Yu and Morrison (2004), and amplicon libraries prepared using dual index method based on Kozich et al. (2013). Microbial community data were analysed using mothur v1.44.0, to generate operational taxonomic unit (OTU) tables and statistical analysis conducted using AMOVA (analysis of molecular variance) with the Bray Curtis dissimilarity metric to determine microbial community distance, and linear discriminant analysis effect size to determine discriminant features associated with treatments.
Results: At 0600 h on recovery day 1, prior to re-feeding, there was a greater abundance of OTU assigned to Methanobrevibacter and unclassified Spirochaetaceae compared to baseline. Microbial community diversity differed ($P < 0.001$) between the baseline and recovery period (Figure 1). At 0900 h on recovery day 1 there was greater abundance of OTU associated with Lactobacillus, and at 1800 h an increase in OTU classified as Bifidobacterium and Acidaminococcaceae in recovery compared to the baseline.
Conclusion: Following feed restriction there was an increase in the relative abundance of OTU associated with Methanobrevibacter. Yeast supplementation increased proportions of fibrolytic bacteria during the recovery period. The rumen microbial community had not fully recovered within 12 h of feed reintroduction indicating short term feed restriction may cause longer term changes.

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41. Effect of dietary seaweed supplementation on bovine milk microbiota

E. Newton [a,*], Á. Pétursdóttir [b], G. Ríkharðsson [c], C. Reynolds [a], S. Stergiadis [a], P. Ray [a]

[a] University of Reading, Reading, UK
[b] Matís, Reykjavik, Iceland
[c] Agricultural Society of South Iceland, Selfoss, Iceland

* Corresponding author. E. Newton.

Application: Feeding a seaweed mix of Laminaria digitata:Aschophyllum nodosum (9%:91% on a dry matter basis) at 89g/cow/day to Icelandic dairy cows led to increased milk iodine content and reduction of genera that contain pathogenic species such as Brevundimonas and Stenotrophomonas in the milk. This work can be used to improve management of dairy cows in reducing milk and udder-related pathogenic bacteria that can benefit animal health and food safety.
Introduction: Feeding seaweed to ruminants can benefit animal health, reduce environmental footprint, and improve product quality (Morais et al., 2020). Seaweed supplementation in dairy cow diets (Laminaria digitata:Aschophyllum nodosum mix), significantly increased cow milk iodine content in previous studies (Newton et al., 2021); an element extensively used in modern medicine for its antimicrobial properties (Eggers, 2019). This study aimed to investigate the effect that iodine-rich milk from cows fed seaweed would have on the milk microbiota, including potentially pathogenic bacteria.
Material and methods: Icelandic cows (20) were split into two experimental groups: (i) control/no-seaweed (CON, n = 10), and (ii) seaweed (SWD, n = 10, 89g/cow/day). Groups were balanced for parity, lactation stage, milk yield, and milk contents of fat, protein, and somatic cell count. After four weeks of diet adaptation, individual milk samples from all cows were collected weekly for three consecutive weeks (n = 60). Microbial DNA extraction from raw milk was performed using a QIAamp® Fast DNA Stool Mini Kit (Qiagen, Germany). Microbial abundance data were analysed using ANOVA (Minitab 18); with diet, experimental week, and their interaction, being the fixed factors, while cow was the random factor.

Table 1
Relative abundance (%) of genera in milk from cows fed control (CON, no seaweed) and Seaweed diets (SWD, 160 g/cow/day).

	Diet			ANOVA P-values[1]		
Genus	CON n = 30	SWD n = 30	SE	Diet	Week	Diet x Week
Pseudomonas	50.4	47.0	2.51	ns	ns	†
Cutibacterium	10.7	10.9	1.05	ns	ns	ns
Lawsonella	3.98	4.66	0.560	ns	ns	ns
Acetobacter	2.71	4.85	1.389	ns	ns	ns
Staphylococcus	3.24	3.78	0.362	ns	ns	ns
Micrococcus	3.59	3.32	0.468	ns	ns	ns
Corynebacterium	2.56	2.36	0.262	ns	ns	ns
Stenotrophomonas	2.89	1.72	0.527	*	ns	ns
Methyloversatilis	0.81	0.95	0.183	ns	ns	ns
Brevundimonas	1.24	0.50	0.220	***	ns	ns
Ruminococcaceae	0.79	0.77	0.050	ns	ns	ns
Lactobacillus	1.00	0.41	0.403	ns	ns	ns
Streptococcus	0.49	0.62	0.089	ns	ns	ns
Anaerococcus	0.54	0.52	0.063	ns	ns	ns
Turicella	0.55	0.48	0.103	ns	ns	ns
Other[2]	14.4	17.1	1.10	ns	ns	Ns

[1]Significances were declared at *** $P < 0.001$, ** $P < 0.01$, * $P < 0.05$, † $0.05 \leq P < 0.10$[2]Includes taxonomic groups that had abundance of <0.50% in both experimental groups, plus unidentified operational taxonomic units (OTUs).

Results: Milk iodine content was quantified by ICP-MS and was 718 and 1892 μg/ kg for CON and SWD groups, respectively. The relative abundance of bacteria in milk from the two groups are presented in Table 1. Seaweed supplementation in dairy cow diets reduced the relative abundance of the Genus and the corresponding Order of Brevundimonas (-0.74%; $P < 0.05$). Seaweed supplementation also reduced the relative abundance of the Genus and the corresponding Order of Stenotrophomonas (-1.17%; $P < 0.05$). Weighted unifrac β-diversity measurements, indicating divergence between the microbiota in CON and SWD milk, significantly differed between the two dietary treatments. The effect of diet × week interaction was not significant for any bacterial abundances.
Conclusion: Feeding seaweed to cows produces increases milk iodine concentrations and reduces the relative abundance of certain bacterial genera that can contain milk and cow-specific pathogenicity, such as Brevundimonas and Stenotrophomonas in the present study; although all other genera assessed in the present work were not significantly affected by cow diet.

Acknowledgement: Special thanks to the farmers Höskuldur Gunnarsson and Hilda Pálmadóttirfor their help with data collection in the animal trial. Helga Gunnlaugsdóttir and Jóhannes Sveinbjörnsson are acknowledged for their advice on the experimental design.

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42. Effect of live yeast (Saccharomyces cerevisiae) on milk yield, feed efficiency and reproduction of high-yielding dairy cows

I. Algherair *, N. Saunders, J. Goodman, J. Margerison, G. Mann, P. Garnsworthy

University of Nottingham, Nottingham, UK

* Corresponding author. I. Algherair.

Application: Live yeast supplementation can enhance milk yield in early lactation without any detrimental effect on fertility. *Introduction*: Active yeast products have potential to increase milk yield of dairy cows in early lactation by improving rumen conditions. Greater milk yields, however, can sometimes be associated with poorer reproductive performance (Garnsworthy et al., 2008). This study aimed to assess the effect of an active yeast supplement on milk yield and reproduction indicators in high yielding dairy cows.
Materials and methods: Fifty Holstein-Friesian dairy cows were paired at calving according to parity, calving date, predicted milk yield and live weight, and allocated at random to two treatment groups (n = 25). Cows were fed *ad libitum* on a partial mixed ration (PMR; maize, grass and wheat silages (0.75), concentrate blend (0.25) supplying requirements for maintenance plus 30 L milk/day) with additional concentrates during milking at 0.45 kg/L milk yield above 30 L/day. Control PMR contained no yeast, and Yeast PMR contained live yeast (Actisaf Sc47, Phileo UK & Ireland) at 100 billion cfu / cow / day / 10 g. The trial lasted from 7 to 128 days in milk (DIM). Milk yield, live weight and feed intake were recorded daily. Milk samples were analysed for composition on two days per week and for progesterone on three days per week. Pregnancy was confirmed by rectal palpation. Whole-tract digestibility was determined in weeks 7 and 13 of lactation from ratios of acid-insoluble ash in feed and faeces. Data were analysed using Genstat (version 19) with generalised linear mixed models and appropriate error distributions (identity, Poisson, binomial). Fixed effects were treatment (Control, Yeast), calving month, and parity (1, 2, ≥3). Random effects were cow and a non-linear function for week of lactation.
Results:: Cows offered Yeast had greater yields of energy corrected milk and milk fat than Control cows and tended to have greater milk protein yield (Table 1). Dry matter intake, feed efficiency, live weight (731 ± 9.5 kg) and live-weight change (-0.23 ± 0.19 kg/d to 42 DIM) were not affected by treatment, but dry matter digestibility was greater for Yeast than for Control. Intervals to first progesterone rise and conception, incidence of atypical cycles, and proportions of cows conceiving before 130 DIM and overall, did not differ between treatments.
Conclusion: Feeding live yeast to high-yielding dairy cows in early lactation increased milk yield and milk fat yield without increasing dry matter intake by enhancing dry matter digestibility. Increased milk yield was achieved with no detrimental effect on reproductive performance.

Table 1
Mean yields of milk and components, dry matter intake and digestibility, and reproductive indicators for dairy cows offered partial mixed rations without yeast (Control) and with yeast (Yeast) between 7 and 128 days in milk.

	Control	Yeast	SED	P-value
Energy-corrected milk, kg/d	47.7	50.5	1.02	0.009
Milk fat, g/ kg	39.0	39.7	1.10	0.524
Milk protein, g/ kg	32.5	32.3	0.57	0.734
Milk urea, %	0.28	0.27	0.013	0.326
Milk fat yield, kg/d	1.82	1.95	0.051	0.022
Milk protein yield, g/d	1.52	1.59	0.037	0.060
Dry matter intake, kg/d	23.9	24.0	0.65	0.929
Feed efficiency (kg ECM/ kg DMI)	2.08	2.04	0.092	0.862
Whole-tract DM digestibility	0.773	0.798	0.0110	0.034
Interval to first progesterone rise, d	25.0	22.8	2.17	0.313
Atypical cycle incidence[1]	0.32	0.29	0.131	0.830
Conceived before 130 DIM[2]	0.60	0.63	0.140	0.960
Overall conception rate[2]	1.00	0.92	0.056	0.086
Interval to conception, d	113	115	18.3	0.584

[1] Proportion of cows with milk progesterone <3 ng/ml for >45 DIM, >3 ng/ml for >19 days, or <3 ng/ml for >12 days after first oestrous cycle. [2] Cows that conceived of total cows per treatment.

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43. Sustaining a viable food chain requires an evidence based holistic approach

M. Gill

University of Aberdeen, Scotland

The lockdowns associated with managing the impact of the Covid-19 pandemic, reminded us that many of our food chains are global, seasonal and driven by economics. Much of the food we consume is processed and contains components whose geographical origins change during the year, based on price and availability. Accurate estimation of their carbon footprint, let alone of their other environmental impacts, therefore, is not possible. Yet responding to the twin emergencies of climate change and biodiversity loss requires a transformation of our food system. In turn, that transformation requires science to understand the complexities of the impact of different production systems on their contribution to climate change and the impact of climate change on food production in different locations. It then requires careful thought as to how to translate that understanding into principles which consumers are willing to adopt. A holistic approach is therefore essential, but as scientists we need to be honest in recognising the limits of our current knowledge. Integrated assessments at a global scale were very useful in raising awareness of the major environmental issues associated with food production, but global averages are not useful for policymakers working at a national level, trying to achieve multiple goals. The paper will consider some of the challenges and opportunities associated with feeding livestock throughout the year as an example of food chain issues and will postulate how some of these challenges will be influenced by climate change. It will then consider what policy levers there are which can influence the environmental impact of livestock product chains. That background will then be used to suggest how research questions could be better aligned with the development of policy and how research could be used to facilitate dialogue between those developing policy, the private sector and consumers.

44. The need for greater understanding of delivering existing and novel food products without negative impacts on human and planetary health

J. Gilliland

Devenish, Ireland

If livestock production is to have a future it needs to get smarter in how its product and its production system improves human health and environmental health simultaneously. Presenting two case studies to show how that this is possible, and how it can be done with transparency and integrity. The first case study will be on the natural enrichment of animal feed to improve omega 3 levels in chickens and in humans. The second case study will be on how using multispecies swards, instead of a monoculture of perennial ryegrass can reduce greenhouse gas emissions, improve soil health and increase liveweight gain. This presentation shows that there are real practical solutions already out there that can dramatically change how livestock production is perceived and that livestock production will eventually turn out to be part of Society's solution and not just the problem.

45. Alternative proteins for animal and human nutrition

A. Salter

University of Nottingham, UK

The growing, and ageing, global population has a specific requirement for dietary protein which contains sufficient essential amino acids (EAAs) to maintain physiological function. Significantly higher requirements are required during growth, pregnancy, lactation and under certain disease situations. There is also increasing evidence that minimum requirements are significantly increased in the elderly. Protein can be obtained from a wide range of foods, though in general, that derived from animal products is of higher value (in terms of EAA content and digestibility) than most plant sources. However, for those individuals with access to a wide variety of plant-based foods requirements can normally be comfortably met without need to consume animal products. Furthermore, consumption of excessive amounts of animal- derived foods, particularly red and processed meat, is associated with a range of metabolic diseases including obesity, type 2 diabetes, cardiovascular disease and certain cancers. However, in those with less access to a range of plant-base foods (due to availability or affordability), animal products such as meat, dairy produce, fish and eggs represent a vital dietary source of high-quality protein and other essential nutrients. There is increasing concern over the environmental impact of livestock production, including demands on land and water resources as well as the production of greenhouse gases. Much of this concern is associated with the production of crops, often human-edible, for animal feed. Currently, approximately two-thirds of the human edible protein produced globally is used as animal feed. We should therefore be working toward improving the sustainability of animal production, including finding more sustainable sources of protein for animal feed. In this presentation I will explore these alternative protein sources, including underutilized crops, insects and single cell organisms. Specific consideration will be given to the factors which impact on digestibility of such sources including the presence of anti-nutritional factors and the physical properties of the protein itself. Some consideration will also be given to the economic, environmental and safety concerns associated with the wide spread introduction of such products into our food systems. The impact of such factors on the future potential

these novel protein sources in reducing our reliance on animal-derived foods, together with improving the sustainability of the remaining livestock industry, will be addressed.

46. Food systems solutions for reducing animal product food waste in households

C. Reynolds

Center for Food Policy, City, University of London, UK

Of the 1.3 billion tonnes of global food loss and waste, food waste related to animal products such as meat, seafood, and dairy is estimated to be 14%. This is equivalent to ~19% of global animal products production, and is linked the majority of the greenhouse gas emissions and other environmental impacts related to food loss and waste. One prominent method to reduce the environmental impact of animal products is to reduce global food loss and waste. To highlight the global scale of this challenge, this presentation presents the results of a 9 country pilot survey (Brazil, Ghana, India, Kenya, Nigeria, Argentina, Colombia, Peru, and the UK). The results show how different shopping, cooking and packaging options drive household animal products waste. This presentation then proposes possible solutions to reduce household global animal products waste, including product shelf life extension; changing purchase, consumption, and freezer use behaviour; and packaging and portion size modifications. These interventions have been validated using the household simulation model - a discrete event simulation model that replicates the stages and processes of home food purchase, storage, consumption and disposal. Examples of the scale of household waste reduction impacts are given for Chicken breast fillets and Bacon in the UK.

47. Are plant-based diets the silver bullet? Evidence from a sustainability, health and resilience angle

P. Scheelbeek

London School of Hygiene & Tropical Medicine, UK

Rapid and transformation changes in food systems – especially those in the Global North – are a pivotal part of our “race” to stay within +1.5°C of warming above pre-industrial levels. Stimulating consumers to eat more sustainable diets presents a major opportunity for reducing the environmental footprint of food systems. At the same time, shifts towards sustainable diets are highly likely to improve population health. In her talk, Dr Scheelbeek will cover the complex linkages between climate change, diets and health. She will give a number of examples of successful (and less successful) global, national and regional strategies, as well as their co-benefits and co-harms for health, environmental sustainability and resilience. Furthermore, she will discuss the challenges of increasing adherence to “sustainable and healthy dietary guidelines” and the potential leverage points for accelerating dietary change in Europe.

48. The nutritional value of milk and meat, their association with human health/disease and how this is reflected in consumer information

I. Givens

University of Reading, UK

Milk and dairy foods. This will focus on the common misconception that milk and dairy foods are harmful to health as often judged by the fact that they are typically the largest supplier of saturated fats in the diet. This will be explored with reference to recent meta-analyses and new knowledge on the impact of the so-called food matrix. Broadly these indicate no association between dairy consumption and risk of cardiometabolic diseases with some indication of significant negative associations. In addition, milk and dairy foods have functionality beyond that which is expressed in their nutrient composition and this may have implications at some key life stages. This includes the indirect effects of milk proteins on growth in children, in the maintenance of skeletal muscle mass in the elderly and in blood pressure moderation throughout adulthood. Topically, there is now increasing evidence that whey protein, and lactoferrin in particular, may represent a potential strategy in the prevention/treatment of COVID-19.
Meat: Perhaps to a greater degree than for dairy foods meat is often regarded as a detrimental source of fat and saturated fatty acids. There is often little recognition that red meat is a key source of haem iron and the related fact that many adolescents in particular, have very sub-optimal iron intakes in good part due to reducing red meat consumption. There is often very little differentiation between the three broad meat types i.e. red, white and processed meat despite the fact that each has considerably different health related characteristics. There is good evidence around the negative health effects of processed meat, in particular related to the risk of colo-rectal cancer, yet there remains confusion about what constitutes processed meat despite the WHO definitions. Processed meat is a highly variable commodity and there are questions as to whether the health risk is the same for all types and whether there should be separate dietary guidance for red and proceed meat and not the combination as at present.

49. Food labels – a panacea or a trojan horse? What information do food labels provide now, what could they provide in the future and what change will they drive?

K. Halliwell

The Food & Drink Federation, UK

There is a high demand for low carbon lifestyles in the UK. Survey data puts it as high as 88% of customers want food brands to help them live sustainably. One way to facilitate sustainable lifestyles is to provide clear and transparent communication of information, to promote informed choices;

and one place to provide this is on the product label. General food law requires that information provided to consumers should not be misleading. Beyond this, when developing new labelling approaches it is important to consider the legal footing. Information can be provided as a voluntary scheme designed by the individual manufacturer or retailer, or through an assurance organisation, and there are several examples of this with animal welfare and environmental labelling schemes currently in market. Information can also be voluntary but underpinned by legislative requirements, which if provided must follow the prescribed format ; or it can be mandatory. Different aspects of nutrition labelling illustrate these latter two approaches in accordance with the retained Regulation (EU) No. 1169/2011 on food information to consumers. The mechanism adopted is important, as the approach taken can impact speed and scale of adoption, consumer trust in the information, and standardisation of the information provided which in turn impacts on consumer choice. The UK's history of nutrition information also demonstrates that factors outside of legislation can drive a labelling approach forward; where a 5-nutrient front of pack nutrition labelling scheme has been in widespread use in the UK for 15 years but remains voluntary. When considering the implementation of a carbon label it is important to agree what will be measured, to enable standardised, repeatable calculation of information, which in turn will give comparability across different products. It is also important to consider if carbon is the only parameter or if a broader 'eco' label is needed. Once there are defined metrics further consideration should be given to how the information is displayed, an important factor that can help develop both consumer choice and company practices. It is likely we are years away from a widespread adoption of carbon labelling, but work is already ongoing to develop a cross-industry approach to a standardised measurements, the first step on the journey.

50. Animal Solutions to Human Problems

P. Garnsworthy

University of Nottingham, UK

The presentation discusses how although farm animals have provided humans with essential nutrients and many other benefits for over 10,000 years, recently they have become criticised in the media. This criticism has been driven by misinformation and ignores the vital role of animals in society. Animals are not the cause of climate change, the majority do not compete with plant-based human food production for land or water, and animal products are beneficial for human health. Animal production can provide solutions to global challenges of food supply, sustainability, and global warming, but there is room for improvement in efficiency with which we use resources. This lecture will provide a holistic view of animal production in relation to sustainability, food security and climate change and is perfectly placed for anyone with an interest in animal production.

51. Using sustainability scoring to evaluate animal production

D.M. Broom

Cambridge University, UK

Policy decisions about future livestock and other food production require accurate and comprehensive information. Some current discussions are based on evidence concerning only certain aspects of sustainability and certain systems. A sustainability scoring system is presented that takes account of all components of sustainability (Broom, 2021). A system or procedure is sustainable if it is acceptable now and if its expected future effects are acceptable, in particular in relation to resource availability, consequences of functioning, and morality of action. Sustainability scoring systems for food production that consider only monetary or carbon cost omit important aspects of sustainability so are not comprehensive. The sustainability components that affected ten internationally-used beef-production systems included human health, animal welfare, land usage, land area, amount of water used, greenhouse gas production, water pollution and nitrogen and phosphorus cycle disruption, biodiversity loss and carbon sequestration. For each system, published information about all of the life of the animal and all processes in the production of food, fertiliser, etc. per unit of meat in the slaughterhouse were considered. For each component, negative aspects of production were scored from 0 to -5 and it was noted if there was evidence that some consumers avoided purchasing products because of the component. The extent of negative scoring of all components of sustainability combined for the beef production systems are shown in Table 1. Products from degraded pasture, feedlots and indoor housing are all avoided by some consumers. One result of the comparison of beef production systems is that there is substantial variation across systems. A further result is that, partly because ruminants can eat food that humans cannot eat, extensive ruminant production using methods that preserve soil and carbon sequestration will be of value in the future. The best methods utilise high protein plants as a component of forage. Comparisons can be made of all meat and plant products. In order to use world resources efficiently and avoid causing harms, likely future changes include: increased plant food consumption; avoidance of some plant production methods; increased use of animals that consume leaves; greater use of plants producing high protein leaves; more mixed herb, shrub, and tree systems; less feeding of grain to farmed animals; more use of human food waste to feed farmed animals after treatment to avoid disease; more use of herbivorous fish, insects and mammals; and more cell culture of meat and other human food.

Table 1

Extensive pasture, degraded	−26
Extensive pasture, not degraded	−12
Fertilised irrigated pasture, plus concentrates	−23
Fertilised irrigated pasture, no concentrates	−16
Fertilised irrigated pasture, then feedlot	−25
Extensive pasture, then feedlot	−25
Fertilised irrigated pasture, then indoor housing	−26
Extensive pasture, then indoor housing	−26
Indoor rearing, then indoor housing	−29
Semi-intensive silvopastoral	−5

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52. Place-led dairy farming and the forgotten science of rumen physiology

J. Newbold

SRUC, Scotland

Globally, profitable dairy systems are either cow-led (reliant on a high rate of milk production per cow) or feed-led (which, in practice, means pasture-led), with production driven by the availability of a feed resource. Future profitable and sustainable dairy systems will be place-led, delivering a basket of ecosystem services fitting the place – farm, neighbourhood, region, country – where dairying is practiced. The general proposition of this paper is that a renewed and deeper understanding of rumen physiology will help breed, feed and manage the cows needed for future place-led dairy systems. As grazing ruminants, cattle evolved to acquire nutrients from grasses sufficiently quickly to allow them to support a single growing calf. Compared with the cell walls of the leaves of dicotyledonous plants, grass cell walls are low in lignin and can be digested relatively completely, but relatively slowly. Meanwhile, the cell contents of grasses are rich in sugars that can be digested enzymatically by the animal itself. The physiology of the rumen allows the retention of grass cell walls to permit their continued microbial digestion, while expelling cell contents (and microbes) for further digestion post-ruminally. Arguably, the ease with which researchers can quantify regurgitation and pH, and the imperative of reducing methane emissions, has skewed research effort away from rumen contractility and this filtering and retention mechanism. In cow-led systems, with high rates of milk production (driven largely by mammary secretory potential and the dynamic changes in nutrient partitioning during lactation), cows cannot acquire nutrients sufficiently quickly by the retention and relatively complete ruminal digestion of grass cell walls, leading to the substitution of grass (fresh or conserved) by starch-rich forages (e.g., maize silage), cereal grains, sources of undegraded protein, and fats. The rumen physiology of such cows partly resembles that of browsing ruminants, less reliant than grazers on continual pressure and filtration through a mat of retained partially digested plant cell walls.

In pasture-led systems, nutrients are not acquired sufficiently quickly to realise the genetic potential of high-yielding Holstein cows, resulting in foregone milk and/or excessive reliance on mobilized adipose tissue. Future place-led systems may require cows to consume and utilise a mix of grass and non-grass plants from multispecies swards delivering other benefits such as enhanced biodiversity and drought resistance. There is a need for further research on the chemical and physical characteristics of such forages (e.g., the fragility and specific gravity of forage particles) and their interaction with the rumen. Breeding cows (and forages) which maximise the extent of digestion of such mixed forages, versus maximizing the rate of nutrient acquisition (potentially increasing the rate of manure production) may or may not be commensurate with breeding for lower methane emission and emission intensity.

53. Farm Zero C – On a journey to climate neutral dairy farming

K. O'Connor [a], E. Buckley [b], F. Murphy [c]

[a] BiOrbic Bioeconomy SFI Research Centre and School of Biomolecular and Biomedical Science, University College Dublin, Belfield, Dublin 4, Ireland
[b] Carbery Group, Balineen, West Cork, Ireland
[c] School of Biosystems and Food Engineering, University College Dublin, Belfield, Dublin 4, Ireland

Agriculture and Agri-food are a major part of the Irish economy contributing to rural development, job creation, and wealth. The Agri-food industry in Ireland employs over 170,000 people and has an annual turnover of €26 billion (Teagasc Foresight and Foodwise 2025). To sustainably deliver on ambitious growth targets set by industry and nationally (creation of 23,000 direct jobs and added value of 70%) the sector must transform its business models and practices. Agriculture not only provides food but is and will continue to be the supplier of feedstock for the production of materials, chemicals, and energy that are and will increasingly replace fossil-based products. The farm is the start of the value chain in the bioeconomy but much focus in the bioeconomy is on GHG emission reduction and efficiency gains after the farm gate. To be sustainable, the bioeconomy must decarbonise, mitigate against climate change and achieve net zero carbon emissions along all of the value chain. While the carbon challenge is critical restoring biodiversity is also critical. The development of a carbon neutral farm must be in the context of promoting and growing biodiversity as this is critical to farm resilience. The Irish government Climate Action Plan indeed identifies the need to "Deliver substantial verifiable greenhouse gas abatement through adoption of a specified range of improvements in farming practice" (Irish Gov Climate Action Plan 2019). It also identifies the need to support diversification within Agriculture and land use to develop sustainable and circular value chains and business models for lower carbon intensity farming, protection and enhancement of biodiversity, and the production of bio-based products and bioenergy (Irish Gov Climate Action Plan 2019). The bioeconomy is a major platform from an EU perspective to address interrelated challenges such as food security, climate change, dependency on a depleting finite fossil resource, the need for rural development and re-industrialization of Europe (European Commission 2012 and 2018). The Farm Zero C project takes a holistic view of the farm to reduce greenhouse gas emissions and increase the health and resilience of the farm. The project has an interdisciplinary programme of work targeting soil and grassland; animal diet; biodiversity; life cycle analysis, renewable energy, and business plan development using a commercial dairy farm in Ireland as a demonstration farm. Transfer of research data and practices onto a commercial farm will enable farmers to see research in practice and encourage them to get on the path to a sustainable future which will have far reaching social, economic, and environmental consequences. To accelerate uptake of new knowledge the Farm Zero C project is working with replicator farms to help them to establish baseline date for their farms in preparation for implementation of practises from the demonstration farm.

54. Multi-phase feeding of finishing boars reared at up to 140 kg of live weight

D. Solà-Oriol [a], P. Aymerich [b], R. Muns [c,*]

[a] Universitat Autònoma de Barcelona, Barcelona, Catalonia, Spain
[b] Vall Companys, Lleida, Catalonia, Spain
[c] Agri-Food and Biosciences Institute, Belfast, Northern Ireland, UK

* Corresponding author. R. Muns.

Application: Increasing the number of diets offered during the finishing period from 2 to 3 does not compromise growth, improves efficiency at the end of fattening and might reduce overall N intake. *Introduction*: A reduction in the level of dietary crude protein (CP) is being widely considered as means to reduce N excretion from finishing pigs. However, one or two diets fed to pigs for the whole growing finishing period might fail to fulfil pigs' changing nutritional demands. Multi-phase group-feeding systems, which allow for feed composition to be adjusted over time, are designed to reduce overall CP intake while minimizing the risk of under or over-supplying pigs. The present work aimed to study the impact of 2 different phase feeding regimes (2 vs. 3 diets) on growth efficiency of entire male pigs during the finishing phase.
Materials and methods: At 10 weeks of age 52 boars (Duroc x (LD x LW)) were housed in groups of 13 in concrete slatted pens equipped with individual feeding stations to record daily individual feed intake and fed a conventional grower diet. At 12 weeks of age, pigs were distributed to treatments, balancing for body weight: 2 Phase feeding (2P), pigs offered a finisher diet 1 (13.8 MJ/ kg DE, 16% CP, 1.09% Lys) up to 19 weeks of age followed by a finisher diet 2 up to 24 weeks of age (13.7MJ/ kg DE, 14% CP, 0.93% Lys); and 3 Phase feeding (3P), pigs offered finisher diet 1 up to 18 weeks of age, followed by finisher diet 2 up to 21 weeks of age, followed by finisher diet 3 up to 24 weeks of age (13.6MJ/ kg DE, 12.2% CP, 0.77% Lys). Pigs were weighed at 18, 19, 21 and 24 weeks (end of the trial). Feed intake was recorded on the same time points and feed conversion ratio (FCR) calculated. Back fat was measured at 24 weeks on P2 spot using an ultrasound scanner. Data were analysed by ANOVA with pig as experimental unit and pen as random effect employing GenStat 16th edition.
Results: Feeding pigs either a 2P or a 3P did not have an effect on their overall performance from 10 to 24 weeks of age (Table 1). Nonetheless, FCR from 19 to 24 weeks of age was higher in 2P ($P < 0.05$). Back fat of pigs at 24 weeks did not differ between 2P and 3P (13.05 vs. 12.87 ± 0.528 mm, $P > 0.05$). Average total N intake (calculated using ADFI and formulated values for each diet) of P2 and P3 pigs was 5651 vs. 5212 ± 202 g.
Conclusions: Feeding fattening pigs 3 finishing diets did not reduce overall performance compared to feeding 2 finishing diets, while overall N intake was numerically reduced by more than 400g per pig (7.8% reduction). An improvement in feed efficiency was actually observed in 3P pigs in the last weeks of fattening.

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Table 1
Effect of treatment on pigs' body weight, average daily gain (ADG), average daily feed intake (ADFI) and feed conversion ratio (FCR).

	2 Phase feeding	3 Phase feeding	SED	P-value
n° of pigs	*n = 26*	*n = 23*		
10 week weight, kg	28.9	28.8	0.66	0.851
12 week weight, kg	41.4	41.9	1.17	0.694
18 week weight, kg	82.6	83.5	2.78	0.760
19 week weight, kg	92.8	90.2	2.18	0.361
21 week weight, kg	111.5	112.1	2.23	0.788
24 week weight, kg	139.1	138.6	4.25	0.906
ADG 10-24 weeks, g	1139	1131	42.4	0.875
ADG 19-24 weeks, g	1268	1344	56.1	0.424
ADFI 10-24 weeks, g	2722	2416	88.2	0.520
ADFI 19-24 weeks, g	3362	3244	198.5	0.613
FCR 10-24 weeks	2.18	2.13	0.046	0.282
FCR 19-24 weeks	2.65	2.42	0.094	0.018

SED: standard error of the difference.

55. Sows' performance at different litter size number in farrowing pens equipped with an automatic milk replacer feeder

A. Strain [a], M. Connery [b], R. Wregor [b], J. Connolly [b], W. Henry [c], R. Muns [a,*]

[a] Agri-Food and Biosciences Institute, Belfast, Northern Ireland, UK
[b] JMW Farms Ltd., Armagh, Northern Ireland, UK
[c] Rektify Ltd., Armagh, Northern Ireland, UK

* Corresponding author. R. Muns.

Application: Sows in farrowing pens with an automatic milk replacer feeder can rear litters of 15 piglets with a reduced pre-weaning mortality. Nonetheless, our results suggest that the system could support litters of 16 piglets without compromising litter or sow performance.
Introduction: Genetic selection towards hyper prolific sows has resulted in litters outnumbering the number of viable teats and, in occasions, piglets outnumbering viable teats at a room level. Different strategies are available to manage the surplus of born alive piglets: implementing a nurse sow system, artificial rearing, offering supplemental milk replacer to pigs, etc. Automatic milk replacer feeders are not uncommon in commercial farms. The objective of this study was to identify whether sows could successfully rear larger litters when an automatic milk replacer was present in the farrowing pen.

Table 1
Effect of litter size on sow performance during lactation.

Litter size	15	17	*SEM*	*P-value*
n° sows	*12*	*15*		
Live Born piglets	15.93	16.06	0.577	n.s
Pre-wean Mortality, %	0.83	7.27	1.560	<0.05
Number of pigs weaned/sow	14.98	15.77	0.249	<0.10
Av. pig weaning weight, kg	6.89	6.71	0.148	0.558
Back Fat, mm	15.17	17.15	0.729	0.200
Back Fat loss, mm	2.25	2.80	0.530	0.642

SEM: standard error of the mean.

Materials and methods: Under the Animals (Scientific Procedures) Act 1986, a study was conducted in a commercial farm involving 27 sows (LW x LR) and their piglets (n = 433). At cross fostering (24 hour after the onset of farrowing) sows were left with either 15 (Litter15) or 17 piglets (Litter17). Treatment groups were balanced by farrowing day, parity and live born piglets. All sows followed the same management and were fed the same gestation diet (DE 12.4MJ, CP 15.4%). During lactation all sows also followed the same management and were fed the same diet (DE 14.7MJ, CP 16.6%). All piglets had ad libitum access to fresh water and ad libitum access to a milk replacer via an automatic nipple drinker placed at the front of the pen. Any sow with poor condition, less than 14 viable teats and/or less than 10 live born piglets and/or more than 5 stillborn/mummified were excluded from the trial. Cross fostering was achieved keeping the number of piglets transferred to a minimum. Reproduction data (Total born, born alive), number of piglets weaned and litter weaning weight were recorded. Average piglet weaning weight was calculated. Piglet mortality was recorded from fostering to weaning. Back Fat of sows at the P2 spot was recorded with an ultrasound device the day before farrowing and at 28 days post-farrowing. Data were analysed by ANOVA using GenStat 19th edition. The sow was used as the statistical unit.
Results: Individual piglet's performance results are presented in a separate Abstract. Sow performance results are presented in Table 1. Litter17 had higher pre-weaning mortality ($P < 0.05$). Nonetheless, Litter17 had a tendency to wean more piglets per sow ($P < 0.10$). Sows from both treatments had similar back fat before farrowing and lost similar back fat during lactation ($P > 0.05$, respectively).
Conclusion: Litters with 17 piglets, despite having higher pre-weaning mortality, weaned almost one more piglet without reducing the average piglet weaning weight. Automatic milk replacer feeder allow sows to rear 15 piglets at a high survival rate with scope to increase litter up to 16 piglets per sow at cross fostering.

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56. Automatically recorded sow feeder data are associated with indicators of sow welfare

M. Lagoda [a,b,*], L. Boyle [a], J. Marchewka [b], K. O'Driscoll [a]

[a] Teagasc, Animal & Grassland Research & Innovation Centre, Pig Development Department, Fermoy, Cork, Ireland
[b] Institute of Genetics and Animal Biotechnology, Polish Academy of Sciences, Department of Animal Behaviour, Jastrzebiec, Poland

* Corresponding author. M. Lagoda.

Application: Information on sow feeding behaviour recorded by electronic sow feeders (ESF) provides insights into sow welfare and could help in the management of animal health/welfare in large herds.
Introduction: Assessing welfare of sows in large herds can be time-consuming and laborious. However, farms increasingly have technologies that automatically collect data potentially relating to animal health and welfare. Pregnant sows are often fed by ESFs which collect information on their feeding behaviour (Vargovic et al., 2021). This study investigated associations between gilt ESF use patterns and welfare indicators, including the percentage of oral stereotypical behaviour performance throughout pregnancy (OS), skin lesion (SL) counts, locomotion score (LOCO), and hair cortisol concentrations (HCC).
Material and methods: Ethical approval was obtained from the Teagasc Animal Ethics Committee. Gilts (n = 51; 8 time replicates; 7 ± 3.3 gilts/replicate) were housed in a dynamic group, and fed with an ESF, which recorded feeder use data throughout pregnancy. These data were used to calculate the average number of daily ESF visits/gilt, and the average ESF visit duration (min) over the entire pregnancy (predictors). Oral stereotypical behaviours were recorded by direct observations with instantaneous scan sampling (5 min intervals; n = 36 scans/day) 72 hr post-mixing, on d58, and on d107 of pregnancy. Percentage frequency of OS/gilt was then calculated over entire pregnancy. Skin lesions were counted pre-mixing into the dynamic group, 24 hr post-mixing, three weeks post-mixing, and on d108 of pregnancy. Sum of counts across all body regions (head, neck, shoulders, front legs, flanks, back, rump, and hind legs) yielded a total SL count/gilt. Locomotion was scored using a visual analogue scale at service, on d57, on d108 of

Table 1
Associations (regression coefficient ± standard error; SE) between average daily electronic sow feeder (ESF) visits, average ESF visit duration, and gilt welfare indicators.

Variable	Average daily ESF visits				Average ESF visit duration (min)			
	Regression coefficient	SE	F value	P-value	Regression coefficient	SE	F value	P-value
% Oral stereotypical behaviour performance throughout pregnancy	−1.5	0.51	F1,49 = 8.84	< 0.001	2.3	0.95	F1,49 = 5.65	0.021
Skin lesion count day 108	1.5	0.65	F1,49 = 4.98	0.030	−2.0	1.20	F1,49 = 2.90	0.095
Locomotion score day 57	−1.6	0.52	F1,49 = 9.47	< 0.001	2.3	0.97	F1,49 = 5.53	0.023
Hair cortisol concentration day 108 (μg/dL)	−0.01	0.005	F1,48 = 3.88	0.055	0.01	0.010	F1,48 = 1.79	0.187

pregnancy, and at weaning. Hair was shaved on d30, and re-shaved on d108 of pregnancy. Re-grown hair was analysed for HCC. A regression analysis was performed (SAS v9.4; PROC MIXED) to investigate associations between predictors and welfare indicators.
Results: Gilts which visited the ESF more often on a daily basis performed OS less frequently, had more SL on d108, lower (better) LOCO on d57, and tended to have lower HCC on d108 of pregnancy. Gilts which spent longer inside the ESF performed more OS, tended to have fewer SL on d108, and had higher LOCO on d57 of pregnancy (Table1).
Conclusion: Results revealed differences in behavioural and physical gilt characteristics, which were associated with ESF use patterns. Namely, gilts that visited the ESF more often appeared to have improved welfare compared to gilts which on average spent longer inside the ESF. Thus the pattern of ESF use can provide an insight into sow welfare status, and potentially be used to develop as a decision support tool for farmers. This could aid identification of vulnerable animals and the early stages of lameness. Development of algorithms to automatically process ESF use data could contribute to and ease sow and gilt welfare assessments.

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57. Microbial biomarkers for pig performance traits under different social stress challenges

T.Q. Nguyen [a,*], M. Martínez-Álvaro [a], K.M.D Rutherford [a], M.D. Auffret [a], G. Simm [b], R.J. Dewhurst [a], E.T. Baima [c], R. Roehe [a]

[a] SRUC, Edinburgh, UK
[b] University of Edinburgh, Edinburgh, UK
[c] Zoetis Inc, Parsippany-Troy Hills, USA

* Corresponding author. T.Q. Nguyen.

Application: Social stressors such as repeated regrouping and reduced space allowance significantly influence associations between the gastrointestinal microbiome and performance traits of finishing pigs.
Introduction: Social stressors, including repeated aggressive interactions and regrouping, have been shown to influence pig's weight gain (Rutherford et al., 2006) and its microbiota (Nguyen et al., 2020). However, it is not known whether social stress changes specific microbiota-host performance associations. Therefore, we explored how exposing social stress affects the relationships between gastrointestinal microbiota profiles and performance traits.
Materials and methods: The experiment was conducted in accordance with the UK Animals Act 1986 and approved by SRUC's Animal Welfare and Ethical Approval Body. Thirty-eight pigs were distributed into 10 pens balanced for litter of origin and body weight, and subjected to stress (n = 19) or control (n = 19) treatments. The stress treatment consisted of weekly regrouping of animals between pens (resulting in substantial fighting among pigs) and reduced space allowance (~$1m^2$) for four weeks, whilst the control group remained in stable groups with increased space (~$2m^2$). Weekly, animals were individually weighed, individual daily feed intake (DFI) was calculated from pen feed intake (Lee et al., 2016), cortisol concentration was measured from saliva samples. From all pigs, caecum samples were collected at slaughter, microbial DNA was extracted and used in taxonomic characterization based on the 16S rRNA gene. The microbiota data were centred log-ratio transformed to account for its compositionality. Partial least squares models using the microbiota data to predict animal host traits (individual average daily gain (ADG), DFI and feed conversion ratio (FCR)) within treatment group were used to identify microbial genera associated with performance traits, based on variable importance in projection scores ≥ 1.
Results: Pigs in the stress group presented 21.4 ± 5.09 ng/ml higher average cortisol concentration and lower ADG (−0.21 ± 0.04 kg/day) and DFI (−0.35 ± 0.11 kg/day) than the control group. Different microbiota-performance traits associations were revealed within control or stress groups. The most important microbial genera for explaining the variability of performance traits were beneficial. Shuttleworthia, Megasphaera and Lactobacillus, which abundances were desirably associated with higher ADG, DFI, and lower FCR in the control group but undesirably under stress conditions (Table 1). Generally, opportunistic pathogens, such as Treponema, Campylobacter, and Candidatus Saccharimonas, showed unfavourable associations with DFI and ADG in both the stress and control group. Our results indicate that stress should be considered when identifying biomarkers for performance traits in pigs.
Conclusion: Our study provides further evidence of the detrimental impact of stress on production performance of finishing pigs and shows that microbiome-performance traits associations are affected by the stress level of the host.

Table 1
PLS regression coefficients[1] of the important microbial genera for the prediction of host performance traits within stress and control groups. [1]The negative regression coefficients are in shaded cells. Empty cells indicate non-significant associations. FCR (kg/kg), DFI (kg/day), ADG (kg/day).

Microbial genus	Control			Stress		
	FCR	DFI	ADG	FCR	DFI	ADG
Shuttleworthia	−0.08	0.11	0.12		−0.10	−0.09
Megasphaera	−0.01	0.03	0.12	0.04		−0.02
Lactobacillus	−0.10	0.08	0.12	0.05		
Treponema				−0.07	−0.06	
Campylobacter		−0.03	−0.03			0.02
Ca. Saccharimonas		−0.01	−0.08	−0.08	−0.13	−0.02

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58. Post-partum analgesia administration to sows but not split-suckling increased piglet growth and reduced anti-inflammatory treatment of piglets

E.A. Arnaud [a,b,*], G.E. Gardiner [b], K.M. Halpin [b,a], C. Ribas [c,a], J.V. O'Doherty [d], T. Sweeney [d], P.G. Lawlor [a]

[a] Teagasc Pig Development Department, Animal and Grassland Research and Innovation Centre, Fermoy, Co. Cork, Ireland
[b] Department of Science, Waterford Institute of Technology, Waterford, Co. Waterford, Ireland
[c] L'institut Agro, Montpellier SupAgro, 2 place Pierre Viala, Montpellier, France
[d] School of Agriculture and Food Science, University College Dublin, Dublin, Co. Dublin, Ireland

* Corresponding author. E.A. Arnaud.

Application: Post-partum analgesia provision to sows increased piglet growth in the first week post-partum and reduced anti-inflammatory treatment of suckling piglets.
Introduction: Suckling pigs should receive ≥ 200 g of colostrum (Devillers et al., 2011). Split-suckling and/or administering pain relief to sows post-farrowing may help to ensure this. The objective of this study was to assess the effect of split-suckling and post-partum analgesia on growth and medication use in suckling pigs.
Materials and methods: 89 sows blocked on parity, previous litter-size and weight were randomly assigned to one of 4 treatments in a 2 × 2 factorial arrangement; factors being provision of analgesia (yes/no) and split-suckling (yes/no). Meloxicam (Loxicom® Injection, Norbrook, Ireland) at 0.4 mg/kg was administered to sows at release of the placenta (1–10 h post-partum). Split-suckling commenced 4 h after onset of parturition with the six heaviest piglets removed from the sow for 1 h to allow the lightest piglets suckle. This was repeated again after 1.5 h. Medication was administered when joint-ill, lameness, malaise or diarrhoea were observed in piglets and when malaise or vaginal discharge was observed in sows. A combination of antibiotic and anti-inflammatory was injected for illness lasting ≤ 3 days and when > 3 days only antibiotic was administered. Data were analysed using the mixed models procedure in SAS (version 9.4; SAS Institute Inc.) with split-suckling, analgesia and their interaction included as fixed effects, and day post-partum as the repeated measure. Block was included as a random effect and the number of pigs born alive as a co-variate. Means separation was by Tukey adjustment for multiple comparisons. The litter was the experimental unit.
Results: There was a split-suckling by analgesia interaction at day 0–6 where piglets that were not split suckled had increased piglet average daily gain (ADG) when analgesia was administered to the sow ($P < 0.05$). Between day 0 and 6, ADG increased in response to analgesia administration (139 vs 161 ± 6.8 g/day; $P < 0.05$). Piglet ADG from day 6 to 14 and from day 14 to weaning were unaffected by treatment ($P > 0.05$). Analgesia use in sows reduced the volume of anti-inflammatory treatment administered per piglet during lactation (73.8 vs 17.1 ± 18.60 μL/pig; $P < 0.05$) but did not affect antibiotic use. Split-suckling did not affect piglet growth or the volume of antibiotic or anti-inflammatory administered to piglets up to weaning. Treatment did not affect the volume of antibiotic or anti-inflammatory administered to sows during lactation.
Conclusion: The provision of meloxicam at 0.4 mg/ kg of body weight to sows between 1 and 10 hrs post-partum increased piglet growth during the first 6 days after birth and reduced the volume of anti-inflammatory administered per piglet during lactation. Split-suckling did not influence piglet growth or medication usage to weaning.

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59. Understanding public perceptions of dairy cow welfare

A. Jackson [a,*], M. Green [a], J. Kaler [a]

[a] The School of Veterinary Medicine and Science, University of Nottingham, Sutton Bonington, Leicestershire, UK

* Corresponding author. A. Jackson.

Application: Better understanding public perceptions of dairy farming would allow industry to improve communication and adapt farming systems to align with societal expectations.
Introduction: The viability of dairy farming is threatened by concerns over animal welfare. Access to pasture appears a key concern in this debate, questioning the future of systems that house cows year-round. Despite support for grazing, public preferences for how cows are managed appear diverse, with a range of other aspects prioritised including comfort and health and welfare (Jackson et al., 2020). However, what underpins these preferences is not clear, especially: how the public make sense of dairy cow welfare through their own experiences; or how they perceive the different systems in which farmers keep cows.

Materials and methods: Face-to-face semi-structured interviews about dairy farming were conducted with a diverse group of 60 people from across the UK. Interviews were recorded, transcribed and uploaded to NVivo 12 software to aid coding and analysis. Inductive thematic analysis first established different interpretive frames through which participants understood the dairy cow and farmer. Thematic analysis was then used to explore how participants understood three different dairy farming systems described to them verbally and visually. Linguistic analysis using LIWC then Friedman's Test on related samples and post-hoc pairwise comparison with Bonferroni's correction was used to determine differences in style and tone when participants discussed each system. Results were triangulated to qualitative results to provide additional insight.
Results: Frame analysis identified that participants perceived the cow in three ways and the farmer through two. Cow frames revealed unexpectedly strong connections between participants and cows despite superficial contact, framing cows as companions, subordinates or 'revered' beings. Farmers were traditional or modern but in conflicting positive and negative lights, creating confusion about care of the cow. Qualitative analysis by system suggested participants saw the cow as wild but also domesticated, and best managed in a scenario combining access to nature with protection when needed. However, they also deferred to others for guidance on how a cow should live – including the cow herself. Various dairy farming practices were seen as problematic depending on whether the cow was inside or out. Triangulation of these results using linguistic analysis found emotional reactions against housing year-round and confusion about whether grazing year-round was viable, confirming a housing-grazing combination was most logical and acceptable to participants.
Conclusions: These findings suggest the public feel a greater stake in dairy farming than industry currently acknowledges. Conflict about the farmer's motives towards dairy cow welfare create confusion. A system combining access to pasture and housing when needed is emotionally and cognitively most acceptable to the public, and optimal in addressing the cow's needs.

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60. Evaluation of private dairy cow health and welfare standards and associated quality assurance programmes

L. Boyle [a,*], S. More [b], A. Hanlon [b], A. Balzani [b], J. Marchewka [c]

[a] Teagasc, Fermoy, Co. Cork, Ireland
[b] University College Dublin, Dublin, Ireland
[c] IGHZ, Jastrzębiec, Magdalenka, Poland

* Corresponding author. L. Boyle.

Application: Quality assurance programmes (QAp) have potential to improve animal health and welfare (AHW). Our evaluation of four dairy QAp revealed notable examples of best-practice in AHW. However, there was no objective information to substantiate many of the QAp claims indicating the need for greater scrutiny of private standards (PS) and QAp. *Introduction*: The EU strategy for farm AHW shifted from regulatory to voluntary approaches in cooperation with the private sector. This shift to PS opened market opportunities and labelling for consumer choice but may lack the rigour of the guiding principles that underpin public standards. More et al. (2017) developed a conceptual framework to evaluate PS and their associated QAp drawing from principles that underpin public standards in relevant international organisations, including the Sanitary and Phytosanitary Agreement of the World Trade Organization. The aim of this work was to evaluate four PS and associated QAp for dairying in terms of this conceptual framework.
Materials and methods: We evaluated four QAp for dairy production in terms of the framework: Foqus planet, Sustainable Dairy Assurance Scheme, Arlagården, and RSPCA Assured, developed by FrieslandCampina, BordBia, Arla, and the Royal Society for the Prevention of Cruelty to Animals respectively. The evaluation involved review of material available on-line and meetings with company representatives. Information was classified as per the conceptual framework into: (1) primary programme goals; (2) measurable AHW outputs; (3) programme beneficiaries; and (4) programme efficiency, effectiveness and transparency.
Results: Application of the framework to the four QAp revealed deficiencies relating to standard-setting, lack of governance transparency, reporting programme performance and review. Interpretation of the AHW standards was complicated by different goals, drivers, and the lack of output-based measures used to benchmark and evaluate compliance. There were examples of best-practice in AHW such as use of animal based measures and benchmarking but there is a risk that consumers are misled if QAp only adhere to good practice. Transparency is essential for consumers to assess the credibility of QAps.
Conclusion: This analysis raises concern for the credibility of certain claims made by QAp and could potentially erode consumer confidence in PS for AHW. This work also demonstrates the importance of having a standardised framework to guide the development of PS for AHW so they will benefit all stakeholders. Clearly, there is a need for greater scrutiny of PS and QAp. Regulatory oversight may be needed to build confidence among consumers of programme claims.

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61. Effect of parity on dairy cow mobility and subsequent milk yield, feed intake and feed efficiency during lactation

J. Margerison [a,*], C. Geoghegan [a]

[a] University of Nottingham, Nottingham, Nottinghamshire, UK

* Corresponding author. J. Margerison.

Application: Cows of greater parity had imperfect and impaired mobility, which persisted through to mid lactation. While this had no effect on feed efficiency, it has considerable implications for cow welfare, consumer perception and the economic cost of milk production due to treatment costs, which warrants investment into prevention strategies.

Introduction: Lameness has implications for consumer perception and the economic resilience of the dairy industry (Griffiths et al., 2018) and causes substantial pain for dairy cow welfare (Whay and Shearer, 2017). However, previous studies have not assessed mobility score at parturition (MSAP) and its effect on subsequent animal performance. This study aimed to assess MSAP, the time cows had suboptimal mobility and its effect on milk yield, dry matter intake (DMI), feed efficiency and food security.

Materials and methods: This study was completed by observing 53 Holstein-Friesian dairy cattle (LW 610 ± 6.10 kg) that were selected at random (11,000 L/cow/year) from the University of Nottingham dairy herd according to calving date and allocated according to age / parity to one of three groups; 1 (n = 18): 2 (n = 18) and ≥ 3 (n = 18). During early lactation (100 d) individual mobility (0 to 4), DMI, milk yield and composition were measured and or reported weekly. Data was normally distributed and analysed using AVOVA GLM, with differences between means being assessed using Tukey's test, with a confidence interval of 95%.

Results: Older cows in ≥3 lactation had impaired mobility, greater milk (6.8 kg/d), EC milk and component yields and DMI than animals in first and second lactation. There was no effect of parity on milk composition and efficiency with which feed was converted into milk yield, protein, fat and solids (Table 1).

Conclusion: Older cows that had completed more lactations had impaired mobility, greater milk yields and DMI than first and second lactation cows, which had good and imperfect mobility. Lactation and age did not affect feed efficiency. Older cows of ≥3 lactation had imperfect or impaired mobility at parturition and this status continued for 94.4% (± 3.30) of the first 100 d pp of lactation, which indicated that preventing the development of imperfect mobility on some dairy units provides a considerable opportunity to improve dairy cow welfare, consumer perception and economic costs of milk production.

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Table 1
Mean milk, milk composition and component yield, feed intake and feed efficiency (± se) between 0 and 100 days postpartum of dairy cattle that had a good (< 0.5) imperfect (0.5 and 1) and impaired (2 & 3) mobility at parturition.

	Parity (1 to ≥ 3)				
	1	2	≥ 3	SEM	P-value
Mobility score at parturition	0.40	0.75	1.5	0.10	**
Milk yield, kg/d	39.4 [b]	42.0 [b]	46.4 [a]	0.75	***
EC milk yield, kg/d[1]	40.1 [b]	42.2 [b]	47.1 [a]	0.74	***
Milk fat, g/kg	37.0	35.8	36.6	0.68	NS
Milk protein, g/kg	30.0	30.0	30.0	0.29	NS
Total milk fat, kg/d	1.46 [b]	1.50 [b]	1.70 [a]	0.21	***
Milk protein, kg/d	1.18 [b]	1.26 [b]	1.39 [a]	0.11	***
Total milk solids, kg/d [2]	2.64 [b]	2.76 [b]	3.09 [a]	0.55	***
SCC, 00,000 (cells/ml)[3]	26.1 [b]	27.7 [b]	147.6 [a]	14.11	***
Dry matter intake, kg/hd/d	20.4 [b]	21.3 [b]	22.8 [a]	0.32	***
Feed efficiency:					
EC milk yield [1]/DMI, kg/kg	1.98	1.98	2.07	0.45	NS
Milk protein/DMI, kg/kg	0.058	0.059	0.060	0.0013	NS
Milk solids/DMI, kg/kg	0.13	0.13	0.14	0.003	NS

[a,b,c] - Means that do not share a letter are significantly different at P < P < 0.05.
[1] – EC: Energy corrected milk yield, kg = 0.327 x milk yield kg + 12.95 x fat kg + 7.21 x protein kg.
[2] – Total milk solids = kg milk fat + kg milk protein, kg/d.
[3] - SCC: Somatic cell count, Log base[10].

62. Prevalence of growth hormone receptor gene polymorphisms and their possible impact on fertility traits and milk yield of cross-bred dairy cows in Sri Lanka

D.I. Abeygunawardana [a,b,*], R.M.S.B.K. Ranasinghe [b], S.N.T. de Silva [c], R.M.C Deshapriya [d], G.A. Prathapasinghe [a], R.P.V.J. Rajapakse [e]

[a] Department of Livestock and Avian Sciences, Faculty of Livestock, Fisheries and Nutrition, Wayamba University of Sri Lanka, Makandura, Gonawila, (NWP), Sri Lanka
[b] Department of Basic Veterinary Sciences, Faculty of Veterinary Medicine and Animal Science, University of Peradeniya, Peradeniya, Sri Lanka
[c] Department of Nano Science Technology, Faculty of Technology, Wayamba University of Sri Lanka, Kuliyapitiya, Sri Lanka

Table 1
Genotypic and allelic frequencies of SNPs in GHR gene of screened cross bred dairy cattle population in Sri Lanka.

Region	SNP	Allele[1]		Genotype frequency			Allele frequency	
		0	+	00	0+	++	0	+
5 UTR	rs109014416	G	T	0.136	0.127	0.737	0.199	0.801
	rs109231659	G	T	0.788	0.136	0.076	0.856	0.144
	rs134115846	A	G	0.356	0.305	0.339	0.508	0.492
Exon 08	rs385640152	T	A	0.987	0.007	0.007	0.990	0.010

[1] T = thymine, C = cytosine, A = adenine, G = guanine.

[d] Department of Animal Science, Faculty of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka
[e] Department of Veterinary Pathobiology, Faculty of Veterinary Medicine and Animal Science, University of Peradeniya, Peradeniya, Sri Lanka

* Corresponding author. D. I. Abeygunawardana.

Application: Single nucleotide polymorphisms (SNP) associated with desirable traits can be used as molecular markers in the selection of dairy cows with higher genetic potential.
Introduction: SNPs in the growth hormone receptor gene have been reported to be associated with milk production and composition related traits (Blott et al., 2002) as well as reproductive traits (Waters et al., 2010). It needs further investigation in distinct cattle populations in order to understand their effects on fertility and production within different management systems. This preliminary study aimed to detect the possible impact of selected growth hormone receptor gene SNPs on selected fertility phenotypes and milk yield of cross-bred dairy cows in Sri Lanka.
Materials and methods: A population of 153 cross-bred dairy cows reared on three National Livestock Development Board farms was genetically screened for SNPs in the exon 08 and 5' upstream (n = 118) regions of the growth hormone receptor gene using target sequencing method. The General linear Model of SPSS version 26.0 was used to investigate the possible relationships between different genotypes and selected fertility traits (average calving interval, number of services per conception, and age at first calving) and average milk yield. The fixed factors considered were genotype and farm. Parity was included as a covariate.
Results: Altogether four SNPs in the growth hormone receptor gene were identified in the cows examined for this study. The reported genotype and allele frequencies are given in Table 1. The SNP, rs1099014416 was significantly associated with average calving interval and age at first calving. Cows with GG genotype calved at a relatively younger age (918.51 ± 113.42 days) compared with cows with TT and GT genotypes (1212.89 ± 88.22 and 1275.18 ± 38.31days). Meanwhile, cows with GG genotype showed longer calving intervals (543.41 ± 43.29days) compared to GT and TT genotypes. The other SNPs did not show any association with any of the traits tested in this study.
Conclusion: SNP rs109014416 has the potential to be used as a genetic marker for fertility-related traits for selection of cross-bred dairy cows in Sri Lanka. But the finding of this preliminary study should be validated with a larger population.

Uncited reference

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63. Towards preventing transmission of digital dermatitis treponemes by cattle foot trimming knives

A. Gillespie [a,*], S. Carter [a], R. Blowey [b], N. Evans [a]

[a] University of Liverpool, Liverpool, UK
[b] Appithorne, Gloucester, UK

* Corresponding author.

Application: Develop a protocol to eliminate a bovine digital dermatitis (BDD) treponeme infection reservoir, communicate to end users and identify if advice is used.
Introduction: BDD is a highly prevalent infectious foot disease of cattle. Active lesions cause pain and lameness making BDD an important economic and welfare concern. Spirochaetes of the genus Treponema are the most commonly implicated microbes within BDD lesions. Treponemes contaminate cattle hoof knives during foot trimming, and lack of washing of hoof trimming equipment has been identified as a risk factor for high BDD prevalence; therefore, hoof knives are considered an infection reservoir (Wells et al., 1999; Sullivan et al., 2014). The aims were 1) determine survival time of BDD treponemes on hoof knife blades, 2) develop a disinfection protocol to eliminate treponemes from hoof knife blades, 3) communicate the protocol to those working with cows' feet and determine its uptake.

Materials and methods: To determine survival time, BDD-associated treponemes (two species) were applied to hoof knife blades and swabs collected at five time points. Five disinfectants were tested in the laboratory using a 20-second contact time, then three progressed to field trials, where 133 feet with BDD lesions were trimmed and blades swabbed before and following hoof-trimming and after blade disinfection. Swab DNA extraction and PCR were used for treponeme detection, as well as swab inoculation into culture media and phase contrast microscopy and PCR after 6 weeks' anaerobic incubation. After promoting the disinfection protocol, a survey was undertaken to assess research impact on foot-trimming hygiene knowledge and practice.

Results: Treponemes were viable (culturable) for two hours on hoof trimming knives. 2% Virkon, 2% sodium hypochlorite and 1:100 FAM30 were efficacious for preventing growth of laboratory applied BDD treponemes (Gillespie et al., 2020a).In field (farm) trials, 1/22 cases exhibited treponeme culture from a hoof knife after foot-trimming when no direct BDD lesion contact was made, whilst lesion contact in 47/111 cases produced viable cultures, indicating potential for transmission (Gillespie et al., 2020b). Washing hoof knives in 1:100 FAM30, 2% sodium hypochlorite or 2% Virkon for 20 seconds (full AHDB protocol: https://ahdb.org.uk/reducing-spread-of-DD) prevented treponeme culture from knives (Gillespie et al., 2020a). After advertising and knowledge exchange of the AHDB protocol for hoof-trimming equipment disinfection: 35/80 end users surveyed were more aware of the risk of BDD transmission via this route, and 36/80 had enhanced hygiene practices (Gillespie et al., 2021).

Conclusion: Foot-trimming knife blade disinfection can reduce the risk of spread of viable BDD treponemes between cows. Communication of a recommended disinfection protocol by AHDB Dairy and University of Liverpool has enhanced awareness and influenced those working with cows' feet to improve their hygiene practices.

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64. Association of teat hyperkeratosis on gross milk composition in dairy cows

M. Moschovas [a], S. Karneris [a], T. Pnevmatikos [a], E. Tsimpouri [a], A.I. Gelasakis [a,*], I. Bossis [b]

[a] Laboratory of Anatomy & Physiology of Farm Animals, Agricultural University of Athens, Athens, Greece
[b] Laboratory of Animal Husbandry, School of Agriculture, Aristotle University of Thessaloniki, Thessaloniki, Greece

* Corresponding author. A. I. Gelasakis.

Application: Teat hyperkeratosis in dairy cows affects somatic cell counts in milk. Estimating the exact effects on gross milk composition will aid in herd health management and improve milk quality.

Introduction: Mastitis is one of the greatest health concerns in the dairy industry, leading to major monetary losses. Teat hyperkeratosis, which occurs from poor milking conditions, increases the somatic cell counts and the risk of mastitis infection. Therefore, the effect of teat hyperkeratosis on milk quality traits should be also thoroughly investigated. The objective of the study was to identify the effects of teat hyperkeratosis on fat-, protein-, lactose-, solid-non-fat (SNF) and total-solids (TS) content.

Materials and methods: The study was performed using a two-step approach. During farm visits, animal ID, lactation number, days-in-milk (DIM), daily milk yield (DMY) and teat hyperkeratosis (scores 0–3 for each teat, as presented by Gleeson et al., 2004) were recorded for each individual cow. On the second step, 1st and 2nd lactation cows were excluded from the study, as they presented with low rates of teat abnormalities. Finally, a total of 304 ≥ 3rd lactation Holstein-Friesian cows from one dairy farm were enrolled in the study. Milk samples were collected from the studied cows and tested for fat, protein, lactose, SNF and TS content using the MilkoScan™. Using DMY records, daily fat- (DFY), protein- (DPY), lactose- (DLY), SNF- (DSNFY) and TS yield (DTSY) were calculated on grams. SPSS v23 was used for data analyses, which included descriptive (mean ± standard error) and analytical statistics. Univariate analysis of covariance was used as presented in the following model:

$$_{\text{Yikmn}} = \mu + _{\text{LPi}} + _{\text{LSk}} + _{\text{FHm}} + _{\text{HHn}} + \alpha_1 * \text{DMY} + _{\text{eikmn}}$$

where, Y_{ikmn} = dependent variables (DFY, DPY, DLY, DSNFY, DTSY), μ = overall mean, LP_i = fixed effect of lactation period (i = 3 levels; 3rd, 4th and > 4th lactation), LS_k = fixed effect of lactation stage (3 levels; 1 = 1–40 DIM, 2 = 41–170 DIM, 3 = 171 + DIM), FH_m/HH_n = fixed effect of teat hyperkeratosis in front/hind teats (4 levels; 1 = normal teats, 2 = at least one teat with score 1, 3 = at least one teat with score 2, 4 = at least

Table 1
Effects of lactation period, lactation stage, teat hyperkeratosis and daily milk yield (DMY) on daily fat- (DFY), protein- (DPY), lactose- (DLY), solid-non-fat- (DSNFY) and total-solids yield (DTSY) (g).

	DFY	DPY	DLY	DSNFY	DTSY
Lactation period	0.759	0.426	2.623	1.763	1.125
Lactation stage	2.079	0.880	3.522*	2.586	3.298*
Front teat hyperkeratosis	2.098	0.081	1.477	0.378	2.342
Hind teat hyperkeratosis	0.519	0.722	0.726	0.785	0.611
DMY (g)	159.870**	1643.606**	8638.285**	5464.548**	1152.841**

* P ≤ 0.05.
** P ≤ 0.001.

one teat with score 3), a_1 = linear regression coefficient of DMY, e = error term.
Results: Overall, 64.8% (197/304) and 79.9% (243/304) of the studied cows had no hyperkeratosis in the front and the hind teats, respectively. Mean DFY, DPY, DLY, DSNFY and DTSY were 1538.3 ± 52.99, 1100.4 ± 21.21, 1622.9 ± 36.15, 2982.2 ± 62.10 and 4536.9 ± 106.64 g, respectively. The effects of lactation period, lactation stage, DMY, teat hyperkeratosis are presented in Table 1.
Conclusion: Teat hyperkeratosis was not significantly associated with gross milk composition, indicating that it may not affect milk quality traits. Research focusing on each udder quarter will further clarify the exact effects of teat end hyperkeratosis and morphology on milk quality.

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65. Whole-farm modelling of dairy beef production systems

M. Kearney [a,*], P. Crosson [b], E.O. Riordan [b], J. Breen [a]

[a] University College Dublin, Belfield, Dublin, Ireland
[b] Teagasc Grange, Dunsany, Meath, Ireland

* Corresponding author. M. Kearney.

Application: Pastoral dairy beef steer production systems can be profitable and environmentally friendly whilst contributing to feed-food competition in a positive manner.
Introduction: The abolition of European Union (EU) milk quota and subsequent expansion of the dairy herd has resulted in a greater proportion of beef derived from the dairy sector (European Commission, 2015). Future beef consumption in the EU is predicted to be greater than production (European Commission, 2015) which may incentive greater productivity of dairy beef systems. At the same time, there is greater focus on sustainable food production practices and therefore, the economic, environmental and feed-food competition performance of dairy calf to beef systems are of interest.
Material and methods: An evaluation of physical, economic, feed-food competition and environmental performance from early maturing, late maturing and Holstein-Friesian origin sired steers on high and low input systems was undertaken. The Grange Dairy Beef Systems Model (GDBSM; Ashfield et al., 2013) was augmented with the incorporation of greenhouse gas (GHG) emissions (Foley et al, 2011) and food-feed (Mosnier et al, 2021) submodels. Data was entered into the extended GDBSM to determine key system performance metrics.
Results: Variation in beef and concentrate price along with the proportion of grazed grass in the animal diet were found to be the key drivers of profitability. Age at slaughter had the greatest impact on greenhouse gas emissions. The level of input usage and the composition of concentrate rations were important determinants of feed-food competition performance.
Conclusion: Finishing dairy steers at pasture represents the most profitable system which, when combined with earlier slaughter ages, resulted in lowest GHG emissions and highest food/feed ratios. The analysis can be used to inform future research priorities and policy for dairy beef systems.

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Table 1
Economic appraisal (€/head) of production systems for EM, FR & LM steers.

	Production System								
	EM 20 M	EM 24 M	EM 28 M	FR 20 M	FR 24 M	FR 28 M	LM 20 M	LM 24 M	LM 28 M
Livestock Sales	1052	1362	1481	955	1258	1410	1146	1468	1594
Calf purchase price	181	181	181	64	64	64	237	237	237
Gross output value	872	1181	1299	892	1194	1346	910	1231	1356
Variable costs									
Grazing (fertiliser)	53	59	89	52	64	94	51	56	88
Silage	48	128	156	49	101	170	48	126	162
Concentrate feeds	216	373	199	208	349	194	219	393	197
Other	171	217	227	188	235	253	171	222	233
Total variable costs	488	777	672	498	749	711	489	797	680
Total fixed costs	188	263	337	187	263	341	199	262	338
Gross margin	384	404	628	394	446	635	434	474	676
Net margin	196	141	290	207	183	294	235	212	338
Net margin (per farm)	28,158	15,437	22,228	29,820	19,469	21,352	34,981	14,852	26,275
Cost per kg carcass (€/kg)	2.98	3.55	3.16	2.82	3.33	3.14	3.02	3.49	3.17

66. Modelling impacts of precision livestock farming tools on carbon footprints of a suckler beef system

J.M. Bowen [a,*], H.J. Ferguson [b], J. Bell [c], C.A. Duthie [a], R.J. Dewhurst [a]

[a] SRUC, Edinburgh, UK
[b] SRUC, Edinburgh, UK
[c] SAC Consulting, Edinburgh, UK

* Corresponding author. J. M. Bowen.

Application: This work shows the benefit of using precision livestock technologies in reducing product and on-farm emissions enabling more sustainable beef production systems.
Introduction: The use of precision livestock farming (PLF) technologies can support management decisions to improve animal health, welfare and production, and its use is increasing globally. Whilst these technologies are not designed to directly reduce greenhouse gas (GHG) emissions, they can do so by increasing the productivity of the animal and resource use efficiency, reducing the overall carbon footprint of the farm. The aim of this work was to model the effects of PLF technologies on whole farm and product emissions in predominantly grazing beef enterprises.
Materials and methods: Data from the Cattle Tracing System (CTS) was used to define a baseline average enterprise for Scotland based on a spring calving upland suckler system, where cattle spent an average of 54% at grass (April-September). Agrecalc, SAC Consulting's carbon footprinting tool, was used to model scenarios of PLF use on whole farm and product emissions. Each scenario was compared to the baseline, scenarios included PLF use to: reduce slaughter age by (i) 1-month (RAS1), (ii) 2-months (RAS2) and (iii) 3-months (RAS3), (iv) improve fertility and (v) improve health and welfare. Parameters impacted by introduction of technology were adjusted for each scenario (note that each scenario modelled single technological solutions and did not consider combinations of technologies): age and weight at slaughter, kill out percentage, age at first calving, number of calves born and reared, cow and calf mortality, and live weight gain. Associated changes in land needed for home grown feed and bedding, and purchased feed and bedding requirement were also included in each scenario. Manure in all scenarios were treated as farmyard manure and diets remained constant across all scenarios.
Results: Reductions in total kgCO2e ranged from 2% (RAS1) to 9% (improving health and welfare Table 1). Reductions per unit of product (kgCO2e/kg deadweight) ranged from 1% (RAS1) to 17% (improving health and welfare; Table 1).
Conclusion: Introduction of PLF use on farm resulted in reduced emissions (both total farm and per unit of product). Technologies designed to improve health and welfare showed greatest reductions, this was driven by reductions in mortality and improvements in live weight gain leading to reduction in slaughter age in the scenario.

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Table 1
Emissions ($kgCO_2e$) per unit of product (beef; kg deadweight) and total farming emissions for each scenario and corresponding % change relative to baseline.

	Baseline	RAS1 (% change)	RAS2 (% change)	RAS3 (% change)	Fertility (% change)	Health & Welfare (% change)
Total $kgCO_2e$	1,058,615	1,023,109 (−2%)	991,863 (−5%)	973,729 (−7%)	1,007,261 (−4%)	949,722 (−9%)
$kgCO_2e$/kg deadweight	37.56	37.0 (−1%)	36.3 (−3%)	36.3 (−3%)	33.7 (−10%)	31.3 (−17%)

67. The effect of precision livestock farming technologies and improved efficiency on the carbon footprint of an average Scottish dairy farm

H. Ferguson [a,*], J. Bowen [b], J. Bell [b], C.A. Duthie [b], R. Dewhurst [a]

[a] SRUC, Dumfries, UK
[b] SRUC, Edinburgh, UK

* Corresponding author. H. Ferguson.

Application: Use of precision livestock farming (PLF) tools intended to improve fertility, health and welfare, and the resulting improvements in efficiency, can result in reductions in on-farm and product greenhouse gas emissions of average Scottish dairy farms (total emissions from farming ($kgCO_2e$), emissions from milk ($kgCO_2e$) and emissions from fat and protein corrected milk ($kgCO_2e$/kg FPCM)).
Introduction: Precision livestock farming tools are increasingly being used in daily herd management to improve health, welfare and overall production. Whilst not intended to directly reduce greenhouse gas (GHG) emissions on-farm, these tools can do so by improving the overall efficiency of a system, thereby reducing the carbon footprint of the enterprise, and product emissions. This work aimed to model the effects of commercially available PLF technologies intended to improve fertility, health and welfare on whole enterprise and product emissions from an average Scottish dairy farm.
Materials and methods: Data for Scotland from the Cattle Tracing System (CTS) were collated and utilised to create a baseline average Scottish dairy farm, based on an 8000 L, 225 cow, all year-round (AYR) calving system with pasture access. The baseline farm and scenarios based on the effects of PLF technology introduction were modelled using the carbon footprinting tool Agrecalc (SAC Consulting), for whole farm and product emissions, and each scenario compared to the baseline. Scenarios included S1) improved fertility, S2) improved fertility and yield and S3) improved health. Parameters expected to be affected by introduction of technology (e.g. calving interval, replacement rate, mortality, and yield) and associated feed, bedding and land changes were considered in the model. No management changes, such as change in percentage of sexed semen usage, were considered.
Results: Reductions in total CO_2e from farming were 0.43% (S1), 0.47% (S2) and 0.35% (S3) (Table 1). Reductions in total kgCO2e from milk were 7.31% (S1), 2.50% (S2) and 2.87% (S3) (Table 1). Reductions in kgCO2e/kg FPC (fat protein corrected milk) ranged from 6.77% (S1) to 8.27% (S2, S3) (Table 2).

Table 1
Total emissions from farming (kgCO2e) (total emissions, including emissions from meat), product emissions (kgCO2e) (milk) and kgCO2e/kg FPC for each scenario and percentage change relative to baseline.

	Baseline	S1 Fertility (% change)	S2 Fertility + Yield (% change)	S3 Health (% change)
Total emissions from farming ($kgCO_2e$)	2,672,264	2,660,879 (−0.43%)	2,659,760 (−0.47%)	2,662,850 (−0.35%)
Total emissions from milk ($kgCO_2e$)	2,520,977	2,336,760 (−7.31%)	2,457,829 (−2.50%)	2,488,504 (−2.87%)
$kgCO_2e$/kg FPC Milk	1.33	1.24 (−6.77%)	1.22 (−8.27%)	1.22 (−8.27%)

Conclusion: Improving efficiency via improved fertility, health and welfare achieved through the use of PLF technology can reduce overall and per product emissions on an average Scottish dairy farm. Tools intended to improve health and welfare, and those intended to improve fertility which also led to improved yields, had the biggest impact on total enterprise and per kg product emissions. In future, there is a need to consider Scottish infrastructure limits on milk processing capacity and associated transport, and herd sizes, when considering the impacts and improvements these PLF technologies can have on Scottish farm emissions.

Acknowledgements: SRUC receives funding from Scottish Government. This work was funded through the FACCE ERA-GAS, ERANET SUSan, ICT-AGRI ERANET and DEFRA funded GrASTech project.

68. Machine learning algorithms perform better than multiple linear regression in predicting manure nitrogen output from lactating dairy cows

X. Chen [a,b,*], H. Zheng [b], H. Wang [b], T. Yan [a]

[a] Agri-Food Biosciences Institute, Hillsborough, Down, UK
[b] Ulster University, Belfast, Antrim, UK

* Corresponding author. X. Chen.

Application: Accurate prediction of manure nitrogen (MN) output from lactating dairy cows by using machine learning algorithms can help to develop appropriate N manipulation strategies for dairy farming.
Introduction: Multiple linear regression (MLR) analysis is widely used for evaluation of MN output from livestock production. However, some recent research has shown that machine learning algorithms, e.g. artificial neural networks (ANN), random forest regression (RFR), support vector regression (SVR), might have a great potential to capture the complex interactions between variables for development relationships between production outputs and resource inputs (e.g., animal, diet and management) (Murdoch et al., 2019). Therefore, the objective of the present study was to compare the predictive performance of different machine learning algorithms against MLR approach in predicting MN output of lactating dairy cows.
Materials and methods: Data used were collated from 43 total diet digestibility studies with 951 lactating dairy cows undertaken at Agri-Food and Biosciences Institute in Northern Ireland between 1990 and 2015. The data from studies undertaken between 1990 and 2002 were used as the training dataset (n = 564) and undertaken between 2005 and 2015 as the testing dataset (n = 387). Four models (MLR, ANN, RFR and SVR) for prediction of MN output were developed using the training dataset and then evaluated using the testing dataset and the root mean square error (RMSE) with 10-fold cross validation for comparison of their predictive performance. The Pearson correlation matrix and variance inflation factor (VIF) technique and stepwise procedure were applied for feature selection. The ANN, RFR and SVR models were fitted using R package neuralnet, randomForest and e107, respectively.
Results: For the prediction of MN using features selected by the Stepwise method, the ANN model has a significantly higher prediction accuracy (lowest RMSE value, $P < 0.01$) when compared to MLR, RFR and SVR models (Table 1). No significant differences in RMSE values were observed among MLR, RFR and SVR models. When using features selected by the VIF method, a similar result was obtained that ANN model has a significantly lower RMSE value than the RFR and SVR models. The ANN has a lower mean residual MN (predicted – measured, 0 vs. 25 g/d) and a lower SD value (32.8 vs. 36.6) than the MLR (Figure 1). The majority of the plot data with the ANN model was evenly distributed around the y = 0 line (Figure 1), but most of the plot data with the MLR model was above that line. These results indicate that the ANN model could accurately predict MN excretion from dairy cows, while MLR, on average, overestimated MN excretion.
Conclusion: The ANN model performs better for prediction of MN output in lactating dairy cows in the present study when compared with the approaches of MLR, RFR and SVR.

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Table 1
Predictive performance of different modelling approaches for MN output.

Feature selection method	Features selected[1]	RMSE[2]				Sig.[2]
		MLR	RFR	SVR	ANN	
Stepwise	NI + LW + MY	44.7[b]	46.8[b]	44.9[b]	34.7[a]	$P < 0.01$
VIF	NI + LW + MY + FP + DNC + DMEC	/	38.3[b]	45.3[c]	28.5[a]	$P < 0.01$

[a,b,c] Means within a row with different superscripts differ ($P < 0.05$).
[1] NI = N intake; DNC = diet N concentration; MY = milk yield; FP = forage proportion; LW = live weight; DMEC = diet metabolisable energy concentration.
[2] The significance was determined using Tukey Honest Significant Difference (HSD) test.

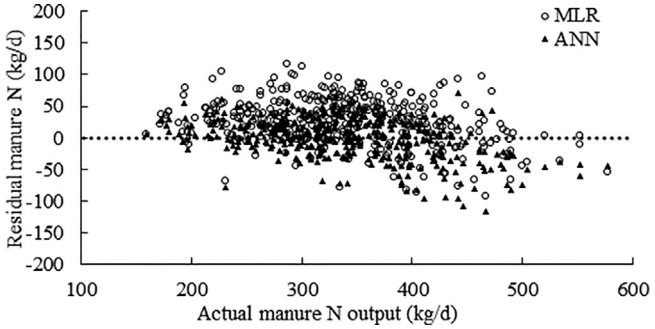

Figure 1. Relationship between actual and residual MN output of dairy cows with manure N predicted using MLR against ANN.

69. Food futures: Providing smart feedback to enhance farm sustainability

A. Aubry [a,*], R. McGuire [b], J. Birnie [b], N. Scollan [b], S. Morrison [a]

[a] Agri-Food and Biosciences Institute, Hillsborough, Down, UK
[b] Queen's University Belfast, Belfast, UK

* Corresponding author. A. Aubry.

Application: Commercial application is a key aspect of this science-based sustainability platform, by including it into farm quality assurance schemes that can be used by the industry and consumers to drive higher integrity and trust food systems. *Introduction*: Quantifying and enhancing the sustainability of agri-food production is key to sustain and build markets locally and internationally. The Agri-Food Quest 'Food Futures' project developed a reporting tool to capture, credit and drive positive behavioural change among livestock farmers and their stakeholders, in order to enhance the sustainability of Northern Ireland agri-food production. A key objective was to identify SMART feedback mechanisms to present the performance of each farm and encourage behavioural change.
Materials and methods: Building upon literature and legislative reviews and consultations with scientists and stakeholders, more than 30 metrics were developed under the pillars of Economic, Environmental and Social sustainability. Each metric is comprised of up to seven indicators, each scored between 0 and 10, with 10 representing either the optimum status, best practice or the most efficient farms. This tool was applied on 30 dairy, sheep and beef farms. A number of options were then explored to present the results for each farm and these were discussed at a series of meetings with participating farmers and other stakeholders.
Results: The feedback mechanisms included, for each pillar: 1) a simple rev counter to illustrate the farm's overall score, 2) a metric circle to present the score for each metric (Figure 1), 3) a chart (Figure 2) to benchmark the farm score against the average for each sector (dairy, beef, mixed farms) and 4) a table using a traffic light system to recommend actions that can be taken to improve the scores. This feedback is presented using an interactive dashboard. The preferred outputs were the benchmarking chart and the action table, because these can be used to identify realistic solutions that are working for other farmers such as using covered slurry storage and improving soil management, e.g. by rectifying excessive or low levels of P & K. Metric circles are also particularly useful to facilitate the definition of a minimum desirable score for each metric. Because some of the social metrics cannot be scored, the approach taken to provide feedback was different: subjective assessments can instead be used successfully to raise the awareness of potential well-being issues, in the form of questionnaires, information leaflet and knowledge exchange hub imbedded in the dashboard to inform on available resources and strategies.
Conclusion: Key attributes for a smart feedback of sustainability performance include i) benchmarking analyses, ii) clear, practical and targeted advice and iii) interactive and real time individual outputs to monitor progress. The platform developed in this project enables users to visualise key strengths and weaknesses, set up realistic targets, identify and implement actions and explore relationships among key metrics.

Figure 1. Metric circle of a farm to show the score obtained for each economic & efficiency metric.

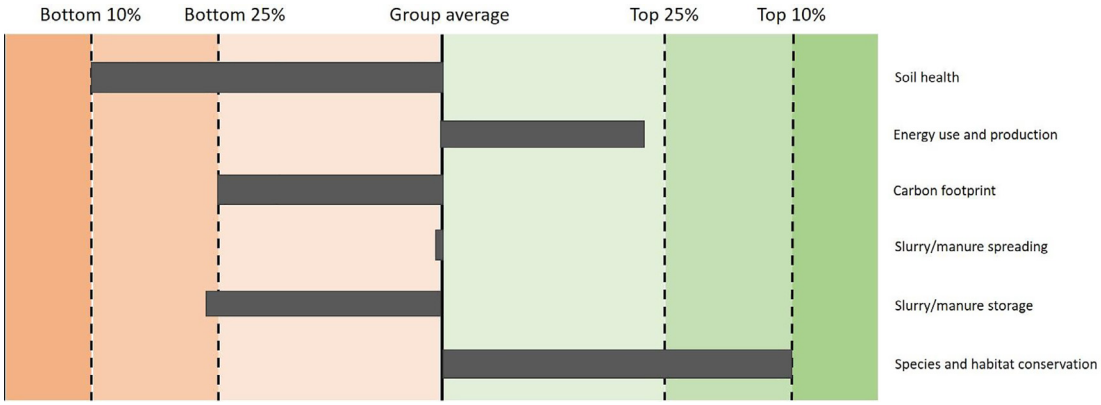

Figure 2. Benchmarking chart for a farm's environmental performance (selected metrics).

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70. Using past progeny growth data to inform ewe culling strategy

A. Jones [a,b,*], T. Takahashi [a,b], B. Griffith [a], S. Demirkaya [a], R. Vincent [a], P. Harris [a], J Rivero [a]

[a] Rothamsted Research, Okehampton, Devon, UK
[b] University of Bristol, Langford, Somerset, UK

* Corresponding author. A. Jones.

Application: By quantifying the commercial benefit of selectively culling ewes based on readily available on-farm data, we can promote the uptake of evidence-based farming and thereby contribute to efficiency improvements across the industry.

Introduction: The productivity of sheep farms is often limited by inadequate management (Foley et al., 2011). Amongst numerous interdependent variables to quantify performance of sheep farms, one of the most useful indicators is the pre-weaning growth rate of lambs (Jones et al., 2021), which, in turn, is driven by the ewe's rearing ability through lactation. Selective replacement of ewes has therefore been identified as a promising strategy to improve the profitability of commercial sheep farms (Lima et al., 2020). Using high-resolution lamb data and matched ewe data collected at the North Wyke Farm Platform in Devon, UK, this study investigated the commercial benefit of strategically culling ewes based on the growth performance of past years' progeny, with a particular focus on the flock-wide lamb performance in the subsequent season.

Materials and methods: The performance of 56 twin-bearing Suffolk × Mule ewes was quantified by the average pre-weaning daily growth rate of their past progeny. All ewes were sorted according to this variable, with the 12 highest (top 20%) and the 12 lowest (bottom 20%) performing ewes designated as 'top' and 'bottom' groups. Inter-group difference in pre-weaning growth performance of the current year's progeny (24 lambs each) was then evaluated based on the standard *t*-test. A flock-level simulation was subsequently conducted, whereby a proportion of ewes were virtually culled and replaced at the weaning of 2019–2023 seasons, either: (i) selectively from the bottom of the performance list, or (ii) randomly from the oldest cohorts. Using the results of this simulation, the system-wide production and economic impacts of the two strategies were quantitatively compared. All statistical analysis were conducted using R version 4.1.2.

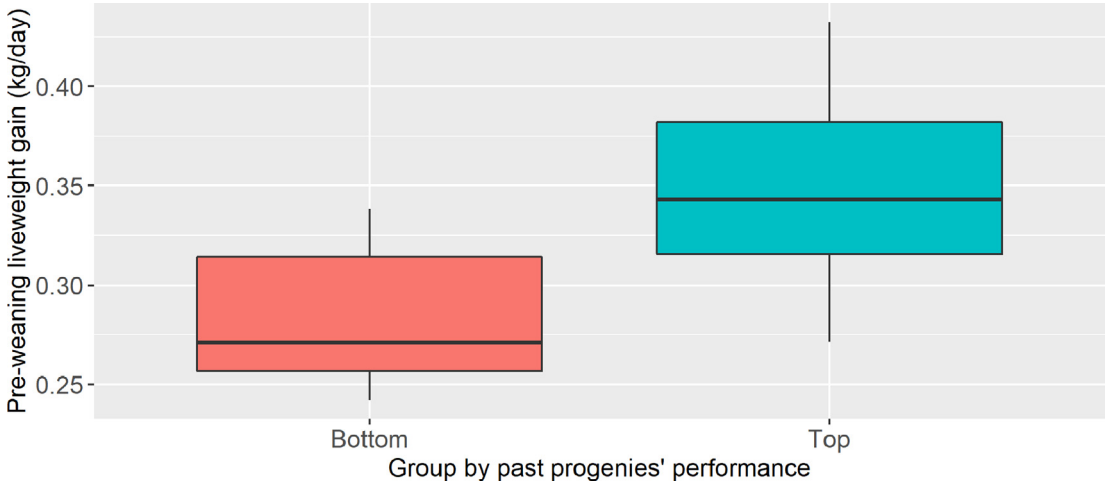

Figure 1. Pre-weaning growth of 2020 lambs by ewes selected for past lamb pre-weaning growth.

Results: The pre-weaning growth rate of lambs from ewes in the top group (348 g/day) was significantly (P = 0.001) higher than that of lambs from the bottom group (283 g/day), resulting in a difference of 65 g/day (Figure 1). Lambs from top group ewes had a higher average carcass value per lamb (£94.26) compared to lambs from bottom group ewes (£89.49). Simulated culling demonstrated cumulative improvements in flock-level lamb growth across multiple years, as poorer performing but otherwise healthy ewes, which would not previously have been replaced, were removed pre-emptively from the flock.
Conclusion: Targeted culling of lower performing ewes can have a substantial impact on cumulative improvements in sheep flock efficiency. Future work will investigate the incorporation of ewe health status to further improve the commercial relevance of the proposed framework.

Acknowledgements: Work funded by BBSRC (BBS/E/C/000J0100 and BBS/E/C/000I0320).

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71. Examining the social construction of sheep and beef farmers' antimicrobial stewardship knowledge: Roles, realities and reflection

C. Doidge [*], J. Kaler

[1] University of Nottingham, Sutton Bonington, UK

* Corresponding author. C. Doidge.

Application: This study shows how veterinarians have a major role in antimicrobial stewardship through their dialogue and prescribing practices with farmers. *Introduction*: Antimicrobial stewardship (AMS) can be considered as a concept that is socially constructed by people and organisations in positions of power. It is created through the implementation of responsible use guidelines, legislation that restricts antimicrobials for certain uses, and the use of targets. However, research shows that farmers' representations of what is socially acceptable antimicrobial use does not always align with responsible use guidelines and targets. The aim of this study was to understand the social processes in which farmers' knowledge of AMS are constructed.
Materials and methods: Semi-structured interviews were conducted in-person with sheep and beef farmers in England and Wales. Sixty-nine farmers were contacted and thirty-four were interviewed. The transcripts were analysed using reflexive thematic analysis through the lens of social constructionist theory. The theory states that knowledge is constructed and maintained through social interaction.
Results: Five themes were generated from the analysis: knower and non-knower roles; conflicting social realities; thinking reflexively; deviation from accepted standards; and uses and abuses of power. Veterinarians were recognised by farmers as holding a role as a "knower" in transmitting knowledge of AMS, which was reaffirmed through the symbolic action of prescribing antimicrobials. Farmers believed that veterinarians were able to account for multiple farming realities through adapting AMS standards for the local conditions of each farm. Many farmers had noticed a change in the language their veterinarians used around antimicrobials over the past few years. This made farmers reflect on their own antimicrobial use and, in turn, change their practices. In particular, the knowledge that the routine use of prophylactic antimicrobials was unacceptable was shared amongst farmers and had become an accepted standard. However, some farmers noted that "other" farmers were deviating from this accepted standard. They suggested that these "other" farmers were naïve to antimicrobial stewardship because they did not engage with social processes surrounding AMS. A few farmers also suggested that some "other" farmers intentionally dismissed information as a way to manage uncomfortable knowledge. Although farmers in this study sometimes talked negatively about "other" farmers who carried out unacceptable antimicrobial practices, they cautioned that communicators such as veterinarians should not do this. Communicators were seen as being in position of power that can label practices as "good" or "bad", but this had social consequences. Farmers reported feeling stigmatized if communicators labelled their antimicrobial practices as "bad" or "irresponsible".
Conclusion: This research shows that conversation between farmers and veterinarians, where veterinarians actively encourage farmers to participate in dialogue, may be a powerful way to construct AMS knowledge. It is important to consider the power dynamics between those in "knower" roles and those receiving information to ensure these conversations are effective. Focusing on how recommended practices can save money and improve productivity and animal health, rather than labelling practices as "bad" may prevent stigmatisation by concentrating on a common goal.

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72. Modelling the effects of twinning on the economics of pasture-based suckler beef systems

A. Bergin [a,b,*], D. Kenny [a], M. McGee [a], A. Kelly [b], P Crosson [a]

[a] Teagasc, Grange, Meath, Ireland
[b] University College Dublin, Belfield, Dublin 4, Ireland

* Corresponding author. A. Bergin

Application: Twinning has potential to enhance profitability on suckler beef systems by increasing carcass output.
Introduction: An objective of suckler beef systems is to maximise weaned calf weight per cow in a cost-effective manner. Twinning is a technology that can increase the number of calves and weaned weight per cow. For example, Echternkamp et al. (2007) found that, for cows birthing twins compared

Table 1
Physical performance and financial results of twinning scenarios.

Scenario[1]	Base	CR1.5(9)	CR2.0(9)	CR1.5(-3)	CR2.0(-3)
Cows calving (head)	72.5	61.9	56.3	62.6	57.6
Carcass output (kg/ha)	452	529	576	526	569
Gross output (€/ha)	1,824	2,145	2,341	2,131	2,310
Total costs (€/ha)	1,494	1,545	1,594	1,550	1,599
Net margin (€/ha)	330	600	747	581	711

[1] CR1.5 (9) = Calving rate of 1.5 calves per cow with post-weaning performance 9% greater than base. CR2.0 (9) = Calving rate of 2.0 calves per cow with post-weaning performance 9% greater than base. CR1.5 (-3) = Calving rate of 1.5 calves per cow with post-weaning performance 3% lower than base. CR.2.0 (-3) = Calving rate of 2.0 calves per cow with post-weaning performance 3% lower than base.

to singles, weaned calf weight per cow calving was 52% greater. The objective of this study was to quantify the effect of increasing twinning rate through long-term genetic selection on the economic performance of pasture-based suckler beef systems.
Materials and methods: The Grange Beef Systems Model (Taylor et al., 2020), a bioeconomic model of suckler beef systems, was augmented to include a module defining the impact of twinning using data from Echternkamp et al. (2007) and Cummins et al. (1994). This module accounted for the implications of twinning on cow (e.g. calving rate, calving difficulty, fertility and feed energy demand) and calf (mortality, live weight gain and carcass characteristics) traits in suckler beef systems. The farm system modelled was a spring-calving suckler herd taking progeny through to beef as steers and heifers at 24 and 20 months of age, respectively. Farm size was 50 ha with a baseline stocking rate of 2.4 LU/ ha. To reflect different proportions of the cow herd bearing twins, the analysis was conducted for three calving rates; 1.0 (base scenario), 1.5 and 2.0 calves per cow. Given the lack of consistency between published studies, two scenarios were compared with the base scenario whereby post-weaning performance of twin-born progeny were either (i) 3% less than or (ii) 9% greater than single-born progeny.
Results: Increasing twinning rate (i.e. the number of calves per cow) decreased the number of cows calving (range: 23% to 14%), increased carcass output (range: 16 to 27%) and increased farm net margin (range: 76% to 126%) compared to the baseline scenario.
Conclusion: When part of a defined breeding and management programme twinning has the potential to substantially improve net margin on suckler calf-to-beef farms.

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73. Global Zoonotic Disease – The UK perspective

V. Busin

University of Glasgow, Scotland

The World Health Organization definition of zoonosis is “A disease that is naturally transmissible from vertebrate animals to humans”. This definition encompasses over 200 diseases worldwide, with new and emerging diseases increasing this number constantly. Countries like the UK are in a privileged position of having well-functioning veterinary and public health services, which allow for potentially serious threat to be quickly identified and act upon. Veterinary surveillance, in particular, is an essential tool designed to ensure effective and early detection of animal related problems, which could severely affect animal health and welfare, trade and public health. In the case of zoonotic diseases, active surveillance for the control of *Mycobacterium bovis* is a perfect example of the ongoing efforts to prevent the spread of this harmful bacteria to cause human tuberculosis. Through scanning surveillance, levels of endemic diseases can be monitored and identification of new, emerging and exotic conditions enables for the planning, implementation, and evaluation of risk mitigation actions. Salmonellosis due to *Salmonella dublin* is currently often diagnosed through diagnostic material submitted to official veterinary laboratories and its reportable status allow to assess the risk to human health from animal sources and to provide expert advice to private veterinary practitioners and human health professionals on the prevention measures of human infection. Because of the ongoing trend in globalization and because diseases do not recognize boundaries, an international approach to the control of zoonotic diseases is necessary. Agencies like the World Organization for Animal Health (OIE) and the Food and Agriculture Organization of the United Nations (FAO) allow for a truly coordinated approach to be implemented. Their roles in veterinary surveillance are mainly to facilitate data sharing and technology transfer between countries and to collect, analyze and disseminate (the same principle of surveillance at a national level) information on high-risk animal disease outbreaks. Finally, for all these systems to be truly effective, collaboration is the key. We all have a part to play, from animal keepers, vets, scientists, academics and industry partners and through research and dissemination of key findings we can actively contribute in ensuring public health arising from human-animal interactions.

74. Emerging Zoonoses – Using the One Health concept as a framework for Risk Analysis and the development of blended Control Strategies

M. Shakespeare

Ministry of Defense, UK

This presentation aims to explain and describe in detail how the One Health concept can be used to drive an assessment framework, using knowledge of the environment, people, animals and zoonotic pathogens to enable effective control and management of emerging diseases.

In the last two decades, a number of major zoonoses have emerged. They have progressed to cause epidemics, a pandemic, or have become endemic. They include West Nile Virus, SARS-CoV-2 and Highly Pathogenic Avian Influenza. It is likely that others will emerge in the future, with the WHO estimating that at least 60% of future novel diseases will be caused by zoonotic pathogens.

Addressing the harm that these diseases can cause is best done by using the One Health Concept, where the interactions between the three elements of animal, human, and environmental health are recognized as equally important in developing control and mitigation strategies.

Each of the One Health elements needs to be examined in detail, commencing with a detailed examination of the environment, and then progressing to an understanding of how humans, animals, and the pathogen interact with it, and with each other.

To do this effectively requires each of the elements to be broken down into its constituent components - for instance population sizes, density, geographic range etc. This does not only require knowledge, but the use of structured analytical techniques, such as modified Critical Path analysis, or Analysis of Competing Hypotheses. These can be used to deliver a detailed predictive assessment, which includes the identification of infective pathways, and possible critical control points.

Once undertaken, the analysis allows the use of risk management tools such as the 4Ts (Tolerate, Treat, Terminate and Transfer) to support decision making on development of infection control strategies. This allows the development of a blended approach to harm reduction across the One Health pillars, including strategies for treatment and prevention.

Although the concept is simple, the practical implementation of both the analysis, and the identification of critical control points, can be challenging, especially with a novel pathogen, such as SARS-CoV-2.

Usually, the primary assessment only provides limited understanding, in support of an initial containment strategy; it is usually drawn from both veterinary and medical experience of similar zoonotic pathogens. As an outbreak progresses, the pathogen can mutate, or adapt, and events such as transmission from humans into susceptible animal species.

This increases complexity, and requires a constant review of the analytical outcomes, and related control measures. It will also alter technical requirements, such as monitoring, testing and genetic sequencing, to identify novel variants with risks dissimilar to the original strain.

Currently in the UK, the potential risk that emerging pathogens pose is assessed through a pan governmental body, the Human and Animal Infections and Risk Surveillance (HAIRS) group. They support the decision making of the Advisory Committee on Dangerous Pathogens (ACDP) on the appropriate containment and preventative measures for emerging zoonoses.

75. Lessons from cross-species transmission of influenza

J. Daly

University of Nottingham, UK

Influenza A arguably remains the ultimate emerging and re-emerging viral pathogen. Influenza A viruses frequently cross species barriers and have evolved and adapted to become established in a broad range of species. This presentation will take a retrospective look at inter-species transmission events and discuss how human activities are leading to increased likelihood of further pandemics caused by influenza and other viruses.

76. Effect of turmeric and Aspilia africana on the reproductive performance of rabbit does in umudike abia state nigeria

M.A. Oguike *, M.P. Atteh, J. Ezea

Michael Okpara University of Agriculture, Umudike/Umuahia, Abia/Nigeria, Nigeria

* Corresponding author. M.A. Oguike.

Application: The use of Combination of turmeric and Aspilia africana in the diets of rabbits to ameliorate their respective adverse effects on growth and conception rate of rabbit does.
Introduction: Growth and conception rate are among the key physiologic and reproductive parameters in animal production. Turmeric has antioxidant and anti-inflammatory properties. Aspilia africana depressed reproduction and improve growth in rabbits (Etim and Oguike, 2014, 2015), and turmeric improve testis histology. Combined effects of turmeric and Aspilia africana on reproduction and growth are not clear. This study aims to ascertain their effects on reproduction and growth in rabbits.
Materials and methods: Thirty six rabbit does, aged 4 to 5 months, average weight 1.65 kg were used in a CRD with 4 treatments, T1, T2 T3 and T4, with 9 does per treatment. Does in the treatments were fed diets not-supplemented with turmeric and Aspilia africana (T1, control), 2.5 g turmeric (T2), 2.5 g Aspilia africana (T3), a blend of 2.5 g each of turmeric and Aspilia africana (T4)/kg feed. Test ingredients were dried and ground before inclusion to the diet. The diet contained 16.06% crude protein and 2579.64 MJ. Rabbits were fed for 60 days before breeding and data collected on reproductive performance. Five bucks were randomly used to breed the does. Data generated were analysed using ANOVA according to Steel and Torrie (1980).
Results: Results are presented in Table 1. Receptivity, though not significant showed that T3 took longer time to mate while T1 responded faster. Control has the highest significant ($P < 0.05$) conception rate and T3 least. The birth weight of the kits was significantly different. The litter weaning weight of was significantly ($P < 0.05$) higher than others. Litter size at birth and weaning, stillbirth and mortality were not significant ($P > 0.05$).
Conclusion: Higher litter weaning weight of T3 and T4 showed that A. africana improved growth rate. Blend of A. africana and turmeric improved conception rate compared to group treated with Aspilia africana.

Table 1
Performance of does fed diets supplemented with turmeric and *Aspilia africana.*

Parameters	T_1	T_2	T_3	T_4	SEM
Ave. Receptivity (minutes)	1.00	2.00	3.00	2.00	0.22
Ave Conception rate (%)	86.00[a]	66.00[b]	53.33[c]	68.58[b]	3.77
Ave. Gestation length (days)	28.33	31.33	29.67	30.67	0.03
Ave. Litter size at birth (n)	6.33	5.55	5.33	6.33	0.55
Ave. Litter size at weaning (n)	5.33	4.00	4.60	6.33	0.46
Ave. Litter weight at birth (g)	60.71[a]	44.55[b]	45.17[b]	53.04[ab]	2.27
Ave. Litter weight at weaning (g)	347.99[b]	343.08[b]	464.00[a]	399.33[ab]	10.08
Ave. Still birth (n)	1.33	1.00	0.67	1.33	0.23
Ave. Pre-weaning mortality (%)	0.67	0.67	0.33	0.00	0.05

[a,b,c] means along the same row with different superscripts are significant ($P < 0.05$). SEM = standard error of men.

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77. Chemical composition of feed and performance of weaner rabbits fed Leucaena leucocephala and Gliricidia sepium leaf meals

O. Akinteye, O. Adelusi, D. Ekunseitan, A. Oso, C. Onwuka *

Federal University of Agriculture, Abeokuta, Ogun, Nigeria

* Corresponding author. C. Onwuka.

Application: Air dried leaf of Leucaena leucocephala and Gliricidia sepium included in concentrate supplement fed to weaner rabbits improved their feed intake.

Introduction: The rapid increase in the world population in general and in Nigeria in particular has aggravated animal protein deficiency (Amata and Okorodudu, 2016), which is due to the high cost of feed ingredients especially protein sources. Rabbits are a highly prolific animal and have the ability to convert plants into animal protein by directly consuming forages. Leucaena leucocephala and Gliricidia sepium are tropical and multipurpose legumes that have the potential of being used as plant protein sources, possessing the ability to provide large quantities of high-quality forage matter all-year-round (Kabi and Lukatome, 2013). This study aims to evaluate the chemical composition of diet and performance of weaner rabbit fed Leucaena leucocephala and Gliricidia sepium leaf meals.

Materials and methods: Leucaena leucocephala and Gliricidia sepium leaves were harvested and air dried by spreading it on the floor for 4–5 days to allow it dry and milled with 3 mm sieve size, it was stored in an air-tight container prior to the commencement of the experimental trial. A total of twenty four unsexed weaner rabbits were allotted to four dietary group of six animals each in a completely randomized design, each group were divided into three replicates of two animals each. The diets were formulated as 0% leaf meal, 10% Leuceana leucocephala, 10% Gliricidia sepium and 5% Leucaena leucocephala + 5% Gliricidia sepium and were analyzed for crude protein, crude fibre, ether extract, acid detergent fibre, acid detergent lignin, neutral detergent fibre and ash. The experiment lasted for 8 weeks, during which data were collected on feed intake and weight gain. The initial weight of rabbits was taken before allocating them into treatments. Data were collected on their initial body weight, weekly feed consumed and changes in the body weight and were determined on a weekly basis. Data generated from the experiment were subjected to one-way analysis of variance in a Completely Randomized Design. Significant means were separated using Duncan's Multiple Range Test (Duncan, 1955) of SPSS (2015) at 5% level of probability.

Results: Table 1 shows the chemical composition of the test ingredient. Table 2 shows the performance of weaner rabbits fed diets containing Leucaena leucocephala and Gliricidia sepium leaf meals, there were significant difference in the total feed intake. Rabbits fed 5% LL + 5% GS had the highest (9635.00 g) total feed intake while the control diets had the lowest (6740.67 g).

Conclusion: Improved feed intake of rabbits can be achieved by feeding Leucaena leucocephala and Gliricidia sepium mixtures with concentrate at 5% LL + 5 %GS.

Table 1
Chemical composition (%) of Leucaena leucocephala and Gliricidia sepium.

Parameters	Levels of inclusion of Leucaena and Gliricidia sepium leaf meal (g/kg DM)					
	0%meal	10%LL	10%GS	5%LL + 5%GS	SEM	P-value
Dry matter	54.60[c]	69.16[b]	70.52[b]	78.05[a]	2.02	0.00
Crude protein	8.46[c]	12.00[ab]	11.14[b]	12.40[a]	0.36	0.00
Crude fibre	4.67[d]	7.43[a]	5.97[c]	6.66[b]	0.23	0.00
Neutral detergent fibre	23.93[d]	28.05[c]	31.53[b]	35.50[a]	0.99	0.00
Acid detergent fibre	10.63[c]	13.13[b]	13.43[b]	15.42[a]	0.40	0.00
Acid detergent lignin	2.24[c]	3.05[a]	2.62[b]	3.14[a]	0.08	0.00
Ether extract	2.40[d]	2.81[c]	3.36[b]	3.75[a]	0.12	0.00
Ash	5.36[d]	5.99[c]	7.26[b]	8.84[a]	0.30	0.00

Table 2
Performance characteristics of weaner rabbits fed experimental diets.

Parameters (g)	Levels of inclusion of Leucaena and Gliricidia sepium leaf meal (g/kg DM)					
	0%meal	10%LL	10%GS	5%LL + 5%GS	SEM	P-value
Initial weight	823.83	817.50	818.17	855.50	38.25	0.99
Final weight	1815.50	1752.67	1884.50	1999.83	46.08	0.28
Weight gain	991.67	935.17	1066.33	1144.33	83.65	0.29
Average daily gain	17.71	16.70	19.04	20.43	0.72	0.29
Total feed intake	6740.67[c]	8533.00[b]	8724.33[b]	9635.00[a]	124.50	0.00
Feed efficiency	6.98	9.81	8.39	8.66	0.24	0.21

[a,b,c] Means along the same rows with different superscript are significantly different ($P < 0.05$).
SEM- Standard error mean, LL- Leucaena leucocephala, GS- Gliricidia sepium, ADF- Acid detergent fibre, ADL- Acid detergent lignin, NDF- Neutral detergent fibre.

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78. Carcass and organ characteristics of growing rabbits fed graded levels of dried Pineapple pulp as a replacement for maize

M.E. Adeolu [a,*], C.F.I Onwuka [b]

[a] Department of Animal Health and Production Technology, Rufus Giwa Polytechnic, Owo, Ondo State, Nigeria
[b] Department of Animal Nutrition, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria

* Corresponding author. M.E. Adeolu.

Application: Properly dried Pineapple pulp is another good source of energy that could replace maize grain in the diets of monogastric animals.
Introduction: Rapid growth rate in population of Nigeria calls for increase in animal protein supply and availability to the populace. Global grain shortage had caused keen competition between man and livestock and this has led to astronomical increase in price of maize, hence the need to search for alternative, non-conventional feed ingredients that can substitute maize in animal's diet.
Materials and methods: Test ingredient, Pineapple pulp was sourced and sun-dried for 5 days to 10% moisture content. Five treatment diets (0%, 10%, 20%, 30%, and 40% levels) were formulated from dried Pineapple pulp. Thirty 30 breeds (New Zealand white X Flemish Giant) growing rabbits of both sexes at 7 weeks old with weight range of 450–550 g were used for the study arranged in a completely randomized Design (CRD) with 6 rabbits per treatment. Animals were fed and watered ad libitum for 10 weeks. Hygienic environment was maintained. Wilted Tridax procumbens was given the animals as basal diet. At the end of the feeding trial, carcass yield and organ characteristics was determined by sampling three rabbits from each treatment weighed, starved overnight, stunned and slaughtered. Cut parts (thigh, shoulder, loin and head); visceral organs (liver, lungs, spleen, kidney, heart and abdominal fat) were removed and their weight expressed as percentage of their live weight. Data collected were subjected to analysis of variance (ANOVA) and significant means were separated by Duncan Multiple Range Test.
Results: There were no significant different in carcass yield across all treatment. Live weight of the animal increased significantly ($P < 0.05$), highest with diet 3 (250.83%) and the least value was obtained from diet 4 (116.67%). Also, for visceral organs; lungs and abdominal fat were significantly ($P < 0.05$) influenced by dietary treatment, lungs with the value of 0.80% and diet 3 was least with 0.43%. Abdominal fat was highest with diet 3 (0.63%) while diets 1,2,4,5 were not significantly different from each other but significantly low to value obtained from diet 3. The level of significance observed in lungs and abdominal fat did not impact animal's health negatively.
Conclusion: Inclusion of dried pineapple pulp up to 40% had no significant effect on the dressing percentage, weight of the heart and liver. It was recommended that dried pineapple pulp can be used in the diets of rabbit to replace maize up to 40% without deleterious effects.

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79. Variation in age at first calving over a twelve-year period in a high-yielding dairy herd

L. Ross *, P. Garnsworthy, J. Margerison

University of Nottingham, Sutton Bonington, UK

* Corresponding author. L. Ross.

Application: Efficiency of heifer rearing can be improved by considering not only mean age at first calving, but also proportion of heifers within the recommended age range.
Introduction: The mean age at first calving (AFC) in the UK is 27 months (Hank and Kossaibati, 2020). This is later than the recommendation of 24 months (730 days). Increased AFC reduces fertility (Cooke et al., 2013), longevity and lifetime daily yield (Eastham et al., 2018), and increases rearing costs (Boulton et al., 2017). The aim of this study was to quantify variation in AFC in heifers born over a 12-year period in a high-yielding dairy herd.
Materials and methods: Records were analysed from 889 Holstein-Friesian heifers born between 2007 and 2018 at a university dairy herd. Herd annual milk yield averaged 11,000 litres per cow and management was similar throughout the study period. Cows were housed continuously and calved all year round. Heifers were reared indoors from birth to calving and mated using artificial insemination. Heifers were gradually weaned at 85 d and fed a total mixed ration to support (postweaning) growth rates of 0.7 kg/d. Data for AFC were analysed using Generalised Linear Models in GenStat with year of birth as the fixed effect, Poisson error distribution and logarithm link function.
Results: Distribution of AFC varied yearly and was positively skewed. Between 2007 and 2018 AFC averaged 756 d and ranged from 557 d to 1071 d. Yearly mean AFC ranged from 706 d in 2008 to 813 d in 2015 ($P < 0.001$). Of 889 heifers that calved, only 34.7% calved within the target range of 700 to 760 d.
Conclusion: AFC was highly variable. Mean AFC masks the long tail of older heifers which add to greater rearing costs, reduced efficiency, and management challenges. Proportion of heifers achieving target AFC was low and this should be considered when evaluating heifer rearing efficiency and targets. Assessment of factors contributing to a later AFC is recommended.

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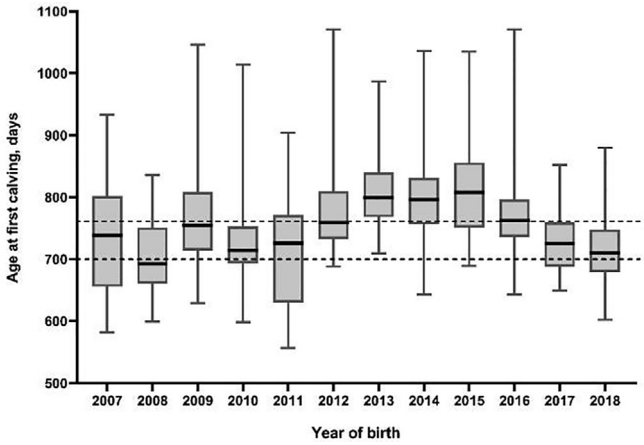

Figure 1. Distribution of age at first calving in Holstein-Friesian heifers born between 2007 and 2018, with recommended calving age between 700 and 760 days.

80. Impact of daytime pasture access on the performance of dairy cows milked via automatic milking systems

D. McConnell *, K. Huson

AFBI, Belfast, UK

* Corresponding author. D. McConnell.

Application: The results of this study demonstrate to farmers the extent to which summer grazing can be incorporated with automatic milking technology in high yielding dairy systems, and the economic value of this management strategy.
Introduction: Grazed grass remains the most cost-effective feedstuff available to Northern Irish dairy farms and future environmental and societal challenges are likely to require the continued use of grazed pasture. In recent years introduction of automatic milking systems (AMS) has been

Table 1
Impact of daytime pasture access on dairy cow performance.

	Housed	Grazing	SED	P-value
Milk yield (kg/cow/d)	37.2	32.6	1.42	0.003
Total experimental yield (kg)	3130	2741	127.1	0.003
Milk fat (%)	4.01	3.85	0.116	NS
Milk protein (%)	3.37	3.34	0.064	NS
LW change (kg)	26.9	4.74	5.91	<0.001
TMR intake (kg/cow/d)	17.0	7.9	0.36	<0.001
Total dietary intake (kg DM/cow/d)	25.4	17.9	0.64	<0.001

associated with a move to all year round housed systems in an attempt to minimise the potentially negative impact of full-time grazing during summer on milking frequency and animal performance (Lyons et al., 2014). This study sought to evaluate the impact of partial access to pasture alongside AMS on animal performance and farm profitability.

Materials and methods: A continuous design experiment was conducted with 48 spring-calving dairy cows (12 parity 1, 36 parity 2 +) during summer 2020. Two groups, balanced for days in milk (106 days), parity (2.3) and pre-experimental milk yield (39.8 kg/d) were allocated to two separate treatments: 1. Full-time housing: animals were fed a grass-silage based TMR (M + 24 kg/cow) and fed concentrate to yield above this at a rate of 0.45 kg/litre in the AMS. 2. Day-time grazing, housed at night: animals were offered the same TMR at night (restricted to 50% of allowance of the housed treatment) and offered 2-way grazing during daytime at a rate of 7.5 kg DM/cow/d. Pasture was accessible from 04:00 to 19:30. Average pre- and post-grazing herbage mass, and grass utilisation was 2987 kg DM/ha, 1925 kg DM/ha and 76.0%, respectively. This group were also fed to yield through the AMS (0.45 kg/litre). Animal performance, feed intake, milking behaviour and grazing efficiency were monitored throughout the 100 day study. Data were analysed using repeated measures analysis in Genstat.

Results: Milking frequency was significantly higher from the grazing treatment (3.62 milkings/day; P = 0.033) relative to the housed treatment (3.47 milkings/day). There was no significant difference in day or night time visits, or visit interval (P > 0.05, average = 236 minutes). Average grass DMI of grazing cows was 4.96 kg DM/cow/day. Housed animals consumed on average 7.5 kg DM/cow/day more than grazing animals. Housed cows produced more milk than those in the grazing treatment (37.2 vs 32.6 kg/cow/day, P = 0.003) however there was no significant difference in milk quality (Table 1). Despite poorer animal performance from grazed cows, margin over feed costs was greater from grazed relative to housed cows (£5.91 vs £5.65/cow/day) resulting in a difference of £26/cow per 100 day grazing period.

Conclusions: The study indicated that within AMS, daytime access to pasture resulted in reduced milk output but lower overall feed costs. Therefore, daytime pasture access could be considered as a management strategy to meet societal expectations for both grazing activity and lower environmental impact, without negatively impacting on farm profitability.

Acknowledgments This work was co-funded by DAERA and AgriSearch.

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81. Productivity, efficiency and milk fatty acid profile of Jersey crossbred cows in low-input dairy systems

S. Ormston [a,*], H. Davis [b], G. Butler [b], E. Chatzidimitriou [c,b], K. Theodoridou [d], S. Huws [d], T. Yan [e], C. Leifert [f,g], S Stergiadis [a]

[a] University of Reading, Reading, Berkshire, UK
[b] Newcastle University, Newcastle upon Tyne, Northumberland, UK
[c] French Agency for Food Environmental and Occupational Health and Safety, Maisons-Alfort, France
[d] Queens University Belfast, Belfast, Antrim, UK
[e] Agri-food and Biosciences Institute, Hillsborough, Down, UK
[f] University of Oslo, Oslo, Norway
[g] Southern Cross University, Lismore, Australia

* Corresponding author. S. Ormston.

Application: Holstein-Friesian (HF) × Jersey (HF × J) cows in low-input pasture-based dairy systems can maintain productivity (compared to HF cows) and improve milk protein content and feed efficiency; while increasing the proportion of short-chain fatty acids (SCFA) in milk).

Introduction: Traditionally, high-yielding Holstein-Friesians (HF) have been used in the UK dairy industry. However, concerns regarding cow health and fertility has prompted exploration of alternative breeds (Davis et al., 2020). Jersey (J) cows have shown greater feed efficiency, and improved health and fertility compared with HF in low-input systems (Vance et al., 2013) and are commonly used for crossbreeding. However, thorough investigations into productivity, production efficiency and milk composition of the HF × J crossbreds are scarce in the UK. This study aimed to compare the performance of HF vs HF × J in low-input systems, including milk yield and composition (solids and fatty acid (FA) profiles) and feed efficiency.

Materials and methods: Milk samples (HF = 96, HF × J = 123) from 73 cows (HF = 32, HF × J = 41) in four low-input pasture-based dairy farms were collected on three occasions (spring, summer and autumn 2012). Animal diet and breeding data were simultaneously gathered via written questionnaires. Milk solids and FA profiles were determined using NIRS and GC, respectively. Estimated dry matter intake (DMI) and pasture intake were calculated based on average breed live weight and recorded milk yield. Data were analysed by linear mixed effects models (SCC after log-transformation) using breed (HF, HF × J), season (spring, summer, autumn) and their interaction as fixed factors, and cow ID as random factor. Multivariate

Table 1
Effect of cow breed on productivity, efficiency and fatty acid composition HF, Holstein Friesian; HF × J, Holstein Friesian × Jersey; DMI, dry matter intake. Significant differences were declared at P < 0.05. [a] Milk (kg)/DMI (kg) [b] Milk (kg)/concentrate DMI (kg); [c] Milk (kg)/non-grazing DMI (kg of conserved forage and concentrate).

Production parameters					Fatty acids (g/ kg milk fat)				
Productivity	HF	HF × J	SE	P-value		HF	HF × J	SE	P-value
Milk Yield (kg/day)	21.3	20.5	1.02	0.496	SFA	675	702	6.3	<0.001
Fat (g/ kg milk)	38.6	37.5	1.25	0.114	MUFA	277	254	5.2	<0.001
Protein (g/ kg milk)	34.6	37.5	0.64	<0.001	PUFA	47.9	44.3	1.42	0.047
Lactose (g/ kg milk)	44.1	45.4	0.57	0.154	n-3	13.9	13.9	0.49	0.998
SCC (×1000/ml milk)	175	174	50.8	0.426	n-6	15.4	14.2	0.52	0.069
Efficiency					n-3:n-6	0.99	1.06	0.050	0.133
Feed efficiency [a] (FE)	1.10	1.22	0.048	0.020	*t*FA	45.3	43.6	1.91	0.573
Concentrate efficiency [b]	8.46	7.95	0.581	0.378	*t*FA (exc) VA	22.4	20.2	0.77	*0.061*
Non-grazing efficiency [c]	7.74	6.96	1.029	0.448	AI	2.62	2.98	0.100	0.006

redundancy analysis (RDA; using CANOCO 5) assessed the relative impact of diet and breed parameters on milk yield and composition (solids and FA profiles) and feed efficiency. ***Results***: HF × J cows produced milk with more protein (+2.9 g/ kg milk) and had better feed efficiency (+120 g milk/ kg DMI) (Table 1). HF × J milk contained more saturated FA (SFA; +27.3 g/kg total FA) and less monounsaturated FA (MUFA; –23.7 g/ kg total FA) and polyunsaturated FA (−22.3 g/ kg total FA) and had higher atherogenicity index (Table 1); although the higher SFA content was mostly related with increased SCFA contents. The RDA showed that Jersey breed was not correlated to productivity and efficiency parameters but was positively correlated with milk SCFA, C14:0, LA, n-6 PUFA, DPA and DHA and negatively correlated with MUFA, t11 C18:1, c9 C18:1, c9t11 C18:2 and C18:0. ***Conclusions***: HF × J cows had higher milk protein content and feed efficiency than HF cows and these are desirable traits in low-input dairy systems. The differences in SFA contents were relatively small and mostly associated with SCFA and unlikely to have an impact on human health.

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82. Effect of dietary crude protein level on nitrogen excretion and retention in growing Holstein heifers

C. Katongole *, H. McDowell, T. Yan

Agri-Food and Biosciences Institute, Hillsborough, UK

* Corresponding author. C. Katongole.

Application: Increasing dietary crude protein (CP) level beyond 120 g/kg DM did not result in improved nitrogen (N) retention rate, but increased N excretion in growing Holstein heifers.
Introduction: The basic approach to reduce N excretion in cattle, and hence increased N use efficiency is feeding protein at concentrations that closely match the animal's requirements. Most of the N fed above requirements is excreted in urine as urea, which is susceptible to N losses to the environment through ammonia volatilization, nitrate leaching, and nitrous oxide emissions. Since lactating cattle have a central importance to economic stability of dairy enterprises, their N excretion has been subjected to relatively more studies compared to replacement heifers (Zanton and Heinrichs, 2008). This study evaluated the effect of dietary CP level on N excretion and retention in growing dairy Holstein heifers.

Table 1
Effect of dietary CP level on N excretion and retention SEM = Standard error of least square means [a,b,c] Least square means in the same row with different superscript letters differ (P < 0.05).

	Dietary CP Content, g/kg DM			P-value			
	120	144	167	SEM	Diet	Linear	Quadratic
DM intake, kg/d	7.1	6.7	7.6	0.26	0.079	0.174	0.044
N intake, g/d	135.5[c]	154.7[b]	201.8[a]	4.47	<0.001	<0.001	0.020
N excretion							
Faecal N, g/d	51.7[b]	50.3[b]	57.5[a]	1.36	0.005	0.006	0.017
Urinary N, g/d	55.0[c]	74.0[b]	105.1[a]	3.28	<0.001	<0.001	0.119
Manure N, g/	106.7[c]	124.3[b]	162.6[a]	3.83	<0.001	<0.001	0.034
Faecal N, % N intake	38.2[a]	32.8[b]	28.6[c]	0.95	<0.001	<0.001	0.594
Urinary N, % N intake	40.9[b]	48.1[a]	52.3[a]	1.88	<0.001	<0.001	0.624
Manure N, % N intake	79.5	80.5	81.4	2.31	0.832	0.595	0.849
Faecal N, % manure N	48.2[a]	40.9[b]	35.6[c]	0.98	<0.001	<0.001	0.292
Urinary N, % manure N	51.2[c]	59.1[b]	64.4[a]	0.98	<0.001	<0.001	0.292
N retention							
Retained N, g/d	28.6	30.3	39.3	4.61	0.255	0.112	0.514
Retained N, % N intake	20.8	19.6	19.5	2.03	0.832	0.595	0.849

Materials and methods: This study was conducted at the Agri-Food and Biosciences Institute, Hillsborough, UK, using 24 dairy Holstein heifers, averaging 314 days old, 287 kg live weight (LW), and 2.71 body condition score (BCS). The heifers were blocked by age, LW and BCS into 8 blocks of 3 heifers, and then randomly assigned within blocks to one of three total mixed rations (TMRs), resulting in 6 heifers per TMR. The TMRs contained a forage-to-concentrate ratio of 0.57:0.43 (DM basis), and 120, 144, and 167 g CP/ kg DM, which were achieved using ryegrass silage and 2 concentrate meals containing similar ME (12.9 MJ/kg DM) but different CP concentrations (134 and 260 g/kg DM). The heifers were fed once daily, and the amounts were adjusted to obtain approximately 10% orts daily throughout 24-day experimental periods. The first 18 days were for adaptation to TMRs, followed by 6-day total collections of faeces and urine, and feed intake data. Data were analysed using the PROC MIXED procedure of SAS for repeated measures. The model included diet, and interactions of diet × day and day × block as fixed effects, with BCS as a covariate. Linear and quadratic effects of CP level were also determined.
Results: All results are presented in Table 1. DM intake tended to be higher ($P = 0.079$) with the high CP diet. N intake, faecal N, and manure N increased in a linear and quadratic manner ($P < 0.05$) with increasing CP level (Table 1). Urinary N, and the proportion of N intake appearing in urine increased linearly, while that appearing in faeces decreased linearly ($P < 0.05$). The proportion of faecal N in total N excretion decreased linearly, while that of urinary N increased linearly ($P < 0.05$). Although N retention increased numerically with increasing CP level, the differences weren't significant. Similarly, dietary CP level also had no significant effect on retained N as a proportion of N intake.
Conclusion: Increasing dietary CP level can significantly increase urinary N excretion. Dietary CP concentration can be reduced by up to 120 g/kg DM without compromising N retention in growing dairy Holstein heifers.

Acknowledgement: Department of Agriculture, Environment and Rural Affairs.

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83. Comparing the effectiveness of ratios of manure nitrogen to potassium and phosphorus on estimating in vitro ammonia emissions from dairy manure varied in urinary to faecal nitrogen ratio

Y. Song [a,*], M. Bai [b], D. Chen [b], G. Hepworth [b], P. Cheng [a]

[a] The University of Melbourne, Shepparton, Victoria, Australia
[b] The University of Melbourne, Melbourne, Victoria, Australia

* Corresponding author. Y. Song.

Application: Ratio of nitrogen (N) to potassium (K) is a better biomarker to reflect manure ammonia (NH_3) emission than N to phosphorus (P) from dairy manure.
Introduction: There is no research that compares the effectiveness of ratios of N: K and N: P on estimating NH_3 emission as biomarkers from dairy cattle manure with different manure compositions (Lee et al., 2011; Hristov et al., 2009). Therefore, this study aimed to prove which ratio will be a better biomarker on estimating the cumulative manure NH_3 emission when the manure is varied in urinary to faecal N ratio(UN: FN).
Materials and methods: A total of 20 random-selected dairy cattle, were chosen from Melbourne University farm. Cattle urine and faeces samples were collected separately. An acid trap based in vitro incubation system was set up to measure manure NH_3 emissions for 15 days with two different treatment ratios of UN:FN. They were UN:FN = 1:1 vs. UN:FN = 2:1. Each treatment group had four replications, and each replication contained 600 g of reconstructed manure. Daily manure and acid trapped NH_3 samples were collected to quantify manure N:K and N:P, and NH_3 emissions, respectively. All data were analyzed by linear regression and ANOVA in Genstat.
Results: The cumulative NH_3 emissions from 15 days were higher from UN:FN = 2: 1 treatment than UN:FN = 1:1. The cumulative NH_3 emissions were negatively correlated with manure N:K and N:P (Figure 1 A and B; n = 15). Figure 1A shows significant negative relationships between the cumulative NH_3 emissions and manure N:K with the slope of correlation of −1.61 ($R^2 = 0.48$, $P \leq 0.001$, S.E. = 0.10) and −3.61 ($R^2 = 0.83$, P

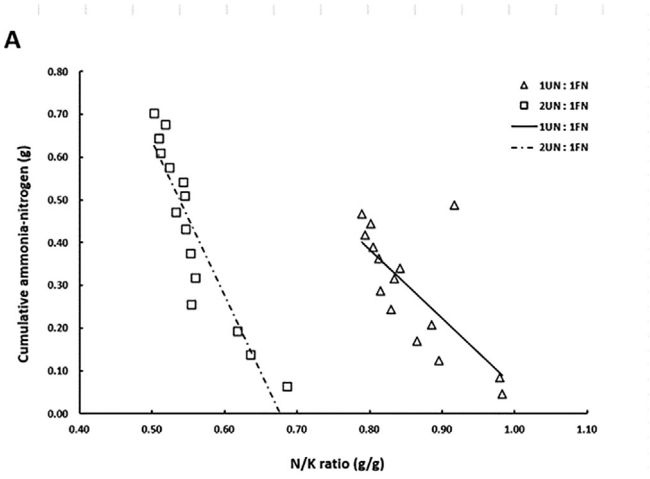

Figure 1. The regression analysis of the cumulative NH_3 emission paired with the manure ratios of N:K and N:P.

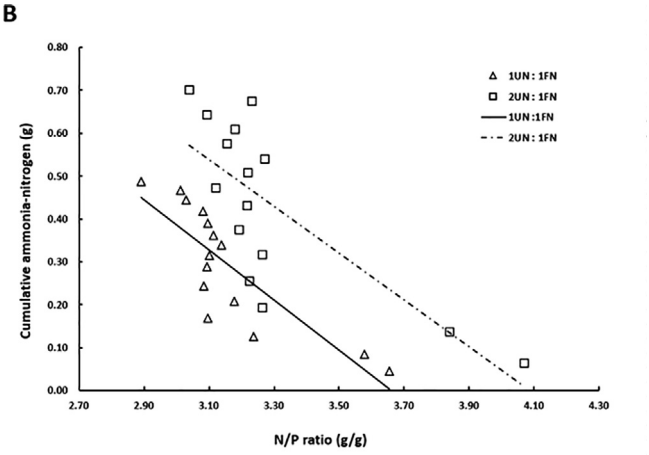

Figure 2.

≤ 0.001, S.E. = 0.08) for the UN:FN = 1:1, and UN:FN = 2:1, respectively. Figure 1B shows significant negative relationships between the cumulative NH_3 emissions and manure N:P with the slope of correlation of −0.59 (R^2 = 0.67, P ≤ 0.001, S.E. = 0.08) and −0.55 (R^2 = 0.54, P ≤ 0.001, S.E. = 0.14) for the UN:FN = 1:1 and UN:FN = 2:1, respectively.

Conclusion: Over the 15-day incubation period, the N:K ratio was proved to be a better biomarker to reflect manure N losses than N:P when dairy cattle manure varied in UN:FN = 2:1. When UN:FN = 1:1, the N:P ratio was proved to be a better biomarker to reflect manure N losses than N:K.

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84. Analysis of maternal behaviour score in a commercial sheep breeding programme

K. Hay [a,*], J. Roden [b], N. Lambe [a], S. Jarvis [c], C. Dwyer [a]

[a] SRUC, Edinburgh, UK
[b] Innovis, Aberystwyth, UK
[c] Edinburgh University, Edinburgh, UK

* Corresponding author. K. Hay.

Application: Maternal behaviour score is a heritable trait that is related to lamb survival and growth.

Introduction: Maternal behaviour is important for lamb survival, as ewes perform many behaviours that effect the chances of a lamb surviving (Dwyer et al, 2016). Collecting maternal behaviour data at lambing is time consuming and not suitable for collecting large volumes of data. The aim of this study was to investigate if a simple scoring system would be effective and heritable.

Materials and methods: 19,452 maternal behaviour scores were collected over 14 years, across 24 farms and 12 different breed lines that make up the Innovis breeding programme. Maternal behaviour was scored on a 3-point score (1) the ewe shows a high level of maternal interest, (2) the ewe shows limited interest in her lamb and (3) the ewe shows no interest in her lamb. Significance of fixed effects were assessed using multiple linear regression in GenStat. Significant fixed effects were flock, lambing batch, ewe age, ewe breed, pre-tupping weight, lambing day and number of lambs scanned. All 2-way interactions were fitted, and 2 significant interactions were found flock × ewe age and flock × number of lambs scanned. This model was used to estimate heritability by fitting an animal model in ASReml using 121,858 pedigree records over 21 generations. Initial analyses investigated if the maternal behaviour score was related to number of lambs reared and the ewes' lambs combined 8-week weight by conducting pairwise t-tests.

Results: The above model produced a heritability for maternal behaviour score of 0.041 with a standard error of 0.008. Ewes scored 1 on the maternal behaviour score, on average reared a larger number of lambs than ewes that were scored as poorer mothers (2 or 3), however ewes that scored 3

Table 1
Mean number of lambs by ewes scored 1, 2 or 3 on the maternal behaviour score and P-values for pairwise comparisons between scores.

	Mean number of lambs reared			P-values for pairwise t-tests		
	Maternal score 1	Maternal Score 2	Maternal Score 3	Score 1 & 2	Score 1 & 3	Score 2 & 3
All ewes	1.51	1.20	1.40	<0.001	0.005	<0.001
Singles	0.98	0.88	0.96	<0.001	0.44	0.12
Twins	1.76	1.35	1.65	<0.001	0.003	<0.001
Multiples	2.04	1.49	1.55	<0.001	0.004	0.87

Table 2
Mean sum of 8-week weights by ewes scored 1, 2, or 3 on the maternal behaviour score and P-values for pairwise comparisons between scores.

	Mean sum of lambs 8-week weight (kg)			P-values for pairwise t-tests		
	Maternal score 1	Maternal Score 2	Maternal Score 3	Score 1 & 2	Score 1 & 3	Score 2 & 3
All ewes	28.9	22.2	24.7	<0.001	0.003	0.02
Singles	20.4	15.2	16.3	<0.001	0.006	0.25
Twins	33.9	26.4	30.6	<0.001	0.13	0.08
Multiples	42.9	28.9	23.6	<0.001	<0.001	0.27

reared more lambs than ewes scored 2. When all ewes were analysed together there was a significant difference between all pairwise t-tests (Table 1). Table 2 shows similar results for the mean sum of lamb's 8-week weight, where ewes scored 1 reared heavier lambs than ewes that scored 2 or 3, but ewes scored 3 reared heavier lambs than ewes scored 2. All pairwise t-tests were significant when all ewes were analysed together.
Conclusions: The maternal behaviour score had a low but significant heritability. The score is linked to number of lambs reared and the 8-week weight of her offspring. The larger number of lambs reared and heavier combined 8-week weight for ewes scored a 3 compared to 2 could be due to more intervention in the ewes scored a 3. This maternal behaviour score could be useful in selecting for ewes that have better maternal ability. Further analysis will look at adjusting number of lambs reared and 8-week weights for other fixed effects.

Acknowledgements: Thanks to Innovis for funding my PhD and to all the breeding partners who collected data.

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85. A retrospective cohort study into lamb losses on a hill sheep farm, with a particular focus on the role plochteach plays in lamb performance and blackloss

F. McAuliffe [a,b,*], N. Sargison [b], A. McLaren [a], F. Brulisauer [c], A. Kent [d], D. McCracken [a]

[a] SRUC- Hill and Mountain Research Centre, Crianlarich, UK
[b] Royal (Dick) School of Veterinary Studies, University of Edinburgh, Edinburgh, UK
[c] SAC- Veterinary Services, Inverness, UK
[d] NatureScot, Edinburgh, UK

* Corresponding author. F. McAuliffe.

Application: Improving our understanding of blackloss may enable shepherds to alter management strategies and reduce losses, leading to improvements in hill sheep farming productivity, and helping to increase their sustainability and welfare.
Introduction: Blackloss is the unexplained loss of lambs on extensive hill grazings in the Highlands and Islands of Scotland. Reported figures for annual blackloss give an average of 18.6% (Tongue et al., 2016), whilst anecdotal evidence suggests that plochteach (a hepatogenous photosensitisation disease, also known as yellowses) may be a contributing factor. The aim of this study was to investigate the role that plochteach has in blackloss, as well as its effect on lamb performance, in two hill flocks.
Materials and methods: Data were available for 2,080 lambs born between 2014 and 2019 in SRUC's Auchtertyre (AT, 1,760 lambs) and Corrie (AC, 320 lambs) flocks. Lamb presence/absence was recorded using EID tags, and count data was used to calculate marking (June) to weaning (August)

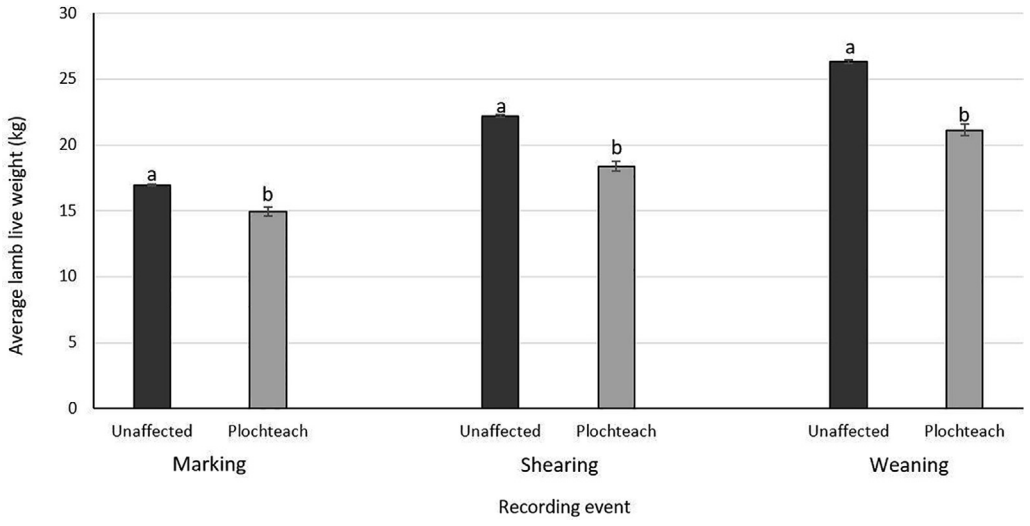

Figure 1. Live weights of unaffected and plochteach lambs at recording events (different subscripts denote significant differences (P < .001) within each event).

levels of blackloss. Plochteach was diagnosed through external photosensitisation symptoms on the ears and/or back. The impact of plochteach on lamb growth was investigated using GenStat (VSN International, 2018). A General Linear Model was fitted with the live weight of lambs at recording events (marking, shearing (July) and weaning) set as the response variable and Year (6 levels; 2014 to 2019), Sex (3 levels; male, female & unknown), Litter Size (3 levels; unknown, single & multiple), Ewe Crop (5 levels; 1, 2, 3, 4 & 5+), Flock (2 levels; AT & AC), and Plochteach (2 levels; yes or no) set as the fitted terms.

Results: The six-year average of blackloss observed between marking to weaning was 9.9% in AT and 5.2% in AC lambs. During the six-year period plochteach incidence rates were 7.5% and 2.2% respectively. Incidence of plochteach in the blackloss populations was 17.6% (AT) and 0.0% (AC). There was a statistically significant ($P < .001$) weight difference between unaffected and plochteach lambs at marking (16.98 ± 0.08 kg, 14.93 ± 0.33 kg), shearing (22.22 ± 0.11 kg, 18.40 ± 0.39 kg) and weaning (26.33 ± 0.12 kg, 21.13 ± 0.44 kg).

Conclusion: The data suggests that plochteach is a cause of blackloss within these flocks. The results also show that it can have a significant effect on lamb growth rate which will have a negative impact on the performance and financial results from these lambs. Further investigation to improve our understanding of plochteach, to reduce the incidence/impact of the disease and identify appropriate treatment options, would be beneficial.

Acknowledgements: This PhD is funded by SRUC and NatureScot and registered at the University of Edinburgh's Royal (Dick) School of Veterinary Studies. It involves collaboration between SRUC, University of Edinburgh, NatureScot and SRUC Veterinary Services. Thanks to the SRUC farm and technical staff involved in data collection.

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86. Understanding moxidectin knowledge, application and resistance on sheep farms

J. McIntyre [a,*], L. Miskell [b], E. Morgan [b], F. Lovatt [c], R Laing [a]

[a] Institute of Biodiversity, Animal Health and Comparative Medicine, University of Glasgow, Glasgow, UK
[b] School of Biological Sciences, Queen's University Belfast, Belfast, UK
[c] Flock Health Ltd., Barnard Castle, UK

* Corresponding author at: J. McIntyre.

Application: Findings from this project indicate the need for improved anthelmintic product labelling and farmer support to ensure a clearer understanding of how, when and why products should be used. Findings suggest best practice guidelines are not always correctly understood and that more needs to be done to encourage sustainable use.

Introduction: Anthelmintic resistance is increasing. In the UK, nematode parasites are managed using various management practices, however, most farmers rely heavily on anthelmintics. Guidelines available for sheep farmers aim to encourage sustainable use of these anthelmintics, with specific guidelines for moxidectin established in 2020. This is a broad spectrum endectocide with persistent action against re-infection by L3 of several nematode species, including Teladorsagia circumcincta and Haemonchus contortus, the main nematode pathogens of sheep and goats. This study aimed to identify how Scottish sheep farmers use moxidectin and whether they have 'head' (adults/L4 survive treatment) or 'tail' (L3 able to establish infection during the persistency period) resistance to moxidectin.

Materials and methods: A questionnaire was widely distributed via online and paper formats to farmers across Scotland, including 7000 copies distributed within a popular farming publication. In addition, six farmers were voluntarily recruited to the study to submit sheep faecal samples following their flock treatment with moxidectin. Samples were submitted 13-22 days post-treatment and again 42.5 days (median, range 40-45 days) after oral treatment, and 91 days (88-100 days) after 2% Long Acting injection. Faecal egg counts, sensitive to one egg per gram, were performed and worm species identified by PCR. Statistics performed in R included Wilcoxon Rank Sum tests to compare differences in faecal egg counts and proportion tests to analyse questionnaire results.

Results: Although the questionnaire could not be conducted in person during 2021, seventy-six farmers responded; they represented all four regions of Scotland and flock size ranged from <50 breeding ewes to >1000. Moxidectin knowledge varied: when asked about moxidectin use in 2020, 24% of 71 farmers completing paper questionnaires wrote down products other than moxidectin and some misunderstood the product target species, or parasite epidemiology. Most farmers did not appear to be following recommended sustainable guidelines; only 28% left some sheep in a group untreated at

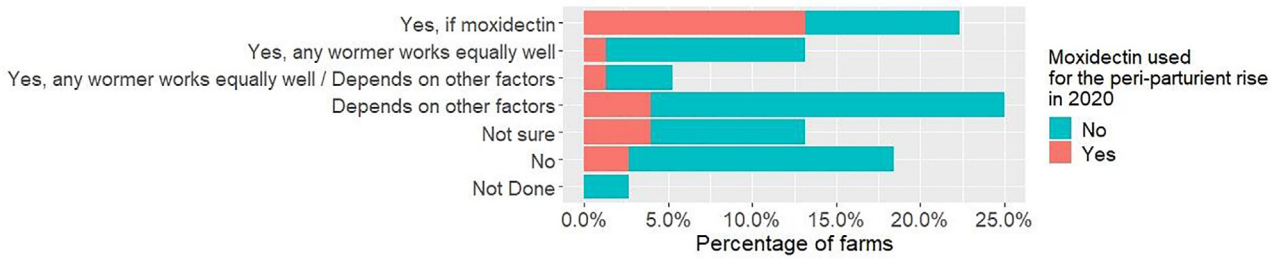

Figure 1. 'Do you think that lambs do better if you treat their ewes with a wormer at lambing time?'

least once when using moxidectin, and the percentage untreated was often low. Behaviours and beliefs surrounding treatment of the peri-parturient rise varied (Figure 1). PCR identified T. circumcincta or H. contortus on five farms following moxidectin treatment.
Conclusions: Moxidectin is widely used by sheep farmers across Scotland. Knowledge of which products contain moxidectin and how and why it should be used varies considerably. A large proportion of farmers who responded do not appear to be employing moxidectin sustainably, yet few perceive any resistance.

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87. The impact of internal parasitism on milk production and udder health of dairy goats in low-input pastoral farming systems

V. Papanikolopoulou [a,*], A.I. Gelasakis [b], E. Papadopoulos [c], S. Vouraki [a], A. Soufleri [a], G. Arsenos [a]

[a] Laboratory of Animal Husbandry, School of Veterinary Medicine, Faculty of Health Sciences, Aristotle University of Thessaloniki, Thessaloniki, Greece
[b] Laboratory of Anatomy and Physiology of Farm Animals, Department of Animal Science, School of Animal Biosciences, Agricultural University of Athens, Athens, Greece
[c] Laboratory of Parasitology and Parasitic Diseases, School of Veterinary Medicine, Faculty of Health Sciences, Aristotle University of Thessaloniki, Thessaloniki, Greece

* Corresponding author. V. Papanikolopoulou.

Application: Managing internal parasitism in extensively reared dairy goats can improve their overall performance and health leading to increased profitability of farms.
Introduction: Parasitic infections are dominant in grazing ruminants worldwide, with potentially severe impacts on their health and welfare associated with loss of appetite, anaemia and other pathological implications (Mavrot et al., 2015). In small ruminants, parasitism can adversely affect their health, milk yield and quality, resulting in substantial losses of marketable products (Cringoli et al., 2009). However, relevant studies in dairy goats are limited. Therefore, the objective here was to assess the effect of parasitic infections on milk production and udder health of dairy goats in low-input systems.
Materials and methods: A total of 294 dairy goats from two indigenous Greek breeds, Skopelos (n = 74) and Eghoria (n = 86) and one foreign breed Damascus (n = 134) were randomly selected. The herds involved (n = 7), were representatives of low-input pastoral system characterized by grazing throughout the year. Individual faecal samples were collected monthly for two consecutive milking periods. Parasitic burden and morphological identification of parasitic elements were performed using the modified McMaster technique; parasitic infection was confirmed when >50 eggs or larvae/g of faeces were detected. Milk yield (MY) and corresponding milk fat-, protein-, lactose-, and solids-non-fat- (SNF) content as well as somatic cell count and total viable counts, were assessed monthly. The impact of either single-parasite infection or concurrent infection, on the above traits was evaluated using mixed linear models. Models accounted for fixed effects of farm, milking period, age, and days from kidding and the random effect of the animal. Data analysis was done with R statistical software using the "lme4" package.
Results: Results showed significant effects of internal parasitism (nematodes, cestodes, lungworms) on MY and milk composition ($P < 0.05$, Table 1). Animals free of parasitic infections produced an average MY equal to 1.6 ± 0.96 kg, with average protein content and yield, lactose yield and SNF yield of 3.7 ± 0.5%, 57.3 ± 32.0g, 68.9 ± 41.7g and 140.0 ± 81.9g, respectively. Single parasitic infection had a negative effect on prior mentioned traits with a decrease of 4.7 ± 2.01%, 1.5 ± 0.59%, 6.2 ± 1.88%, 4.5 ± 2.2%, and 4.8 ± 1.97%, respectively. Likewise, the above milk production traits were adversely affected by concurrent parasitic infection with a decrease of 4.2 ± 1.97%, 1.2 ± 0.59%, 5.6 ± 1.86%, 4.2 ± 2.02%, and 4.4 ± 1.94%, respectively. There were not any significant effects ($P > 0.05$) on somatic cell count and total viable counts.
Conclusion: The results suggest that internal parasitism has no significant effect on udder health, but has adverse effects on MY and milk composition of dairy goats reared under low-input systems. Under these systems, it is essential that farmers implement effective antiparasitic control programs.

Acknowledgements: This research has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under the grant agreement n° FP7-266367 (SOLID).

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Table 1
Effects of gastrointestinal nematodes and concurrent infection (nematodes, cestodes, lungworms) on milk production traits (values shown on natural log scale).

Traits	Gastrointestinal nematodes infection			Concurrent infection		
	Coefficient	SE	P-value	Coefficient	SE	P-value
Milk yield (kg, ln)	0.046	0.019	0.026	0.041	0.019	0.036
Protein content (%, ln)	0.014	0.006	0.018	0.011	0.005	0.049
Protein yield (g, ln)	0.060	0.018	0.002	0.054	0.018	0.003
Lactose yield (g, ln)	0.044	0.021	0.036	0.040	0.020	0.041
Solids-non-fat yield (g, ln)	0.046	0.019	0.020	0.040	0.019	0.025

88. Identification of factors associated with variation in gastrointestinal nematode faecal egg counts in periparturient ewes; towards development of targeted selective treatment guidance

E. Williams *, P. Brophy, H. Williams, R. Jones

IBERS, Aberystwyth University, Aberystwyth, Ceredigion, UK

* Corresponding author. E. Williams.

Application: Gastrointestinal nematode (GIN) faecal egg counts (FEC) in peri-parturient ewes are associated with body condition score (BCS), age, DAGG scores and breed. These traits can form the basis of targeted selective treatment (TST) guidance for peri-parturient ewes to control GINs whilst limiting anthelmintic resistance (AR) development.

Introduction: GIN infections cost the European sheep industry €157-477 million annually (Mavrot et al., 2016). Anthelmintic treatment of peri-parturient ewes against GIN maximises flock productivity, however, anthelmintic applications must be limited to minimise AR development. TST can reduce anthelmintic use without affecting productivity, and reduces AR development (Kenyon et al., 2013), however, only 29% of GB farmers implement ewe TST (Williams et al., 2021a) despite evidence of its applicability (Williams et al., 2021b). Identifying ewes for TST can be challenging, therefore the aim was to evaluate traits associated with variating peri-parturient FECs to guide future TST protocols.

Materials and methods: Faecal samples were collected from 226 ewes, 48h post-lambing on 7 Welsh farms. Ewes had lambed indoors and their age, breed, BCS, DAGG score, number of lambs scanned and born alive was recorded. Ewe breeds included Mule (n = 153), Suffolk/Suffolk X (n = 31), Texel/Texel X (n = 27) and hill breeds (n = 15), with each breed present on at least 4 farms. FECs were conducted within 24h of collection using the Mini-Flotac method. Multivariate negative binomial mixed models were created using glmmTMB package in R to identify factors significantly associated with FEC. A random intercept was added to the model to account for variation in FECs between farms and models were built using stepwise process where non-significant variables were removed from the model sequentially. The model with best fit was identified using the Akaike Information Criterion (AIC) and validated using residual diagnostic tests via DHARMa and Performance packages in R.

Results: A mean ewe FEC of 440 eggs per gram (range 0 – 4575), litter size of 1.87, BCS 2.56 and mean age 3.46 was observed, with 5% of ewes displaying DAGGs. The final model (Table 1) identified BCS and age as significant factors negatively associated with ewe FEC ($P < 0.01$). Suffolk/Suffolk X ewes and ewes with a DAGG score >0 displayed significantly higher FECs ($P < 0.001$). Measures of mean litter size were not present in the final model ($P > 0.05$).

Conclusion: BCS, age, DAGG score, and breed are significant indicators of peri-parturient FEC and should be considered in TST protocols. Future research is required to identify optimal proportion of peri-parturient ewes treated to maximise production and minimise pasture contamination, whilst maintaining sufficient susceptible GINs in refugia to dilute resistant population.

Acknowledgements: Aberystwyth University, HCC, KESS2

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Table 1
Best fit negative binomial mixed model identifying factors associated with peri-parturient ewe FEC.

Variable		B	S.E	Z	P-value
Intercept		7.03	0.34	20.83	<0.001
BCS		-0.22	0.08	-2.74	0.006
Age		-0.20	0.06	-3.49	<0.001
Dagg score	>0	0.71	0.21	3.36	<0.001
	0	Reference	-	-	-
Breed	Suffolk or Suffolk X	0.63	0.18	3.54	<0.001
	Texel or Texel X	0.31	0.18	1.68	0.092
	Hill breed	-0.46	0.26	-1.79	0.073
	Mule	Reference	-	-	-

89. Challenges and opportunities for farmers and calf rearers

J. Margerison

University of Nottingham, UK

Farmers and calf rearers aim to enhance animal health through disease prevention strategies included in herd health plans, which include investment in housing, biosecurity, hygiene and staff training that lower the cost of treatment (morbidity), labour and losses due to mortality. These along with good nutrition and feeding management increase the average daily gain (ADG) and increase the proportion of animals that achieve timely maturity targets and optimal lifetime performance, which increases the economic returns and food security from the agricultural industry, while lowering the carbon footprint (CFP) and risk of antimicrobial resistance (AMR), while enhancing welfare. Other challenges include changes in food consumption, consumer perception and misinformation, which is exasperated by a lack of practical understanding of the importance of livestock in sustainable land

use along with the limitations that climate and soil type place on land use opportunities. All of these factors need to be considered in the development of sustainable food production strategies.

90. Accurate parameter estimation in calves using non-linear growth models

Y. Huang [a,*], N. Jonsson [a], P. Johnson [a], R. Dewhurst [b], D. Eckersall [a]

[a] Institute of Biodiversity, Animal Health & Comparative Medicine, University of Glasgow, Glasgow, UK
[b] Scotland's Rural College, Dumfries, UK

* Corresponding author. Y. Huang.

Application: Applying an exponential model provides more accurate estimates of treatment effects than linear models in calves up to four months old, potentially providing greater statistical power to detect effects of treatments, using the same number of animals.
Introduction: The effect sizes of interventions on livestock growth are usually based on before-and-after measurements that generate linear slopes as estimates of average daily gain in bodyweight (BW). However, organismal growth follows a non-linear curve that can be divided into: an initial accelerating rate of gain, followed by an approximately linear phase, and finally a decelerating rate of gain. The aims of the study are to find the most suitable model for early life in calves according to goodness-of-fit and birthweight estimations, and to assess accuracy of the best fitting model in effect size parameter estimation.
Materials and methods: From 02/2019 to 02/2020, at Crichton Royal farm, 399 mixed-breed calves (crossbred Aberdeen Angus, Holstein-Friesian, British Blue and Limousin) were weighed manually within 24h after birth and weighed automatically using Biocontrol weighing platforms at each drinking station. There were 174,072 automated BW recordings, ranging from 1d of age (mean ± SD; 14 ± 11d) up to 126d (66 ± 24d). For each calf, average daily BWs were modelled using linear ($BW = at + b$), quadratic ($BW = at^2 + b$), cubic ($BW = at^3 + b$), power ($BW = t^a + b$) and exponential ($BW = be^{at}$) relationships, where t = age in days, a = growth rate and b = initial weight. Models were compared on (1) goodness-of-fit using AIC and R^2, (2) accuracy of birthweight estimation, and (3) ability of their growth rate estimates to discriminate between subgroups that are known to influence growth rates. For the third analysis, breed and sex were included as independent variables in generalized linear models with dependent variables being growth rate estimates from the best fitting model or from the linear model, fitted for each calf. The differences between R^2 estimates (reflecting precision of effect estimation) from the two methods from each calf were bootstrapped with 1,000 replicates and parameters determined for breed, sex and their interaction.
Results: Figure 1a shows the five models fitted to a calf and mean growth trajectories that were predicted for all calves. The exponential model had the best goodness-of-fit and provided more calves with the most accurate estimated birthweights (Figure 1b). The exponential model provided R^2 (mean 15%) for breed, sex and their interaction that were 8 percentage points (pp) higher (95% CI: 4 - 12 pp, $p < 0.05$) than linear model estimates (mean 7%) (Figure 1c).
Conclusion: The exponential model was the best model for early life in calves and gave higher effect estimate precision, implying that alternatives to linear slope estimates might provide greater power in experimental studies.

Acknowledgement: We thank Agri-EPI Centre Ltd for provision of Biocontrol equipment.

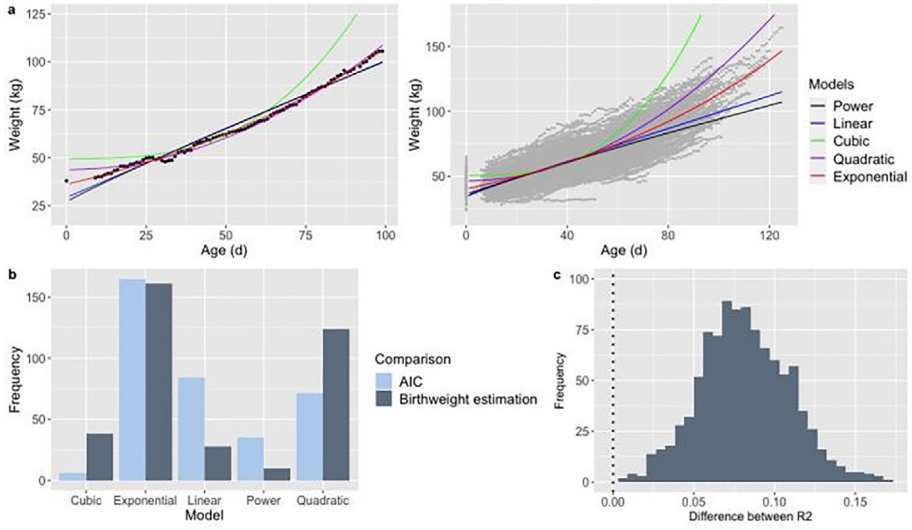

Figure 1. (a) The bodyweights of a calf and all calves with predicted growth trajectories of models, (b) model comparisons, and (c) differences between R^2 from the exponential model and the linear model from each calf determined for breed, sex and their interaction.

91. The influence of birth weight on dairy Holstein heifer calf health and growth prior to weaning

A. Carroll [a,*], E. Bleach [b], L. Williams [a]

[a] Hartpury University, Hartpury, Gloucestershire, UK
[b] Harper Adams University, Newport, Shropshire, UK

* Corresponding author. A. Carroll.

Application: It's essential to support successful growth of dairy calves to ensure efficient and profitable production systems. Lower birth weight calves should be managed separately, allowing for farmer intervention to minimise health challenges experienced and support growth.

Introduction: A critical issue for the dairy industry is achieving target growth rates in dairy calves, which affects the age at first calving for dairy heifers and has financial repercussions. Neonatal calf diarrhoea and enteric infections are among the main causes which can be as a consequence of insufficient calf growth and/or stress in early life. It was found that calves experiencing any form of disease had significantly higher mortality rates. According to the AHDB Dairy Calf to Calving project, most farms are not achieving heifer growth targets, with 70% of farms under target at weaning. This study aimed to assess if birth weight influenced number of health challenges experienced during pre-weaning and if this subsequently affected final weight at weaning.

Materials and methods: Holstein heifer calves (n = 16) from Hartpury Home Farm were separated from dams at birth and housed individually. Colostrum was fed at 10% birth weight within 4hours followed by 2L of GLW Lifetime Elite milk replacer (17% oil, 26% protein) feed twice daily. Calves were moved to group pens (n = 14) at 1 week old and group fed to weaning (mean age 84 days). Calf starter was offered ad libitum. Calf weights and average daily gains were tracked via the calf unit recording system. Challenges were recorded and included periods when medical intervention was needed (high temperature, diarrhoea, enteric infection, nasal/ocular discharge). Data was analysed using SPSS (version26). Shapiro-Wilk normality test was conducted. A linear regression was used to assess whether birth weight influenced number of challenges experienced and if this significantly predicts weight post-weaning. Model selection via linear regression was set at $P < 0.05$.

Results: Lower birth weight calves (30–35 kg) experienced more challenges than those with high birth weight (Figure 1) prior to weaning. Average daily gain was also reduced as a consequence (Table 1). The linear regression model was significant, explaining 35% ($R^2 = 0.348$) of the variance

Table 1
Means (standard error in parenthesis) for birth weight, challenges experienced, weight at weaning and average daily gain based on birth weight ranges.

Birth Weight Ranges kg	Calf Numbers per Range	Mean Birth Weight kg	Mean Number of Challenges	Mean Weight at Weaning kg	Average Daily Gain kg
30–35	n = 4	31.5 (±0.9)	10.8 (±4.4)	138.5 (±6.9)	1.2 (±0.1)
36–40	n = 4	37.5 (±0.7)	5.0 (±2.1)	160.6 (±6.3)	1.5 (±0.1)
41–45	n = 4	42.8 (±0.9)	3.0 (±1.4)	168.3 (±2.7)	1.6 (±0.0)
46–51	n = 4	48.3 (±0.9)	0.3 (±0.3)	165.8 (±8.5)	1.4 (±0.1)

Table 2
Linear regression relationship between birth weight, challenges and final weight.

	F	B	t	p	R^2	RMSE
Birth weight & Challenges	(1,14) = 7.47	−0.542	−2.73	0.016	0.348	5.05
Challenges & Final weight	(1,14) = 7.17	−1.62	−2.68	0.018	0.339	14.12

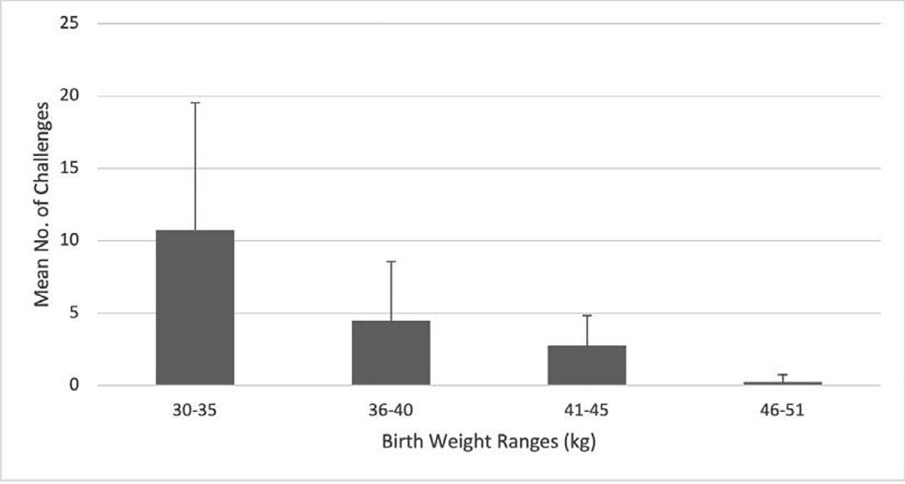

Figure 1. Mean challenges experienced over pre-weaning based on birth weight ranges.

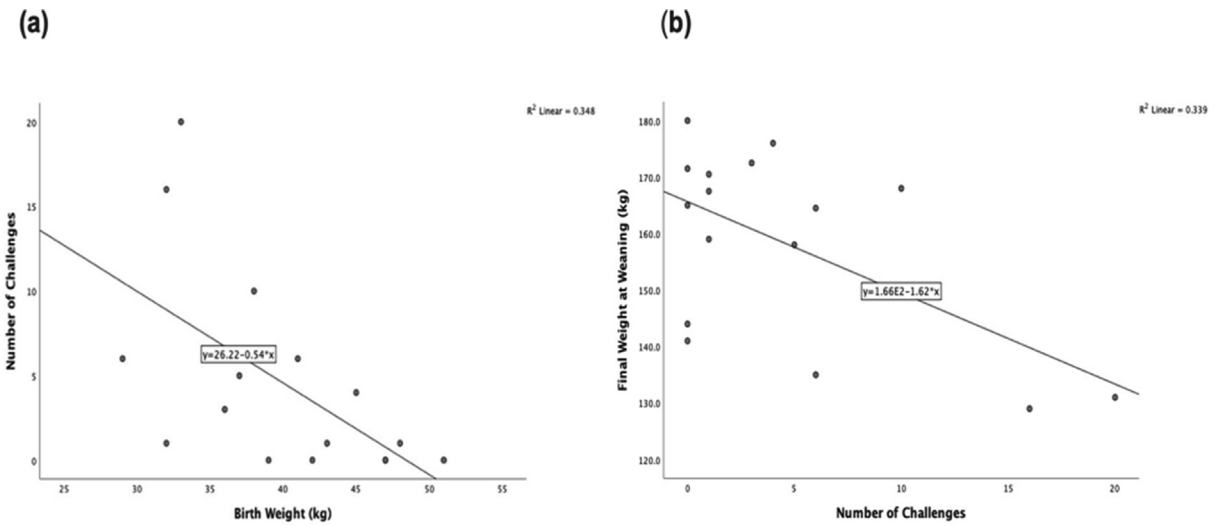

Figure 2. (a) The relationship between birth weight and challenges experienced pre-weaning and (b) the relationship between challenges experienced pre-weaning and weight at weaning.

between birth weight and number of challenges and explaining 34% (R^2 = 0.339) of the variance between the number of challenges and final weight at weaning (Table 2) (Figure 2).

Conclusion: Dairy calves with lower birth weights experienced more challenges over the pre-weaning period, with average daily gains reduced. Thus, having an effect on final weights post-weaning. R^2 values were low indicating birth weight and challenges as limited predictors of calf health and final weight. However birth weight was seen to be a better predictor of challenges.

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92. The effect of foster-cow rearing on dairy calf growth and health

O.F.D Bolton *, G.L. Charlton, E.C.L. Bleach

Harper Adams University, Newport, Shropshire, UK

* Corresponding author. O.F.D Bolton.

Application: Foster-cow rearing may be a suitable alternative method to rear dairy calves which does not negatively impact calf growth or health.

Introduction: The environmental impact of farming is a growing concern in the UK and around the globe. Improving productivity and efficiency reduces the environmental impact of dairy farming (Capper et al., 2009) and should be prioritised. Calf mortality, impaired growth and supressed health represent an economic loss and impact the efficiency and sustainability of dairy farms. Alternative rearing systems are an emerging area of research and of particular interest to producers is foster-cow rearing (Bolton et al., 2021). This study examined the impact of foster-cow rearing on the growth and health of dairy calves.

Materials and methods: The study was conducted on a commercial spring block calving dairy farm in NW England. Calves (n = 35) were removed from their dams within 6 hours of birth and all received 2 teated bottle feeds of colostrum (2L) within 12 hours of birth. Heifers (n = 16) and bulls (n = 19) (mixed breeds) were randomly allocated to either Foster-cow (n = 17) or Control (n = 18) for a period of 8 weeks. Foster calves were allowed unlimited access to foster-cows (2.8 calves/cow) and Control calves were fed unpasteurised whole milk (2L twice daily) from teated bar feeders. All calves were group housed on straw and had access to ad libitum silage, concentrate and water. Health of calves were recorded twice weekly using the Wisconsin Calf Health scoring system (McGuirk and Peek, 2014) whereby lower scores indicate better health, and weight of calves was measured twice weekly from birth using a weigh band. The effect of treatment was analysed through repeated measures general liner model processed in SPSS (Version 28).

Results: The live weights of calves are shown in Figure 1. Daily live weight gain did not differ between the groups (Control = 0.604 kg (+/- 0.044), Foster = 0.705 kg (+/- 0.033), P = 0.529), however effect of time was significant (P < 0.001) and time*treatment interaction was significant (P = 0.014). Health scores (Figure 2) of Foster calves were significantly lower than Control calves (P = 0.016), the effect of time was significant (P < 0.001) and time*treatment interaction was significant (P = 0.041).

Conclusion: Overall calf growth was not affected by treatment however significant interactions make it difficult to interpret the full effect of foster-cow rearing which may be more apparent over a longer rearing period. Foster-cow rearing improved the health of calves during the milk feeding period and since early calf health influences subsequent performance, foster-cow rearing may reduce the environmental footprint of calf rearing.

Acknowledgements: The authors acknowledge funding from Devenish Nutrition and the Silcock Fellowship for Livestock Research and are grateful for farmer participation in this study.

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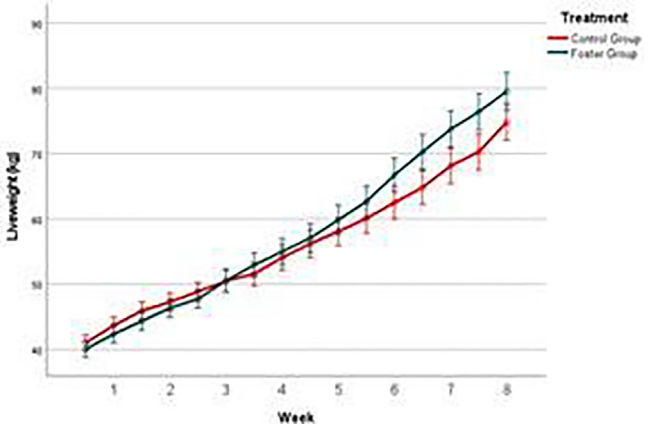

Figure 1. Mean (+/- SEM) calf weights from birth to 8 weeks of age.

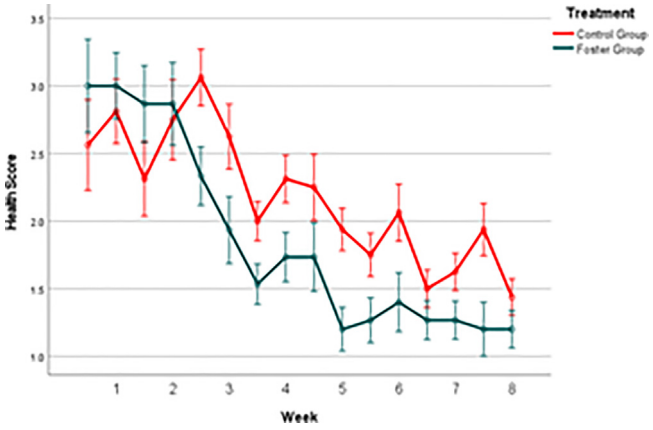

Figure 2. Mean (+/- SEM) calf health scores from birth to 8 weeks of age.

93. Quantitative analysis of individual differences in dairy calf feeding behaviour: insights from methods in behavioural ecology for precision livestock farming

C. Carslake [a,*], F. Occhiuto [a], J. Vazquez Diosdado [a], J. Kaler [a]

[a] University of Nottingham, Sutton Bonington, UK

* Corresponding author. C. Carslake.

Application: Improving our understanding of between and within individual variation in dairy calf feeding behaviour may enable improved applications, such as health monitoring, by use of computerised milk feeders.

Introduction: The increasing sophistication and affordability of sensors for livestock is driving a paradigm shift in how we manage livestock. For example, so-called precision livestock farming, promises to cut carbon emissions and improve efficiencies by providing early warning systems for ill health. However, despite the increasing use of computerised milk feeding for dairy calves, no algorithms exist that can accurately infer calf health from its feeding behaviour. An initial step towards this goal is to quantify normal individual variation in feeding behaviour. Individual differences can be examined at the between individual level (how much individuals differ in their average behaviour) and at the within individual level (how much

Table 1
Measures of behavioural variation for different feeding behaviours in calves.

	Feeding rate	Feeding time	Meal frequency	Meal size
Repeatability				
Estimates	0.41	0.39	0.36	0.04
CI	0.30–0.52	0.04–0.25	0.25–0.45	0.02–0.7
Coefficient of Variation in Predictability				
Estimates	0.32	0.17	0.10	0.13
CI	0.24–0.42	0.10–0.24	0.02–0.17	0.08–0.18

an individual's behaviour varies around its mean). Here we use methods from the behavioural ecology literature to quantify between and within individual variation in calf feeding behaviour.
Materials and methods: A computerised milk feeder recorded the feeding behaviour of 64 Holstein-Friesian heifer calves, housed in small groups, for 35 days at the Centre for Dairy Science and Innovation, University Of Nottingham, UK. 57 000 visits to the feeder were summarised into different feeding behaviours, calculated per calf per day. Calves were health scored twice weekly and clinically sick calves (n = 14) excluded from the analysis. We calculated repeatability (the proportion of total variation explained by between individual differences) by use of multi-level models and variance partitioning. We calculated the coefficient of variation in predictability (the degree to which individuals differ in their residual variation around their respective means) by use of double-hierarchical generalized linear models. Finally, we use a multivariate double-hierarchical model to test if calves that have more meals had higher feeding rates. All analysis was carried out in R (version 4.1.0).
Results: Repeatability estimates indicate that individual calves displayed substantial between individual differences in their average behaviour for feeding rate, meal frequency and feeding time (Table 1). Minimal between individual differences was observed for meal size. The coefficient of variation in predictability shows that calves with predictable and unpredictable feeding rates were present in our study, but for other behaviours calves were more homogenous in the degree to which their behaviour varied around their respective means. Outputs from the multivariate model indicate that behavioural types for feeding rate and meal frequency were positively correlated (R = 0.35 (CI: 0.06 – 0.60)) indicating that calves with higher feeding rates had more meals.
Conclusion: Implementing a behavioural ecology approach is a useful way to quantify differences in feeding behaviour.

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94. Factors affecting feeding and activity behaviours in healthy pre-weaned artificially reared calves

B. Riley [a,b,*], C.A. Duthie [a], A. Corbishley [b], J.M. Bowen [a], C. Mason [a], D.J. Bell [a], M. Haskell [a]

[a] SRUC, Edinburgh, UK
[b] University of Edinburgh, Edinburgh, UK

* Corresponding author. B. Riley.

Application: An understanding of factors affecting healthy calf behaviour will guide the development of behaviour-based tools for disease detection.
Introduction: Behaviour is increasingly being researched as a tool for early disease detection in artificially reared calves. However, it is important to understand how other factors such as sex, and breed may affect healthy calf behaviour. This is to improve the sensitivity and specificity of behaviour-based tools, as alert accuracy is a major concern for animal keepers when discussing technology-based disease detection.
Materials and methods: One hundred and fourteen dairy bred calves from two herds (herd A = 43 calves, herd B = 71 calves) entered group pens of 12-14 calves at approximately seven days of age and left the study when weaning began at 40 days of age. Calves were bedded on straw with *ad-libitum* access to racks of straw and concentrate and a single automatic milk feeder with an automated weighing platform *(Biocontrol)*. Seven litres of acidified milk replacer (mixed at a rate of 150g/L) were available daily. Activity behaviours were recorded using a leg-mounted 3-axis accelerometer (*Icequbе)*. Health was scored daily using the Wisconsin calf health score method. To ensure only days where calves were healthy were included, Data was removed for days when medication was given, health scores were intermediate or high, and for 3 days either side. Calves with at least 10 consecutive healthy days were included and the middle 10 days of the healthy period were taken to achieve a balanced dataset. For parameters with a normal distribution a generalised linear mixed model was constructed using REML in R with animal number nested within group as random effects. Fixed effects tested were live weight, age, sex, herd, season of birth, age of inclusion into the group, dam parity, birth weight and sire breed type (beef or dairy). Model selection was carried out using the Akaike information criterion.
Results: Thirty-one calves were included in the analysis. Live weight, age, sex, herd, season of birth and age of inclusion into the group had significant effects on activity or milk feeding behaviours. Dam parity, birth weight and sire breed type had no significant effects on the behaviours studied. The results of the final models are presented in Table 1.

Table 1
Factors affecting behaviour in healthy pre-weaned calves with P < 0.1 in the final model.

Behaviour	Fixed effect	Level	Effect size	Confidence interval	P-value
Lying bouts /day	Season	Autumn	Reference	Reference	Reference
		Summer	6.8	2.6–10.8	0.01866
		Winter	−0.4	−3.4–2.7	0.78657
	Herd	B	Reference	Reference	Reference
		A	4.0	1.1–6.5	0.00816
	Sex	Female	Reference	Reference	Reference
		Male	−3.2	−6.4–0.1	0.07107
Motion index/day	Age		−61.5	−96.2–−25.8	0.000883
	Sex	Female	Reference	Reference	Reference
		Male	−653.98	−1360.5–3.3	0.065207
Motion index units/ standing bout	Age		−3.1	−4.9–−1.0	0.00143
	Age at inclusion into group pen		−11.2	−18.88–−2.2	0.00652
Visits to milk/day	Weight		0.08	0.02–0.14	0.00727
Volume milk/ visit	Weight		−5.4	−11.1–−0.3	0.0454

Conclusion: When building behaviour-based disease detection tools, models should account for other calf factors including weight, age, and sex to improve accuracy. While there has been much research into changes in calf behaviour with social housing and greater milk allowances but there is very little literature on other factors that affect behaviour in pre-weaned calves.

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95. Examination of the bronchial lymph node and cranial lung lobe messenger RNA and micro RNA transcriptome response, following an experimental challenge to dairy calves with bovine herpes virus 1

S. O'Donoghue [a,*], D. Johnston [a], B. Earley [a], M.S. McCabe [a], K. Lemon [b], C. Duffy [b], M. McMenamy [b], S.L. Cosby [b], J. Kim [c], J.F. Taylor [c], D.W. Morris [d], S.M Waters [a]

[a] Animal and Bioscience Research Department, Animal & Grassland Research and Innovation Centre, Teagasc, Grange, Meath, Ireland
[b] Veterinary Science Division, Agri-food and Biosciences Institute, Stormont, Belfast, Northern Ireland, UK
[c] Division of Animal Sciences, University of Missouri, Columbia, Missouri, USA
[d] Discipline of Biochemistry, National University of Ireland, Galway, Ireland

* Corresponding author. S. O'Donoghue.

Application: Differentially expressed microRNA's (miRNA's) and their target genes, may identify potential therapeutic targets for Bovine Respiratory Disease (BRD) infection.
Introduction: BRD is a primary cause of morbidity and mortality in cattle of all ages, both in Ireland and internationally. Bovine Herpes Virus 1 (BoHV-1), a double-stranded DNA virus of the alphaherpesvirus subfamily, is a primary BRD causative pathogen. There are limited data on the host transcriptome response (lung tissue) in dairy calves and on the microRNA (miRNA) transcriptome following BoHV-1 infection. Therefore, the study objective was to elucidate the changes in gene expression, and the miRNA transcriptome, following an experimental challenge with BoHV-1 in dairy calves.
Materials and methods: Holstein-Friesian calves (149.2 ± 23.82 days) were either challenged with BoHV-1 inoculum (10^7/mL x 8.5mL per animal) (n = 12) or mock challenged with sterile phosphate buffered saline (PBS) (n = 6). Calves were euthanised on day 6 post-challenge. Lungs were scored for the presence of lesions and bronchial lymph node and cranial lung lobe tissues were collected. Tissue aliquots were flash frozen at -80°C for RNA-Seq and small RNA-Seq. Total RNA (including small RNA's) was extracted from tissue aliquots using the Qiagen RNeasy Plus Universal Mini Kit. RNA sequencing was performed using an Illumina Novaseq 6000 (150 bp paired-end) and small RNA-Seq samples were sequenced on an Illumina NextSeq 500 (75 bp single-end). RNA-Seq analysis, from quality assessment to differential expression, was undertaken and sequenced reads were aligned to the ARS-UCD1.2 bovine reference genome. Small RNA-Seq analysis was performed and data were aligned to the ARS-UCD1.2 reference genome. Messenger RNA (mRNA) targets of differentially expressed (DE) miRNA's were determined using Targetscan and context++ scores were calculated using Targetscan and ViennaRNA. Target genes with a weighted context++ percentile rank of 99 were used for subsequent analysis. Pathway and functional enrichment analysis was performed on DE genes and DE miRNA's ($P < 0.05$, FDR < 0.05) using the ClusterProfiler package in R.
Results: Multidimensional scaling (MDS) revealed a clear separation between the BoHV-1 challenge and control groups based on bronchial lymph node gene expression changes. A total of 337 genes were DE in the bronchial lymph node ($P < 0.05$, FDR < 0.1, fold-change > 2) between the two treatments. Additionally, there were 334 DE genes in the healthy cranial lobe tissue and 67 DE genes in the lesioned cranial lobe tissue. A total of 62, 55 and 14 miRNA's were DE ($P < 0.05$, FDR < 0.1, fold-change > 1.5) in the bronchial lymph node, healthy cranial lobe and lesioned cranial lobe tissues, respectively. The KEGG pathways enriched ($P < 0.05$, FDR < 0.05) across all tissues were 'Influenza A' and 'Herpes Simplex Infection'.
Conclusion: The miRNA's involved in the bronchial lymph node and cranial lung lobe transcriptome response to BoHV-1 and their target genes, could potentially contain variants which influence susceptibility to BoHV-1.

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96. Intake, growth and carcass traits of steers offered grass silage supplemented with barley- and maize-based rations containing flaked peas, flaked beans, maize dried distillers grains or maize gluten feed

R. Kennedy [a,b,*], A.P. Moloney [a], E.G. O'Riordan [a], A.K. Kelly [b], M. McGee [a]

[a] Teagasc, Grange, Meath, Ireland
[b] University College Dublin, Belfield, Dublin, Ireland

* Corresponding author. R. Kennedy.

Application: Indigenous cereals and legume-protein sources can replace imported energy/protein feed ingredients as supplements to grass silage for beef cattle.
Introduction: In Northern Europe there is growing interest in exploiting indigenous cereals (barley) and legumes rather than imported cereals (maize) and by-products (e.g. maize-based) as animal feedstuffs. There is little published information comparing the relative feeding value of rolled barley and maize meal, and beans, peas, maize dried distillers grains (MDD) and corn gluten feed (CGF) as protein (+energy) sources in concentrate rations offered as a supplement to grass silage. The objective of this study, therefore, was to determine intake, growth and carcass traits of beef cattle offered grass silage supplemented with rolled barley or maize meal-based rations containing legumes or maize by-products.
Materials and methods: Late-maturing suckler-bred steers (n = 80; 575 kg, s.d. 21.3; 18-months, s.d. 1.0) were blocked by sire breed and weight, and within block were randomly assigned to one of eight supplement treatments, formulated to be isonitrogenous (135g crude protein (CP)/ kg dry matter (DM)): 1.Rolled barley (622g/ kg fresh weight basis) plus flaked peas (300 g/ kg), 2.Rolled barley (722g/ kg) plus flaked beans (200g/ kg), 3.Rolled

Table 1
Effect of cereal type and protein source as supplements to grass silage on steer intake and performance.

	Cereal type				Protein source					
	Barley	Maize	SEM	P-value	Peas	Beans	CGF	MDD	SEM	P-value
Dry matter intake (kg/day)	10.5	10.4	0.09	NS	10.2	10.4	10.5	10.5	0.14	NS
Daily live weight gain (kg)	0.98	0.99	0.031	NS	0.96	0.96	1.02	0.99	0.046	NS
FCR (kg DM/kg LW gain)	11.23	10.82	0.361	NS	10.80	11.54	10.45	11.30	0.54	NS
Slaughter weight (kg)	680	681	3.4	NS	678	678	685	681	5.1	NS
Carcass weight (kg)	388	385	2.4	NS	390	383	387	384	3.6	NS
Kill-out proportion (g/kg)	570	565	2.9	NS	576	566	565	564	4.3	NS
Daily carcass gain (kg)	0.77	0.74	0.022	NS	0.79	0.73	0.76	0.73	0.033	NS
Carcass conformation (1-15)	8.5	8.2	0.19	NS	8.8	8.2	8.1	8.3	0.28	NS
Carcass fat (1-15)	6.4	6.9	0.23	NS	6.4	6.8	7.0	6.3	0.34	NS

barley (637g/ kg) plus CGF (285g/ kg), 4.Rolled barley (780 g/ kg) plus MDD (142g/ kg), 5.Maize meal (507g/ kg) plus flaked peas (415g/ kg), 6. Maize meal (622g/ kg) plus flaked beans (300g/ kg), 7.Maize meal (522g/ kg) plus CGF (400 g/ kg), 8.Maize meal (702g/ kg) plus MDD (220g/ kg). All concentrates contained 50 g/ kg molasses, and were balanced for minerals/vitamins. To decrease rumen degradable protein concentration, peas and beans were flaked (Mendowski et al., 2021). Steers were individually offered 4 kg concentrate DM daily (in two feeds) in addition to grass silage (779 g/ kg DM digestibility, 110 g CP/ kg DM) ad libitum, for 110 days. Live weight, feed conversion ratio (FCR), ultrasonic measures of muscle and fat depth, carcass weight, and carcass conformation and fat score were determined. Data were analysed using ANOVA with terms for cereal type, protein source, their interactions and block in the model.

Results: There were no interactions ($P > 0.05$) between cereal type and protein source (Table 1). Intake, growth, FCR, carcass weight, kill-out proportion, estimated carcass gain, carcass conformation and fat score did not differ ($P > 0.05$) between cereal type or protein source. Rump-fat gain (mm) was greater for beans (9.74) and CGF (9.06) compared to MDD (6.73, $P < 0.05$) with peas being intermediate (7.73); all other ultrasonic measures of body composition did not differ between treatments.

Conclusion: Under these experimental conditions, the feeding value of barley was equivalent to maize, and peas or beans were equivalent to CGF or MDD when included in a concentrate ration offered as a supplement to grass silage.

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97. Associations between the rumen microbiome and host performance traits are substantially stable throughout the finishing phase of beef cattle

J. Lima [a,*], M. Martinez-Alvaro [a], J. Mattock [b], M.D. Auffret [c], C.A. Duthie [a], M. Cleveland [d], R.J. Dewhurst [a], M. Watson [a,e], R. Roehe [a]

[a] Scotland's Rural College (SRUC), Edinburgh, UK
[b] University of Edinburgh, Edinburgh, UK
[c] Agrifirm, Drongen, Belgium
[d] Genus plc, DeForest, Wisconsin, USA
[e] The Roslin Institute, Edinburgh, UK

* Corresponding author. J. Lima.

Application: Understanding whether rumen microbiome samples taken at slaughter are representative of the entire finishing phase is crucial for accurately identifying microbial biomarkers of host traits.

Introduction: Cattle live in symbiosis with bacteria, protozoa, and fungi (microbiota) in their rumen, which ferment feed into volatile fatty acids, microbial protein, and vitamins that the host animal uses to produce meat and milk. During fermentation excess H_2 can be produced and used by

Table 1
Variance (%) in performance traits explained by microbiome profiles from rumen samples taken at each time point Percentage of variance of host performance traits explained by ALR abundances of 1049 microbial genera (upper table part) and of 1901 microbial genes (lower table part) using PLS analyses.

Dataset	Time point (TP)	FCR	ADG	DFI	RFI	CH_4 (g/kg DMI)	CH_4 (g/day)
Microbial genera	First TP	44.8	54.3	71.5	66.6	54.1	77.0
	Start test	70.2	67.8	78.3	44.7	57.4	51.4
	Mid test	56.2	62.6	61.4	80.2	58.5	74.2
	End test	52.4	61.2	53.8	56.8	60.4	63.9
	Chamber	60.4	47.1	45.3	54.6	66.6	53.9
	Slaughter	48.7	44.5	55.1	53.7	64.4	65.5
Microbial genes	First TP	82.9	82.6	88.1	83.3	88.0	80.6
	Start test	65.2	63.8	77.5	64.4	85.6	83.4
	Mid test	71.0	73.3	78.3	72.2	87.2	88.5
	End test	78.5	78.8	79.2	73.2	84.3	83.0
	Chamber	76.2	77.7	82.1	77.0	87.0	79.4
	Slaughter	70.9	66.9	76.8	75.0	82.0	80.1

archaea to produce the greenhouse gas methane (CH_4). Rumen microbiome (microbiota and their genes) compositions were previously shown to be phenotypically and genetically associated with cattle traits (Lima et al. 2019; Martínez-Álvaro et al., 2021). The identification of microbial biomarkers to predict host traits is often based on microbiome profiles generated from rumen samples at slaughter but whether these are representative of previous growth stages is unclear. The main objective of our research was to analyse the temporal stability of the rumen microbiome throughout the finishing phase, and of its associations with host traits feed conversion ratio (FCR), weight gain (ADG), daily feed intake (DFI), residual feed intake (RFI), and CH_4 emissions. Additionally, we explored the stability of associations between host-genomically influenced microbial genes (HGIMG), and estimated breeding values (EBVs) of host traits.

Materials and methods: Twenty beef cattle had their rumen microbiome sampled at 6 time points (one month apart): at 418 ± 32 of age (FTP), start (ST), mid (MT), and end (ET) of a 56-day performance test, after respiration chamber CH_4 production measurements (CH), and slaughter (SL). Microbial DNA was extracted and whole metagenome sequenced to obtain abundances of microbial genera and genes. Accounting for the compositionality of microbiome datasets, microbial genera and genes abundances were additive logratio (ALR) transformed using references Oribacterium and K00858, respectively. ALRs were used to calculate correlations (r) between time points, and partial least squares (PLS) models to predict each trait at each time point. HGIMG were identified in Martínez-Álvaro et al. (2021) based on 245 beef steers.

Results: Microbiome compositions were highly stable throughout finishing, showing strong correlations between time points for microbial genera (from $r_{FTP\text{-}ET}$ = 71% to $r_{MT\text{-}ET}$ = 87%) and genes (from $r_{FTP\text{-}ET}$ = 81% to $r_{MT\text{-}ET}$ = 89%). Microbiome profiles were strongly associated with host traits throughout the finishing phase (Table 1), with genera explaining between 44.5% (ADG_{SL}) and 80.2% (RFI_{MT}), and genes explaining between 63.8% (ADG_{ST}) and 88.5% (CH_4 $(g/day)_{MT}$) of the host traits' variability. HGIMG were strongly associated with EBVs, explaining between 57.5% (RFI_{ST}) and 83.3% (ADG_{CH}) of their variability.

Conclusion: Microbiome profiles are highly stable throughout finishing, suggesting that slaughter samples are representative of the entire finishing phase. Metagenomic profiles from samples taken throughout the finishing phase can be used to predict the genetic merit of host traits.

Acknowledgements: The project was funded by Scottish Government, BBSRC, and Genus PLC.

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98. Has the COVID-19 pandemic affected citizen opinions regarding beef production and consumption?

D. Enriquez-Hidalgo [a,b,*], V. Mansky [c], D. Teixeira [d,e], R. Larraín [f], M.J. Hötzel [g]

[a] Bristol Veterinary School, University of Bristol, Langford, Somerset, UK
[b] Sustainable Agriculture Sciences, Rothamsted Research, Okehampton, Devon, UK
[c] Facultad de Agronomía e Ingeniería Forestal, Pontificia Universidad Católica, Santiago, Chile, Santiago, Región Metropolitana, Chile
[d] Instituto de Ciencias Agroalimentarias, Animales y Ambientales (ICA3), Universidad de O'Higgins, San Fernando, VI Region, Chile
[e] Animal Welfare Program, Monells, Cataluna, Spain
[f] Facultad de Agronomía e Ingeniería Forestal, Pontificia Universidad Católica de Chile, Santiago, Region Metropolitana, Chile
[g] Laboratorio de Etologia Aplicada, Universidade Federal de Santa Catarina, Florianópolis, Santa Catarina, Brazil

* Corresponding author. D. Enriquez-Hidalgo.

Application: Beef production stakeholders should consider that citizens expressed high negative perceptions regarding beef production and consumption but had lower expectations of beef consumption reduction after the pandemic. To improve citizen's negative attitudes towards beef production, stakeholders need to do more to educate citizens of the positive aspects of beef production systems: welfare, environmental and health.

Introduction: Beef production is one of the agriculture sectors with major environmental impacts (Godfray and Garnett, 2014). The COVID-19 pandemic caused lockdowns, food access restrictions and highlighted different sources of information (e.g. the zoonotic origin of coronaviruses) which may have affected citizen s' opinions regarding beef production and consumption (Attwood and Haja, 2020). The aim of the study was to explore citizens' opinions regarding beef production and consumption as affected by the COVID-19 outbreak. *Material and methods:* Chilean participants were surveyed at the beginning of the pandemic (April 2020) and in October 2021 (n = 300/yr). They were asked: (Q1) If they consume meat, (Q2) if they have reduced beef consumption in the last year; (Q3) what do they plan to do with their beef consumption in 3 to 5 years; (Q4) what do they think the Chilean population WILL and (Q5a) SHOULD do about beef consumption and (Q5b) why. Then they were asked their level of agreement (0 totally disagree to 4 totally agree): (Q6) Greenhouse gases are emitted in beef production; (Q7) Need to reduce beef consumption; (Q8) Beef production is negative for the environment and (Q9) Beef is bad for human health. Data were analysed using Chi square.

Results: Twenty percent of participants did not consume meat and more participants reduced beef consumption in 2020 than in 2021 (53 vs. 29%, $P < 0.001$). In 2020, fewer participants planned to reduce their beef consumption (Q3; $P < 0.001$, Figure 1a) and thought that Chileans will reduce it (Q4; $P < 0.05$) in 2020 than in 2021. More participants though that Chileans should reduce beef consumption than in 2021 (Q5a; $P < 0.01$) and their answers were mainly related to environmental (2020: 31%; 2021: 38%), health (2020: 27%; 2021: 25%) and animal welfare (2020: 16%; 2021: 9%) concerns. >45% agreed with Q6 and Q7, but >45% did not agreed with Q9. Agreement level reduced from 2020 to 2021 for Q8 and Q9 ($P < 0.05$), but not for Q6 or Q7 ($P > 0.05$).

Conclusion: Citizens expectations towards beef reduction are high but reduced with the pandemic. Participants had a negative perception of beef production but disagreed that beef is bad for human health and these opinions were accentuated by the pandemic (Figure 2).

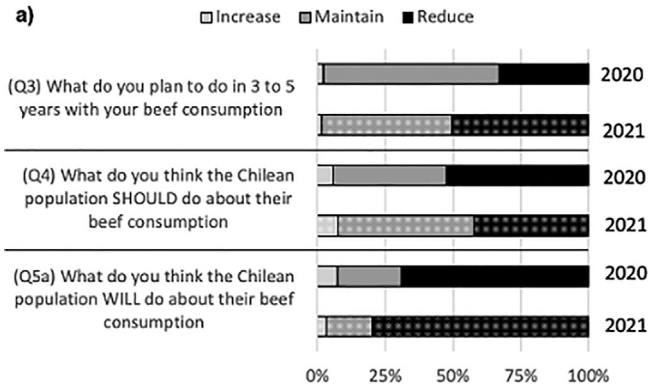

Figure 2.

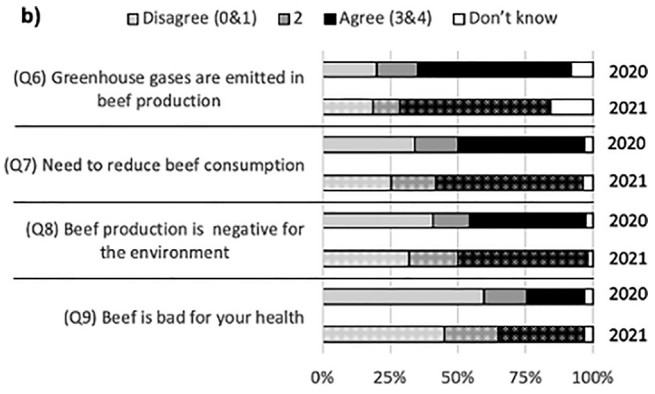

Figure 1. Citizens' (a) beef consumption opinions and (b) agreement of different beef production aspects..

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99. Nanopore sequencing of the respiratory virome in beef-suckler weanlings diagnosed with bovine respiratory disease

K. Ní Dhufaigh [a,*], M. McCabe [a], P. Cormican [a], I. Cuevas-Gomez [a], M. McGee [a], T. McDaneld [b], B. Earley [a]

[a] Teagasc, Dunsany, Meath, Ireland
[b] United States Department of Agriculture (USDA), Agricultural Research Service (ARS), US Meat Animal Research Center (USMARC), 844 Rd 313, Clay Center, NE, USA

* Corresponding author. K. Ní Dhufaigh.

Application: Extensive investigation of the viral community associated with bovine respiratory disease may lead to the development of new therapeutic targets.
Introduction: Bovine respiratory disease (BRD) is a leading cause of morbidity and mortality of cattle placed in feedlots. The study objective was to use metagenomic nanopore sequencing and targeted real time (RT) qPCR to compare the respiratory virome in BRD and healthy beef-suckler weanlings on the day of clinical diagnosis of BRD (day-BRD).
Materials and methods: One hundred and fifty-three beef-sucker weanlings (209 days old [SD: 35.8] and 306 kg [SD: 26.3]) were purchased through auction marts, and housed indoors for the duration of the study (Cuevas-Gómez et al., 2020). Weanlings were vaccinated after 24 h of housing against Clostridia and common BRD viral and bacterial agents (BoHV1, M. haemolytica, BRSV, BPI3). Sterile –flocked swabs were inserted 12 cm into the nasopharynx of each calf and gently rotated on day-BRD. Thirty animals with BRD and 30 matched healthy control animals were selected for metagenomics. Viral nucleic acids were enriched by bead-beating and nuclease treatment. DNA and RNA was extracted and purified using the MinElute Virus kit and ds cDNA was generated and purified. The Rapid PCR Barcoding kit created pooled sequencing libraries and sequenced on R9.4.1 flowcells on a MinION Mk1C. Controls were included on each flowcell. Data analysis were performed via EPI2ME and GUPPY. A One Step TaqMan™ Fast Virus mix was used to quantify BCoV and BRAV on day- BRD in unenriched samples. Data were tested for normality using PROC UNIVARIATE of SAS (9.4), and analysed using the PROC MIXED procedure.

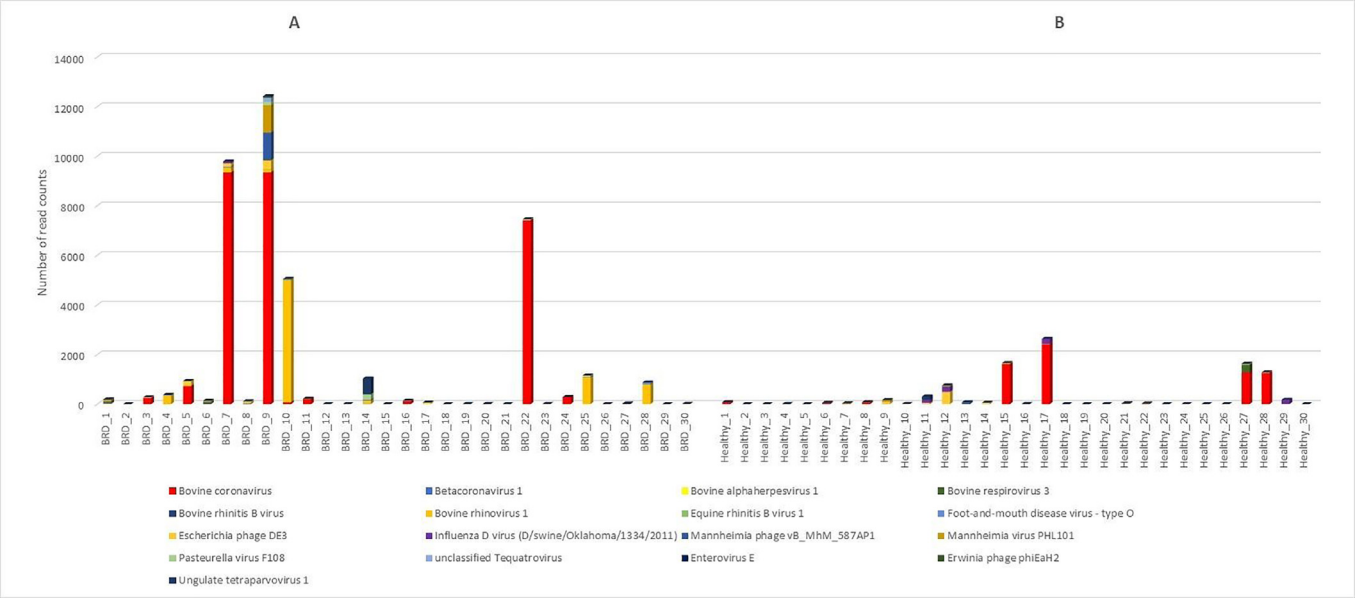

Figure 1. The total viral read counts and viruses identified by metagenomics for A) BRD cohort and B) the healthy cohort.

Results: BRD naturally developed within the BRD cohort (Cuevas-Gómez et al., 2020). A total of 75 viruses were identified, with a read count of ≥20, in the healthy cohort and 115 viruses in the BRD cohort (Figure 1). The common BRD agents (BRSV, BPI3, and BoHV1) were detected at low levels by sequencing. Using qPCR to target two viruses (Ct cut off point of ≤ 37), all samples were positive for BCoV (healthy, mean Ct 22.24; SD 6.97 v BRD, mean Ct 20.07; SD 7.07). Twenty two samples were positive (+) for BRAV in the healthy cohort (Ct 14.58; SD: 3.29) and 23 samples were BRAV+ in the BRD cohort (Ct 10.5; SD: 3.24). There was no difference ($P > 0.05$) in mean (SD) Ct values between healthy and BRD for BCoV.
Conclusion: A diverse and complex virome was found in weanlings by metagenomics. Two viruses were selected for RT qPCR based on high read abundance (BCoV and BRAV). No statistical difference was found between healthy and BRD suggesting that healthy animals could possibly be asymptomatic carriers of BCoV and BRAV.

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100. Microbiome-driven breeding strategies are capable of improving average daily gain at different stages of growth in beef cattle

M. Martínez-Álvaro [a,*], J. Mattock [b], O. González-Recio [c], A. Saborío-Montero [c], J. Lima [a], Z. Weng [d], C.A. Duthie [a], R. Dewhrust [a], M. Cleveland [d], M. Watson [b], R. Roehe [a]

[a] Scotland Rural College, Edinburgh, UK
[b] The Roslin Institute, The University of Edinburgh, Edinburgh, UK
[c] Instituto Nacional de Investigaciones Agrarias, Madrid, Spain
[d] Genus PLC, Madison, USA

* Corresponding author. M. Martínez-Álvaro.

Application: Our work sheds light on the role of microbial metabolism on the growth trajectory of steers at phenotypic and genomic levels and provides insight into the potential benefits of using microbiome information in future genomic beef breeding programs. ***Introduction:*** The growth rate of beef steers is of substantial economic importance to improve feed efficiency and exhibits variations during the finishing period. Investigating the phenotypic and genomic factors underlying temporal variation in growth rate can help to maximize this performance and feed efficiency at each stage. The ruminal microbiome, partially determined by host genetics, is critical to steer growth, but its role in this temporal variation is unclear. Our objective was to investigate whether ruminal core microbial gene abundances (MGs) can be used as phenotypic and genomic biomarkers of steer growth rates at different stages of finishing and thus integrated into a microbiome-driven breeding strategy to increase growth rate over time.
Materials and methods: We used phenotypic, genomic, and ruminal metagenomic data from 363 steers from different breeds offered ad libitum forage or concentrate-based diets. Body weights were recorded weekly for 4 months when animals were aged between 394 ± 32 and 505 ± 33 days old, and consecutive monthly growth rates were calculated (ADG_1, ADG_2, ADG_3, ADG_4). Genomic and metagenomics data are described in Martinez-Álvaro et al. 2021a. Firstly, MGs acting as phenotypic biomarkers for each growth rate were identified using PLS analysis as described in Martinez-Álvaro et al.,

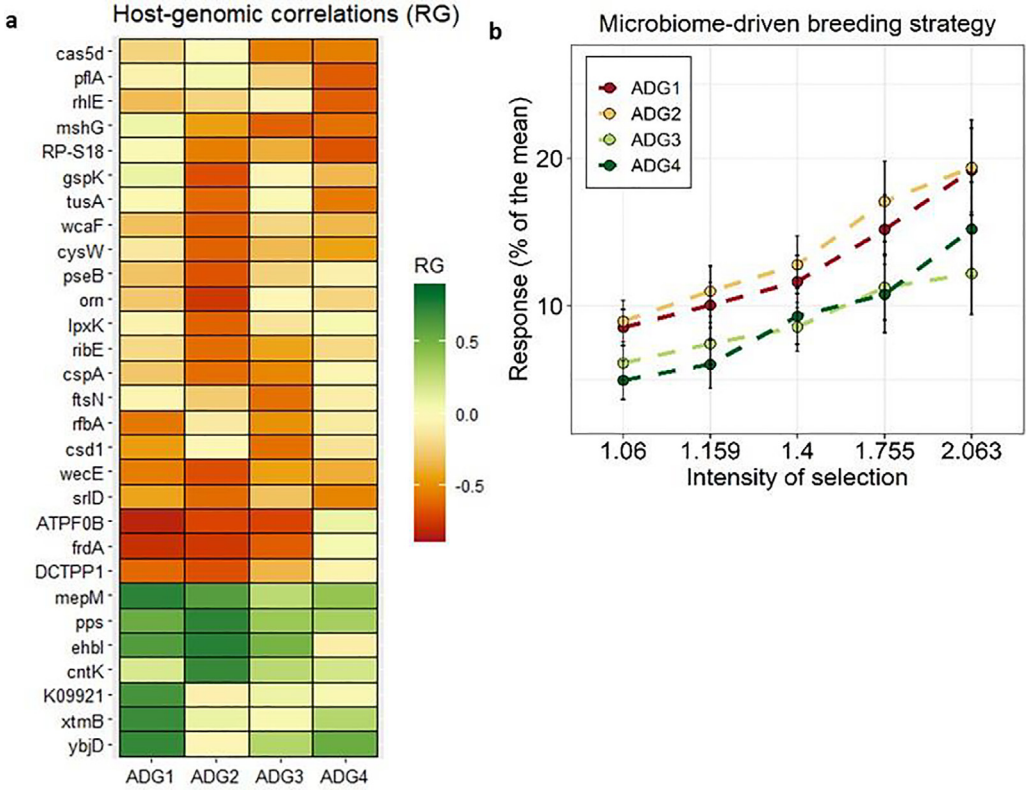

Figure 1. a. Rg between growth traits and 29 MGs selected for microbiome-driven breeding aiming to increase growth rate at all phases b. Expected responses to selection.

2021b. Secondly, we checked which of these phenotypic biomarkers were under the influence of the host genome and calculated their host genomic correlations (rg) with growth rates using bivariate GBLUP models solved with Bayesian methods. Thirdly, we developed a microbiome-driven breeding strategy based on those MGs that have the same sign in their host-genomic correlations with all growth rates, aiming to identify a consistent MG-set to increase growth rate at different stages.

Results: Using PLS models, we identified 295, 262, 296, and 309 MGs that showed phenotypic predictive ability for ADG_1, ADG_2, ADG_3, ADG_4 ranging from 66.8% to 78.1%; of these, 184 were under host genomic influence (h^2 from 0.16 ± 0.12 to 0.45 ± 0.18). One-hundred-twenty-eight had a non-zero rg (probability≥90%) with at least one of the growth traits (rg from |0.42| to |0.89|). We selected 29 with the same sign in their rg with all growth traits (Figure 1a) to develop a microbiome-driven breeding strategy based on their abundance. Growth rate-EBVs were predicted with 0.60 ± 0.03 to 0.71 ± 0.02 accuracy, and expected responses to selection at a selection intensity of 2.063 ranged between 12-19% of the mean with higher improvement in the earlier two months of the finishing period (Figure 1b).

Conclusions: Microbiome information is highly informative for phenotypic but also genomic predictions of longitudinal growth rates in a microbiome-driven breeding strategy.

Acknowledgments: Scottish Government, BBSRC, Genus PLC.

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101. Effect of bull beef diet on hair cortisol concentration, and associations with behavioural temperament in cattle

P.M. Donnelly [a,*], N.H. Rutherford [b], M. Ornaghi [c], F. Rubino [a], F. Godoy Santos [a], F.O. Lively [b], G. Arnott [a], S.A. Huws [a]

[a] Institute for Global Food Security, School of Biological Sciences, Queen's University Belfast, Belfast, Northern Ireland BT9 5DL, UK
[b] Livestock Production Sciences Branch, Agri-Food and Biosciences Institute, Hillsborough, Northern Ireland BT26 6DR, UK
[c] Research and Development Department, Innovation and Science Centre, Safeeds Animal Nutrition, Cascavel, Paraná, Brazil

* Corresponding author. P.M. Donnelly.

Application: Diet and rearing environment of cattle are known to have a substantial influence on animal productivity, however, their impact on welfare is less well defined. Hair cortisol provides a quantitative approach to measure long-term animal welfare throughout production.

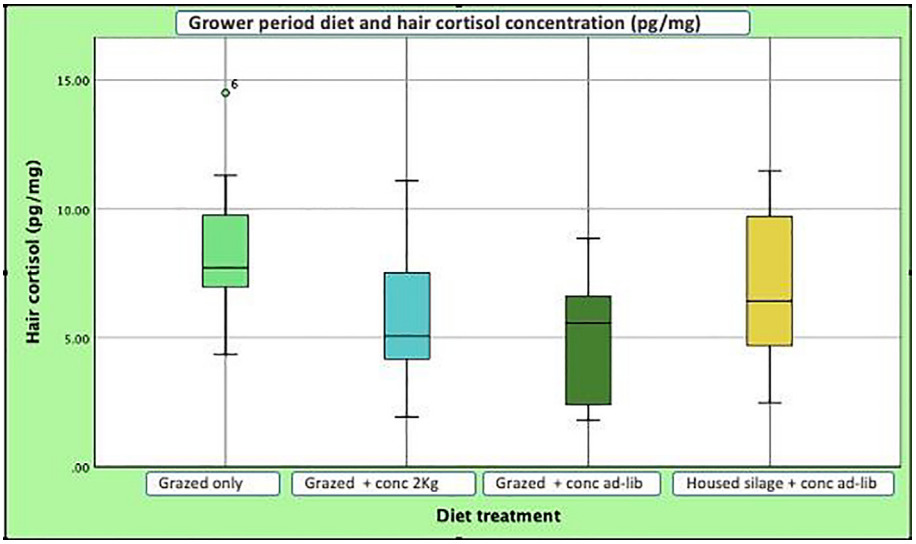

Figure 1. Bull hair cortisol concentrations during the grower period for each dietary group.

Introduction: The increasing study of the environmental sustainability of livestock production has created opportunities to further animal behaviour and welfare research, including investigating the gut-brain axis within cattle. Hair cortisol concentration is an intensifying field of welfare research as a biomarker of chronic-stress over long time periods. This provides advantages over established acute-stress biomarkers such as plasma cortisol which fluctuate rapidly in response to hypothalamic-pituitary-adrenal axis activity. The aim of this study was to assess the impact of a summer rotational grazing system and winter housing on hair cortisol concentration and temperament of Holstein bulls.
Materials and methods: 54 bulls were allocated to one of four growing diets during the summer period, prior to a common winter finisher diet. The growing diets were; (T1) housed silage, with concentrates ad-lib; (T2) grazed, with concentrates ad-lib; (T3) grazed, with concentrates 2 kg per head per day; and (T4) grazed only. All bulls were subsequently transitioned onto a single finisher diet of silage and concentrates ad-lib, for winter housing. Behavioural temperament tests were conducted on the bulls at the end of both grower and finisher periods, with shaved hair samples collected from the bulls head at these time points. Behaviour tests of exit-speed, feed-rank, human-approach, and crush-score provided ethology data for temperament determination. Hair cortisol concentration was determined by steroid hormone extraction and ELISA assay. Behavioural test data were analysed by non-parametric Spearman's and Kendall's correlation to determine temperament. A Principal Components analysis of the temperament and hair cortisol concentration data was utilised to create an output score. This enabled the bulls to be ranked based on behavioural extremes of temperament (flightiness-docility). Hair cortisol concentration data could also be utilised as a retrospective indicator of physiological stress experienced by bulls during each treatment.
Results: Summer growing period hair cortisol concentration was significantly higher within the grazed only group (Kruskal-Wallis-H 9.949; df3, $P = 0.019$) in comparison to the three other dietary groups. This likely indicates grazed only experienced chronic nutritional stress, as consequence of depleted grass growth during a drought; nutritional stress was offset in groups with access to concentrates. Statistically, significant correlations in exit-speed (*P 0.011) and crush-score (**$P = 0.003$) were evident between growing and finishing periods, indicative of temperament. Spearman's' correlations were also significant ($r_s = -0.250$, $P = 0.037$) between hair cortisol concentration and bull exit-speed; bulls with high hair cortisol concentrations had faster crush exit-speeds.
Conclusion: These findings indicate the effectiveness of hair cortisol concentration for the measurement of chronic-stress in cattle over long time periods and provide an innovative approach to understand bovine welfare. This study provides molecular and ethological insights into the associations between host behaviour, rearing environment and diet on beef bulls.

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102. Sensory characteristics of muscle from Angus-sired suckler bulls finished at pasture, with or without concentrate supplementation, at 15 or 19 months of age

A. Moloney [a,*], S. Wilson [b], C. Lenehan [a], L. Moran [c], E. O'Riordan [a], M. O'Sullivan [b], J. Kerry [b], F. Monahan [d], M. McGee [a]

[a] Teagasc, Grange, Dunsany, Meath, Ireland
[b] University College Cork, Cork, Cork, Ireland
[c] Teagasc, Ashtown, Dublin, Ireland
[d] University College Dublin, Belfield, Dublin, Ireland

* Corresponding author. A. Moloney.

Application: If the sale of beef cattle was not limited by a carcass fatness specification, lower-cost pasture-based suckler bull finishing systems could be a viable option on many beef farms.
Introduction: Suckler bull beef production usually involves a post-weaning indoor feeding period based on conserved forage supplemented with concentrates or concentrates offered ad libitum. In temperate climates, finishing cattle from pasture decreases the cost of production. Carcass fat

Table 1
Carcass classification and sensory characteristics of longissimus muscle from Angus-sired suckler bulls finished at pasture with or without concentrate supplementation [1]Scale (1-15) [2]Scale: tenderness (1 = extremely tough, 8 = extremely tender), flavour (1 = very poor, 8 = very good), firmness (1 = very mushy, 8 = very firm), texture (1 = very poor, 8 = very good), overall acceptability (1 = not acceptable, 8 = extremely acceptable), SED = Standard error of the difference between means.

Age at slaughter	15 months		19 months			Significance		
Concentrates (C)	0	3.2 kg dry matter	0	3.2 kg dry matter	SED	Age	C	Age*C
Carcass weight (kg)	257	273	342	368	6.8	***	***	NS
Carcass fat score[1]	5.8	5.8	6.3	7.4	0.45	**	NS	NS
Tenderness[2]	4.45	4.39	4.43	4.05	0.382	NS	NS	NS
Flavour	4.29	4.62	4.30	4.22	0.403	NS	NS	NS
Firmness	4.35	4.47	5.02	5.32	0.380	**	NS	NS
Texture	4.29	4.08	4.21	3.99	0.304	NS	NS	NS
Acceptability	4.39	4.26	4.28	4.15	0.363	NS	NS	NS

classification is an important determinant of carcass acceptability by meat processors in the Republic of Ireland, based in part, on a perceived association with meat eating quality. Lenehan et al. (2017) reported that carcasses of spring-born Angus-sired suckler bulls were adequately finished (fat score ≥6.0, scale 1-15) from pasture, with or without concentrates at 19, but not at 15 months of age. Slaughter at a younger age reduces the environmental footprint of beef production (Herron et al., 2021). The objective of this study was to determine if these differences in age and fat classification were reflected in the sensory characteristics of the meat.

Materials and methods: Sixty Spring-born Aberdeen Angus-sired 'weanling' bulls were assigned to a two (slaughter age, 15 or 19 months) by two supplements (0 or 3.2 kg dry matter of a barley-based concentrate daily) factorial arrangement and turned out to pasture on 7 April. Concentrates were introduced immediately post-turnout for 15-month bulls and 97 days later for 19-month, bulls. The 15- and 19-month bulls were slaughtered 63 and 193 days post-turnout, respectively, and the longissimus thoracis muscle collected (Lenehan et al., 2017). Sensory testing of 14 day aged meat was conducted using untrained assessors who rated, on an 8-point hedonic scale, tenderness, overall flavour, overall firmness, overall texture and overall acceptability (Moran et al., 2021) (Table 1). Data were analysed using the REML procedure of Genstat (16th edition). Breed maturity, concentrate supplementation, their interactions and block (weight) were considered fixed effects, and the interaction of assessor, breed maturity and concentrate supplementation a random effect.

Results: Despite the 15-month bulls not achieving the fat classification currently required (6.0, scale 1-15 on the EUROP carcass classification grid), there was no difference in overall acceptability of the meat (Table 1).

Conclusion: Carcass fat score is a poor indicator of meat eating quality of meat from suckler bulls. The current market specification of a minimum carcass fat score, if based on meat eating quality, is not justified.

Acknowledgements: Funding from the Irish Department of Agriculture, Food and the Marine Competitive research programmes (11/SF/322, BullBeef).

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103. Effect of dietary metabolisable protein concentration upon the frame growth of housed Aberdeen-Angus cross Holstein steers and heifers during the growing phase

J. McCaughern [a,*], R. Evans [a], E. Upton [a], sN. Naylor [a], R. Wilkinson [a], R. Small [b]

[a] Harper Adams University, Newport, Shropshire, UK
[b] AHDB, Kenilworth, Warwickshire, UK

* Corresponding author. J. McCaughern.

Application: Increasing dietary metabolisable protein concentration above recommendations during the growing phase has no effect upon frame growth.

Introduction: The metabolisable protein (MP) system (AFRC, 1993) is currently the official system for calculating the energy and protein requirements of beef cattle within the United Kingdom. This system is however over 25 years old, and it is generally accepted that AFRC (1993) under predicts protein requirements (Cottrill et al., 2009), whilst large sectors of the beef sector continue to express protein requirement in terms of crude protein. This study aimed to examine the effect of increasing dietary MP concentration upon the performance of growing Aberdeen-Angus cross Holstein steers and heifers.

Materials and methods: Sixty Aberdeen-Angus cross Holstein steers (30) and heifers (30) with live weights of 390 and 363 kg, were allocated to 1 of 2 dietary treatments consisting of low (71 g/ kg of DM; LMP) and high (84 g/ kg of DM; HMP) overall MP concentrations respectively. Both diets were based upon grass silage, and supplemented with concentrates to provide the same metabolisable energy and crude protein concentrations of 10.3 MJ/ kg of DM and 140 g/ kg DM. The increase in MP concentration of the HMP diet was achieved by the substitution of rapeseed meal for a protected rapeseed source. All animals were housed in straw bedded pens in groups of five, with three pens per treatment group. Both diets were fed as total mixed rations, and restricted to achieve an approximate daily live weight (LW) gain of 1.2 kg/day throughout the housed period. The dry matter intake of each pen was monitored by recording the quantities of feed offered, and weighing back refusals on a weekly basis. Performance parameters for each

Table 1
Effect of dietary metabolisable protein concentration on animal performance.

	Steers		Heifers			P-value		
Item	LMP	HMP	LMP	HMP	SED	Sex	MP	Int
Initial LW (kg)	392	387	365	361	4.3	<0.001	0.271	0.762
Housed period (days)	137	137	137	137	–	–	–	–
Final LW (kg)	563	564	531	540	5.4	<0.001	0.280	0.306
Daily LW gain (kg/d)	1.25	1.29	1.21	1.30	0.032	0.469	0.040	0.335
Dry matter intake (kg/d)	11.05	11.19	10.85	10.95	0.497	0.544	0.749	0.960
Final wither height (cm)	137	136	130	130	0.7	<0.001	0.765	0.120
Final heart girth (cm)	193	193	190	189	1.1	0.008	0.590	0.931

animal were recorded at the beginning of the housed period, and then at monthly intervals until turnout. All performance parameters were analysed by ANOVA as a 2 x 2 factorial randomised block design using Genstat version 18.
Results: There was an effect ($P < 0.001$) of animal sex on LW, with steers being 27 and 28 kg heavier than heifers at the beginning and end of the study respectively. Animals offered the high dietary MP concentration also had a 0.07 kg/d greater ($P < 0.05$) LW gain throughout the study period. Steers had a greater ($P < 0.01$) wither height and heart girth at the end of the study, although measures of frame growth remained unaffected ($P > 0.05$) by dietary MP concentration.
Conclusion: Increasing dietary MP concentrations during the growing phase has the potential to marginally increase growth performance, but does not alter frame growth in Aberdeen-Angus cross Holstein cattle.

Acknowledgments: The authors gratefully acknowledge the funding provided by AHDB Beef and Lamb.

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104. Effect of dietary metabolisable protein concentration during the housed growing phase upon the finishing performance of Aberdeen-Angus cross Holstein steers and heifers at grass

J. McCaughern [a,*], R. Evans [a], E. Upton [a], R. Wilkinson [a], R. Small [b]

[a] Harper Adams University, Newport, Shropshire, UK
[b] AHDB, Kenilworth, Warwickshire, UK

* Corresponding author. J. McCaughern.

Application: Increasing dietary metabolisable protein concentrations above recommendations during the housed growing phase has no effect upon the finishing performance of Aberdeen Angus cross Holstein steers and heifers.
Introduction: It has been well established, that complex nutritional interrelationships exist between growing and finishing phase performance in crossbred beef cattle (Sampio et al., 2017). One such relationship, may centre around metabolisable protein (MP), where dietary concentrations have been observed to directly alter the performance of finishing cattle (Sitorski et al., 2019). This study aimed to examine the effect of increasing dietary MP concentration during the housed growing phase upon the finishing performance of Aberdeen-Angus cross Holstein steers and heifers at grass.
Materials and methods: Sixty Aberdeen-Angus cross Holstein steers (30) and heifers (30) were housed with initial live weights of 390 and 363 kg in the autumn of 2020. These animals were then allocated to 1 of 2 dietary treatments for a period 137 days. The treatments diets were based upon grass silage fed with additional concentrates, and consisted of a low (71 g/ kg of DM; LMP) and high (84 g/ kg of DM; HMP) dietary MP concentration respectively. Both diets were formulated to be isoenergetic. All of the cattle were subsequently turned out to finish at grass on the 6th of April 2021, with live weights of 564 and 536 kg at turnout for the steers and heifers respectively. The cattle were grazed as one group in a rotational paddock grazing system consisting of 10 paddocks (1 ha/paddock; 10 ha total grazing area). Target pre- and post-grazing covers were 2500-3000 and 1500 kg DM/ha respectively. Steers were selected for slaughter at fat class 3 = , whilst heifers were selected at fat class 4-. Performance parameters for each animal were recorded at turnout, and again immediately prior to slaughter. All parameters were analysed by ANOVA as a 2 x 2 factorial design in Genstat V18.

Table 1
Effect of housed dietary metabolisable protein concentration upon finishing performance at grass.

	Steers		Heifers			P-value		
Item	LMP	HMP	LMP	HMP	SED	Sex	MP	Int
Turnout LW (kg)	563	564	531	540	5.4	<0.001	0.280	0.306
Final LW (kg)	631	631	560	569	9.5	<0.001	0.557	0.530
Daily LW gain (kg/d)	0.45	0.48	0.26	0.22	0.031	<0.001	0.742	0.216
Killing out % age	50.0	49.5	49.7	50.5	0.01	0.502	0.779	0.199
Carcase value (£)	1109	1090	992	1003	33.0	0.005	0.863	0.540
Final wither height (cm)	141	141	132	133	1.3	<0.001	0.539	0.700
Final heart girth (cm)	207	207	199	200	1.6	<0.001	0.788	0.690

Results: There was an effect ($P < 0.001$) of animal sex upon performance, whereby steers were heavier than heifers throughout the duration of the grazing period, with growth rates which were 0.22 kg/d higher. Steers also had increased ($P < 0.01$) measures of frame growth and carcase value compared to heifers at the end of the study. In contrast, there was no residual effect ($P < 0.05$) of dietary MP concentration upon any performance parameter.
Conclusion: Increasing dietary MP concentrations during the housed growing phase above recommendations does not influence the finishing performance of Aberdeen-Angus cross Holstein steers and heifers at grass.

Acknowledgments: The authors gratefully acknowledge the study funding provided by AHDB Beef and Lamb.

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105. The impact of environment on the accuracy of beef cattle measurements using video image analysis

H. Nisbet [a,b,*], N. Lambe [a], G. Miller [a], A. Wilson [b], D. Barclay [c], C.A. Duthie [a]

[a] Scotland's Rural College, Edinburgh, Midlothian, UK
[b] The University of Edinburgh, Edinburgh, Midlothian, UK
[c] Innovent Technology Ltd., Turriff, Aberdeenshire, UK

* Corresponding author. H. Nisbet.

Application: The accuracy of live animal parameters, extracted in real-time from 3-Dimensional (3D) images, can be impacted by external factors such as the environment in which the images are captured.
Introduction: Video image analysis technology can be used to map the morphometrics of cattle to create parameters which can be used with other animal information to predict post-slaughter carcass characteristics. Three-dimensional images measured on-farm were previously found to predict EUROP fat and conformation grades with 54% and 55% accuracy respectively (Miller et al., 2019), indicating the potential for implementation of objective methods for assessing carcass value on farm. The aim of the current work was to assess the impact of the environment on the accuracy of 3D measurements obtained from the live animal.
Materials and methods: Data were collected from four commercial farms, one research farm and one commercial abattoir, with eight Basler Time-of-Flight near-infrared cameras (Basler Inc., Exton, PA) being used to create 3D scans of live beef cattle. The cameras were either (i) suspended 3m above an automated weigh platform (Beef Monitor, Richie Agricultural, and Scotland) or (ii) suspended 3m above a raceway in the lairage of a commercial abattoir. As cattle passed under the cameras, a 3D scan was captured and 60 potential predictor variables (widths, lengths, heights, ratios, areas and volumes) were extracted in real time by Innovent Technology Ltd. using Halcon software (MVTech Software GmbH, Munchen, Germany). Univariate statistics was carried out for all variables, however the current work focuses on length measurements. The data from the farm cameras were compared with that of the abattoir cameras, assessing the impact the environment can have on the accuracy of measurements.
Results: A scatter plot (Figure 1) showed that all camera units produced similar total length measurements (LengthToT) of the cattle, suggesting that they were recording this variable consistently. Plots of length measurements of the cattle from the tail head to the widest point of the rear, as a proportion of LengthToT (LengthTR_Prop) (Figure 2a) and length measurements from the widest point of the rear to the widest point of the middle as a proportion of LengthToT (LengthRM_Prop) (Figure 2b) show the measurements of the farms units to be visually different to measurements from the abattoir units. Additional analysis showed this to be a significant difference ($P < 0.05$), with parameters extracted from the abattoir camera unit having a larger LengthTR, while a smaller LengthRM. Further investigation indicated that the setup in the abattoir was leading to incorrect recordings when identifying the width measurements which determine the different lengths. This was often due to cattle touching the walls of the race, leading to inconsistencies in measurements.
Conclusion: For accurate measures to be extracted from 3D scans of live cattle, the animals must be positioned in a suitable environment, where external factors, such as the walls of a race cannot interfere with automated measurements.

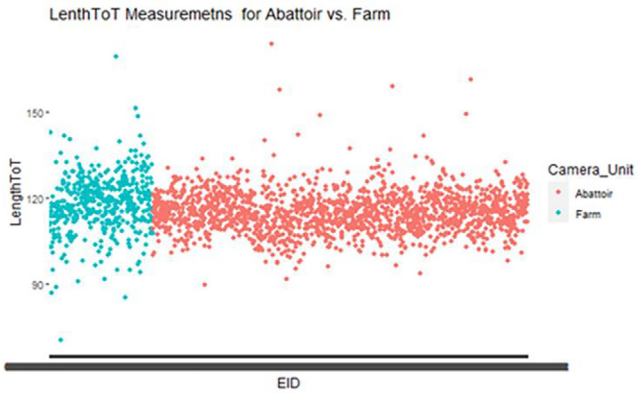

Figure 1.

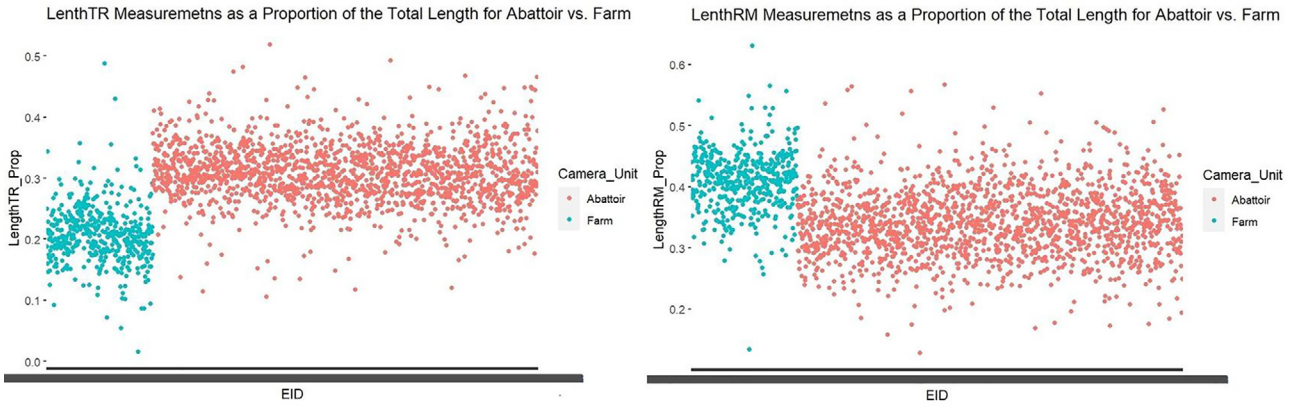

Figure 2.

Acknowledgements: Funded by SRUC and AHDB.

Reference

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106. A novel compound-specific stable isotope approach to gain fundamental insights into the routing of hydrogen in sheep

S. Smith [a,*], M.R.F. Lee [b], R.G. Wilkinson [b], s.N. Naylor [b], M. Roffet-Salque [a]

[a] Organic Geochemistry Unit, School of Chemistry, University of Bristol, Cantock's Close, Bristol BS8 1TS, UK
[b] Agriculture and Environment Department, Harper Adams University, Edgmond, Newport, Shropshire TF10 8NB, UK

* Corresponding author. S. Smith.

Application: An improved understanding of hydrogen routing in ruminants is crucial for improving ruminant production, animal health and reducing environmental impact.
Introduction: Carbon metabolism is well studied in ruminants, but the routing of hydrogen from water and feed to ruminant tissues and enteric methane remains largely unexplored. Hydrogen is involved in key metabolic processes of interest in agriculture and veterinary science, such as fermentation, biohydrogenation and methanogenesis in the rumen and fatty acid biosynthesis in adipose tissues. Hydrogen has two stable isotopes (protium ^{1}H and deuterium ^{2}H), which differ in neutron number. The stable hydrogen isotopic compositions (recorded as $\delta^{2}H$ values) of hydrogen sources (feed and drinking water) are distinct (Cormier et al., 2018), thus there is potential to investigate their relative contributions in these metabolic pathways in various animal tissues. Currently, only bulk hydrogen isotopic analysis of animal lipids and proteins has been carried out (Heaton et al., 2008; Kirsanow and Tuross, 2011). Analysis of specific lipids within ruminant tissues allows inter- and intra-tissue isotopic relationships to be explored.
Materials and Methods: Sheep (n = 5) raised in a commercial flock were slaughtered in October 2020 aged 1-2 years. Subcutaneous adipose tissue and blood serum were collected for lipid extraction and preparation prior to gas chromatography (GC) analysis. $\delta^{2}H$ values of palmitic ($C_{16:0}$) and stearic ($C_{18:0}$) acids in adipose and blood serum were determined by gas chromatography-thermal conversion-isotope ratio mass spectrometry (GC-TC-IRMS). Mann-Whitney tests with a significance level of 0.05 were performed using SPSS software.
Results: The $C_{18:0}$ fatty acid was significantly more depleted in deuterium than $C_{16:0}$ fatty acid in both adipose (10‰, P = 0.047) and blood serum (51‰, P = 0.009). Adipose $C_{16:0}$ fatty acid was significantly more depleted than the blood serum $C_{16:0}$ fatty acid (23‰, P = 0.016), while the $C_{18:0}$ fatty acid was significantly more enriched in deuterium in adipose compared to blood serum (17‰, P = 0.009; Fig. 1). These results demonstrate for the first time that there is compound-specific inter- and intra-tissue variation in hydrogen isotopic composition in sheep, likely reflecting differing hydrogen sources and metabolism. ***Conclusion:*** Fully investigating the hydrogen isotopic relationships between ruminant tissues, feed and water at the compound-specific level has implications in agricultural, veterinary and climate sciences. To achieve this, we are carrying out a feeding experiment (using drinking waters with distinct hydrogen isotopic compositions) to unravel hydrogen routing in sheep tissues; to determine the relative contributions of hydrogen sources to different fatty acids; and to probe the hydrogen source in enteric methane.

Acknowledgement: The authors acknowledge funding from the Royal Society (RGF\EA\181067).

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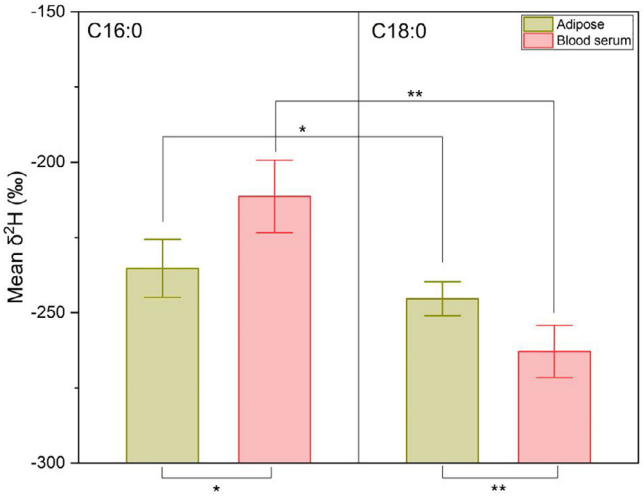

Figure 1. Mean δ2H values of adipose and blood serum $C_{16:0}$ and $C_{18:0}$ fatty acids recorded from 5 sheep. Error bars are 1 standard deviation.

107. Substitution of soybean meal with canola meal increases growth rate and heavy carcass weight in Chios lambs

M. Lagonikou [a,*], E. Tsimpouri [a], O. Zervogianni [a], V. Ntoulma [a], E. Denezi [b], D. Gelasakis [c], I. Bossis [d], A.I. Gelasakis [a]

[a] Laboratory of Anatomy and Physiology of Farm Animals, Department of Animal Science, School of Animal Biosciences, Agricultural University of Athens, Athens, Greece
[b] Denezis A.E., Argos, Greece
[c] Agrifood Research and Innovation Center, Volos, Greece
[d] Laboratory of Animal Husbandry, Department of Agricultural Sciences, School of Agriculture, Forestry and Natural Resources, University Campus, Aristotle University of Thessaloniki (AUTh), Thessaloniki, Greece

* Corresponding author. M. Lagonikou.

Application: Reduction of soybean meal (SBM) in farm animal diets is a challenge for sustainable livestock production. Canola meal (CM) could replace SBM in diets of fattening dairy breed lambs, without affecting growth rate and carcass weight.
Introduction: Social, trade, and economic issues of SBM production have driven animal nutrition research to alternative, locally produced feedstuffs, such as CM. The aim of this study was to evaluate the effects of replacing SBM with CM in the diet of fattening Chios lambs on growth rate and heavy carcass weight.
Material and methods: Seventy-five ~3 months old, weaned Chios lambs (40 males and 35 females) were used. Lambs were block by gender to treatment and then randomly assigned into two equal groups, the soybean-fed group (Group A) and the canola-fed group (Group B). The diets were isocaloric and isonitrogenous and lambs in the two groups were equally fed (300-350 g and 600-850 g of alfalfa hay and concentrates, respectively, according to the fattening stage). Lambs were fattened for four months. Their body weights (BW) were measured weekly and their live BW (LBW) at the end of the fattening period was measured two days before slaughter. Hot (HCW) and cold carcass weight (CCW) were recorded after slaughter. SPSS 26.0 for Windows (SPSS, IBM, USA) was used for the statistical analyses. General linear models (GLM) were used to estimate the fixed effects of diet and sex on LBW, HCW, and CCW, and a mixed linear model for repeated measures to estimate the fixed effects of the diet, sex, and fattening month and the random effect of lambs on their average daily gain (ADG).
Results: Mean values of LBW, HCW, and CCW for Group A were 39.6, 23.1, and 22.5 kg, respectively, while values for Group B were 40.6, 24.2, and 23.6 kg. In lambs fed CM LBW, HCW, and CCW were increased by 1.9, 1.5, and 1.4 kg, respectively compared to lambs fed SBM (Table 1). Moreover, LBW, HCW, and CCW were significantly higher in male lambs (Table 1). Mean ADGs for Group A and Group B were 174 and 185 g/d, respectively. After adjusting for the effects of diet, sex, and time, Group B lambs had 22 g/d higher estimated marginal mean of ADG compared to Group A (Table 2). In male lambs, ADG was 56 g/d higher compared to females ($P < 0.001$). ADG during the first two months of fattening was higher compared to the last (Table 2).
Conclusion: Replacement of SBM by CM in Chios lamb fattening diets had favorable effects on ADG, pre-slaughter LBW, HCW, and CCW.

Table 1
Parameter estimates of live bodyweight at the end of fattening period (LBW), hot (HCW) and cold carcass weight (CCW).

	LBW (kg)			HCW (kg)			CCW (kg)		
Parameter	B	SE	Sig.	B	SE	Sig.	B	SE	Sig.
Intercept	26.1	2.75	***	14.13	1.72	***	13.64	1.70	***
Group A	−1.9	0.89	*	−1.46	0.56	*	−1.44	0.55	*
Group B			Ref.			Ref.			Ref.
Female	−5.5	0.90	***	−2.41	0.56	***	−2.34	0.56	***
Male			Ref.			Ref.			Ref.
IBW	0.9	0.13	***	0.55	0.08	***	0.55	0.08	***

B: Coefficient, SE: Standard error, Ref: reference category, * $P < 0.05$, *** $P < 0.001$.

Table 2
The effects of diet, sex, fattening month, and initial body weight on the average daily gain (g/d).

Parameter	B	SE	Sig.
Intercept	204.0	29.01	***
Group A	−22.4	9.08	*
Group B			Ref.
Female	−56.2	9.20	***
Male			Ref.
Month 1	48.5	12.75	***
Month 2	43.8	12.54	***
Month 3	14.1	11.68	NS
Month 4			Ref.
IBW	−0.8	1.34	NS

B: Coefficient, SE: Standard error, Ref: reference category, * $P < 0.05$, *** $P < 0.001$, NS: Not significant.

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108. The effects of feed intake at two stages of maturity on the body composition of cross-bred lambs

T. Keogh [a,b,*], H. Oddy [c], B. Allworth [a,b], S. McGrath [a,b]

[a] Fred Morley Centre, School of Agricultural, Environmental and Veterinary Sciences, Charles Sturt University, Wagga Wagga, NSW, Australia
[b] Gulbali Institute, Charles Sturt University, Wagga Wagga, NSW, Australia
[c] Livestock Industries Centre, NSW Department of Primary Industries, Armidale, NSW, Australia

* Corresponding author. T. Keogh.

Application: This research will improve the predictability and nutritional management of growing lambs and will advance the current understanding of energy transactions in ruminants.
Introduction: As lambs approach maturity, they begin to deposit more energy as fat and less as protein, altering the efficiency of their growth (Oddy and Sainz, 2002). However, there are interactions between the energy density of feed eaten and the partitioning of energy between protein and fat (Graham, 1980) due in part to the rapid response of visceral organs to changes in feed intake (Oddy et al., 2019). Experiments with a growth restriction phase often limit energy intake by restricting supply and, as a result, protein weight is initially lost mainly in the viscera which then rapidly increases during realimentation (Ball et al., 1997). The aim of the current experiment was to accurately record energy transactions in growing lambs with knowledge of stage of maturity, feed intake and body composition. We used CT scanning to obtain repeat measurements of the proportion of fat and lean in the empty body on the same animals.
Materials and methods: Feed intake, growth rate, body composition and diet digestibility were recorded over two experiments run sequentially. Lambs (n = 108) were fed a pelleted diet for eight weeks in a 36-pen feedlot at both four (period 1) and eight months of age (period 2). Lambs were fed daily either a high (3.5% of live weight) or a low intake (2.5% of live weight). Between feeding periods lambs grazed dry pasture. At the commencement of period two, half of the previously low intake lambs were switched to high intake and vice versa. Lambs were CT scanned at the beginning and end of both feeding periods to measure rumen volume and body composition. Digestibility of the diet was determined for each feed intake level during both feeding periods.
Results: In the first period, lambs grew at 190 ± 28 g/day (high) and 77 ± 24 g/day (low) consuming 16.1 ± 0.3 and 10.0 ± 0.1 MJ ME per day respectively. During the second period, lambs grew at 173 ± 12 g/day (high) and 78 ± 11 g/day (low) consuming 16.5 ± 0.1 and 11.7 ± 0.1 MJ ME

Table 1
Estimated body component weights of lambs at differing stages of maturity and nutrient intake. [1]Values are least-square means, standard error of the mean (SEM) and P-value from analysis of variance model; column-wise superscripts indicate different treatment means ($P < 0.05$).

	Empty body weight (kg)	Fat weight (kg)	Protein weight (kg)	Empty body weight (kg)	Fat weight (kg)	Protein weight (kg)
	Period 1 start			Period 1 end		
High	25.0	4.5	3.8	35.7^{a}	9.4^{a}	4.9^{a}
Low	24.3	4.3	3.7	28.6^{b}	6.3^{b}	4.1^{b}
SEM	0.4	0.2	0.1	0.4	0.2	0.1
P-value	n.s.	n.s.	n.s.	<0.001	<0.001	<0.001
	Period 2 start			Period 2 end		
High/High	31.8^{a}	6.2^{a}	4.7	42.9^{a}	13.0^{a}	5.6^{a}
High/Low	31.8^{a}	6.5^{a}	4.7	37.0^{b}	10.0^{b}	5.0^{bc}
Low/High	29.0^{b}	5.3^{ab}	4.4	40.6^{c}	12.3^{a}	5.3^{ab}
Low/Low	29.2^{b}	5.0^{b}	4.5	34.5^{d}	8.9^{b}	4.7^{c}
SEM	0.5	0.3	0.1	0.5	0.3	0.1
P-value	<0.001	0.03	0.08	<0.001	<0.001	<0.001

per day respectively. The digestibility of the diet was 70.4% DMD, and not different between intake levels or stage of maturity. Estimated empty body, fat and protein weights at the start and end of each period are presented in Table 1. In the first feeding period, the proportion of energy retained as fat was 0.88 ± 0.02, and 0.9 ± 0.05 for high and low intake groups respectively. In the second period, the proportion of energy retained as fat was 0.93 ± 0.01, and 0.97 ± 0.02 for high and low intake groups respectively. Between feeding periods, mostly fat weight was lost for all lambs; however, protein weight increased for the previously low intake lambs.

Conclusions: Lambs in earlier stages of maturity and with higher energy intake are more efficient at utilising energy intake for gain. Between the feeding periods, energy intake limited growth but dry matter intake was not restricted and, as a result, lambs did not exhibit the weight loss/gain that is typically reported. Further analysis of CT scans is required to separate the compositional changes in both the viscera and carcass for greater insight.

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109. Prime lamb production from grazed grass – Monthly variation in herbage trace mineral concentrations and adequacy of supply

T. Keady [a,*], D. Hession [a], N. Kendall [b], J Hanrahan [c]

[a] Teagasc, Animal & Grassland Research & Innovation Centre, Mellows Campus, Athenry, Co Galway, Ireland
[b] School of Veterinary Medicine and Science, University of Nottingham, Loughborough, Loughborough, Leicestershire, UK
[c] School of Veterinary Medicine, University College Dublin, Dublin, Ireland

* Corresponding author. T. Keady.

Application: The seasonal variation in the concentrations of key trace minerals in pasture should be reflected in the design of nutritional management strategies on lowland sheep farms.

Introduction: Adequate intake of minerals is essential for maintaining growth, health and reproduction of livestock; marginal deficiencies can have a substantial impact on performance and health. Herbage is the major source of minerals in grass-based-systems but there is a paucity of information on seasonal variation. The objective of the current study was to evaluate monthly variation in the concentration of trace minerals in swards grazed predominantly by sheep.

Materials and methods: Farms (n = 56) were selected, based on geographical location, soil type and farm system, as being representative of lowland sheep producing areas throughout Ireland. Pre-grazing herbage samples were taken monthly (March to November) from 3 selected paddocks per farm, representative of sward type/age of all paddocks that sheep grazed. Herbage was cut to the expected post-grazing sward height (4 cm in March and April, 5 cm in May and 6 cm from June to November) by taking 20 cuts randomly within each paddock. A total of 1115 samples were analysed for a suite of 22 minerals as described by Hession et al. (2021). Sixty four samples classified as being contaminated were removed from the data set. A mixed model (Proc MIXED, SAS 9.4) with month of sampling as a fixed effect and farm and paddock within farm as random terms was used for data analysis. Farm means for each trace mineral were compared with dietary requirements of dry ewes and lambs as specified by the National Research Council (NRC, 2007).

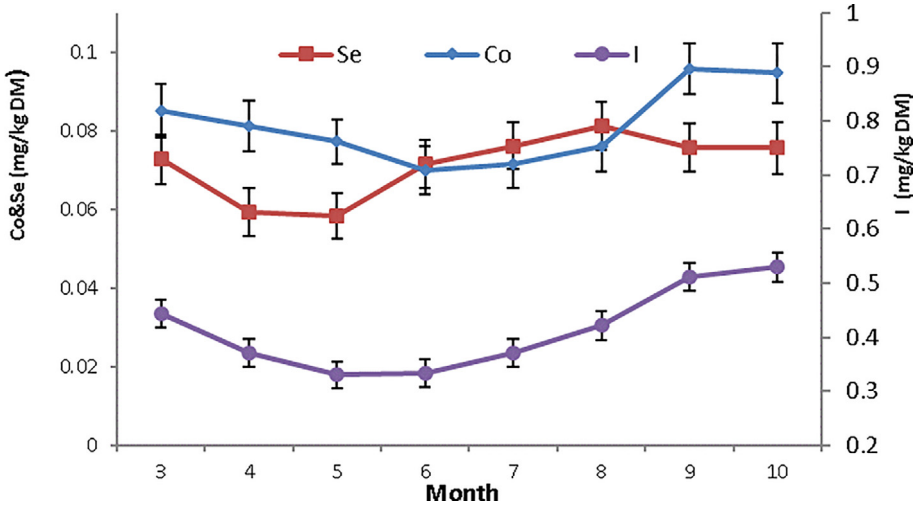

Figure 1.

Table 1
Dietary mineral requirements of sheep and the incidence of deficient, marginal and sufficient farms [1] Based on NRC (2007) maintenance requirements of an 80 kg ewe and requirements of growing lambs. [2] Mean farm herbage concentration of < 0.10, <4, <0.5, <0.05, and <26 mg/kg DM (for deficient); 0.10 to 0.20, 4 to 5, ≥0.5, 0.05 to 0.3 and 26 to 32 mg/kg DM (for marginal); >0.2, >5, ≥ 0.5, >0.3 and >32 for mg/kg DM (for sufficient) for Co, Cu, I, Se and Zn, respectively.

Trace mineral	Mean mineral herbage concentration (mg/kg DM)	Requirement[1] (mg/kg DM)	Farm classification[2] (%)		
			Deficient	Marginal	Sufficient
Co	0.089	0.10 – 0.20	73	27	0
Cu	7.8	4 – 6	0	0	100
I	0.44	>0.5	80	-	20
Se	0.091	0.05 – 0.5	11	89	0
Zn	31.0	26 – 33	23	55	22

Results: Month of sampling had a significant effect ($P < 0.001$) on herbage concentrations of Co, Cu, I, Se and Zn. The concentration of Co was lowest in June and July and increased ($P < 0.01$) in Sept and Oct (Fig. 1). The concentration of I declined between March and June and was higher ($P < 0.001$) in Sept and Oct relative to all other months. The concentration of Se was at a minimum in April/May and was higher in June ($P < 0.01$), July, August, Sept ($P < 0.001$) and Oct ($P < 0.01$). Herbage Cu concentration increased during the grazing season being lower in March than in May ($P < 0.05$), July, August, Sept ($P < 0.001$) and Oct ($P < 0.01$). Zn concentration was higher in June ($P < 0.05$), July, August, Sept ($P < 0.001$) and Oct ($P < 0.01$) than in March or April. The proportion of farms classified as deficient, marginal or sufficient for trace minerals is presented in Table 1. The majority of farms were deficient for Co (73%) and I (80%), deficient or marginal for Se (100%) and Zn (78%), and sufficient for Cu (100%).
Conclusion: Trace element concentrations in herbage vary significantly throughout the grazing season. The concentrations of Co, I and Se were deficient or marginal on most farms. Herbage on all farms had sufficient Cu.

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110. Assessing performance and feed efficiency of Exlana ram lambs

M.J. Rivero [a,*], A.K. Kelly [b]

[a] Rothamsted Research, North Wyke, Okehampton, Devon, UK
[b] School of Agriculture and Food Science, University College Dublin, Belfield, Dublin, Ireland

* Corresponding author. M.J. Rivero.

Application: This is the first study reporting performance and feed efficiency of the low-input, low-maintenance hair maternal sheep breed Exlana. This preliminary dataset will allow to rank Exlana relative to other breeds.
Introduction: Exlana is a composite hair maternal sheep breed which, according to the National Sheep Association, in addition to the lack of need for shearing, this maternal breed has also been developed for prolificacy and mothering traits. The females are selected for the ability to lamb outdoors with minimum intervention. However, the performance efficiency is unknown. By producing more efficient low-input sheep, more meat will be produced using fewer resources (e.g. land, supplementary feed) while reducing GHG emissions. The aim of this study was to assess the performance and feed efficiency of Exlana ram lambs.
Materials and methods: Two batches of 30 ram lambs (mean age 150 d, ranging from 121 to 183 d) were assessed for 6 weeks each (after 2-w of adaptation) in slatted-floor pens equipped with 24 BioControl® automatic intake recording units. Lambs were arranged in groups of four or six lambs per pen, with four feed bins each, two filled daily with hay and two with hay pellets. Lambs' body weight (BW) was recorded at the start and end of the 6-w assessment period, and twice a week throughout. The residual feed intake (RFI) was calculated using the data on dry matter intake (DMI), BW and average daily gain (ADG) with SAS® software. Descriptive statistics were generated to characterise the breed in terms of performance and feed efficiency, and regressions were used to determine linear effects of RFI on performance using Genstat 21st edition.

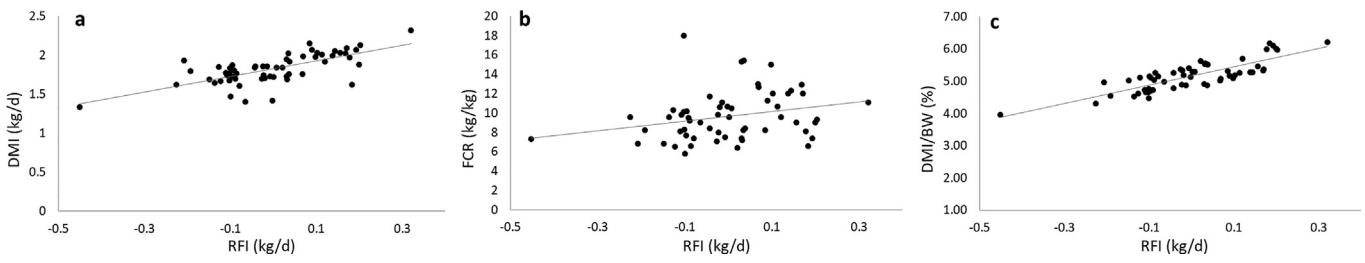

Figure 1. Relationship between RFI and DMI (a), FCR (b) and DMI/BW (%, c) for 58 Exlana ram lambs.

Results: Two lambs were excluded from the analysis due to health issues. Mean initial, final and metabolic BW were 31.3 (range: 21.1 to 37.0 kg), 39.6 (range: 30.4 to 46.0 kg) and 8.38 kg (range: 3.90 to 12.0 kg), respectively. Mean ADG was 199 g/d, ranging from 93 to 286 g/d, whereas DMI averaged 1.827 kg/d, ranging from 1.332 to 2.217 kg/d. The RFI ranged from -0.452 to 0.321 kg/d, whereas feed conversion ratio (FCR) averaged 9.66 kg feed per kg ADG, ranging from 5.80 to 18.0. There was a positive linear relationship between RFI and DMI ($r = 0.69$, $P < 0.001$) and FCR ($r = 0.27$, $P < 0.05$). The greatest correlation was with DMI expressed as %BW ($r = 0.82$, $P < 0.001$) (Fig. 1). No correlations were found between RFI and ADG, BW or age.
Conclusion: This first study allowed to characterise the Exlana ram lambs in their performance and feed efficiency. Significant correlations were found between RFI and relevant productive variables.

Acknowledgements: This study was funded by the ERDF's Environmental Futures & Big Data Impact Lab project, the BBSRC through the Soil to Nutrition ISP (BBS/E/C/000I0320) and the Centre for Innovation Excellence in Livestock (CIEL).

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111. Identification and characterisation of lipid species from grass vs concentrate finished lamb using non-targeted UHPLC-MS/MS lipidomic profiling analysis

L. Perkins [a,*], D. Dannenberger [b], B. Fuchs [b], B. Green [a], N Scollan [a]

[a] Queen's University Belfast, Belfast, UK
[b] The Leibniz Institute for Farm Animal Biology, Dummerstorf, Germany

* Corresponding author. L. Perkins.

Application: Non-targeted UHPLC-MS/MS analysis successfully identified discriminatory lipid species from grass vs concentrate finished lamb meat and has provided a foundation for confirmation of dietary biomarkers for grass-finished lamb.
Introduction: Pasture feeding ruminants is an efficient way of increasing omega-3 (n-3) polyunsaturated fatty acids (PUFA) in muscle. In ruminants, n-3 PUFA is almost exclusively incorporated into muscle phospholipids (Bessa et al, 2015), indicating that individual lipid species may play an important role in human health (van der Veen et al, 2017). Muscle FA profiles are routinely analysed using GC-FID; however, recent advances in analytical techniques now allow for a more profound insight into individual lipid classes and species. This study aimed to identify and characterise lipid species from lambs finished on grass vs concentrate diets using non-targeted UHPLC-MS/MS and detect potential biomarkers for grass-based feeding.
Materials and methods: Lipid species from lamb muscle finished on grass ($n = 15$) or concentrate ($n = 11$) were extracted using a chloroform: methanol methodology. Samples were analysed using UHPLC-MS/MS in the positive and negative ion mode. Differences between lipid species from the grass and concentrate treatment were analysed using a t-test (SPSS, version 25) and presented using heat maps (MetaboAnalyst 5.0). Area Under Receiver Operating Characteristic (AUROC) analysis was used to determine biomarker potential (MetaboAnalyst 5.0).
Results: A total of 222 lipid species from six classes were analysed. Nine lipid species were identified as different between treatments ($P < 0.01$; Figure 1). The greatest discriminatory response was documented in LPC (18:2) and PE (18:1e_18:1) for the concentrate and grass treatment, respectively. From this, LPC (18:2) was identified as a potential biomarker for the concentrate treatment, with an AUROC score of 1.0. Alternatively, lipid species PE (18:1e_18:1) had an ROC score of 0.967 (Figure 2), the highest scoring grass species.
Conclusion: Using non-targeted UHPLC-MS/MS analysis successfully identified discriminatory lipid species from grass vs concentrate finished lamb muscle and provided a foundation for future confirmation as dietary biomarkers for grass-finished lamb.

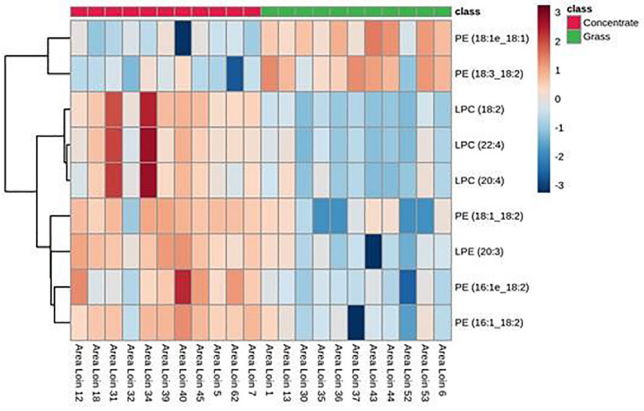

Figure 1. Nine identified significantly different lipid species (t-test) from lambs finished on grass vs concentrate.

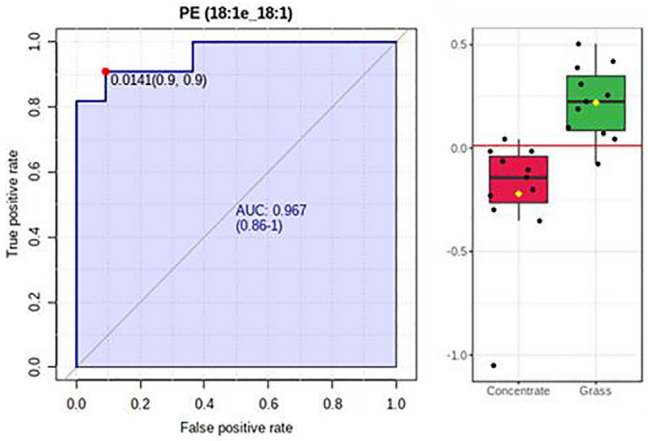

Figure 2. AUROC for lipid species PE (18:1e_18:1) from grass-finished lamb.

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112. Insects as sustainable feed alternative for ruminants: chemical composition and in vitro gas production

L.E. Robles-Jimenez [a], B.S.E Cardoso-Gutierrez [a], E. Vargas-Bello-Perez [b], O.A. Castelan-Ortega [a], M. Gonzalez-Ronquillo [a,*]

[a] Universidad Autonoma del Estado de Mexico, Toluca, State of Mexico, Mexico
[b] University of Copenhagen, Grønnegårdsvej, Copenhagen, Denmark

* Corresponding author. M. Gonzalez-Ronquillo.

Application: This study showed that Yellow mealworm and Noctonecta spp had high protein (396- 486 g/ kg DM) and fat (247 – 70 g/ kg DM) contents, respectively.
Introduction: Insects are considered a sustainable protein source for feed as a supplementary protein source for livestock production. Typically, soybean meal (SBM) are the major protein source and are commonly used in ruminant diets. Therefore, to meet the increasing demand for animal products, innovative solutions and alternative sustainable feedstuffs are needed for replacing conventional protein in animal diets. This study evaluated the protein quality of larvae of black soldier fly (Hermetia illucens, BSF), yellow mealworm (Tenebrio molitor, YMW), and an aquatic insect Noctonecta spp. (N) of which we do not know how high the ruminal degradation of insect meals can be. We therefore determined the chemical composition, ruminal fermentation and in vitro gas production of these insects in comparison with conventional protein sources such as fishmeal (FM) and SBM.
Material and methods: Chemical composition and in vitro gas production technique was performed, using 0.800 g DM of each ingredient. Each sample was incubated in triplicate in glass flasks with 90 ml of buffer solution and 10 ml of ruminal liquid, and the incubation was repeated in 3 consecutive runs. The bottles were incubated in an incubator oven at 39 °C. The gas volume was recorded at 3, 6, 9, 12, 24, 36, 48, 72 and 96 hours of incubation

Table 1
Chemical composition (g/ kg DM) and in vitro rumen gas kinetics of different protein sources.

	Treatment						
Variable	BSF	YMW	Noctonecta	Fishmeal	SBM	SEM	P-value
Organic matter	843^{b}	925^{a}	938^{a}	828^{b}	939^{a}	11.95	0.0001
Crude protein	383^{e}	448^{c}	486^{b}	517^{a}	440^{d}	0.516	0.0001
$IVDP_{96h}$	228^{d}	243^{d}	282^{c}	330^{b}	440^{a}	5.395	0.0001
Ether extract	356^{a}	247^{b}	70^{c}	58^{d}	24^{e}	1.416	0.0001
Gas Production parameters							
B	91.71^{b}	79.0^{b}	50.7^{b}	85.2^{b}	288.5^{a}	11.611	0.0001
C	0.031^{b}	0.025^{bc}	0.066^{a}	0.013^{c}	0.027^{bc}	0.0034	0.0001
Lag time	-1.075^{ab}	-2.627^{b}	-1.423^{ab}	-2.482^{ab}	-0.781^{a}	0.3685	0.0280
Gas production, mL gas/g DM							
12h	31.48^{b}	26.78^{b}	30.28^{b}	15.32^{b}	95.12^{a}	4.267	0.0001
24h	47.51^{b}	37.33^{b}	37.58^{b}	23.38^{b}	134.49^{a}	5.107	0.0001
96h	87.63^{b}	73.03^{b}	53.68^{b}	56.24^{b}	267.37^{a}	8.702	0.0001
DMD96	0.500^{c}	0.785^{b}	0.690^{b}	0.717^{b}	0.983^{a}	0.021	0.0001

using a pressure transducer. In vitro gas production (GP) kinetics were determined by adjusting the model proposed by Krishnamoorthy et al. (1991) GP = B (1-e-Ct), Where B represents the total production of gas (mL gas/g initial DM); C the rate of degradation in relation to time (h-1); and Lag time (h-1). After in vitro incubation periods, dry matter disappearance (DMD96, mg/100 mg) was determined. A complete randomized design was performed, and significant effects of treatments were declared at $P < 0.05$.

Results: Chemical analysis (g/ kg DM) showed that the highest CP content was for FM (517) followed by Noctonecta (486) and YMW (448). Fat content was higher for YMW and BSF (247 and 350, respectively) and lower for SBM (24). In vitro degradable protein (IVDP) was similar (around 60%) for SBM, BSF, YMW and N, being lower for FM (19%). "B" fraction, and gas yield at 24h was higher ($P < 0.001$) for SBM compared with to other treatments. DMD96 was higher for SBM followed by YMW, N and Fish Meal.

Conclusion: Protein content from YMW and Noctonecta was similar to SBM, while protein content from BSF was similar to that of Fish Meal. Insect meals seem to be promising protein alternatives for ruminant diets (Table 1.).

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113. Application of juvenile hormone analogue, pyriproxyfen, increases protein and reduces fat proportion in yellow mealworms

V. Hill [*], T. Parr, A. Salter, J. Brameld

[1] University of Nottingham, Loughborough, Leicestershire, UK

* Corresponding author. V. Hill.

Application: *Tenebrio molitor* (yellow mealworms) treated with juvenile hormone analogue (JHA), pyriproxyfen, have greater crude protein and reduced fat contents than controls, providing a potential treatment to enhance insect nutritional profiles for animal feed and human food.

Introduction: Insects are an underutilised source of high-quality protein which is potentially more sustainable than traditional sources (Hawkey et al., 2021). *Tenebrio molitor* (TM) larvae could partially replace soya in animal feed, but there is little research to optimise their nutritional profile. This study aimed to determine whether pyriproxyfen, a JHA that prevents pupation impacts protein and fat yield in dried TM larvae and their potential as an alternative protein source.

Materials and methods: TM larvae (Monkfield Nutrition Ltd) were allocated to one of four wheat bran (WB, 250g) treatment groups (four dishes per treatment, n = 300/dish): Control (WB only), a vehicle control of Acetone (WB plus 3 ml acetone), Low dose (WB + 3 ml of 0.165 mg/ml pyriproxyfen in acetone), and High dose (WB + 3 ml of 1.25 mg/ml pyriproxyfen in acetone). Larvae were kept in a dark incubator (25°C, 60% humidity), and fed *ad libitum* for 35 days, with 10g of WB and water, refreshed every 3 or 4 days. Dead larvae were removed throughout. At day 35, mealworms were killed, then freeze-dried for 72 hours. Crude protein per 100 grams of dry matter (DM) was determined via nitrogen content using a Flash EA 1112 Elemental Analyser and fat per 100 grams of DM through Soxhlet ether extraction. Data were analysed by one-way ANOVA (Genstat 20th edition), followed by Bonferroni post-hoc tests as appropriate ($P < 0.05$).

Results: Crude protein content (per 100g DM) was greater for mealworms treated with pyriproxyfen than both controls (Figure 1: $P < 0.001$), with a positive relationship between dose and crude protein content. Fat content (per 100g DM) was lower in pyriproxyfen treated mealworms than controls (Figure 2: $P < 0.001$) with a negative relationship between dose and fat content. Acetone treatment did not affect protein or fat contents compared to the untreated Control. Mealworm group weight was significantly greater for the Low, but not High, dose group and this was associated with a significantly increased mortality rate in the High dose group (compared to both control and Low dose groups).

Conclusion: Pyriproxyfen treatment significantly increased crude protein and reduced fat content of mealworms. Further work is required to determine the mechanisms involved and whether such treatment has any negative impact on animals, or humans, consuming them.

Acknowledgements: This work was funded by the University of Nottingham and BBSRC.

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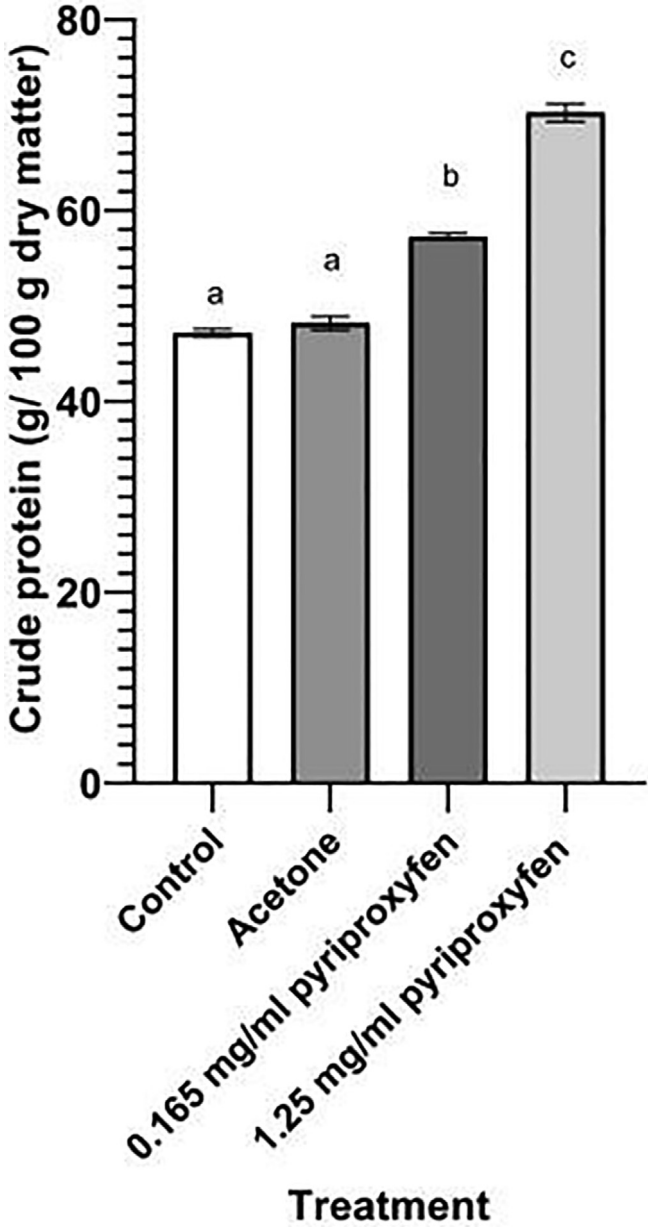

Figure 1. Crude protein content (grams per 100 g dry matter). Pyriproxifen treated mealworms contained more crude protein than control groups. Bars with different letters are significantly different ($P < 0.05$ Bonferroni).

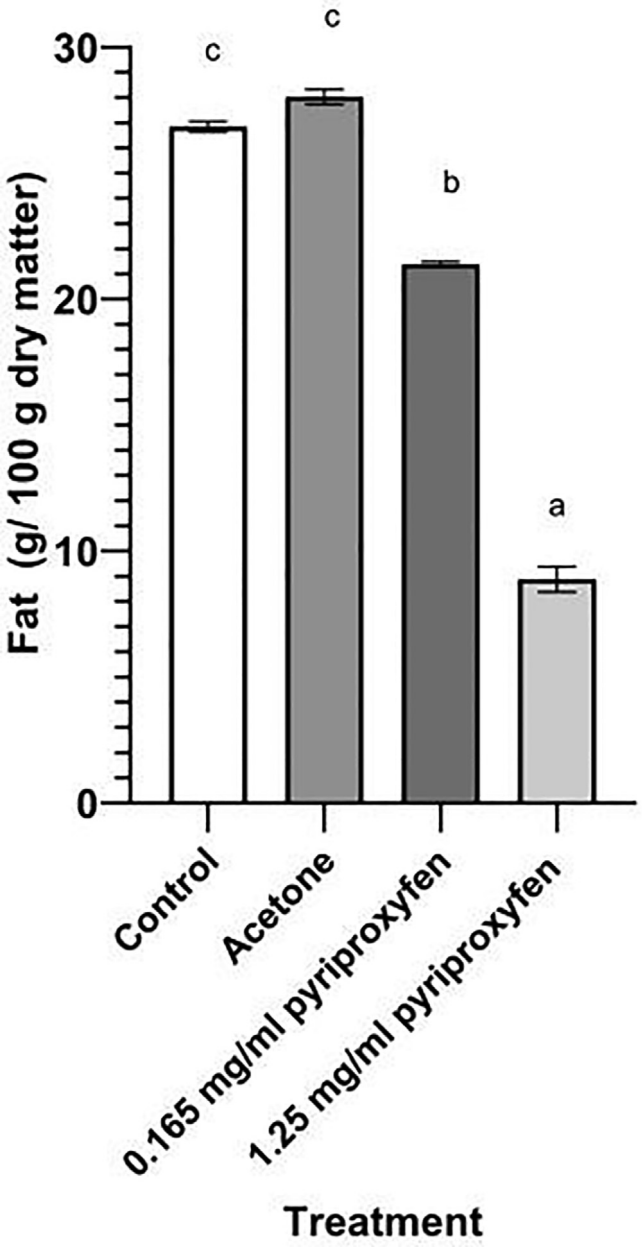

Figure 2. Fat content (grams per 100 g dry matter). Pyriproxifen treated mealworms contained less fat than control groups. Bars with different letters are significantly different (P 0.05 Bonferroni).

114. Insect Farming and Breeding: Supplying an Alternative Protein

T. Farrugia

Beta Bugs Ltd, Scotland

Insects-as-feed provide a way of increasing agricultural output to meet the demands of global population growth (Huis, 2015). Insects can produce regional, resilient and sustainable animal feed ingredients (protein and fat) from organic waste, promoting circular bioeconomy. The black soldier fly, Hermetia illucens, could replace unsustainable fishmeal and soymeal in aquaculture and livestock feeds, reducing overfishing and deforestation (Tomberlin and Van Huis, 2020). Insect production will contribute to UK net-zero targets and ensure that the UK agri-food supply chain is not disrupted by global market volatility and climate change. The UK imports almost 100K tonnes of fishmeal (seafish) and 2.2M tonnes of soymeal per year and feed accounts for ~70% of pig and poultry production costs. Insects-as-feed cannot yet compete on price-point with fishmeal or soymeal, slowing market growth. Two developments that will make insects-as-feed competitive are improved production, by scaling, improved genetics, and by selective breeding. Scaling is underway - commercial facilities producing up to 15K tonnes of protein and 5.3K tonnes of fat per year are in operation. The EU industry projects annual outputs of 1.2M tonnes of protein and 420k tonnes of fat per year by 2025. In this talk, we will: 1. Explore the development of the insect protein industry, how it operates, and the emergence of horizontal segmentation., 2. Have a closer look at the UK industry, outlining

the key players and organizations which are helping this industry emerge and take flight, 3. Explain how genetics and selective breeding can contribute to the further development of this industry.

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115. Insect meal improves the survival rate and boosts performance when replacing fishmeal in Whiteleg Shrimp Diets

R.G. Hermes *, M.J. Zorrilla, N.J. Piggott

Nutrition Technologies, Singapore

* Corresponding author. R.G. Hermes.

Application: Feeding animals with insect meal is a sustainable way to replace fishmeal, which relies on harvesting limited wild fish stocks. Insect meal can have the added benefit of improving the growth performance and farmer profitability.
Introduction: Per-capita seafood consumption is rising globally and along with greater pressure from consumers for seafood produced in sustainable ways. Southeast Asia accounts for one third of the global shrimp production, however the vast majority of the raw materials need to be imported at a high cost and carbon footprint to support a growing production. The most promising alternative protein for feed applications is the Black Soldier Fly (*Hermetia illucens*) larvae; a saprotrophic species with nutritional characteristics that closely match those required by most aquacultured species. The objective of this study is identifying the best inclusion rate of *Hi.*Protein® Black Soldier Fly (BSF) meal to partially replace the fish meal (FM) in the diets of whiteleg shrimp.
Materials and methods: One thousand four hundred healthy shrimps (1.8g) were divided into 5 treatments with 7 replicates each. Treatments were: 1) Control: 0% inclusion of BSF meal; 2) 5% FM replacement: inclusion of 1.3% of *Hi.*Protein®; 3) 15% FM replacement: inclusion of 3.9% of *Hi.*Protein®; 4) 25% FM replacement: inclusion of 6.6% of *Hi.*Protein®; and 5) 35% FM replacement: inclusion of 9.3% of *Hi.*Protein®. Each tank contained 350L of water and contained an aeration system, and a biofilter bucket. The trial lasted 42 days. It measured the live performance, the survival rate, water quality parameters and the economic analysis. Data were analysed using SPSS (version 25) software, applying the one-way analysis of variance (ANOVA), followed by the Duncan test to determine differences among treatments. All significant tests shall be at $P < 0.05$ levels. Results were presented as mean ± standard deviation.
Results: In Table 1 the live performance data at the end of the trial is summarised. The 25% FM replacement (6.6% inclusion of *Hi.*Protein®) treatment resulted in a higher live yield per tank, due to a higher survival rate ($P < 0.05$). As the feed intake was similar for all treatments, the best FCR was observed with the 25% FM replacement. There are several likely explanations as to why a 25% FM replacement presented better live performance. It may be due to a more adequate amino acid profile for whiteleg shrimp and the presence of chitin, which has been reported to have immune-modulating effects and better gut histology parameters. The lauric acid found in the insect meal has been reported to have antimicrobial properties which benefit animal health.
Conclusions: The results of this trial in Vietnam demonstrate that insect meal can replace fishmeal with the benefit of a better baseline live performance and also provided increased resilience against the challenging environments. Conducting economic analysis of the raw material costs and performance improvements, we found that *Hi.*Protein® can be included in feed formulations with commercially affordable outcomes for the farmer.

Acknowledgements: The authors would like to acknowledge the Shrimpvet Lab, in Vietnam, for the trial implementation and the scientific report.

Table 1
Live Performance Results. ^{ABC}means significant statistical differences among treatments.

Treatments	Indiv. Initial Weight (g)	Indiv. Final Weight (g)	Survival Rate (%)	Feed Intake/ tank (g)	Live Yield/ tank (g)	FCR (g/g)
Control (Basal)	1.79 ± 0.5	12.72 ± 0.9	84.6 ± 7.7^{C}	509.1 ± 8.9	429.6 ± 37.1^{B}	1.43 ± 0.11^{A}
5% FM replacement	1.80 ± 0.5	12.64 ± 1.1	87.9 ± 6.4B^{C}	513.3 ± 19.1	444.5 ± 51.5^{AB}	1.34 ± 0.05^{AB}
15% FM replacement	1.78 ± 0.5	13.14 ± 0.8	87.5 ± 6.3B^{C}	525.0 ± 26.7	460.6 ± 52.3^{AB}	1.31 ± 0.10^{BC}
25% FM replacement	1.79 ± 0.5	12.96 ± 1.1	96.8 ± 2.8^{A}	519.6 ± 25.4	502.2 ± 47.0^{A}	1.19 ± 0.07^{D}
35% FM replacement	1.80 ± 0.5	13.13 ± 1.1	93.6 ± 5.8^{AB}	516.5 ± 19.6	492.0 ± 56.4^{A}	1.22 ± 0.10^{CD}
P-values	*0.990*	*0.808*	*0.030*	*0.675*	*0.047*	*0.001*

116. Zero Waste or Beyond Waste?

W. Clark

Zero Waste Scotland, Scotland

Agriculture is unique amongst human activities. Whilst it is well understood that the production and consumption of food is a key driver of climate change, and agriculture is itself (significantly) negatively affected by this climate driven change, it also holds the keys to the solution (Kanianska et al.,

2016). However, “even if all known mitigations of carbon emissions were taken up rapidly, the industry can only deliver an estimated 19% of the aspirational reduction target by 2035, highlighting the urgent need to advance technologies and develop innovations including carbon efficiency, soil health, animal health and welfare, and much more to address this critical issue” (CEIL', 2020). Further significant emissions reductions from the livestock sectors are possible (Rojas-Downing et al., 2017). This can be achieved, by reducing production and consumption, by lowering emission intensity of production, or by a combination of the two (Henchion et al., 2017). However, given increasing global populations and demographic shifts alongside convergence towards the western diet (Azzam, 2021), and the criticality of animal proteins and trophic upgrading with reference to current and future food security (Weindl, 2020), consumption is unlikely to change at the speed or scale required (Bengtsson et al., 2018). This leaves production emissions reduction as a key pathway to advance sustainability in the near term. Overall, feed production and processing contributes about 45% of the GWP for the whole livestock sector (Grossi et al., 2019). Similarly, 95% of the GWP for a farmed Atlantic salmon arrives with the feed (Mcgoohan et al., 2021). At the same time, feeds approximate 60% of the cost of raising an animal, and we waste more than 33% of the food we produce (Zero Waste Scotland, 2019). This means that if we can solve feed, if we can substitute the high intensity ingredients with sustainable and renewable materials, if we can upcycle organic surplus and food wastes, we can deliver a positive and inclusive change, we can optimise resource efficiency and enable decarbonisation across a range of sectors, and we can protect our farmers along with their rural and coastal communities they support. By advancing the circular economy through biotechnology at farm and community level, we can capture food waste and other organic surplus including gaseous emissions and effectively upcycle them to sustainable and renewable nutrient dense feeds and other high value products. Farm business models diversify, supply chains consolidate and accelerate, adaptation becomes proactive, and the industry can move beyond waste into a restorative and regenerative space. However, the cost of transition is significant, and this cannot be the responsibility of farmers, or consumers therefore policy is critical. Governments across the European Union and beyond have been addressing this by moving to national level policy instruments focused on enabling and accelerating this transition to more sustainable production and consumption of protein since 2014 (Clark & Lenaghan, 2020). The climate emergency and more recently the global pandemic have highlighted just how delicate our food systems are, and this is increasingly reflected in the new iterations of protein strategies from 2021 (Clark, 2021). Farmers and downstream value chains in these countries are already maximising opportunity as a result, hence the questions, should the UK adopt a similar approach? How can we get beyond waste? And can we enable future growth ambitions without it costing the world?

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117. Corn fermented protein a commercially viable alternative protein for aquaculture and livestock

P. Williams

Green Plains Renewable Energy, Omaha, Nebraska, USA

Application: Corn fermented protein (CFP) is a 52% protein concentrate (as received) produced by mechanical separation of whole stillage from a dry grind ethanol plant without the use of any exogenous chemical processing aids that can be used as a high protein concentration in diets for livestock.
Introduction: Derived from a fermentation process and containing spent yeast components (24% of the dry matter) the CFP has unique characteristics as a fermented, functional protein concentrate.

Table 1

Diet	Initial BW (g/fish)	Final BW (g/fish)	TGC	FCR	WG (g/fish)	FI (g/fish)
A (Control)	380.84	1073.06	0.25	1.04	692.21	718.20
B (10%CFP + 15%FM)	381.71	1062.68	0.25	1.04	680.97	707.93
C (15%CFP + 15%FM)	374.94	1024.64	0.24	1.04	649.69	667.80
D (20%CFP + 15%FM)	378.47	1029.88	0.24	1.07	651.41	698.48
SEM	3.88	25.00	0.01	0.01	21.56	20.90
P-value	0.65	0.49	0.44	0.36	0.47	0.42

Materials and methods: Apparent digestibility coefficient (ADC) of CFP was measured in salmon (initial body weight = 25.3 ± 0.3 g) hand-fed three diets over a 39-day experimental period, containing 0% CFP (Reference Diet; A), and different blends of the Reference Diet with CFP (7.5% CFP: 92.5% Reference; B: 15% CFP: 85% Reference; C) using titanium dioxide as the indigestible marker. In a growth trial Atlantic salmon (initial body weight 379.0 ± 6.4 g) were randomly allocated into 12x750-L tanks (30 fish/tank, n = 3) and fed for 84 days, four experimental diets based on European formulations with fishmeal inclusion limited to 15%, in which graded levels of CFP (0%, 7.5%, 10% and 15%) substituted soy bean concentrate in the formulation. Diets were formulated using the ADC's of CFP recorded in the digestibility study. ***Results:*** The ADC of protein in the 3 diets were similar (P = 0.2341) ranging from 94.0% dry matter digestibility (diet A) to 95.3% (diet B) and 94.3% (diet C). There were no significant differences in the ADC of dry matter (P = 0.0659), protein (P = 0.0832), or lipid (P = 0.2623) in the CFP product comparing 7.5% or 15% inclusion levels. ADC of protein in CFP was 96.3%. In general there were no significant differences in the ADC of any of the essential amino acids (P > 0.05) when CFP was included at 7.5 or 15%. However, compared to the reference diet both diets B and C had significantly higher apparent digestibility of leucine (P = 0.0024) and lysine (P = 0.025). There was no effect of dietary inclusion of CFP up to 15% on fish survival or performance (Table 1). Excellent thermal growth coefficient (TGC ~ 0.25) and outstanding FCR (~1.0) were achieved across all diets.
Conclusion: The results have important implications for the European bioethanol industry demonstrating that CFP is a valuable alternative protein concentrate recovered from the dry grind ethanol process that can replace soy protein concentrate in dietary formulations for Atlantic salmon.

118. Use of yellow mealworm (Tenebrio molitor) as a protein source on growth performance, and carcass traits in growing lambs

L.E. Robles-Jimenez [a,*], S. Angeles [b], A.H. Ramirez-Perez [b], B. Fuente [b], J.M. Pino-Moreno [b], B.S.E. Cardoso-Gutierrez [a], I.A. Dominguez-Vara [a], M. Gonzalez Ronquillo [a]

[a] Universidad Autonoma del Estado de Mexico, Toluca, State of Mexico, Mexico
[b] Universidad Nacional Autonoma de Mexico, CD Mexico, Mexico

* Corresponding author. L.E. Robles-Jimenez.

Application: Use of Tenebrio molitor meal in sheep diets as an alternative protein source does not affect carcass yield of lambs.
Introduction: Soybean meal and fish meal are conventional sources of vegetable and animal protein, respectively. Their high demands on animal feed increase their costs; hence their future production becomes unsustainable due to the large-scale use of natural resources. Insects have been studied as sources of protein; they grow rapidly in minimal spaces. Furthermore, its waste can be used as organic fertilizers in crop production, thus supporting a closed circular economy (DiGiacomo & Leury, 2019). Tenebrio molitor is an insect rich in proteins and lipids, it can be used as an alternative protein source in ruminant feeding. The objective of this study was to evaluate the effect of Tenebrio molitor meal as an alternative to vegetable (soybean meal) and animal (fish meal) protein sources on slaughter weight and carcass yield of lambs.
Materials and methods: This study lasted 60 days; 24 lambs were completely randomized (8 lambs / treatment) to one of three isoprotein and isoenergetic diets (15% CP; 11 MJ ME / kg DM). The protein source was the only factor of diet variation. The control diet (SBM) included 150 g of soybean meal / kg DM, which was replaced by fish meal (FM) and Tenebrio molitor meal (TM) in the other diets, the slaughter body weight (SBW, kg) was recorded; the lambs were slaughtered according to the Official Mexican Standard for the humane slaughter of animals (NOM-033-SAG / ZOO-2014). The hot carcass weight (HCW, kg) was recorded and used to calculate the hot carcass yield [HCY% = (HCW / SBW)*100]. The thickness (mm) of back fat was measured at the level of the 10th rib. After 24 hours post slaughter, cold carcass weight (CCW, %) and cold carcass yield (CCY, %) of the cold carcass were recorded; pH and temperature (°C) were also recorded. Data were analyzed for a completely randomized design, using the PROC GLM (SAS statistical package; 2002). The results present least squares means with standard errors; significant effects were declared at P < 0.05.
Results: Slaughter body weight, hot carcass yield %, cold carcass yield %, fat thickness at 10th rib, pH and temperature were similar (P > 0.05) between lambs fed with different protein sources. Lower carcass weights (P < 0.05) were registered forlambs feeding with TM compared to SBM diet.
Conclusion: The chitin content present in the exoskeleton of Tenebrio molitor meal could have been the result of a lower intake and digestibility, and therefore a lower HCW and WCC, even if the diet has been isoprotein and isoenergetic, however, Tenebrio molitor meal is an alternative source of protein that can replace soybean meal or fish meal, without impairing yield, fat thickness, pH of lamb carcasses.

Acknowledgement: This project was supported by Catedras COMECyT 2021, Grant CAT2021-0070.

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Table 1
Slaughter body weight (SBW) and characteristics of the carcass of lambs fed with soybean meal (SBM), fish meal (FM) and Tenebrio molitor meal (TM) as protein sources.

	Treatment			SEM	P-value
Variable	SBM	FM	TM		
SBW (kg)	40.15	36.95	36.04	1.2385	0.0716
HCW (kg)	18.49[a]	16.69[ab]	15.99[b]	0.6736	0.0441
CCW (kg)	18.03[a]	16.17[ab]	15.52[b]	0.6643	0.0394
HCY (%)	46.03	45.22	44.31	0.9491	0.4593
CCY (%)	44.87	43.83	43.02	1.0225	0.3454
Fat 10th rib (mm)	2.75	3.31	2.63	0.4597	0.5475
pH 24h	6.62	6.87	6.46	0.1383	0.6549
Temperature 24h (°C)	11.87	11.81	11.91	0.9731	0.7613

119. Human mental health in relation to Animal Assisted Interventions - it's all about the connections

C. Binney

Halcyon Clinical, Worcestershire, UK

In this introductory talk for the companion animal symposium, I will explain the context for the many and varied ways that human-animal connections have supported human mental health and the growing need for this support, exacerbated by the pandemic. From my practitioner lens as a clinical psychologist working with young people, I will briefly touch on the role of companion animals and the physical and emotional connections between humans and non-human animals. This will lead to a greater exploration of the more targeted areas of animal assisted interventions, specifically animal assisted therapy using illustrated examples of the practical applications. Whilst I will acknowledge the importance of considering both sides of the human animal interaction, this talk will concentrate more on the human mental health aspects. I will conclude that *connections,* between human and animal scientists, therapists and their animals, and researchers and practitioners, are paramount in ensuring ethical and evidence-based practice that continues to develop. After introducing the context, I will start by explaining what we mean by various animal assisted terminology and look at what is 'behind' the scenes of a structured, planned and goal orientated animal assisted therapeutic intervention including some theories of the mechanisms involved connecting physical, emotional, social and psychological elements. I will briefly update on the current state of animal assisted therapy research with areas to consider going forwards including a newly proposed integrative model of human-animal interaction recently presented by leading researchers in the field. I will then provide case examples to bring the work to life showing the connection between science and practice. The overarching thread throughout the talk will be the notion of *'connections'* (i.e. links, bonds, associations and relationships) and how important they are to both understanding and developing the ethical practice and impact of human-animal interactions on human mental health. Connections highlighted in this talk will include amongst others: psychological theory and animal assisted practice, social connections (relationships, attachment, empathy), researchers and practitioners. I will conclude by acknowledging this rapidly growing area and its exciting potential to impact human mental health particularly if we acknowledge and embrace the connections in the field.

120. Animal Assisted Therapy with Alpacas

J. Savage

Lower Bush Alpacas, Rochester, Kent, UK

Application: This presentation relates to the practical application and benefits for human mental health, of human animal interaction within the structured field of Animal Assisted Therapy (AAT).
Introduction: The presentation is given by Jemeela Savage, a Clinical Psychologist and alpaca owner, practising in Animal Assisted Therapy in Kent, UK.
Materials and methods: Integrative, evidence-based psychological therapy within an AAT framework. Case examples will be used to illustrate the work undertaken by the presenter. Relevant research, literature and underpinning theories will be referenced and the unique aspects of working both outdoors and with herd animals will be highlighted. Some of the considerations and challenges inherent in this kind of therapeutic work will also be discussed. In contrast, for example to canine-assisted interventions, alpacas are prey and herd animals who show clear behavioural responses to their environment, which can be used to make inferences about their internal state. The social nature of these animals combined with their reticence to interact with humans who fail to give adequate consideration to their needs lends itself to the practice of AAT, allowing individuals to share information with their therapist in a variety of ways, including through discussion of the alpacas' behaviour and personality. That the therapy takes place outdoors also adds to the experience in a number of ways including facilitating engagement, the benefit of nature for emotional well-being and encouraging people to be considerate of our natural world.
Results: Case dependent – examples of outcome will be given for the cases discussed and include decreases in low mood and anxiety as demonstrated by clinically significant changes in scores on validated measures.
Conclusion: Providing evidence-based psychological therapy within an AAT framework can promote client engagement, facilitate the development of the therapeutic relationship, and provide greater opportunities for reflection and interpretation as well as result in meaningful change for clients in terms of self-reported symptoms and progress towards collaboratively agreed goals. Further research is needed specifically in relation to camelid-assisted Therapy in order to ensure safe, effective and efficient practice.

121. Assessment of steaming over soaking commercially available Timothy hay on dry matter and hygiene parameters, intended for feeding guinea pigs

M.L. Leake *, D. Nash, S. Girdwood

Aberystwyth University, Aberystwyth, UK

* Corresponding author. M.L. Leake.

Application: Steaming commercially produced hay for feeding small herbivores is a potential solution for mitigating hay-induced disease in guinea pigs.
Introduction: Grass hay is the core component of domesticated guinea pig diets to meet daily nutritional requirements and protect dental and digestive health (Reiter, 2008; Clauss, 2012; DeCubellis and Graham, 2013). However, consuming poor hygiene quality hay can induce respiratory and digestive disease. This study investigated whether steaming or soaking, in accordance with common equine methods (Hotchkiss, 2007), improved hay hygiene without nutrient losses, and are when intended for feeding small herbivores.
Materials and methods: Hay samples from three UK-sold Timothy commercial hay brands (CHBs - Brand A, B and C) and one non-CHB hay (the control, sourced from a university equine yard) were subjected to three treatment conditions: untreated, steamed in a stovetop appliance at 100 °C for 20

minutes, or soaked in cold tap water for 10 minutes. Dry matter (DM) was quantified via oven-drying procedures (n = 16: five per brand and one control) and contaminants were counted using a haemocytometer slide (n = 13: four per brand and one control) to assess nutrient losses and hygiene changes respectively following treatment. One-way ANOVAs, Welch's T-tests and Kruskal-Wallis H-tests ($P < 0.05$) with appropriate post hoc tests were used to compare untreated and treated values to explore the post-treatment effects of steaming versus soaking. Inter-brand differences in treatment responses were also investigated to compare percentage change values.

Results: Steaming caused no significant DM losses compared to when untreated for brand B and C and significantly reduced contaminant counts for brand A and the non-CHB hay. In contrast, soaking did not significantly reduce contaminant counts for any hays and resulted in significant DM losses across the brands of 6.2 to 7.7 % compared to when untreated. Inter-brand comparisons demonstrated significant differences across CHB and non-CHB hays in contaminant changes following both steaming and soaking (Kruskall-Wallis H test: $P < 0.001$). Furthermore, branded hay lost significantly more DM after soaking than non-CHB hay (Games-Howell: $P < 0.001$ for each).

Conclusion: Steaming is a potential solution for hay-induced disease in guinea pigs by improving CHB hygiene quality without significant nutrient losses. However, due to inter-brand differences in contaminant changes after steaming, further research to characterise causational factors is essential to apply steaming effectively to all hays branded for guinea pig feeding.

Acknowledgement: The author acknowledges Aberystwyth University for enabling this study to occur as an undergraduate dissertation.

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122. Reducing GHG Emissions; Policy, Politics, Pledges and Pressure

N. Miller

R A Miller & Son Farming, RH&W, UK

Overview of UK Climate Change Policy and COP26 - the challenge for agriculture in navigating a positive path to Net Zero as demand for food rises. With the reduction of methane emissions now an urgent strategic goal what future for the ruminant sector? Will science, health or traditional husbandry underpin low emission grazing systems?

123. Policy challenges of GHG mitigation

M. MacLeod

Independent Consultant, UK

Globally, food security has improved markedly over the last 20 years. Economic development has enabled hundreds of millions of people to escape from monotonous, nutrient-deficient diets. However, this has also led to increases in the greenhouse gas emissions from food supply chains. The demand for all the main livestock commodities is forecast to continue increasing over the next 20 years. Meeting this demand without significant increases in GHG emissions requires that the emissions per unit of output are reduced (or mitigated). This talk will flag up some promising mitigation measures and discuss challenges they raise for policy.

124. Microbiome-driven breeding to reduce methane emissions from beef cattle

R. Roehe

Scotland's Rural College, UK

Emissions of the highly potent greenhouse gas (GHG) methane (28 times of CO2) contribute globally to about 39% of the total GHG emissions associated with livestock production and is produced mainly by cattle. Methane is an unnecessary by-product of microbial conversion of feed in the cow's largest stomach, the rumen, by methanogenic microbes (Archaea) and released through the animal's mouth and nose into the environment. Our research highlights that improvement of specific metabolisms, associated with essential microbial conversion of human inedible feed like grass by the ruminal microbiome (bacteria, protozoa, fungi, and their genes), will reduce methane emissions from cattle. These specific microbial metabolisms are reflected by the composition of the rumen microbiome which we revealed to be linked to the host cattle genome. In particular, the abundances of rumen microbial genes are highly informative to predict methane emissions. Of the abundances of 1,141 rumen microbial genes, 369 were heritable and some of these were significantly host genomically correlated to methane emissions. Because the biological functions of these microbial genes are known, interesting ruminal biological processes associated with low methane emitting cattle could be revealed. For example, high abundances of microbial genes diverting substrates necessary for methane metabolism to produce the amino acid arginine were negatively host genomically correlated (r_{gCH4} = -0.74 and -0.93) with methane emissions. Therefore, the composition of the rumen microbiome sampled from animals can be used to breed low methane emitting cattle without its extremely costly measurement. When this rumen microbiome-driven breeding for methane mitigation is intensively used in a cattle population we predicted based on data from our beef experiments, a reduction in methane emissions of up to 8% per year or cumulatively of up to 50% within 10 years. This microbiome-driven breeding can also be used to simultaneously improve the efficiency of animals to

convert grass into meat which reduces the carbon footprint of beef and increases the profitability of its production. Our research also suggests that microbiome-driven breeding and dietary intervention are additive mitigation strategies and therefore can be efficiently combined to reduce methane emissions from cattle.

125. Myth busting greenhouse gas emissions from Scottish agriculture – a SEFARI funded Fellowship

G. Miller

SRUC, Scotland

Gemma undertook a SEFARI funded Fellowship in partnership with the National Farmers' Union of Scotland (NFUS). The aim of the Fellowship was to tackle contentious issues in the discourse around greenhouse gas (GHG) emissions and Scottish agriculture. The topics identified as being the most contentious included enteric methane emissions, soil carbon sequestration in grassland (and the role animal agriculture plays in achieving it), and forestry on organic soils, but nitrous oxide emissions, upland grazing, and arable production were also tackled. Outputs from the Fellowship included summaries of the current state of research / knowledge on agricultural GHG emissions in Scotland, aimed at farmers and industry stakeholders, with accompanying infographics. This Fellowship offered the opportunity to 'myth bust' agricultural GHG emissions and to help direct efforts towards meeting net zero targets. This presentation will explore some of the findings from the SEFARI Fellowship relevant to animal agriculture as well as drawing on results from research undertaken at SRUC's Beef and Sheep Research Centre, including from the GreenCow respiration chamber facility.

126. The impact of genotypic information on changes in breeding value accuracy for health traits in meat sheep

K. Kaseja [a,*], J. Yates [b], E. Smith [b], G. Banos [a], J. Conington [a]

[a] SRUC, Easter Bush, Roslin Institute Building, Edinburgh EH25 9RG, UK
[b] The British Texel Sheep Society, Stoneleigh Park, Warwickshire, UK

* Corresponding author. K. Kaseja.

Application: Including genomic data in breeding values estimation increases the accuracy of prediction leading to increased rates of genetic gain and reduces the risks associated with making selection decisions in breeding programmes. In order to accelerate improvements in sheep footrot (FR) and mastitis (CMT), having a well-phenotyped and genotyped cohort of animals ('reference population') within a structured breeding programme is beneficial to all animals recorded within it.

Introduction: Estimated Breeding Values (EBVs)help breeders in breeding decision-making to reach their chosen breeding goals. The accuracy value reported for each EBV indicates how trustworthy the estimates are and helps to reduce the risk of making erroneous selection decisions. For traits that have low heritability, can be only measured at the end of life or are sex-limited, the accuracy values often tend to be relatively low. This study shows how the inclusion of genomic information from single nucleotide polymorphism (SNP) arrays, can increase the accuracy of prediction of breeding values.

Materials and methods: A dataset containing 10,193 sheep genotypes, and 4,787 CMT, and 9,123 FR records collected on 30 farms between 2015 and 2019 was used in this research. Animals were genotyped using four different density SNP arrays from Illumina: OvineHD, OvineSNP50, OvineLD and OvineLD2. The SNP data were subjected to standard quality control procedures including removing genotypes with a call rate $<89.4\%$, minor allelic frequency < 0.05, not in Hardy–Weinberg Equilibrium ($P > 0.01$) or failing the parentage check using Hayes (2011) methodology. Remaining genotypes were imputed to a subset of 45,686 most informative SNPs from OvineSNP50 using FindhapV3 (VanRaden, 2011). Both CMT and FR phenotypes were expressed on a 0-4 scale and analysed as the sum of the scores for two sides of the udder (max = 8 CMT) or the four hooves (max = 16 FRT), and normalised using Log_e (sum score + 1) (McLaren et al. 2018). Breeding values were estimated using conventional BLUP including only pedigree data as well as single-step BLUP (SS-BLUP) by including the genomic information.

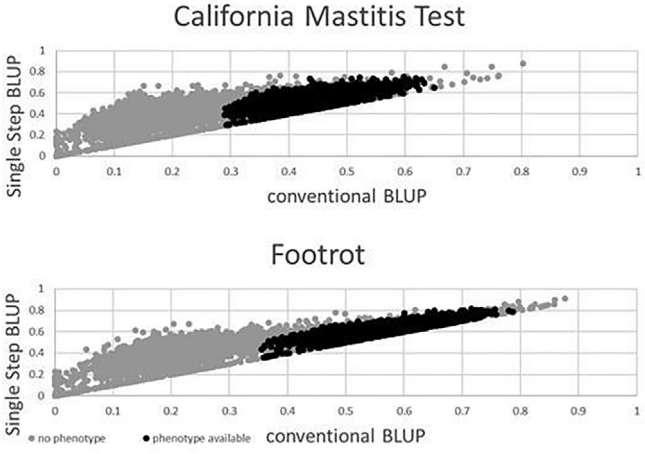

Figure 1. The relationship between EBV accuracies estimated using conventional BLUP and single-step BLUP.

Results: Figure 1 shows the relationship between the EBV accuracies from conventional vs SS-BLUP analyses. The average unit increase in accuracy (0 to 1 scale) for CMT and FR, respectively, was 0.06 and 0.08 for phenotyped and 0.14 and 0.21 for non-phenotyped animals. The maximum accuracy gain was estimated to be 0.30 and 0.18 for phenotyped animals and 0.52 and 0.47 for non-phenotyped animals, for CMT and FR, respectively.
Conclusion: Animals without phenotypic data gain the most in EBV accuracy when genotypic information is included into the estimation of breeding values. Improving both genotyping and phenotyping would enhance the accuracy of genetic evaluations.

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127. Sheep rumen volume as a methane proxy – terminal sire breed comparison and relationships with breeding values for production traits

N. Lambe [a,*], J. Gordon [b], K. McLean [b]

[a] SRUC, Crianlarich, West Perthshire, UK
[b] SRUC, Edinburgh, Midlothian, UK

* Corresponding author. N. Lambe.

Application: Reticulo-rumen volume can be used in sheep breeding programmes as a proxy for methane emissions, to help reduce GHG output from the national flock.
Introduction: Increased volume of the reticulum and rumen (RRvol), measured by CT scanning, and is associated with increased methane emissions (Goopy et al., 2014; Lambe et al., 2019). Relative to live weight, RRvol differs between divergent breeds and is moderately heritable (Lambe et al., 2021), suggesting potential to alter RRvol, hence methane emissions, by breeding. This study compares RRvol between terminal sire breeds and investigates within-breed relationships with estimated breeding values (EBV) for production traits.
Materials and methods: CT images from ram lambs, scanned within the national breeding programme, were analysed to measure RRvol (Lambe et al., 2021). Five breeds were represented – Charollais (CHAR), Hampshire Down (HD), Meatlinc (ML), Suffolk (SUFF), Texel (TEX) (Table 1). Lambs were CT scanned in 2019, except for 43 Meatlinc in 2017 and 27 Meatlinc in 2020, to provide sufficient data per breed. Mixed model linear regression (Genstat, VSN International, 2015) investigated breed effects on RRvol, fitting a covariate of live weight (model A) or age (model B) at scanning, and a random flock effect. Interactions of each covariate with breed were tested, but was only significant and retained in model A. The effects of EBVs for production traits (from Sept. 2021 genetic evaluations; Table 2) on RRvol were tested within-breed, fitting each EBV (or index value) individually with live weight and flock in the fixed effects model.
Results: Adjusting for live weight, CHAR and TEX had significantly smaller RRvol than HD lambs (average 13 and 16% smaller), with SUFF and ML not significantly different from other breeds (Table 1). Adjusting for age, TEX and ML had significantly smaller RRvol (by 10-23%) than other breeds.

Table 1
Number of lambs and flocks per breed and least-squares means for RRvol.

Breed	n lambs	flocks	LS mean RRvol (l) Model A	Model B
CHAR	129	16	6.941[a]	7.699[b]
HD	102	15	7.966[b]	8.156[b]
ML	98	4	7.948[ab]	6.251[a]
SUFF	106	14	7.467[ab]	7.435[b]
TEX	265	34	6.726[a]	6.706[a]

Values within column sharing a superscript are not significantly different ($P < 0.05$).

Table 2
Regression coefficients - change in RRvol (l) per EBV unit increase

EBV	CHAR	HD	ML	SUFF	TEX
Scan weight	-	-	-	-	-
Ultrasound fat depth	-0.690**	-	-0.910**	-	-0.503**
Ultrasound muscle depth	-0.233*	-	-	-	-0.228**
CT Fat weight	-0.663*	-	-	-	-
CT Lean weight	-	-	-	-	-
CT Muscularity	-	-0.169*	-	-	-
CT Eye muscle area	-0.307***	-	-	-	-0.246***
Terminal Sire Index	-0.007***	-	-	-	-0.003*

* <0.05, ** <0.01, *** <0.001, - non-significant

Lower EBV values for fat, muscle and muscularity traits tended to be associated with higher RRvol measurements, although effects of the EBVs on RRvol often fell below significant levels, especially in SUFF, ML and HD (Table 2).

Conclusion: Significant terminal sire breed differences (10-23%) were identified for RRvol, at a fixed age or live weight. Elsewhere, within-breed selection on methane emissions found that a 20% RRvol reduction was associated with an 11% methane reduction (Rowe, 2021). Smaller RRvol was generally associated with higher composition and muscularity EBVs, suggesting no trade-off with these production traits within-breed.

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128. Estimation of In Vitro Ammonia Emissions from Stored Sheep Manure using Nitrogen Isotopic Fractionation

H. Khanaki [a,*], R. Dewhurst [b], B. Leury [c], S.Y. Song [a], L. Cheng [a]

[a] The University of Melbourne, Dookie Campus, Victoria, Australia
[b] Scotland's Rural College (SRUC), Edinburgh, UK
[c] The University of Melbourne, Parkville Campus, Victoria, Australia

* Corresponding author. H. Khanaki.

Application: Nitrogen isotopic fractionation (known as $\delta^{15}N$; ‰) may be used directly to estimate in vitro ammonia emission from stored sheep manure.

Introduction: Estimation and mitigation of ammonia emissions from manure is urged to support sustainable development of the livestock industry. Changes in the $\delta^{15}N$ of manure and their relationship with cumulative ammonia emissions may be useful to estimate emitted ammonia from livestock manure. Hristov et al. (2009) showed there was a positive relationship between manure $\delta^{15}N$ and cumulative ammonia emissions from cattle manure during a 14-day in vitro incubation period ($P < 0.001$, $r^2 = 0.76$). However, Lee et al. (2011) showed the positive relationship between cattle manure $\delta^{15}N$ and cumulative ammonia emission was sustained only for the first 6 days of a 30-day in vitro incubation. The discrepancy between Lee et al. (2011) and Hristov et al. (2009) is likely because the urine to faeces ratio difference, as it is one of the major factors that influences manure ammonia emission. Therefore, this study aimed to establish the relationship between $\delta^{15}N$ of sheep manure and cumulative ammonia emissions from samples differing in urine to faeces ratio.

Materials and methods: Four sheep were used as donors of urine and faeces during a 21-day nitrogen balance study (6 days collection). For sample collection, sheep were housed in individual metabolic cage, and a bucket with a layer of plastic mesh was placed under the drainage channel of each cage to retain faeces. No preservative was used for urine and faeces. An acid trap based in vitro sheep incubation system was set up, similar to that used by Lee et al. (2011). The experiment was conducted for 10 days and designed to look at the effects of altering volume of urine to faeces ratio (i.e., 1.85 for Control group vs. 1.28 for treatment group). Each group had 5 replications and each replication contained 462 g and 534 g of manure for Control and treatment, respectively. Daily manure sub-samples and acid trap samples were collected to quantify $\delta^{15}N$ and ammonia emissions, respectively. All data were analyzed by polynomial regression analysis in GenStat.

Results: Manure $\delta^{15}N$ was highly correlated with the cumulative ammonia emission (Figure 1, $n = 100$, $r^2 = 0.73$, $P < 0.001$; $Y = -0.0177\ X^2 + 0.3851\ X - 0.9158$, while Y = cumulative ammonia emission (ranged from 0.17 g to 1.15 g) and X = manure $\delta^{15}N$ (ranged from 2.9 ‰ to 8.8 ‰).

Conclusion: There is a potential use of manure $\delta^{15}N$ to estimate in vitro ammonia emission from sheep manure over 10-day incubation periods.

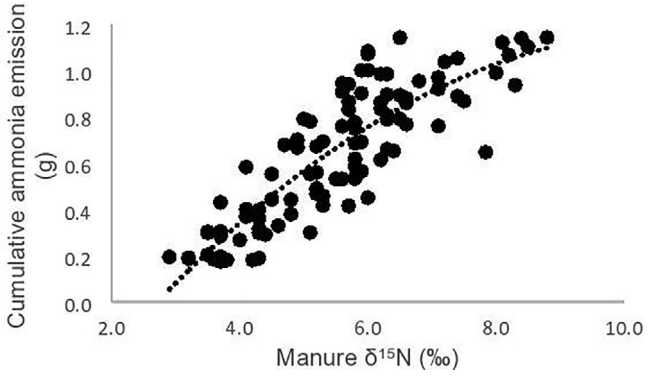

Figure 1. The relationship between manure $\delta^{15}N$ (‰) and cumulative ammonia emission (g/vessel/day).

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129. The genetics of body condition score in Scottish Blackface hill ewes

A. McLaren [a,*], N. Lambe [a], J Conington [b]

[a] Scotland's Rural College, Crianlarich, Perthshire, UK
[b] Scotland's Rural College, Edinburgh, Midlothian, UK

* Corresponding author. A. McLaren.

Application: This preliminary study suggests there is potential to include body condition score traits into future breeding programmes to improve the resilience of Scottish Blackface hill ewes.
Introduction: Body condition scoring is a relatively quick and simple tool that farmers can use to monitor and manage their ewes. The aim of this study was to estimate genetic parameters for body condition score (BCS) in Scottish Blackface hill ewes at, and between, different handling events throughout the year.
Materials and methods: Data were available from 8,335 ewes reared on two extensively managed hill farms between 1999 and 2019. Traits investigated were BCS at: pre-mating (PBCS; n = 23,903 records); pregnancy scanning (SBCS; n = 20,691 records); pre-lambing (LBCS; n = 13,364 records); mid-lactation (MBCS; n = 13,198 records) and weaning (WBCS; n = 20,567 records). Differences in BCS between handling events was also investigated (Gain). BCS was assessed on a 1-5 scale, as described by Russel et al. (1969). Ewes empty at pregnancy scanning were not included in LBCS, MBCS and WBCS analyses. Genetic parameters and correlations (genetic and phenotypic) were estimated using univariate and bivariate analyses respectively in ASReml (Gilmour et al., 2015). Fixed effects fitted in the model were: ewe age + farm + year + number of lambs + (farm x year) + (farm x ewe age). Interaction terms representing contemporary groups. Number of lambs was the number the ewe was rearing/carrying at each event (not fitted for PBCS). BCS at the initial event was included in the Gain models. Random effects included direct genetic and permanent environment (environmental factors affecting the successive records of an individual). Due to problems with convergence, permanent environment effects were not fitted for WBCS. The pedigree file included sire and dam information for 45,697 animals.
Results: The highest and lowest average BCSs (s.d.) were recorded at pre-mating and mid-lactation and were 2.91 (0.37) and 2.62 (0.40) respectively. Heritabilities estimated for each event, and the genetic and phenotypic correlations between traits, are given in Table 1. The heritabilities estimated for the different Gain traits ranged from 0.07 - 0.12 (all s.e. 0.01).
Conclusion: Most of the traits investigated were heritable, suggesting scope for future genetic selection. The high genetic correlations observed indicate similar genes are involved. The next step will be to assess the relationships between these traits and those associated with ewe performance and litter survival.

Acknowledgments: This work was funded as part of the EU's Horizon 2020 research and innovation programme under Grant Agreement number 772787 (SMARTER). The authors are also grateful for financial support from the Scottish Government's Rural and Environmental Science and Analytical Services Division. Thanks also to farm and technical staff involved in data collection.

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Table 1
Heritabilities (diagonal), genetic (above diagonal) and phenotypic (below diagonal) correlations (with s.e.).

Trait	PBCS	SBCS	LBCS	MBCS	WBCS
Pre-mating BCS (PBCS)	0.14 (0.01)	0.83 (0.03)	0.74 (0.04)	0.82 (0.04)	0.15 (0.21)
Pregnancy Scanning BCS (SBCS)	0.49 (0.01)	0.18 (0.01)	0.94 (0.02)	0.75 (0.04)	0.23 (0.21)
Pre-lambing BCS (LBCS)	0.40 (0.01)	0.53 (0.01)	0.16 (0.02)	0.80 (0.04)	0.05 (0.24)
Mid-lactation BCS (MBCS)	0.27 (0.01)	0.32 (0.01)	0.39 (0.01)	0.12 (0.01)	0.37 (0.21)
Weaning BCS (WBCS)	0.01 (0.01)	0.001 (0.01)	0.01 (0.01)	0.01 (0.01)	0.003 (0.003)

130. A longevity related trait suitable for the genetic evaluation of Merinoland sheep

B. Fuerst-Waltl [a,*], C. Fuerst [b]

[a] University of Natural Resources and Life Sciences, Vienna, Vienna, Austria
[b] ZuchtData EDV-Dienstleistungen GmbH, Vienna, Austria

* Corresponding author. B. Fuerst-Waltl.

Application: The current total merit index (TMI) of sheep shall be extended by the inclusion of the trait longevity. Trait definition and genetic parameter estimation are first steps towards this goal.

Table 1
Number of animals and mean, standard deviation, minimum and maximum for the number of lambings in the defined periods (540/1080/1620/2160/2700 days).

Period	N	Average number of lambings	Standard deviation	Minimum	Maximum
1	14 044	2.28	0.69	1.00	4.00
2	12 642	3.59	1.40	1.00	6.00
3	11 565	4.35	2.13	1.00	9.00
4	10 670	4.48	2.48	1.00	9.64
5	10 507	4.48	2.53	1.00	10.05

Table 2
Heritabilities (on diagonal) and genetic correlations (above diagonal) for the number of lambings in the defined periods (540/1080/1620/2160/2700 days).

Period	1	2	3	4	5
1	0.04	0.98	0.83	0.73	0.66
2		0.03	0.85	0.83	0.78
3			0.03	0.99	0.98
4				0.03	1.00
5					0.03

Introduction: In 2017, official breeding values for sheep and goat breeds were published in Austria for the first time. The TMI for sheep with a focus on meat production, including the non-seasonal land sheep breed Merinoland (Fuerst-Waltl and Fuerst, 2021), comprises the traits average daily gain (direct and maternal), muscle depth, fat depth, lambing interval, lambs born and lambs born alive (maternal and paternal). In the current breeding objective, however, longevity, an essential trait from the complex of functional traits, is missing. While survival analysis has been the 'state of the art' method for a long time, particularly in dairy cattle breeding, many newly established routine genetic evaluations rely on linear models (e.g. Heise and Simianer, 2019). The aim of this work was therefore to define a longevity related trait for Merinoland sheep that can be implemented in routine breeding value estimation based on linear models.
Materials and methods: In a first step, 5 cumulative periods were defined from the first lambing onwards. The target trait is the number of lambings in the periods, i.e. 540, 1080, 1620, 2160 and 2700 days. According to the concept of Brotherstone et al. (1997), the last unfinished period of animals that are alive is considered by extrapolating their expected performance. All other periods are subsequently set to missing for these animals. In the model for genetic parameter estimation, the fixed effects age at first lambing, year-month and herd as well as the random effect herd-year are considered.
Results: Table 1 shows the number of animals, as well as the mean, standard deviation, minimum and maximum of the defined trait in the individual periods. For period 5, up to 2700 days after the first lambing, between 1 and bout 10 lambings could be observed, the mean is 4.48. Table 2 shows the heritabilities and genetic correlations for the target trait, number of lambings in a defined period. Both the heritabilities (h^2 = 0.03 to 0.04) and the genetic correlations (r_a = 0.66 to 1.00) lie within a reasonable range and are consistent.
Conclusion: The target trait analysed seems to be well suited representing longevity. It shall be included in the TMI, considering selected auxiliary traits. The potential selection response, based on model calculations, will be the basis for weighting in the TMI.

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131. Using Commercial PLF Data to Deploy a Resilience Index for Herd Level Advice

J. Statham

RAFT Solutions, UK

Novel proxies were developed for resilience using already existing at-market technology to maximize the cost-efficiency of sensor technologies and obtain reliable phenotypes of complex traits. Definitions and ways to calculate resilience outcomes were lacking; methodology had to be objective and valid to a dairy expert so appropriate ranking of the cows for these traits on farm was possible. For resilience, a combination of longevity, health, robustness, production and reproduction performance had to be considered. This resulted in the following definition for ranking cows: “resilience is the cumulative result of a cow’s ability to recalve (and thus, to extend her productive lifespan), supplemented with secondary corrections for age at first calving, calving intervals, 305-day milk yield, health events and number of inseminations. Different weightings of the included variables were proposed and cross-validated to produce a common equation to calculate the resilience scores. The highest weight was given to the number of parities. One of the main challenges in this work was the availability, completeness and reliability of the data. Sensor technologies record parameters reflecting animals’ performance, behaviours and physiological state. Besides the classical use for event detection, the resulting time series can be characterized to provide information on how animals have performed over time. Two types of sensor features were defined. Type A sensor features generally characterize the sensor measurements relative to the herd peers, and include milk yield, body weight, rumination and activity. Type B sensor features specifically target the identification of dynamics in the time series indicating certain health or fertility events. Several primary algorithms to predict the

resilience and efficiency rankings from the sensor features were tested. These algorithms were deployed to design software that could signal herd level change in resilience and thus provide an evidence base for practical changes in herd management policies.

132. The effects of climate change on UK beef production

H. Bunning

SRUC, UK

We expect beef cattle traits to be affected by the weather the cattle experience, but studies which investigate the effect of weather across the lifetime of an animal are rare and these results are hugely important when modelling the resilience of beef production, especially in the face of climate change.

To predict how a changing climate will affect beef production, firstly, we combined carcass data for over 1.7 million animals from abattoirs, animal location data from BCMS and UK MetOffice HadUK-Grid. Statistical models for each carcass trait (age at slaughter, cold carcass weight, conformation, fat class and growth rate) were produced to estimate the effects of three daily weather parameters (precipitation, maximum temperature and minimum temperature) averaged across the life of the animal. Similar models were also produced to estimate the effect of number of extreme weather days (heatwaves, cold waves, dry days and wet days). Secondly, the age and weight of over 270,000 calves were extracted from the Scottish Beef Efficiency Scheme database and combined similarly with BCMS location data and HadUK-Grid weather data, to give the daily weather experienced by each calf from birth to weighing. Again, models were produced to estimate the effect of three daily weather parameters averaged across the lifetime of the animal, as well number of extreme weather days experienced, for both calf weight and calf growth rate. Results showed lifetime weather, both in terms of average weather and number of extreme days, has significant effects on a range of traits which are important for beef production. In particular, we expect an increase in extreme weather frequency will have a significant negative impact on beef production, both reducing profits and also increasing environmental impact.

133. Practical applications of genomics in livestock farming

D. Berry

Teagasc, Ireland

Application: Genotyping of livestock is now almost ubiquitous in most territories. While many producers genotype their animals to determine parentage and obtain accurate estimates of genetic merit, other practical uses also exist. Such additional uses further improve the return-on-investment for genotyping.

Introduction: Insights into the genome of individuals can be hugely powerful in informing herd breeding and management strategies. While applications of genomics in animal breeding traditionally exploited knowledge on only a few pieces of DNA, the modern application of genomic evaluations utilises information on tens or hundreds of thousands of pieces of DNA. Platforms now exist to genotype individuals at circa. 50,000 locations across the genome at a cost of €20. Translating the generated data into information to help support decision making in livestock farming is of growing importance.

Uses of genomic information: Receiving a genomic evaluation (i.e., more accurate genetic evaluation) is one of the most common reasons for producers to genotype animals. Other uses include 1) parentage assignment, 2) estimating coancestry or inbreeding, 3) traceability, 4) quantifying breed composition, 5) monitoring of major genes and congenital defects including karyotype disorders, and 6) facilitating more precise mating and management decisions. Parent-to-offspring errors vary from 7.6% to 10.0% in sheep, from 10.18% to 13.28% in cattle, and from 8.4% to 14.6% in goats.

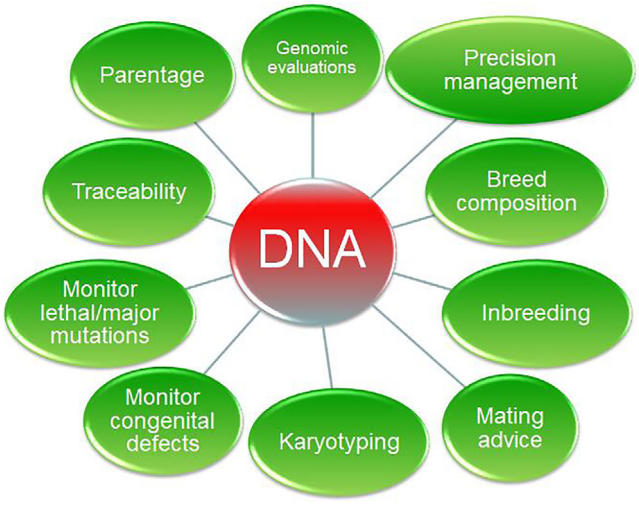

Figure 1.

Genomic information can not only correct parentage mis-recording, but can also be used to assign parents where not recorded. One of the greatest benefits of genomics in the near future will be genomic matings or *precision breeding*. Genotypes can also be used for traceability purposes; for example, the probability of two individuals carrying exactly the same genotype at 10 informative markers (i.e., a minor allele frequency of 0.5) is $5.5x10^{-5}$. The breed composition of an individual parented by at least one crossbred parent cannot be known with certainty without exploiting DNA information. Breed assignment is important to deliver on consumer expectations of traceable food products, as verification for herd-book registration, as well as commanding a higher price for products from certain breeds. Mutations in genes of known lethal effects as well as mutations leading to congenital defects or in genes of known major effect are also now routinely included on most genotyping platforms. Data generated from such genotyping platforms can also be used to detect some karyotype abnormalities especially those associated with an abnormal number of chromosomes pairs. The application of predicting (genetic) predisposition to disease is a rapidly growing discipline in human medicine, as is personalised nutrition. More accurate predictions of genetic merit through the exploitation of genomic information enables tailored management strategies where, for example, animals of greater potential for growth rate or milk yield can be fed accordingly.

Conclusion: Genomic selection, the process of incorporating DNA information into genetic evaluation systems, is improving the accuracy of estimates of animal genetic merit; this results in accelerated genetic gain. Additional uses of genomic information, however, also exist, all of which can contribute to improved performance.

134. Effect of weed presence on the crude protein and neutral detergent fibre contents of three napier grass varieties

T. Adeyemi *, V. OJo, D. Oyaniran, T. Kolajo, R. Fasasi, G. Oluseesin

Federal University of Agriculture, Abeokuta, Alabata, Ogun State, Nigeria

* Corresponding author. T. Adeyemi.

Application: In the absence of weeds, the crude protein (CP) was higher and the neutral detergent fibre (NDF) lower for the local napier grass variety. The presence or absence of weeds did not influence the CP and NDF content of the purple and F1 varieties.

Introduction: Napier grass has been identified as one of the most successful grasses for improving forage availability in the tropics; however, its yield and quality are influenced by a multitude of biotic and abiotic factors, and weeds are known to reduce the quality of forage grasses like napier grass (Ghanizadeh & Harrington, 2019). Knowledge on how the presence of weeds or absence of weeds (through weeding) impacts some quality traits (CP and NDF) of napier grass varieties is worth investigating towards fostering sustainable production.

Materials and methods: This study was conducted during the 2019 – 2020 growing season. A land area measuring 325 m^2 (13 m × 25 m) was used for this study. The napier grass varieties used in this investigation were the local, purple, and F1 varieties. The grasses were planted using vegetative stem cuttings on plots measuring 3 m × 3 m. 4 tonnes/ha of dry poultry manure was applied, due to the low soil N status (0.09 % total nitrogen). The study was a 3 × 2 factorial experiment laid out as a randomized complete block design with the three napier grass varieties and weed presence (+/-) as factors. Two harvests were done in 2019 and one harvest in 2020 (at 65 – 68 % target dry matter content). At each harvest, fresh grass sub-samples weighing 300 g were oven-dried until constant weight, milled, and allowed to pass through a 1 mm sieve screen for each treatment. The CP content of the treatment samples was determined according to AOAC (2000) and the NDF content according to (Van Soest et al., 1991). The CP and NDF data were analyzed using a two-way analysis of variance. Tukey's HSD test was used to separate the means.

Results: There were no significant ($P > 0.05$) changes in the CP content due to the presence or absence of weeds for all varieties. The local variety had the highest ($P < 0.05$) CP content, while the purple variety had the least CP content. However, the least NDF content was recorded for the local variety in the absence of weeds, while changes in the NDF content of the F1 and purple varieties in the presence or absence of weeds were marginal ($P > 0.05$).

Conclusion: CP accumulation was higher in the local napier grass irrespective of weed presence, however, in the absence of weeds, the local variety has the least NDF content. In general, the local variety emerged as the better performing variety based on CP and NDF contents. Table 1..

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Table 1
Effect of weed presence on the crude protein and NDF contents of three napier grass varieties.

Varieties	Weed	CP	NDF
F1 hybrid	Present	98.45^{b}	720.01^{ab}
	Absent	98.53^{b}	710.00^{b}
Local	Present	112.41^{a}	711.60^{b}
	Absent	134.43^{a}	667.13^{c}
Purple	Present	83.63^{c}	722.91^{ab}
	Absent	85.64^{c}	731.22^{a}
		3.89	3.65

^{a,b,c}: means on the same column with different superscripts differ significantly ($P < 0.05$). CP:.Crude protein. NDF: Neutral detergent fibre. SEM: Standard Error of Mean.

135. Effect of soil sources on the chemical composition of two Guinea grass varieties

C .Anotaenwere *, P. Dele, P. Bankole, O. Okukenu, B. Akinyemi, F. Enwete, J. Akinyode, A. Jolaosho

Federal University of Agriculture, Abeokuta, Ogun, Nigeria

* Corresponding author. C. Anotaenwere.

Application: Contaminated soils can alter the chemical composition of the plants thereby reducing nutritive quality.
Introduction: Guinea grass is recognized as an important fodder plant in the places where it is found naturally. It has played an important role in grasslands improvement and livestock feeding (Bamikole et al., 2001). It grows rapidly and occurs in abundance when grown on well-drained fertile soil. Soil is the most important component of the environment, but it is the most undervalued, misused, and abused of the earth's resources (Gokulakrishnan and Balamurugan, 2010). The aim of this study was to evaluate the effect of soil sources on the chemical composition of two Guinea grass varieties.
Materials and methods: The experiment was carried out at Federal University of Agriculture, Abeokuta, Nigeria. The study was a 3 × 2 factorial experiment in a completely randomized design comprising of two factors which are: 3 soil sources (i.e., industrial site, dump site and Fadama (a low-land around a river/stream) which was used as the control) and 2 different varieties (Guinea grass var. Local and Ntchisi) replicated four times. Soils were collected from the three sites and plating was done in a greenhouse. Samples of the dried grasses were milled and analyzed for proximate composition and fibre fraction. The statistical evaluation was done by analysis of variance (ANOVA) and separation was by Tukey HSD on 0.05 probability values using SAS® 9.0 version.
Results: The result showed that the soil source had a significant influence ($P < 0.05$) on the proximate composition and fibre fraction of the grass except for cellulose. Grasses planted on soil sourced from the industrial site had the highest crude protein content, ether extract, and ash content which differ significantly from others. Values recorded for both varieties showed that the Ntchisi variety had higher crude protein and ash content than the local variety. The Local had higher contents across all the fibre parameters determined.
Conclusion: Crude protein of the grasses planted on soil sourced from industrial site were higher than other sources.

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Table 1
Effect of soil sources on the chemical composition (%) of two Guinea grass varieties.

Factors	DM	CP	EE	ASH	NDF	ADF	ADL	HM	CL
Location									
Dumpsite	91.71	6.65^{c}	2.11^{b}	13.73^{c}	67.57^{a}	44.92^{a}	3.41^{a}	22.65^{a}	41.51
Industrial site	91.63	7.78^{a}	2.28^{a}	14.84^{a}	64.56^{b}	43.76^{b}	3.09^{b}	20.80^{b}	40.67
Fadama	91.48	7.01^{b}	2.01^{c}	14.24^{b}	65.77^{b}	43.71^{b}	3.02^{c}	22.06^{a}	40.69
SEM	0.12	0.12	0.01	0.07	0.18	0.15	0.03	0.05	0.12
Variety									
Local	91.74	6.37^{b}	2.12	13.51^{b}	66.87^{a}	44.96^{a}	3.37^{a}	21.90	41.59^{a}
Ntchisi	91.48	7.92^{a}	2.14	15.03^{a}	65.07^{b}	43.30^{b}	2.97^{b}	21.77	40.33^{b}
SEM	0.10	0.10	0.01	0.05	0.15	0.12	0.03	0.05	0.10

^{a,b,c}: Means with different superscript in each column are significantly ($P < 0.05$) different, SEM: Standard Error of Mean, DM: Dry matter, CP: Crude protein, EE: Ether extract, NDF: Neutral detergent fibre, ADF: Acid detergent fibre, ADL: Acid detergent lignin, HM: Hemicellulose, CL: Cellulose.

136. Crude protein and neutral detergent fibre contents of Megathyrsus maximus as influenced by plant spacing and phenological stages

D.K. Oyaniran *, L.N. Azubuike, V.O.A. Ojo, T.A. Adeyemi, M.E. Ilegbedion, G.A. Oluseesin

Federal University of Agriculture, Abeokuta, Abeokuta, Ogun State, Nigeria

* Corresponding author. D.K. Oyaniran.

Application: Narrow spacing of Megathyrsus maximus resulted in higher crude protein and lower neutral detergent fibre contents than wider spacing. The quality of the grass declined rapidly at the late reproductive stage.

Introduction: Harvesting tropical grasses like M. maximus at more advanced stages has been reported to favour biomass accumulation, however, the corresponding quality loss makes the trade-off quite expensive especially when high producing pregnant and lactating cows are the target animals (Aganga et al., 2004). Spatial planting operations like plant spacing has been reported to influence plant yield and quality traits. The dominant hypothesis is that wider spaced plants tend to be of better quality than narrow spaced plants, because of reduced competition when plants are widely spaced

Table 1
Effects of planting spacing and phenological stages on crude protein and neutral detergent fibre of Megathyrsus maximus (g kg^{-1} DM).

			CP				NDF	
Plant spacing	VEG	EAL	LAT	SEM	VEG	EAL	LAT	SEM
1 m × 1 m	88.17^{a}	67.99^{Bb}	45.61^{Bc}	12.29	664.06^{Ac}	678.91^{ab}	740.10^{Aa}	23.27
0.5 m × 1 m	90.07^{a}	68.50^{Bb}	45.72^{Bc}	12.80	665.32^{Ab}	677.31^{ab}	706.81^{ABa}	12.33
0.5 m × 0.5 m	91.67^{a}	74.26^{Ab}	57.03^{Ac}	10.00	616.94^{Bb}	673.78^{a}	683.41^{Ba}	20.74
SEM	1.01	2.01	3.79		15.92	1.52	16.45	

^{a,b,c} means on the same row with different superscripts are significantly different ($P < 0.05$); ^{AB} means on the same column with different superscripts are significantly different ($P < 0.05$); VEG: Vegetative stage; EAL: Early reproductive stage; LAT: Late reproductive stage; CP: Crude protein; NDF: Neutral detergent fibre; SEM: Standard Error of Mean.

(Tilahun et al., 2017). This therefore raises a possibility that wider plant spacing could possibly curtail quality losses associated with harvesting tropical grasses at more matured stages.

Materials and methods: The experiment was 3 × 3 factorial design and replicated three times. M. maximus grass was planted at three plant spacing (0.5 m × 0.5 m, 0.5 m × 1 m and 1 m × 1 m) and harvested at three phenological stages (vegetative – 8 weeks, early reproductive – 11 weeks, and late reproductive stages –13 weeks). The grasses were harvested at each phenological stages at 15 cm above ground level, and sub-samples were oven dried at 65 °C until constant weight, milled, and allowed to pass through a 1 mm sieve screen. The samples were analyzed to determine their CP content according to AOAC (2000) and NDF content according to Van Soest et al. (1991). Data were subjected to two way-analysis of variance and treatment means were separated using Tukey's HSD test.

Result: A significant decline in the CP and a corresponding increase in the NDF content were recorded as M. maximus matured across the phenological stages. The effect of the plants spacing was significant on the CP of the plants at the early and late reproductive stages, and on the NDF content at the vegetative and late reproductive stages. The 0.5 m × 0.5 m spaced plants had higher CP and lower NDF contents (Table 1).

Conclusion: Planting M. maximus at 0.5 m × 0.5 m favoured the accumulation of higher CP and lower NDF contents than the other plant spacing. Also, harvesting M. maximus beyond the vegetative stage resulted in lower CP and higher NDF contents accumulation.

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137 Protein fractions of Elephant grass as influenced by age at harvest and plant spacing

O. Aiyesa [a,*], P. Dele [a], B. Akinyemi [a], F. Enwete [a], O. Awoola [a], A. Adekeye [b], O. Arigbede [a]

[a] Federal University of Agriculture, Abeokuta, Ogun, Nigeria
[b] International Livestock Research Institute, Ibadan, Oyo, Nigeria

* Corresponding author. O. Aiyesa.

Application: Planting Elephant grass with wider plant spacing could allow better forage productivity, and harvesting should be best carried out at an early stage of planting for better nutrient quality.

Introduction: Elephant grass is one of the important forage grasses for pastures in the tropics and is used as one of the major feeds for ruminants (Asmare, 2016) with high production potential under a multi-cut harvesting regime. Animal performance mainly depends on the quantity and quality of forage available to livestock. It is important to determine the nutritional value of forages, because effective livestock production is related to the amount of nutrients in the forage. Therefore, this study was aimed to determine the effect of age at harvest and plant spacing on the protein fractions of Elephant grass.

Materials and methods: This study was carried out at Federal University of Agriculture, Abeokuta, Nigeria. A total land area of 1196 m^2 was used for the experiment and was laid out in a 2 × 2 factorial, arranged in a split plot design consisting of the main plot (age at harvest) and the sub plot (plant spacing). The experiment involved 4 treatments (3 week, 6 week age at harvest and 1 m × 1 m, 1 m × 0.5 m plant spacing) with five replicates. Dried and milled samples were analyzed for crude protein and protein fractions were determined according to modified procedures proposed by Licitra et al. (1996). The statistical evaluation was done by analysis of variance (ANOVA) and separation was by Tukey HSD on 0.05 probability values using SAS® 9.0 version.

Results: The results showed a significant ($P < 0.05$) decrease in the crude protein (CP) with age as well as a decrease as the planting space narrowed as well as the interactions. The protein fractions were affected by both harvest age and plant spacing except for B1 and B2. Fraction B3 and C content of the grass at 3WAC was higher. Fraction A (1.09%) content of the grass at 6WAC was higher than that harvested at 3WAC. The grass planted with 1 m × 1 m plant spacing had the highest value of all the protein fraction content. Crude protein (CP), nonprotein nitrogen (fraction A), true protein rapidly degraded in the rumen (fraction B1), true protein degraded in the rumen at a moderate rate (fraction B2), true protein associated with the cell wall and slowly degraded in the rumen (fraction B3)and insoluble protein (fraction C), weeks after cutback (WAC), standard error of mean (SEM).

Conclusion: Advanced age at harvest and narrower plant spacing had negative effect on the nutrient composition of Elephant grass. Grass spacing at 1 m × 1 m had the higher CP and protein fractions whereas as the plant advanced in age, the quality of the grass decreased.

Table 1
Effect of plant spacing and harvest age on the protein fractions of Elephant grass.

Factors		CP	A	B1	B2	B3	C
Harvest age (WAC)	Plant spacing						
3		16.36[a]	1.01[b]	0.07	0.35	0.79[a]	0.26[a]
6		15.71[b]	1.09[a]	0.07	0.34	0.66[b]	0.19[b]
SEM		0.08	0.01	0.01	0.01	0.01	0.00
	1 m × 1 m	17.18[a]	1.09[a]	0.08[a]	0.37[a]	0.80[a]	0.26[a]
	0.5 m × 1 m	14.89[b]	1.00[b]	0.07[b]	0.32[b]	0.65[b]	0.20[b]
	SEM	0.04	0.01	0.00	0.00	0.01	0.01
Interaction effect							
3	1 m x1m	17.68[a]	1.05[b]	0.08[a]	0.35[b]	0.89[a]	0.31[a]
6		16.68[b]	1.13[a]	0.07[b]	0.39[a]	0.72[b]	0.20[b]
3	0.5 m × 1 m	15.05[c]	0.97[c]	0.07[b]	0.35	0.69[b]	0.21[b]
6		14.73[c]	1.04[b]	0.07[b]	0.29[c]	0.60[c]	0.18[c]
SEM		0.30	0.02	0.00	0.00	0.02	0.01

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138. Evaluation of antimicrobial activity and cytotoxicity of plant leaves extracted from vangueria infausta, eucalyptus globulus and peltophorum africanum

P.M. Moshidi [a,*], M.C. Muya [b], J.F. Mupangwa [c]

[a] UNISA, Johannesburg, Roodeport, South Africa
[b] SACNASP, Pretoria, Pretoria, South Africa
[c] University of Namibia, Windhoek, Namibia

* Corresponding author. P.M. Moshidi.

Application: Evaluation of antibacterial activity and level of cytotoxicity of plant extracts as alternative feed additive to livestock.
Introduction: The prevalence of microbial diseases and their complications are continuously increasing throughout the world mainly due to microbial drug resistance caused by the use antimicrobials as feed additives in livestock (WHO, 2014). The aim of the study was to determine the antibacterial activities and cytotoxicity of plant leaves and essential oils extracted from V. infausta, E. globulus and P. africanum.
Materials and methods: Leaves of three plants were harvested in bushveld, at Ga-Masemola village in Makhuduthamaga local municipality in South Africa. Antibacterial activity leaves extracts was tested using microtiter wells with Mueller–Hinton broth and minimum inhibitory concentration (MIC) assays, bacteria were isolated form the rumen liquor of Holstein lactating cow, while cytotoxicity effect was determined using XTT colorimetric assay. Mean values for MIC and concentration of cytotoxicity were subjected to ANOVA and the significant differences between the means ($P < 0.05$) were determined by the PROC GLM Procedure (SAS 9.1 for Windows; SAS Institute, Cary, NC).
Results: The antibacterial activity of plant extract of V. infausta concentration ranging from 0.39-1.56 mg/ml in gram positive bacteria, and 0.78–1.56 mg/ml in gram negative bacteria. Extracts of E. globulus concentration range between 0.39–1.56 mg/ml in gram-positive bacteria and 0.19–0.78 in gram-negative bacteria. Extracts of P. africanum concentration range between 6.25–12.5 mg/ml in gram-positive bacteria and 3.12 to 12.5 mg/ml in gram-negative bacteria. Essential oil extracts of E. globulus concentration range between 6.25–12.5 mg/ml in gram-positive bacteria and 3.12 to 12.5 mg/ml in gram-negative bacteria. However, *Acidaminococcus fermentans and Klebsiella variicola* bacteria showed no activity in E. globulus essential oil extracts. The evaluation of cytotoxic on Vero cell line by XTT assay resulted in IC_{50} values ranging from 325.8 to > 400 μg/ml for all tested plant extracts.

Table 1
Antibacterial activity of plant extracts (MIC) mg/ml by broth micro dilution testing.

Tested plant (leaves)	Nature	Gram +				Gram -			
		E. vlikiensis	*S. lutetiensis*	*S. azabuensis*	*E. harae*	*E. cloacae*	*A. fermentans*	*K. variicola*	*E. coli*
V.infausta	Crude extract	0.78	0.39	0.78	1.56	0.78	1.56	1.56	0.78
E.globulus	Crude extract	0.39	0.19	0.39	1.56	0.19	0.19	0.78	0.78
P.africanum	Crude extract	6.25	12.5	12.5	12.5	3.12	12.5	12.5	12.5
E.globulus	Essential oil	6.25	12.5	6.25	6.25	12.5	na	na	3.12

Conclusion: The systematic evaluation of cytotoxic activities of aqueous extracts V. infausta, E. globulus, P. africanum, and essential oil of E.globulus has shown no toxicity on Vero cell lines, suggesting that these plants extracts could be used as animal feed additives to modulate rumen microorganisms and rumen fermentation. Such plant extracts might have a great potential as antimicrobial compounds acting against microorganisms.

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139. A detailed analysis of consultations between equine nutritionists and a client

K. Williams *, P. Hastie, J.A. Murray

University of Glasgow, Glasgow, UK

* Corresponding author. K. Williams.

Application: This detailed analysis of client consultations compares the effectiveness of independent and commercially employed equine nutritionists in advising clients on managing ponies with potential to become obese. Raising the issue of obesity, clarity of advice given and empathy rating by the client were measured providing insights as to how professionals can improve consultations with clients.

Introduction: Obesity is prevalent in the UK equine population and failure to recognize the issue has been reported (Ireland et al., 2012). Health care professionals are often reluctant to raise the issue of obesity (Swift et al., 2013). The ability of physicians to demonstrate empathy with clients and clarity of recommendations are associated with positive health outcomes in people and animals (Kipperman and German, 2018). Commercially employed equine nutritionists are often perceived to be incentivized to sell products. This study set out to compare the effectiveness of consultations by independent and employed equine nutritionists exploring language used, their ability to empathize with the client, clarity of advice given and whether employed nutritionists were commercially motivated.
Materials and methods: Independent nutritionists were identified via an internet search and personal contacts of the researcher were invited to participate as employed nutritionists. The 6 nutritionists ranged in experience from 3 to 15 years and were qualified to at least degree level. The consultations were conducted at the client's stable yard or via video conferencing. All consultations were recorded and transcribed anonymously for qualitative data coding using NVivo Pro 12. Transcriptions of the consultations were analyzed using RIAS (Mercer, 2005) - a quantitative medical communication coding system. The client assessed the nutritionists using a CARE (McHale et al., 2019) system developed to measure medic's empathy.
Results: Consultations by independent nutritionists tended to be longer and contain more relationship building. All nutritionists highlighted the potential for the ponies to gain weight and gave general advice about weight management. All nutritionists stated the current diet was appropriate and made suggestions for future changes. One employed nutritionist mentioned a product but did not ask the client to purchase it. All nutritionists scored highly for human empathy. Euphemistic, humorous language (squidge, wobbling) was used by all nutritionists.
Conclusion: Equine nutritionists raised the issue of obesity. None tried to change the existing diet or sell products suggesting commercial nutritionists are not just commercially motivated. High scores for empathy suggest their clients are more likely to follow advice. Humorous, euphemistic language was used which helps to build relationships but further research is required to determine whether it conveys the seriousness of obesity. The weaker area in consultations was clarity of actions highlighting the potential to create more specific guidance for monitoring weight and body fat status in horses.

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140. Does dietary vitamin D3 or UVB wavelength improve the welfare indicators of broiler chickens challenged with social isolation stress?

A. Ogbonna [a,b,*], A. Chaudhry [a], L. Asher [a]

[a] Agriculture Building, School of Natural and Environmental Sciences, Newcastle University, Newcastle Upon Tyne, UK
[b] Department of Animal Production and Livestock Management, College of Animal Science and Animal Production, Michael Okpara University of Agriculture, Umudike, Abia, Nigeria

* Corresponding author. A. Ogbonna.

Table 1
Effects of dietary vitamin D_3 and UVB light on gait and feather score of broiler chickens GS: gait score; FS: feather score; SEM: Standard error of the mean.

Treatment	HD	UVB	SEM	P-value	Non-Isolated	Isolated	SEM	P-value
GS (d23)	0.56	0.56	0.026	1.000	0.44	0.69	0.10	0.07
GS (d37)	1.58^{a}	1.19^{b}	0.106	0.013	1.26	1.50	0.11	0.12
FS (d22)	23.48^{b}	26.88^{a}	1.103	0.031	26.37	23.98	1.10	0.13
FS (d35)	70.76^{b}	74.38^{a}	1.160	0.033	75.16^{a}	69.98^{b}	1.16	0.03

Application: UVB light possesses beneficial effects on welfare indicators of broilers.
Introduction: Stressors are commonly encountered by all farmed species, including chickens, but the impact of these stressors can be influenced by the environmental conditions in which they are kept. These may cause stress with secondary impacts on welfare (Carvalho et al., 2018). Vitamin D_3 is required for optimal performance and can be produced in the skin through ultraviolet-B (UVB) irradiation or absorbed from the diet (Edwards, 2003). Therefore, the objective of this study was to determine the effects of dietary vitamin D_3 and UVB light on feather and gait score of broilers challenged with social isolation stress.
Materials and methods: All procedures were conducted after obtaining approval from the Animal Welfare and Ethical Review Body (AWERB ID: 806), Newcastle University. One day old Ross 308 broiler chicks (n = 128) were weighed and allocated to a dietary vitamin D_3 (control) at 4000 IU/ kg (HD) or a UVB light to evaluate feather and gait score of broilers. Each treatment had 8 replicate pens, each containing 6 broilers, in a 2 × 2 factorial design. Birds were individually gait scored (days 23/37) and feather scored (days 22/35) to determine welfare. Broilers were divided into non-isolated (control) and isolated groups; the isolated broilers were subjected to regular sessions of isolation by putting in a plastic/storage box for 15-minutes daily for 3 days/week for 2 weeks starting from day 10 (90 minutes total isolation) with inter isolation intervals of 48 hours. They had vocal contact but no physical contact with other birds under isolation. Thus, exposing them to a combination of capture, handling, isolation and no access to feed and water. UVB lamps with wavelength: 280–315 nm, intensity; 28.12 μW/cm^2 hung 50 cm above the substrate were used with the lighting schedule of 23L:1D (1–7 days) and 18L:6D (8 to 42 days) in all the treatment groups but were filtered to remove UVB in HD group. Data was analysed using the analysis of variance of SAS 9. 4 software.
Results: UVB and non-isolated birds had better ($P < 0.05$) gait and feather scores compared to their counterparts (Table 1).
Conclusion: UVB light was beneficial to support the welfare of broilers despite physiological challenges.

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141. Effect of plumage colour on performance of Nigerian indigenous chickens

O.D. Osunbayo, O.E. Oke

Federal University of Agriculture, Abeokuta, Abeokuta, Ogun, Nigeria

Application: This study evaluated the Nigeria indigenous chickens – which are an important source of genetic resource – for body weight gain. The mixed plumage coloured birds emerged as the better-performing birds.

Introduction: Indigenous chickens are an important source of genetic pool and have a crucial role to play in the future of poultry breeding programs, being able to improve the genetic pool of chicken populations through heterosis or physiological changes (Tadelle et al., 2000). Wide variation in performance abounds across indigenous chicken populations especially through differences in plumage colours (e.g. white, brown, black, spotted, mixed, etc.), which provides room for selection, especially since indigenous chickens are favoured among poultry farmers in rural areas (Padhi, 2016). For this reason, this study evaluated the performance of some Nigerian indigenous chickens based on plumage colour variations.

Materials and methods: This study was carried out using standard operating procedures following the animal ethics guideline of the College of Animal Science and Livestock Production. 60 Nigerian indigenous chickens of different plumage colours were pooled from the naked neck, frizzled and normal feather chickens genotypes. The birds were allotted to one of 6 treatment groups based on plumage colour (White, Black, Brown, Black and Brown, Black and White, and Mixed). The birds were tagged for identification and subjected to the same management practice. Data on body weight and feed intake were collected and used to make calculations for body weight gain and feed conversion ratio for a total of 16 weeks. Data collected were subjected to a one-way analysis of variance, and treatment means were separated using Turkey's HSD test.

Results: The mixed plumage coloured bird had the highest ($P < 0.05$) weight gain, final weight, as well as the average feed and water intake values (Table 1). The white plumage coloured birds had higher ($P < 0.05$) body weight and final weight gains than the other plumage coloured birds. There was no consistent pattern in water intake, however, the mixed plumage coloured bird had the highest ($P < 0.05$) average water intake value and the least feed conversion ratio value. This implies that the mixed plumage coloured birds consumed less meal to produce higher body weight gains. The white plumage coloured birds also had a better FCR value than the other plumage coloured bird, but a significantly ($P < 0.05$) lower value than the FCR value recorded for the mixed plumage coloured birds.

Table 1
Effect of plumage colour on the performance of Nigerian Indigenous chicken.

	White	Black	Black and brown	Black and White	Brown	Mixed	*P*-value	SEM
Initial (g)	206.76	205.91	205.85	206.13	207.86	217.00	0.9253	8.07
Weight gain (g)	1293.89^{b}	1136.33^{c}	1164.00^{c}	1132.00^{c}	1100.33^{c}	1629.66^{a}	<0.0001	12.14
Final weight (g)	1500.65^{b}	1342.25^{c}	1369.85^{c}	1338.13^{c}	1308.20^{c}	1846.67^{a}	<0.0001	13.75
Average feed intake (g)	2976.67^{b}	2796.59^{c}	2877.06^{bc}	2837.00^{ab}	2817.33^{c}	3253.67^{a}	<0.0001	26.62
Average water intake (g)	12.28^{e}	20.48^{b}	13.49^{d}	15.68^{c}	11.38^{f}	29.68^{a}	<0.0001	0.08
Feed conversion ratio	2.30^{b}	2.46^{a}	2.47^{a}	2.51^{a}	2.56^{a}	2.00^{c}	<0.0001	0.02

^{a,b,c,d,e,f}: means on the same column with different superscript differ significantly ($P < 0.05$); SEM: Standard error of mean.

Conclusion: Birds in the mixed plumage treatment group had better performance characteristics, given their higher weight gain and better feed conversion ratio.

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142. Can body weight be considered to estimate the gizzard meat yield in meat chickens?

M. Naeem *, E. Burton, D. Scholey, A. Alkhtib, S Broadberry

NTU, Southwell, UK

* Corresponding author. M. Naeem.

Application: Body weight in meat chickens could be considered for the estimation of gizzard weight, providing a pre-processing estimate of gizzard meat yield for poultry processors.
Introduction: Gizzard is a nutritionally important tissue: a one-cup serving of cooked chicken gizzards comprises 223 calories, 44 grams of protein and 4 grams of fat. Gizzard is also an excellent source of iron and zinc (Alfaro, 2020). Therefore, estimation of gizzard weight is useful for processors needing to sell gizzard meat. A linear relationship between body weight and gizzard length and width is reported by Mobini (2010). However, there is lack of information on association of gizzard weight and body weights in broiler chickens. The main objective of the study was to propose and develop a simple but robust model to estimate the gizzard weight through body weight in Ross 308 meat chickens.
Materials and Methods: The study was ethically approved by the Ethical Review Committee at Nottingham Trent University, where a total of 50 (day-old Ross 308 as-hatched) broiler chicks had free access to standard broiler pellet diet and water for 21 days. On day 21, all birds were weighed individually, euthanized by cervical dislocation and gizzard weight was recorded after clearing all the gizzard contents. Live body weight was regressed on gizzard weight to produce the linear and non-linear prediction models. R^2 and 95% percentile prediction error (PE) was used to assess prediction accuracy. Box-cox transformation was used to identify the best transformation which increases the linearity of the collected data on body weight and gizzard weight.
Results: Mean (and standard deviation) of body weight and gizzard weight was 773 g (159 g) and 17.1 g (4.73 g), respectively. Body weight and gizzard were highly correlated ($r = 0.7854$, $P < 0.001$). Body weight predicted gizzard weight of 95% of the birds with a prediction error of 37.1%. On box-cox transformation of gizzard weight to $\log_{10}$ the predictability error (PE) of the estimation model was improved from 37.1 to 12.5% (Table 1).
Conclusion: Log_{10} of gizzard weight could be predicted from body weight using a simple linear model with 95% percentile PE of 12.5% in as-hatched meat chickens when they are fed on standard pellet diet. However, further study is needed to investigate the effect of other factors e.g. form or particle size of diet, on changes in the predictability of the model in future.

Table 1
Estimation of gizzard meat yield through body weight in meat chickens.

Model type	Simple linear	Box-cox
Model P-value	<0.001	<0.001
Intercept P-value	<0.001	<0.001
Slope P-value	<0.001	<0.001
Equation	Gizzard weight (g) = -0.96 + 0.023*body weight (g)	Log_{10}(gizzard weight (g)) = 0.769 + 0.0005*body weight (g)
R^2	0.617	0.618
RSE	2.96	0.073
PE 95 % percentile	37.1	12.5

RSE: Residual standard error; PE: prediction error.

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143. Effect of feeding regimen, strain and sex on growth characteristics of four strains of broilers

K. Kareem-Ibrahim [a,*], O. Abanikannda [a,b], S. Nwadialo [b], M. Demehin [b]

[a] School of Agriculture, Lagos State University, Epe, Lagos, Nigeria
[b] Department of Zoology and Environmental Biology, Ojo, Lagos, Nigeria

* Corresponding author. K. Kareem-Ibrahim.

Application: This study revealed superiority of twice daily feeding frequency on total weight gain and average daily gain of four broiler strains.
Introduction: The poultry industry has evolved in recent years owing to the high demand for chicken meat (Patracci, 2013). However about 60% to 70% of production cost is on feed. Thus, it becomes critical to make concerted efforts to reduce feed cost without compromising overall poultry productivity. Feed restriction strategies in broilers can improve feed efficiency; reduce feed cost and mortality, along with the production of quality meat at cheaper rates (Wilson and Beyer, 2000). The objective of this study was to evaluate the effect of feeding the birds twice (12 hourly) or thrice (8 hourly) on some growth characteristics of the birds.
Materials and methods: The study was conducted in the humid tropics of Lagos, Nigeria lying at latitude 6° 28.226′ N and longitude 3° 12.019′ E, with an average annual rainfall of 1693 mm and average temperature of 27.0 °C. The experiment was a randomised complete block design, whereby two replicates for each of the strains were randomly assigned to each of the two feeding regimes (twice or thrice daily) in independent four plots comprising 76 birds (19 for each strain), on deep litter pens. The birds were fed using commercially compounded broiler feeds [Starter (0–4 weeks) and Finisher (5–8 weeks)]. Data collected on weight was subjected to preliminary exploratory boxplot and normality analyses, and at the end of the study total of 211 of the original 304 birds were statistically evaluated. The general linear model ANOVA of Minitab ® was used and the statistical model is given as $Y_{ijkl} = \mu + S_i + R_j + X_k + e_{ijkl}$ respectively investigating the effects of strain (S), regimen (R) and sex (X) on total and average daily gain. Further mean separation was done using Tukey's test.
Results: Strain, feeding regimen and sex of birds all exerted significant ($P < 0.05$) influence albeit at varying levels, on both total weight gain and average daily gain. The model explained 36.2 percent of total variation with each of the factors respectively accounting for 33.23%, 1.37% and 1.60%. The largest source of variation was from the differences in strain, while the least was recorded on the feeding regimen (Table 1).
Conclusion: The study revealed that twice daily feeding had a better impact on the parameters studied, while the male had superior performance over the female and difference due to strain was only pronounced in the Marshall which had the least values in both parameters studied. It is therefore recommended that broiler birds are fed twice daily (12 hourly), thereby reducing labour cost and frequency of disturbance to the birds.

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Table 1
Mean ± Standard Error (S.E.) of effects of strain, feeding regimen and sex on final weight and average daily gain of broiler chickens.

Variables	N	Mean ± S.E. Final Weight (g)	Mean ± S.E. Average Daily Gain (g)	P-value
Strain				p = 0.000
Arbor Acre	45	3074.8 ± 87.5[a]	43.93 ± 1.25[a]	
Cobb	49	3026.7 ± 77.4[a]	43.24 ± 1.11[a]	
Marshall	61	2292.4 ± 44.9[b]	32.75 ± 0.64[b]	
Ross 308	56	2935.8 ± 66.4[a]	41.94 ± 0.95[a]	
Feeding Regimen				p = 0.040
Twice Daily	104	2859.6 ± 62.3[a]	40.85 ± 0.89[a]	
Thrice Daily	107	2743.1 ± 51.9[b]	39.19 ± 0.74[b]	
Sex				p = 0.027
Female	125	2792.6 ± 52.4[b]	39.89 ± 0.75[b]	
Male	86	2812.1 ± 64.4[a]	40.17 ± 0.92[a]	
Overall	211	2800.5 ± 40.5	40.01 ± 0.58	

Means with different superscript within the same column are statistically different ($P < 0.05$).

144. The effect of supplementary milk and creep feeding on post-weaning piglet growth

S. Icely *, A. Mackenzie, S. Mansbridge, A. Stewart

Harper Adams University, Newport, Shropshire, UK

* Corresponding author. S. Icely.

Application: Strategies to increase creep intake may be more beneficial to piglet post-weaning performance than increasing supplementary milk intake.

Introduction: Supplementary milk (SM) is known to improve piglet pre-weaning survival (Kobek-Kjeldager et al., 2020), and creep feeding improves piglet adaptation to weaning, with piglets that have consumed creep feed having higher feed intake immediately post-weaning than those that haven't consumed creep feed (Muns and Magowan, 2018). However, the combined effects of SM and creep pre-weaning on piglet growth are less well understood. This is likely due to difficulties in assessing individual piglet usage of SM and/or creep feed. This study recorded individual piglet usage of SM provided from birth, and creep feed offered from day 11 of suckling.
Materials and methods: Twenty-eight litters of piglets were selected across two batches (cohorts) farrowing six weeks apart. Litters were selected to have supernumery piglets compared to the sow's functional teats (+2 piglets), to effectively model the effect of large litter sizes. Piglets were weighed at birth, d4 and then weekly to weaning (d26). They were assigned a birthweight group: 1: ≤1.04 kg; 2: 1.06–1.52 kg; 3: 1.54–1.90 kg; 4: ≥1.92 kg. Post-weaning, piglets were weighed at d7, 15, 29 and 54. Supplementary milk (Faramate, Volac International Ltd) was offered from birth, and creep feed from d11, both ad libitum. Usage was measured using the PigTrack ® system (Asserva, France), whereby the electronic ID (EID) of each visit to the SM bowl/creep feeder was recorded. Multiple regression was performed using Genstat (20th edition) with the variables: total duration of SM visits (milk du), total duration of creep visits (creep du), weaning weight and grouping factor of birthweight group.
Results: All regression models were simplified to include significant terms ($P < 0.05$) only (Table 1). Milk du was a significant model term relating to piglet ADG from birth-d15 post-weaning. After d7, birthweight group ceased to be a significant factor, whereas weaning weight had a positive effect on ADG from d15-54. Where weaning weight was a significant term, it had the highest contribution to each model, with other terms included having an additive effect. Creep du had a significant positive effect on ADG from weaning until d54, but no effect pre-weaning.
Conclusion: The beneficial effects of creep feeding duration were more persistent than those of SM usage on ADG through to d54 post-weaning.

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Table 1
The effects of SM (milk du) and creep usage (creep du), weaning weight (wn wt) and birthweight group (group) on piglet ADG from birth-d54 post-weaning (pwd54). α: C group 1: 230; 2: 269; 3: 309; 4:322. β: C group 1: 123; 2:158; 3:175; 4:224. Birthweight group 1: ≤1.04 kg; 2: 1.06–1.52 kg; 3: 1.54–1.90 kg; 4: ≥1.92 kg.

Period	Equation	R^2	S.E	P-value
Birth-wean (d26)	C^{α}_{group}-0.007milk du	31.8	47.9	<0.001
Wean-pwd7	C^{β}_{group} + 0.005milk du + 0.016creep du	13.0	94.8	<0.001
Wean-pwd15	107 + 0.007milk du + 0.013creep du + 20.2wn wt	17.5	88.5	<0.001
Wean-pwd29	237 + 0.017creep du + 22.8wn wt	23.9	80.6	<0.001
Wean-pwd54	363 + 0.019creep du + 28.6wn wt	30.8	82.4	<0.001

145. Going green (or blue): Using non-traditional lighting colours to encourage piglets to rest in the creep

C. Keyworth, K. McDermott *

[1] University of Leeds, Leeds, UK

* Corresponding author. K. McDermott.

Application: Encouraging piglets to rest in the creep area could reduce mortality, an important metric for farm profitability. This is of particular importance when considering a potential ban of the farrowing crate and a subsequent move towards loose-farrowing accommodation.
Introduction: Farrowing crates have been used to limit the movement of the sow during lactation to reduce overlying mortality. However, due to the negative impacts on sow welfare, there is increasing interest in moving to temporary or free-farrowing systems. The use of coloured lights may encourage piglets to rest safely in the creep area away from the sow (Sartor et al., 2018; Paggi et al., 2020) reducing overlying mortality risk. This study tested the effect of four lighting treatments on creep usage and piglet mortality.
Materials and methods: This study was conducted at the National Pig Centre, University of Leeds, UK. Ethical approval was granted by the Animal Welfare and Ethical Review Committee. Sows (n = 23) and their litters (353 piglets) were individually housed in JYDEN farrowing pens. LED lights were fitted above heated, covered creep areas. Treatments were blue (n = 6), green (n = 6), white (n = 6) or no light (control; n = 5). Sows were

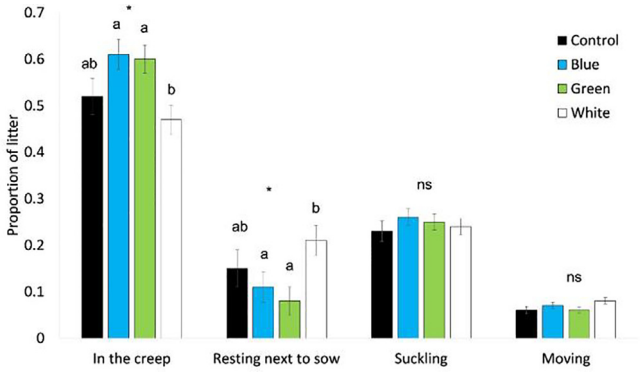

Figure 1. The proportion of piglets in the creep, resting next to the sow, suckling and moving from average day 3-7 post farrowing with no creep light (control; n = 5), blue (n = 6), green (n = 6) or white light (n = 6). Error bars show SE.

crated for approximately 2 days post-farrowing. Any cross-fostering (within a treatment) was recorded. CCTV images were captured every hour from average d3-d7 of lactation (n = 2600 images) to determine the proportion of piglets in the creep, resting next to the sow, suckling and moving around the pen. All mortality was recorded and used to adjust litter sizes. The litter was the experimental unit. Piglet location was analysed as a general linear model in IBM Statistics SPSS 26 with treatment and parity as fixed factors and piglet age as a covariate. Mortality was analysed using Chi-squared.
Results: Piglets with green or blue lights spent more time in the creep than those with a white light ($P < 0.05$; Figure 1). Piglets with a white light spent more time resting next to the sow ($P < 0.05$). There was no difference in the number of piglets suckling or moving around the pen. There was no difference in mortality, with pre-weaning mortalities of 15, 13, 9 and 10% for control, blue, green, and white, respectively although due to low replication, this requires further study to confirm.
Conclusion: Green or blue LED lighting increased the amount of time piglets spent in the creep area in the first 7 days of life suggesting these piglets may have a lower risk from overlying. Larger on-farm studies should be performed to confirm these findings. Technicians and farm staff at the National Pig Centre.

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146. Estimating individual-level pig growth trajectories from group-level weight measurements

C. Taylor *, J. Bacardit, J Guy

[1] Newcastle University, Newcastle, UK

* Corresponding author. C. Taylor.

Application: Being able to track the growth of individual livestock can be beneficial to farmers, however, the cost of RFID systems typically prevents this from being financially feasible. Machine learning approaches can help to alleviate this issue by estimating individual growth trajectories from unknown weight measurements without requiring expensive RFID systems.
Introduction: Despite an increasing number of pig farmers implementing data collection systems to improve farm management, the cost of implementing such systems remains a barrier to many. This is primarily due to the fact that some of the most useful data are on an individual pig level, which requires investment of labour and expense of systems such as RFID tagging (Ruiz-Garcia and Lunadei, 2011). We thus propose an alternative solution, where pen-level weight measurements on pigs, which are significantly cheaper to obtain, are used to estimate individual-level growth trajectories using machine learning models.
Materials and methods: A dataset consisting of live weight and feed intake data for 424 grower-finisher pigs recorded by individual feeding stations (Nedap, Netherlands) was obtained from a commercial UK farm. We emulated group-level weight measurements by sampling from our individual-level weight data. From group-level weight data, we trained a support vector machine algorithm to predict, for each pair of time points, whether those pairs of points belonged to the same pig or not. The support vector machine was then used to estimate likelihood values for each pair of points within each group-level time series. We then clustered these likelihood values using agglomerative clustering with complete linkage, and the resulting clustering tree was cut to produce a fixed number of clusters with each cluster corresponding to an estimated trajectory for one pig. To estimate the performance of the resulting models, we matched the predicted growth trajectories to the true trajectories using the using the Jonker-Volgenant algorithm (Crouse, 2016) to minimise the root mean squared error.
Results: In Figure 1 we exemplify the performance of the algorithm on one example group-level time series for 10 pigs. The predictions for this time series resulted in a root mean squared error of 1.40 kg per pig.
Conclusion: Using this method, it was possible to predict approximate growth trajectories of grower-finisher pigs without using their RFID tag identities. It is, however, currently unclear what the most appropriate metric is for this task, though the exact metric will likely differ depending on how these predictions are utilised. Also, in its current form, this algorithm will likely struggle to generalise between farms and will thus require further work before being applied in commercial settings.

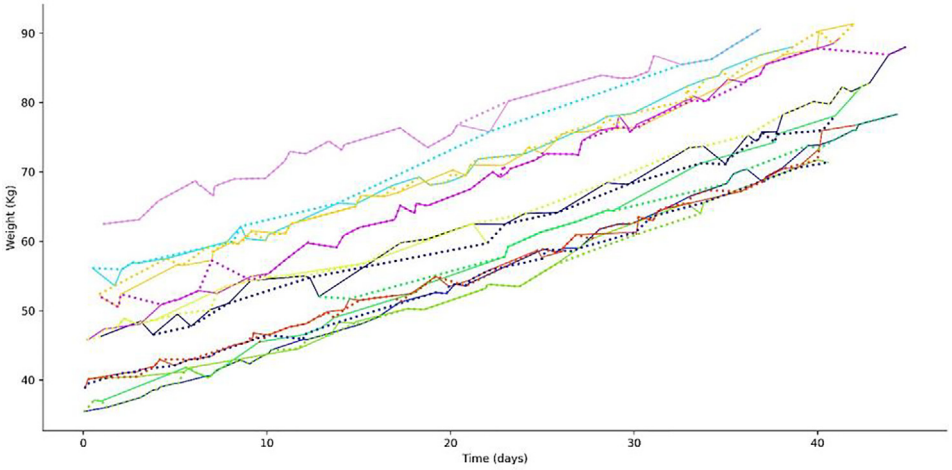

Figure 1. True individual pig growth trajectories using RFID tag identities (solid lines) and predicted growth trajectories obtained from a machine learning algorithm (dotted lines) for 10 grower-finisher pigs. Each colour represents the live weights for an individual pig.

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147. Piglet [StQuote] s performance in litters of different size and access to an automatic milk replacer feeder

R. Muns [a,*], A. Strain [a], J. Connolly [b], M. Connery [b], W. Henry [c], R. Wregor [b]

[a] Agri-Food and Biosciences Institute, Belfast, Northern Ireland, UK
[b] JMW farms Ltd, Armagh, Northern Ireland, UK
[c] Rektify Ltd., Armagh, Northern Ireland, UK

* Corresponding author. R. Muns.

Application: Offering litters ad libitum access to milk replacer did not prevent an increase on pre-weaning mortality when fostering sows with 17 piglets. Nonetheless, surviving piglets in Litter17 performed at the same level as piglets in Litter15.
Introduction: Hyper prolific sows have resulted in litters outnumbering the number of viable teats and, on occasions, piglets outnumbering viable teats at a room level. Different strategies are available to manage the surplus of born alive piglets: implementing a nurse sow system, artificial rearing, offering supplemental milk replacer to pigs, etc. (Baxter et al., 2013). The present study aimed to assess piglets pre-weaning performance when reared in large litters with access to automatic milk replacer feeder.
Materials and methods: A study was conducted in a commercial farm involving 433 piglets born from 27 different sows (LW × LR). At cross fostering (24 hour after the onset of farrowing) sows were left with either 15 (Litter15) or 17 piglets (Litter17). Treatment groups were balanced by parity, day of farrowing, and live born piglets. All sows followed the same management and were fed the same gestation diet (DE 12.4 MJ, CP 15.4%). During lactation all sows also followed the same management and were fed the same diet (DE 14.7 MJ, CP 16.6%). All piglets had ad libitum access to fresh

Table 1
Effect of litter size on piglets pre-weaning performance. ADG: Average daily gain; SEM: standard error of the difference.

Litter size	15	17	*SEM*	*P-value*
n° pigs/n° sows	*178/12*	*255/15*		
Foster weight, kg	1.21	1.31	0.016	<0.05
Wean weight, kg	7.05	6.76	0.463	0.385
ADG, kg/day	0.193	0.181	0.002	0.662
Days from birth to weaning	30.21	30.30	0.480	0.904
Antibiotic Treatment, %	7.30	8.24	0.013	0.699

water and ad libitum access to a milk replacer via an automatic nipple drinker placed at the front of the pen. Any sow with poor condition and/or less than 10 live born piglets and/or more than 5 stillborn/mummified were excluded from the trial. Cross fostering was achieved by keeping the number of piglets transferred to a minimum. Piglets were weighed at fostering and at weaning. Average daily gain (ADG) was calculated. Proportion of piglets that required antibiotic treatment was recorded. Milk replacer intake could not be recorded. Data were analysed using GenStat 19th edition. The sow was used as the statistical unit. Foster weight was used as co-variate for weaning weight.
Results: Sow performance results are presented in a separate Abstract. Pre-weaning mortality in Litter17 was 7.3 ± 1.71% while for Litter15 was 0.8 ± 1.38% ($P < 0.05$). Piglet performance results are presented in Table 1. Weight at cross fostering was 100 g higher for Litter17 ($P < 0.05$). However, treatments did not differ for weaning weight nor for ADG ($P > 0.05$, respectively). The proportion of piglets that required antibiotic treatment during lactation was not affected by treatment ($P > 0.05$).
Conclusion: Despite piglets having ad libitum access to a milk replacer, Litter17 had higher pre-weaning mortality. Nonetheless, piglets that survived, had similar weaning weight and pre-weaning growth in both treatment groups. Litter size did not influence the proportion of piglets requiring antibiotic treatment during lactation.

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148. Impact of dietary sodium diformate in sows on suckling piglets under poor sanitary conditions

C. Lückstädt *, S. Petrovic

ADDCON, Bitterfeld-Wolfen, Germany

* Corresponding author. C. Lückstädt.

Application: Dietary sodium diformate used in sow feed at low dosages acts as a performance enhancer for suckling piglets under commercial conditions. *Introduction*: The application of organic acids and their salts to diets for pigs has been studied extensively under varying conditions (Lückstädt and Mellor, 2011). Despite well-documented effects of diformates on growing pigs, data on their impact when fed to sows during late gestation and lactation, and the subsequent effects on their suckling piglets under commercial conditions are not available. In this trial, a lower dosage (5 kg/t) was used than that normally recommended, to investigate whether further economic improvement could be achieved.
Materials and methods: This study tested the effects of sodium diformate (Formi® NDF, ADDCON) fed to sows on their suckling piglets and was conducted under veterinary supervision. Fourteen sows (DanBred) on a commercial farm (Northern Serbia) were equally divided into two groups, each containing 7 sows and fed a typical lactation diet (corn-wheat-soy based), containing either 0.5% of NDF, or a negative control without the additive, from one week before farrowing till the end of weaning (day 28). The lactation diet was fed ad libitum and daily feed intake measured. The following parameters were monitored at farrowing: number of piglets born alive, individual weight of new-born piglets and litter weight of new-born piglets. At weaning the number of weaned piglets, the individual body weight of weaned piglets and litter weight during weaning was recorded. Data were analysed using the t-test and a significance level of 0.05 was used in all tests.
Results: Feed was well accepted by both groups. Feed intake is only available as pooled data - sows fed the NDF-diet had a numerically higher feed intake compared to the negative control group (+560 g/day, Table 1). At farrowing, the weight and number of piglets born alive increased significantly ($P < 0.05$) due to the addition of the additive: live births increased by 1.5 piglets per sow. Litter weight of piglets differed significantly by more than 2.3 kg, for the NDF-fed sows. No difference was observed for the number of weaned piglets per sow although the weaning weight of the piglets at day 28 was highly significantly ($P < 0.001$) improved (520 g heavier piglets in the NDF-group), leading to a numerically ($P = 0.15$) increased litter weight at weaning of more than 8.5 kg in NDF-fed sows. The uniformity of overall litter weight was also improved. It should be noted that some uncertainty may have resulted from the small sample size.
Conclusion: As previously reported (Øverland et al., 2009, Lückstädt, 2011, Lückstädt and Petrovic, 2019), lower dosages of sodium diformate in sow diets during the suckling period may indirectly support piglet production.

Table 1
Performance parameters of piglets from sows fed with or without sodium diformate (NDF).

Parameter	Control (n = 7)	0.5% NDF (n = 7)	P-value
Daily feed intake sow [kg]	5.18	5.74	-
Piglets born alive, per sow [n]	13.6 ± 1.7	15.1 ± 1.4	0.049
Weight of new-born piglets [kg]	1.41 ± 0.07	1.42 ± 0.07	0.46
Litter weight at birth [kg]	19.11 ± 1.90	21.45 ± 1.99	0.03
Piglets weaned, per sow [n]	10.6 ± 2.4	11.0 ± 1.6	0.36
Weight of weaned piglets [kg]	6.74 ± 0.16	7.26 ± 0.23	0.0003
Litter weight at weaning [kg]	71.17 ± 15.95	79.68 ± 10.59	0.15

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149. Delayed weaning and medicinal ZnO removal from post-weaning diets - the effects on finisher pig growth performance

C Mulvenna *, Ms A Strain, R Muns

AFBI, Hillsborough, UK

* Corresponding author. C. Mulvenna.

Application: The medicinal use of Zinc Oxide (ZnO) in pig diets will be banned in the EU by June 2022. This work shows that the removal of ZnO from the post-weaning diets of pigs regardless of weaning age, did not have any long term effects on pig performance.

Introduction: Much of the previous work on ZnO removal focused on young piglets with few studies considering the long-term effects on performance or health. In previous work (Mulvenna et al. 2021) we observed how extending lactation increased piglet weaning weight, while piglet post-weaning performance was unaffected by the removal of ZnO. This study presents the effect of extended lactation and ZnO removal on finisher pig performance.
Material and methods: Piglets were allocated to one of two experimental groups: litters weaned at 28 days (Lact28) or 35 days (Lact35) of lactation. At weaning, these piglets were assigned to receive one of two dietary treatments (ZnO vs no ZnO) based on sex and body weight (BW). These diets were offered *ad libitum* up to 50 days old. Afterwards, all pigs received the same grower diet to 12 weeks of age. At 10 weeks, all pigs were moved to finishing housing and allocated to pens (8 pigs/pen), balanced for BW and sex. Each pen was equipped with an MLP FIRE feeder which recorded feed intake and BW of each individual on each visit to the feeder. From 12 weeks a finisher diet was offered *ad libitum* (14.4 MJ DE/ kg, 16% CP). Average daily gain (ADG), average daily feed intake (ADFI) and feed conversion ratio (FCR) were calculated for various time points. Performance data were analysed by REML for fitting linear models using GenStat version 19. Days of lactation and ZnO content were included in the model as fixed effects, as well as a two way interaction between fixed effects. Pen and batch were included as random effects. The statistical unit was considered at individual level.
Results: No significant interaction effects were reported, only main effects are presented (Table 1). Post-weaning ZnO supplementation did not have any significant effect on growth performance parameters during the finishing stage. Pigs weaned later (Lact35) displayed a reduced ADG (0.90 vs 1.00 kg/day, $P < 0.05$) between 12–15 weeks compared to Lact28 pigs, despite no difference in ADFI. The BW of Lact35 pigs at 12, 15 and 22 weeks was lower than for Lact28 pigs but the differences were not significant ($P > 0.05$).
Conclusion: Extending the period of lactation or removing medicinal ZnO from post-weaning diets has no long term effects upon pig performance.

Research funded by DAERA.

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Table 1
The effects of weaning age (28 vs 35d) and dietary medicinal Zinc Oxide content on finisher pig growth performance (10 to 22 weeks of age).

	Lact28	Lact35	SED	P-value	ZnO	no ZnO	SED	P-value
No. of pigs	*135*	*126*			*131*	*130*		
10wk weight, kg	29.30	29.90	0.484	0.223	29.89	29.31	0.524	0.293
12wk weight, kg	45.00	44.94	0.900	0.923	45.68	44.27	1.155	0.281
15wk weight, kg	62.87	61.83	1.251	0.416	63.01	61.68	1.495	0.407
22wk weight, kg	118.5	117.5	1.99	0.601	117.5	118.5	2.891	0.715
ADFI 10-12wks, kg/day	1.53	1.55	0.059	0.660	1.51	1.58	0.148	0.628
ADFI 12-15wks, kg/day	2.08	1.98	0.085	0.253	1.96	2.09	0.168	0.447
ADFI 15-22wks, kg/day	2.83	2.77	0.079	0.432	2.68	2.92	0.238	0.330
ADG 10-12wks, kg/day	0.91	0.89	0.034	0.575	0.93	0.87	0.054	0.348
ADG 12-15wks, kg/day	1.00	0.90	0.040	<0.05	0.96	0.94	0.046	0.757
ADG 15-22wks, kg/day	1.17	1.15	0.029	0.638	1.13	1.18	0.040	0.235
FCR 10-12wks, kg/kg	1.74	1.77	0.083	0.758	1.66	1.85	0.217	0.394
FCR 12-15wks, kg/kg	2.23	2.21	0.062	0.751	2.11	2.34	0.270	0.405
FCR 15-22wks, kg/kg	2.49	2.42	0.071	0.316	2.43	2.49	0.210	0.799

150. The effect of rearing environment and the provision of zinc oxide post-weaning on pre- and post-weaning growth performance in pigs

S. Hazelden *, K. McDowall, H. Miller

University of Leeds, Leeds, UK

* Corresponding author. S. Hazelden.

Application: Rearing of pigs in an outdoor paddock pre-weaning provides performance benefits throughout their lifetime and could be sent to slaughter up to two week earlier than indoor reared pigs. While the provision of pharmacological levels of zinc oxide (ZnO) only improved performance for the first four weeks post-weaning.

Introduction: The UK is unique with 40% of the pig breeding herd kept outdoors (AHDB, 2017). Outdoor reared pigs often outperform their indoor reared counterparts post-weaning (Miller et al., 2009) but can have higher mortality (AHDB, 2020). Pharmacological levels of ZnO are commonly used in indoor production, but the upcoming ban requires alternative ways to improve performance. While dietary alternatives are readily researched, management strategies should also be explored. The aim of this research was to compare pig performance when reared indoors or outdoor pre-weaning and provided control or pharmacological levels of ZnO post-weaning.

Materials and methods: Twenty-four Large White × Landrace sows. Twelve sows farrowed indoors and averaged parity 3.1. The remaining 12 farrowed in outdoor paddocks and averaged parity 2.4. Number of piglets born, pre-weaning weight and mortality were recorded. At weaning, 10 pigs per litter were selected and weaned into 2 pens of 5 pigs per pen, balanced for sex, within the same indoor accommodation. From each litter, one pen received control diet, the other a matched diet with pharmacological levels of ZnO (~2500 ppm) for 14 days post-weaning, hereafter pigs received the same commercial feed. Pig weight was recorded every other week until slaughter (~day 116 post weaning) alongside feed intake. Data were analysed in SPSS v24, using a general linear model for pre-weaning data (environment fixed factor, litter as the experimental unit) and a linear mixed model for post-weaning data (environment and treatment as fixed, litter as random factor, pen as experimental unit).

Results: There were no differences in pre-weaning piglet mortality (2 vs 3 pigs/litter; $P = 0.29$) or average weaning weight (7.8 vs 8.0 kg; $P = 0.48$) for indoor or outdoor reared pigs, respectively. Post-weaning, outdoor-reared pigs were heavier at every weigh point from weaning until slaughter (Table 1). The provision of ZnO improved pig performance at days 15 and 29 but this was not maintained after day 29. Between weaning and day 15, the provision of ZnO was more beneficial to indoor reared pigs, with a trend interaction for average daily gain (ADG) and significant interactions for average daily feed intake (ADFI) and feed conversion efficiency (FCE; Table 1).

Conclusion: Piglets reared outdoors were less affected by the weaning process and their continued heavier weights meant they reached slaughter weight faster than indoor reared pigs. This reduced their time within the production system, showing a benefit over the use of pharmacological levels of ZnO.

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Table 1
Pig performance data when reared indoors or outdoors and provided control or pharmacological levels of ZnO post-weaning. Values shown in kg.

Rearing Environment	Indoor		Outdoor			*P-values*		
Treatment	Con	ZnO	Con	ZnO	SEM	*Environment*	*Treatment*	*Environment* Treatment*
Weaning Weight[1,2]	7.75	7.79	7.95	7.99	0.25	0.475	0.894	n/s
D15 Weight[3,4]	9.14	10.88	11.82	12.56	0.27	*<0.001*	*<0.001*	*0.057*
D29 Weight[3]	16.22	17.34	19.59	20.71	0.49	*<0.001*	*0.026*	n/s
Day 43 Weight[2]	25.53	27.99	29.99	30.59	0.75	*0.001*	*0.078*	n/s
Day 57 Weight	35.47	38.40	40.80	41.49	0.97	*0.001*	0.122	*n/s*
Day 71 Weight	48.95	51.10	54.04	54.77	1.26	*0.007*	0.336	*n/s*
Day 85 Weight	63.28	66.67	69.60	70.29	1.25	*0.002*	0.174	*n/s*
Day 99 Weight	76.99	79.86	84.08	84.00	1.33	*0.002*	0.376	*n/s*
Day 116 Weight	93.89	96.96	101.65	101.02	1.95	*0.016*	0.592	*n/s*
ADG 0–15[4]	0.09	0.20	0.26	0.32	0.02	*<0.001*	*<0.001*	*0.059*
ADG 16–29[2]	0.57	0.56	0.68	0.67	0.29	0.002	0.782	n/s
ADFI 0–15[4]	0.16	0.22	0.30	0.30	0.01	*<0.001*	*0.017*	*0.048*
ADFI 16–29	0.80	0.85	0.95	0.99	0.09	0.223	0.223	n/s
FCE 0–15[2,4]	0.49	0.91	0.89	1.06	0.05	*<0.001*	*<0.001*	0.007
FCE 16–29[2]	0.72	0.67	0.70	0.65	0.06	0.785	0.447	n/s

[1] Weight based on pigs selected to go onto the post-weaning trial, not entire litter.
[2] Data shown based on Generalised Linear Model output and Wald Chi-Square test statistic.
[3] Weaning weight included as a covariate.

151 Hierarchical growth models of suckling piglets

F. Mata

CISAS, Instituto Politécnico de Viana do Castelo, Viana do Castelo, Portugal

Application: Animal welfare questions are raised, and breeding aims should seek homogeneous birthweights and functional mammary glands.
Introduction: Larger litter sizes result in increased fighting between siblings to access the more productive teats of the sow, placed in decreasing order in the thoracic, abdominal and inguinal ventral areas of the sow (Skok et al., 2007). There is a progressive trend in teat order development, with piglets initially directing themselves towards teats in the front (Rosillon-Warnier and Paquay, 1984). Predicting the weight of pigs throughout the production stages can be achieved with mathematical models. These models provide a tool for management decisions and are therefore, advantageous to producers (Schinckel and de Lange, 2006). The aim of the present study was to model piglet growth to evaluate how teat hierarchy impacts piglet growth, measured as weaning weight.
Materials and methods: We weighed and observed a total of 140 piglets from 10 sows (14 per sow) from birth to weaning. Mean and standard deviation (SD) weights at day 1 to 7 and then 13, 18, 23 and 28, were calculated for each of the suckling groups. SD were used to calculate 95 % confidence intervals (CI). Significant differences for teat allocation group were tested with ANOVA models for birthweight and weaning weight. The time series of mean weights, upper and lower CI were than used to fit quadratic, cubic and von Bertalanffy curves. It was found that the best fit ($R^2 = 0.99$) and most parsimonious model is the quadratic curve. Microsoft® Excel® for Microsoft 365 MSO (version 2112 Build 16.0.14729.20254) 64-bit, was used in the analysis.
Results: The best fit was achieved with a quadratic curve. Piglets' birthweight correlates positively with higher hierarchy. Higher hierarchical positions choose the most productive mammary glands placed (decreasing order) in the anterior, medium and posterior venter of the sow. Piglets in the different suckling groups studied have significantly different birthweight ($P < 0.05$). The anterior piglets' growth curve differentiates almost immediately (95 % CI) from the beginning and up to weaning from medium and posterior. These last two groups differentiate (95 % CI) their growth from day 20. At weaning (28 days) the three different groups have significantly different weights ($P < 0.01$).
Conclusion: The quadratic curve fit the suckling growth phase of piglets. Teat order is stablished in function of birthweight and influences weight gain throughout the pre-weaning period Fig.

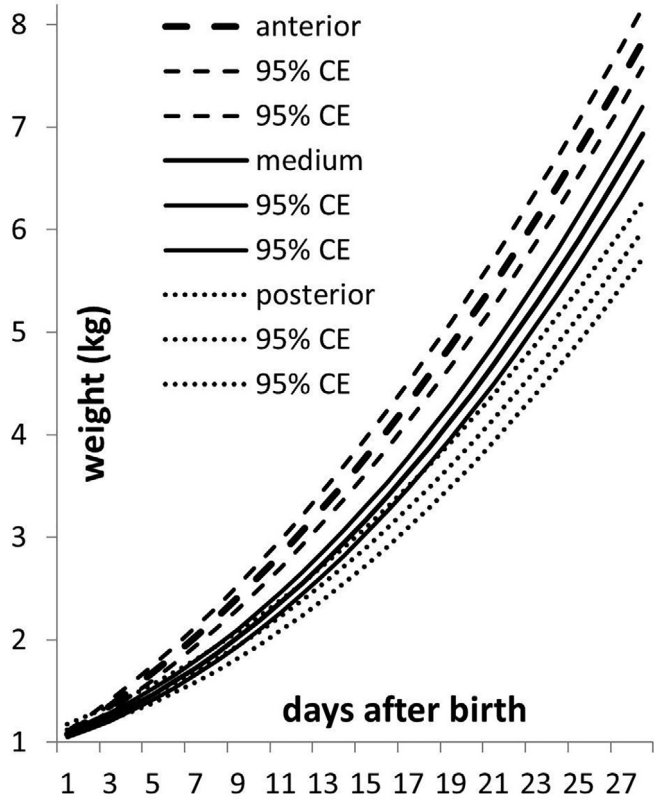

Figure 1. Quadratic curves and respective 95 % confidence envelops (CE) used to model the three groups of suckling piglets being studied.

152. Assessing the accuracy of leg mounted sensors for recording dairy cow behavioural activity in cubicle housing, a straw-bedded yard and at pasture

G. Charlton [a,*], C. Gauld [a], M. Rutter [a], E. Bleach [a]

[a] Harper Adams University, Newport, Shropshire, UK

* Corresponding author. G. Charlton.

Application: IceQube sensors can be used on dairy cows kept in cubicle housing, in straw-bedded loose yards and at pasture, giving them the potential to be used as lifelong sensors.

Introduction: Automated behavioural monitoring systems can help to detect changes in dairy cow health, productivity and reproductive state (Mattachini et al., 2013). On-farm, use of such devices is increasing, so it is important to ensure their accuracy. Therefore, the objective of this study was to assess the accuracy of IceQube® sensors (IceRobotics Ltd, Edinburgh, UK) for recording lying duration, lying and standing transitions and step count of dairy cows housed indoors in cubicle housing, a straw-bedded loose yard and at pasture.

Materials and methods: Holstein Friesian cows at Harper Adams University, UK were fitted with IceQube® accelerometer-based sensors on the hind left leg. The sensors record lying and standing duration, lying and standing transitions and step count. In the cubicle housing, 46 cows were manually observed, 45 cows were observed in the straw-bedded yard and 48 cows at pasture. During manual observations the behaviour of one focal cow was recorded continuously for 2 h by one of four trained observers. The concordance correlation coefficient (CCC) was calculated between IceQube recordings and manual observations of step count and lying and standing times. In addition, the average difference between observed and recorded values were also calculated using the mean absolute deviation (MAD) and bias using the ImerTest (version 3.1).

Results: Lying time (min/h) and standing time (min/h), recorded by the observer and IceQubes were similar in all locations ($P > 0.05$), as were transitions (no./h) in cubicles and the straw yard ($P > 0.05$) and steps/h at pasture ($P > 0.05$). Correlations between the number of steps recorded by the observer and IceQubes were minor in the cubicle housing (CCC = 0.55) and the straw-bedded yard (CCC = 0.60) and were strong at pasture (CCC = 0.93; Figure 1).

Conclusion: IceQube accelerometers on the back leg of dairy cows give an accurate record of lying duration, standing duration, the number of lying and standing transitions and step count of dairy cows in indoor cubicle housing, indoor straw yards and at pasture.

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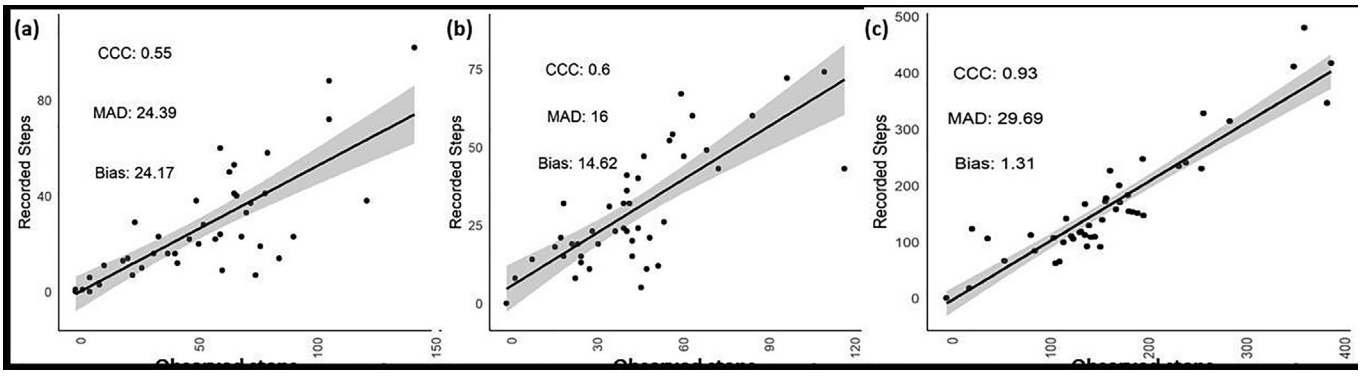

Figure 1. Scatterplot of visually observed and IceQube recorded steps in (a) cubicle housing, (b) straw-bedded yard, (c) at pasture. The regression line (solid line) and confidence interval (shaded area) are presented. CCC = concordance correlation coefficient; MAD = mean absolute deviation

153. The relationship between digestibility and growth performance in domestic rabbit feed containing graded levels of sweetpotato composite meal from two varieties

I. Olaleru [a,*], O. Abu [b]

[a] National Root Crops Research Institute, Umudike, Umudike/Umuahia, Abia State, Nigeria
[b] University of Ibadan, Ibadan, Ibadan, Oyo State, Nigeria

* Corresponding author. I. Olaleru.

Application: Diets containing graded levels of the two varieties of Sweetpotato Composite (SC) did not negatively influence the nutrient digestibility (Crude fibre) or performance (FCR) when compared with the maize-based diets. The use would reassure farmers about the potential of the two varieties of the composite.

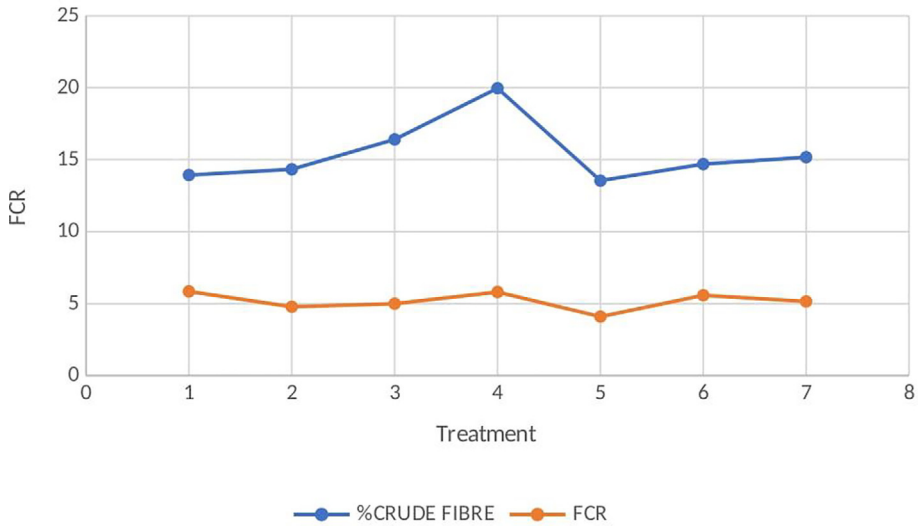

Figure 1. The relationships between digestibility of coefficient and performance (FC) of rabbits fed diets containing graded levels of two varieties of composite sweetpotato TI(0%), T2 (25% OFCSP), T3 (50% OFCS), T4 (75 % OFCS), TS (25% WFCS), T6 (50% WFCS) and T7 (75% WFCS), OFCS - Orange flesh composite sweetpotato; WFCS - White flesh composite sweetpotato.

Introduction: The use of highly digestible feedstuffs offers a higher proportion of nutrient absorption when compared with less digestible feedstuffs (Velayudhan et al., 2015). The small intestine and caecum in the rabbit are enlarged to allow for additional transit time to digest feedstuff of plant origin. This research suggests that the quality of feedstuff affects the nutrient bioavailability which is proportionate to the nutrients absorbed that are eventually utilised in the rabbit body for growth and development. It is not clear whether variations in the digestibility coefficient are indicative of performance (FCR), particularly since high levels of variation between nutrient utilisation exist (Pelegrin-Valls et al., 2020). The aim of the present study was to explore and elucidate relationships that exist between the quality of feedstuffs (two varieties of sweetpotato composite) and digestibility, and its effect on the performance of rabbits.
Materials and methods: Eighty-four 35-day old crossbreed (Chinchilla × New Zealand White) weaned doe rabbits weighing 570.76 ± 42.09 g were randomly allotted to seven dietary treatments (12 rabbits/treatment; 4 rabbits/replicate). The diets were designated as T1-control (0%), 25, 50, and 75% of orange flesh SC meal were T2, T3, and T4 and 25, 50, and 75% of white flesh SC meal were T5, T6, and T7 respectively. Ingredients and chemical composition of diets are reported in Olaleru and Abu (2021). The experiment was carried out in a completely randomised design and lasted for 63 days. The relationship between the quality of feedstuff digestibility and its impact on growth performance was explored through ANOVA using SPSS statistical software package 2011, version 20.
Results: FCR did not significantly differ between treatment groups within the study ($P > 0.05$), though there was a significant difference in the fibre digestibility across the treatment group. Analysis comparing the relationship between the FCR and fibre digestibility across the treatments found that the consistent rise in fibre digestibility did not have an effect on the FCR value. There was some evidence that sweetpotato composite could enhance fibre digestibility as well as improve nutrient utilisation in rabbits.

Conclusion: Observed differences in the fibre digestibility coefficient were not reflected in differences in FCR between treatments in the present studies. Whilst the fibre digestibility coefficient appeared different from another, variation did not necessarily alter their performance (FCR) success.

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154. Potentials of forage-based diet made from mixtures of *Megathyrsus maximus* and *Enterolobium cyclocarpum* plant parts for rabbit feeding

B.A. Abd'Azeez [a], T.A. Adeyemi [a], F.I. Dada [a,*], S.P. Eboda [a], M.B. Ogunsola [a], B.M. Ogundapo [a], A. Oyeyemi [a], V. Ojo [a]

[a] Federal University of Agriculture, Abeokuta, Abeokuta, Ogun, Nigeria

* Corresponding author.B.A. Abd'Azeez.

Application: Rabbit diet made from mixtures of Megathyrsus maximus leaves and Enterolobium cyclocarpum seeds resulted in better feed at a reduced intake level.
Introduction: Most Sub-Saharan countries lack sufficient animal protein, rabbits which fast growth and short generation interval have become popular (Iyeghe-Erakpotobor et al., 2006). For rabbit production, high concentrate feeding cost necessitates the need for cheap alternative feed resources. Sánchez-Laiño et al. (2018) reported that forage like grasses have the potential to replace concentrate diet in rabbit feeding, however, grasses can be low in essential nutrient (e.g. crude protein). In line with the reports of Gugołek et al. (2017) that utilized some legume seeds in rabbit feeding, E. cyclocarpum seeds can serve as good protein supplements to forage grasses in rabbit feeding (Ojo et al., 2018). If the forage based diets are

Table 1
Chemical composition of feed mixtures of Megathysus maximus and Enterolobium cyclocarpum plant parts and performance of rabbits fed the diets.

Parameters	ELM	ESM	ELSM	SEM	P-value
Dry matter (g/kg)	921b	955a	954a	1.37	<0.01
Crude protein (g/kg)	138b	170a	145b	3.52	0.01
Neutral detergent fibre (g/kg)	636	627	637	3.96	0.21
Initial weight (g)	703	707	678	70.33	0.96
Final weight (g)	940	998	893	56.65	0.55
Weight gain (g)	236	292	215	23.47	0.15
Weight gain/day	3.94	4.86	3.58	0.39	0.16
Total feed intake (g)	2558a	2315b	2599a	25.72	<0.01
Feed intake/day	42.6a	38.6b	43.3a	0.43	<0.01
Feed conversion ratio	10.9	8.01	12.6	1.03	0.07

[a,b]: mean values with the same superscript differ significantly ($P < 0.05$); SEM: Standard Error of Mean.

formulated to meet the minimal nutritional requirements of rabbits, they may serve as a cheaper alternative to concentrate diets in rabbit production. We therefore evaluated the performance of rabbits fed M. maximus and E. cyclocarpum plant parts.
Materials and methods: 50 kg of M. maximus (grass) at 6 weeks and 25 kg each of E. cyclocarpum leaves and seeds were harvested, dried, and ground to 3 mm particle size. Three composite diets were formulated and presented in mash form following the proportions: 75% M. maximus + 25% E. cyclocarpum seeds (ESM), 75% M. maximus + 25% E. cyclocarpum leaves (ELM), and 75% M. maximus + 12.5 ESM + 12.5% ELM (ESLM). The diets were formulated to meet the NRC requirement of protein and fibre for growing rabbit and fed a basal 50 of commercial pellet diet daily. 18 New Zealand white grower bucks, about 5 weeks of age were assigned in a completely randomized design to the three treatments (6 animals per treatment). Data on body weight, feed intake, weight gain and feed conversion ratio were collected and analysed using one-way analysis of variance with Tukey's HSD as the post-hoc test. The animal ethics and standard guideline of the College of Animal Science and Livestock Production was followed.
Results: There were significant ($P < 0.05$) differences only in the daily and total feed intake in rabbits fed the mash treatment diets. Rabbits fed the ESM diet had the least ($P < 0.05$) feed intake value, but comparable weight gain and feed conversion ratio with the other treatments (Table 1).
Conclusion: The ESM diet is promising, having comparable weight gains and FCR values with the other treatments, despite lower feed intake values.

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155. Stability of the rumen microbiome of dairy cows during a single lactation cycle

T. Snelling [a,*], C. Johnson [a], H. Warren [b], J. Taylor-Pickard [b], N. Adams [b], L. Sinclair [b]

[a] Harper Adams University, Edgmond, Shropshire, UK
[b] Alltech UK Ltd, Stamford, Lincolnshire, UK

* Corresponding author. T. Snelling.

Application: The rumen microbial community and metabolism of dairy cows was measured at each month throughout the lactation cycle. This provided an insight into fixed factors: time of lactation cycle and individual cow and variables including diet, that affect the stability of the microbial microbiome.
Introduction: The lactation cycle of a dairy cow is approximately 305 days with peak milk production at 50–80 days followed by a gradual decline leading to a dry period. Previous cross-sectional studies of the rumen microbiome of dairy cows at different stages of lactation revealed an apparent instability of some microbial groups corresponding to days-in-milk (Zhu et al., 2021). The longitudinal study presented here followed a small cohort of cows sampling monthly through a single lactation cycle to link rumen microbiome diversity and discriminant taxa with the stage of lactation and diet.
Materials and methods: Milk yield and composition were recorded from four Holstein-Friesian dairy cows over a period of seven months commencing post-peak milk production. Digesta samples were taken via ruminal cannula once per month for volatile fatty acids (VFA) analysis and DNA extraction. DNA was extracted based on Yu and Morrison (2004) and 16S rRNA gene amplicon libraries prepared and sequenced using Illumina MiSeq (Kozich et al. 2013). Milk and VFA data were analysed using analysis of variance. Sequence data were parsed using MOTHUR (Schloss et al., 2009) to produce a table of operational taxonomic units. Beta diversity was measured using Bray Curtis metric and statistical significance determined using AMOVA. LEfSe with LDA score > 3.0 was used to identify discriminant OTUs.
Results: Mean milk yield per cow declined from peak lactation until the final month before the dry period. Rumen acetate, decreased with concurrent increase of propionate in the months following peak lactation. Differences in rumen VFA were also detected between individual cows ($P < 0.001$). Microbial communities clustered by solid and liquid digesta phases and individual cows ($P < 0.001$). A change of diet in late lactation stage was also associated with a shift in microbial community composition with a reduction of Proteobacteria from 9.0% to 1.3% (Figure 1). Moreover, within digesta phase, diet and individual cow factors, the microbiome also differed ($P < 0.05$) by month of lactation.
Conclusion: Change in diet had the strongest effect on the composition of the rumen microbiome, with potential to lead to dysbiosis. However, there was also variability within diet at different lactation stages suggesting natural temporal instability of some microbial taxa during the lactation cycle.

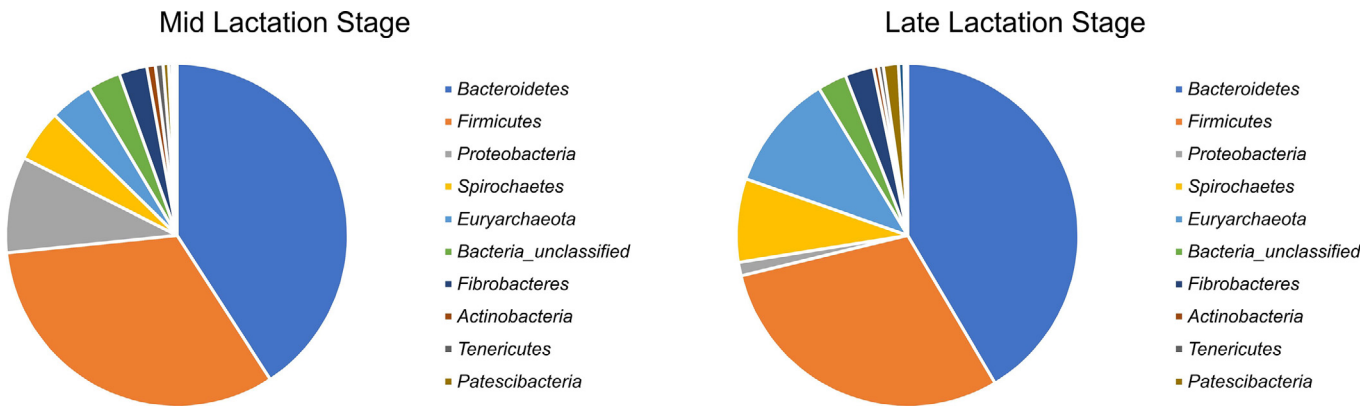

Figure 1. Phylum summaries of the rumen microbiome and reduction in Proteobacteria at different lactation stages as a response to dietary change.

Acknowledgement: This study was funded by Alltech UK Ltd.

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156. An investigation into the response of grazed multispecies swards to nitrogen fertiliser application

C. Hearn [a,b,*], M.B. Lynch [b,c], M. Egan [a], M. O'Donovan [a]

[a] Teagasc Moorepark, Fermoy, Cork, Ireland
[b] University College Dublin, Belfield, Dublin, Ireland
[c] Teagasc Johnstown Castle, Wexford, Ireland

* Corresponding author. C. Hearn.

Application: Utilizing swards which include legumes and herbs, along with grasses, on grazing focussed dairy farms can increase pasture production across various nitrogen application levels.
Introduction: Farmers are coming under increasing pressure to reduce nitrogen (N) fertilizer use on grassland farms. Legumes, including clovers, can provide N to a sward through a symbiotic relationship with rhizobium bacteria which fix atmospheric N into plant utilizable forms (Egan et al., 2018). The inclusion of herbs in grazing swards has recently been promoted as another pathway towards increasing sward yield under grazing, largely through greater soil nutrient utilization which is achieved via the niche complementarity of herb rooting structures with those of clovers and grasses (Grace et al., 2018). The objective of the current study was to quantify the dry matter (DM) yield of various swards at four different levels of N fertilizer.
Materials and methods: A grazing plot trial was established in 2019 with four sward mixtures sown as follows: perennial ryegrass (Lolium Perenne L.; PRG) (G); PRG, chicory (Chicorium intybus; Ch) & ribwort plantain (Plantago lancelota; Pl) (GH); PRG, white clover (Trifolium repens; WC) (GC); PRG, WC, Ch & Pl (GCH). Nitrogen fertilizer was applied to all sward mixtures at four different rates of 0, 100, 150 and 200 kg N/ha/year. Plots were grazed on 8 occasions between March and October 2020; the whole plot area was grazed by thirty dairy cows when the G 200 N sward had a pre-grazing yield of approximately 1200 kg DM/ha. Sward yield was measured immediately prior to each grazing. Nitrogen fertilizer was applied to each plot in February and immediately after each grazing, excluding the final grazing (October), as appropriate for each treatment. Proc mixed (SAS 9.4) was used to analyse herbage yield.
Results: Compared to the 0 N treatment, swards including clover had little yield response up to 150 N, both GC and GCH had increased yield at 200 N (Table 1). The GH sward increased DM production at 100 N although there was little further increase in DM production at 150 N or 200 N. Within N treatments G swards consistently produced less DM than all other sward types.
Conclusion: All swards responded to increasing levels of N fertilizer although yield response differed according to sward composition. In agreement with Grace et al. (2018), sward DM yield tended to increase as sward complexity increased across all N application levels.

Table 1
Annual DM production (kg DM/ha) of swards per nitrogen treatment (kg N/ha/year). * [1,2,3] Means within a column with different superscripts differ significantly ($P < 0.05$). $ [a,b,c] Means within a row with different superscripts differ significantly ($P < 0.05$). ^ Sward treatments abbreviated: G – Grass; GH – Grass & Herb; GC – Grass & Clover; GCH – Grass, Clover & Herb.

Sward mixture	0 N	100 N	150 N	200 N
^G	*$5326[1a]	6976[1b]	7899[1c]	8304[1c]
GH	6755[2a]	8374[2b]	8890[2,3b]	9270[2b]
GC	7300[2a]	8171[2a]	8143[1,3a]	9273[2b]
GCH	8526[3a]	8710[2a]	9448[2a,b]	10072[2b]

Acknowledgement: The authors would like to acknowledge the financial support of VistaMilk (16/RC/3835) in completing this work.

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157. Effect of lysolecithin supplementation in milk on performance of suckling female dairy calves

M. Mandouh [a,*], R. Elbanna [a], H. Abdellatif [a]

[a] Department of Nutrition and Clinical Nutrition, Faculty of Veterinary Medicine, Cairo University, Giza, Egypt

* Corresponding author. M. Mandouh.

Application: The supplementation of lipid emulsifier (Lysolecithine) in the early life of dairy calves improved their feed efficiency.
Introduction: The early life stage of calves is very important for their future production. Nutrition plays a vital role during this stage (Soberon et al., 2012). Lysolecithin is an emulsifier that enhances animal production (Pan et al., 2013). Therefore, the aim of the current study is to investigate the growth and general health-promoting effect of lysolecithin on newborn female dairy calves.
Materials and methods: In a 12 weeks' experiment, a total of 30 female Holstein calves (3 days old) were blocked by body weight and allocated into three groups (n = 10/ group). The first group was fed on pasteurised whole milk only (control group; CON), the second group was fed on whole pasteurised milk supplemented with lysolecithin (dissolved in milk at a dose of 6 g/head/day; LECL). The third group received the lysolecithin in milk at a dose of 12 g/head/day (LECH) up to weaning (d 84), calves were fed individually. Calf starter was offered free of choice to all calves in the different experimental groups starting from two weeks of age. Bodyweight and body conformation were recorded every 4 weeks and calf starter intake was recorded weekly. Blood samples were collected at the end of the experiment and used for the determination of liver and kidney function metabolites, data were statistically analysed using PROC MIX procedures of SAS 9.4.
Results: Lysolecithin at both levels of supplementation did not affect the body weight as well as body conformation ($P > 0.05$). Calf starter intake was significantly reduced in a dose-response manner due to lysolecithin supplementation compared to the control group ($P = 0.03$) at the third month of the experiment (w8-12) (Figure 1). Calf starter intake decreased in the third month only ($P = 0.03$) in lysolecithin received groups (LECL and LECH) compared to the control one (CON)). Serum levels of ALT, AST, albumin, A:G ratio, and creatinine were significantly reduced ($P = 0.05$) in lysolecithin supplemented calves compared to the control ones (Table 1).
Conclusion: Lysolecithin did not affect calf starter intake at the first two months of age and it improved nutrient utilization afterward as seen by reduced calf starter intake, and reaching the same body weight, therefore, it could be concluded that supplementation of lysolecithin as an emulsifier to suckling dairy calves could improve their performance and general health status.

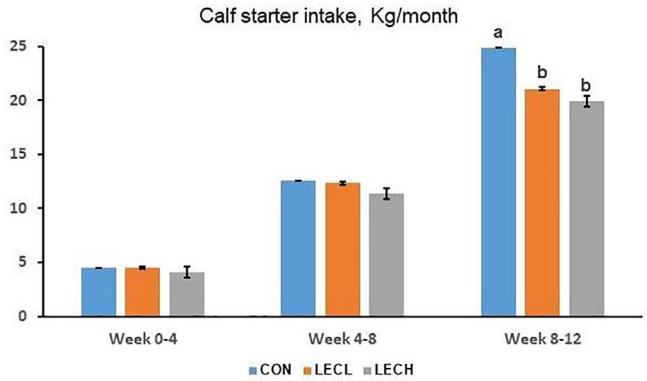

Figure 1. Effect of lysolecithin on calf starter intake in female Holstein calves.

Table 1
Effect of lysolecithin on liver and kidney function metabolites of female Holstein dairy calves.

Item	Treatment				
	CON[1]	LECL[2]	LECH[3]	SEM	*P*-Value
ALT[4]	22.67[a]	14.50[b]	12.67[b]	2.02	0.01
AST[5]	99.40[a]	63.00[b]	66.33[b]	6.61	0.01
Albumin	3.57[a]	3.08[b]	3.10[b]	0.17	0.05
A: G ratio[6]	1.36[a]	1.06[b]	1.09[b]	0.07	0.01
Creatinine	1.09[a]	0.86[b]	0.89[b]	0.06	0.04

[1]Control group did not receive lysolecithin supplement.
[2]Group recived 6 gof lysolecithin/head/day in milk.[3]Group received 12 g of lysolecithin/head/day in milk.[4]Alanine aminotransferase.[5]Aspartate aminotransferase.[6]Albumin: globulin ratio.[a,b]Means within a row with different superscripts differ ($P \leq 0.05$).

Acknowledgement: The authors would like to acknowledge Dr Ahmed Elolimy for helping with statistical analysis.

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158. The effect of adding palm dates during ensiling on the fermentation and nutrient features of ryegrass and brassica based silages

A. Alrumaih [a,b,*], A. Chaudhry [a], J. Standen [a]

[a] Newcastle University, Newcastle upon Ty, UK
[b] Qassim University, Buraydah, Al-Qassim, Saudi Arabia

* Corresponding author. A. Alrumaih.

Application: Adding date-palm as an energy source may help improve the nutritive value of fresh and ensiled forages.
Introduction: Nutritionists have been testing a variety of feed ingredients and forages for animal feeding, depending on their quality, price, and availability. Date-palm (Phoenix dactilifera), especially the amount that is surplus to human consumption could be used as an affordable ingredient to supply substantial contents of sugars and other nutrients (Ogungbenle, 2011). This study investigated the effects of ensiling different amounts of dates with either ryegrass, or different brassica forages on effluent, alongside fermentation and nutritional values of resulting silages.
Materials and methods: A 2x4x3 factorial design in triplicate was applied to evaluate the effect of ensiling 4 amounts (0%, 5% 10% and 20%) of seedless whole date palm (SWDP) with about 229 g of three chosen forages: Rape × Kale (Redstart), Rape × Kale (Swift) and Ryegrass. Harvesting from field was conducted using a Netta 7.2 V Grass Trimmer. Forage samples were cut into small pieces of 3–5 cm in length and then wilted for 72 h inside a shed (due to cold and wet weather). The SWDP were each cut into 6–8 pieces (0.25–0.5 cm) before ensiling each mixture in triplicate separately in copolymer polypropylene (PP) 2.5 L buckets. Buckets were completely filed and covered by its lid being fitted with a water-sealed one-way plastic valve as described by Palić et al. (2011). After 60 days of ensiling, the buckets containing forage mixtures without or with SWDP were opened to collect representative samples. These ensiled forages alongside their frozen un-ensiled counterparts were analysed for fermentation characteristics and nutritional composition by using an NIR analyser calibrated for wet forages. The data were subjected to Anderson Darling for the normality test. The data were then statistically analysed by applying Analysis of Variance (ANOVA) in GLM procedures of SPSS software to study the effects of forage type, SWDP and their interaction at $P < 0.05$. Means were compared by using Tukey's test at $P < 0.05$. *Result*: Oil-A has increased in silage ($P < 0.01$), although D-value, ME and CP have decreased in silage compared to the fresh forages ($P < 0.01$, $P = 0.02$ and $P < 0.01$) respectively. In term of SWDP addition, as percentage increased, CP, Oil-A and Ash percentages linearly decreased ($P < 0.01$, $P < 0.01$, $P < 0.01$), although, DM, D-value and ME were linear increased ($P < 0.01$, $P < 0.01$, $P < 0.01$).There was an interaction between forage form (fresh or silage) and SWDP % ($P < 0.01$).
Conclusion: The SWDP addition appeared to have changed the chemical composition of mixture due to dates sugar content. Further studies are ongoing to examine the effect of SWDP addition on the in vitro dry matter (IVDMD) and organic matter (IVOMD) digestibility.

Acknowledgement: The authors thank Qassim University, Qassim, Saudi Arabia for funding.

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159. Modelling growth in Suffolk sheep with insufficient mature weight records for polynomial random regression models

E. Mutch [a,b,*], R. Mrode [b], M. Coffey [b], G Simm [a]

[a] University of Edinburgh, Edinburgh, Edinburgh, UK
[b] Scotland's Rural College, Edinburgh, Edinburgh, UK

* Corresponding author. E. Mutch.

Application: Mature weight records are rarely recorded in sheep which necessitates novel modelling methods to accurately predict genetic value for growth and optimize high quality food production for a growing human population.
Introduction: Random regression modelling has been used across multiple animal species to model longitudinal data (Schaeffer, 2004). The random regression model accounts for the correlation between measures of the same trait and the wide environmental variability involved in growth, but this requires many weight records. However, mature weight records are often neglected. This study aimed to develop models for growth data in Suffolk sheep that is insufficient for polynomial random regression modelling due to a lack of mature weight records. Two methods were employed. In method A missing mature weight records were predicted for the animals based on their sires and the years in which the lambs were born and then analyzed with random regression models using polynomials or simple linear regression for animal and permanent environmental (PE) effects. Method B used a random linear regression animal model to model animal and PE effects.
Materials and methods: This project was conducted with a dataset provided by AHDB with records from 14,870 Suffolk sheep. It included multiple weight records for each animal, with a total of 42,244 records. Four weight recordings were identified for the analysis including birth weight, weaning weight (9 weeks), scan weight (21 weeks), and mature weight. There were 89 mature weight records. Method A began with filtering the data in R to

include only animals with a mature weight. The sires and birth years of these animals were identified and a prediction model for each of the ten sire groups and each of the year groups was made. The prediction model was: Mat weight = birthweight + weaning weight + scan weight. Mature weights were analyzed in a random regression model with polynomials of order 1 for animal and PE effects. Method B used an animal model with the recorded mature weights alone. A three-generation pedigree was formed in R using a match function and a full pedigree provided by AHDB. A random regression was fitted with a linear age effect. All analyses were done in ASREML, and genetic parameters were estimated.
Results: Models in Method A with polynomials failed to converge but the linear model converged. Method B resulted in an additive genetic variance of 0.016 for birth weight (BW), 13.58 for weaning weight (WW), 68.688 for scan weight (SW), and 990.92 for mature weight (MW). This corresponded to heritabilities of 0.015, 0.487, 0.687, and 0.759 respectively. The correlations were: BW, WW = 0.4603, BW, SW = 0.0151, BW, MW = 0.0040, WW, SW = 1.0, WW, MW = 1.0, MW, SW = 1.0. The estimates of heritabilities from the method A with linear regressions were slightly higher than method B at: 0.007, 0.192, 0.539, and 0.947 respectively.
Conclusion: Simple linear regression models resulted in possibly useful genetic parameters for growth but some fine tuning of approach is required.

Acknowledgement: The authors acknowledge funding from AHDB.

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160. Body condition scoring as a rapid predictor of Longissimus dorsi muscle depth and subcutaneous fat thickness in Chios fattening lambs

E. Tsimpouri [a,*], M. Lagonikou [a], A. Diamantatou [a], D. Gelasakis [b], E. Denezi [c], I. Bossis [d], A.I. Gelasakis [a]

[a] Laboratory of Anatomy and Physiology of Farm Animals, Department of Animal Science, School of Animal Biosciences, Agricultural University of Athens (AUA), Athens, Greece
[b] Agrifood Research and Innovation Center, Volos, Greece
[c] Denezis A.E., Argos, Greece
[d] Laboratory of Animal Husbandry, Department of Agricultural Sciences, School of Agriculture, Forestry and Natural Resources, University Campus, Aristotle University of Thessaloniki (AUTh), Thessaloniki, Greece

* Corresponding author. E. Tsimpouri.

Application: Longissimus dorsi muscle depth (LMD) and subcutaneous fat thickness (SFT) cannot be easily measured in a production setting. Body condition score (BCS) could be used as an alternative for their gross estimation in fattening dairy breed lambs.
Introduction: Body condition score is a rapid and convenient indicator, of lambs' nutritional status and carcass quality, although commonly confounded by breed. In dairy lambs, studies to associate BCS with LMD and SFT are scarce. The objective was to assess the relationship between LMD, SFT and BCS in Chios lambs at the last stage of fattening for the production of heavy carcasses.
Materials and methods: Seventy-three Chios fattening lambs (39 males and 34 females) were enrolled in this preliminary study. Body condition score was recorded for each lamb using a five-degree scale with 0.25 increments (1 = emaciated, 5 = obese), and B-mode ultrasound scanning was applied on the left of the spine between the 4th and 5th lumbar vertebrae, at 30 (-30d) and 2 days (-2d) before slaughter (~7 months of age). Longissimus dorsi muscle depth and SFT were measured at the deepest point. Data were analyzed using SPSS v23. Descriptive statistics (mean ± SE) were calculated and a mixed linear model was used as described below: $Y_{ijk} = \mu + \beta_1 \times BCS + G_i + T_j + \gamma_k + e_{ijk}$ where, Y_{ijk} = LMD, SFT, μ = intercept, β_1 = fixed effect of the regression coefficient of BCS, G_i = fixed effect of the gender (i = 2 levels, 0 = male, 1 = female), T_j = fixed effect of the ultrasonography time (j = 2 levels, 1 = 30 days before slaughter, 2 = 2 days before slaughter), γ_k = random effect of the k^{th} lamb, e_{ijk} = residual error.
Results: At −30d, overall mean values of BCS, LMD, and SFT were 3.2 ± 0.03, 22.5 ± 0.38 mm, and 3.9 ± 0.18 mm, respectively. The respective values at −2d were 3.4 ± 0.05, 23.2 ± 0.37 mm, and 4.4 ± 0.15 mm. Descriptive statistics of LMD and SFT for different BCS classes are presented in Table 1. A one-degree increase in BCS was associated with 4.33 mm ($P < 0.001$, 95% CI: 3.05 to 5.61) and 1.36 mm ($P < 0.001$, 95% CI: 0.79 to 1.94) increase in LMD and SFT, respectively. Gender and ultrasonography time were not significantly associated with LMD and SFT.
Conclusion: Changes of LMD and SFT at the lumbar region are sufficiently described by BCS during the last month of fattening for the production of heavy Chios lamb carcasses.

Acknowledgements: This research has been co-financed by the European Union and Greek national funds through the Operational Program Competitiveness, Entrepreneurship, and Innovation, under the call RESEARCH-CREATE-INNOVATE (project code: T1EDK-04393/MIS:5063368 'InnoLambMeat').

Table 1
Longissimus dorsi muscle depth (LMD) and subcutaneous fat thickness (SFT) (mean ± SE) per body condition score (BCS) class.

	30 days before slaughter			2 days before slaughter		
BCS class (1–5 scale)	n	LMD (mm)	SFT (mm)	n	LMD (mm)	SFT (mm)
2.50–2.75	12	19.2 ± 0.96	2.5 ± 0.32	11	18.9 ± 1.03	3.1 ± 0.41
3.00–3.25	41	22.3 ± 0.42	3.8 ± 0.20	18	23.0 ± 0.50	4.4 ± 0.33
3.50–3.75	20	24.8 ± 0.58	5.1 ± 0.33	33	24.0 ± 0.43	4.6 ± 0.17
≥4.00	0	-	-	11	25.7 ± 0.72	5.2 ± 0.29

n: number of lambs, SE: standard error.

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