Genetic changes in ruminants: Historic trends and future prospects

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Abstract

The major ruminant species, dairy and beef cattle and sheep, represent a rather heterogeneous group as regards genetic improvement, which to a large extent reflects their respective breeding structures. In the UK, the beef cattle and sheep industries still span many different breeds, have small herds/flocks, and have been relatively unaffected by agribusiness investment, and are assumed to have a traditional pyramid breeding structure, in which progress is determined by a small number of breeders. Recording of production information, which to date has focussed on terminal sire characteristics, is relatively recent, and until the use of across herd evaluations, genetic progress was probably limited. However in recent years there have been gains in both growth and muscling. There is little evidence or concern for undesired consequences in commercial flocks, partly because of the extensive use of crossbreeding in these industries, which exploits both breed complementarity and heterosis.

By contrast, the dairy industry is now dominated by purebred Holsteins. Increasingly breeding activities are both global in scope and dominated by a small number of large breeding companies. Because most traits of interest are only expressed in the female, improvement programmes have continued to focus on progeny testing, with test daughters in many herds. Most recording schemes and promotional activities emphasise production and type traits. The dairy industry is also notable for the publication of bull progeny test results, so that top bulls can then be used as sires of the next generation of by all companies. These bull evaluations now extend to international rankings.

Data from the US indicates continuing genetic progress for production traits in the Holstein, particularly since the 1960s, by when progeny testing had been established, frozen semen widely used, and adequate statistical procedures in place for evaluating bulls. Genetic progress is also evident for type traits. There is now growing concern and evidence of undesirable genetic changes in fertility, disease incidence and overall stress, despite improved nutrition and general management. Altering this situation will require both the recording of such traits and the use of that information by breeding companies, especially in sire selection.

Introduction

This paper will discuss past genetic changes in sheep, beef and dairy cattle, albeit in a rather selective manner. In particular, the discussion of sheep and beef cattle will focus on the UK experience. While this may seem unduly restrictive, these industries need in almost all circumstances to be looked at from a national perspective, because the national populations tend to be fairly self-contained. By contrast, the dairy breeding industry, and especially the now dominant Holstein, is international in its organisation and marketing. Evidence will be presented on past genetic changes, and some attempt will be made to identify factors which have or will affect rates of change, and the likely direction of future selection efforts.

Sheep

The UK industry, while it is one of the world's largest sheep producers, poses interesting challenges to genetic improvement. For example, there are reckoned to be over 70 purebreeds of sheep in the UK, many more crossbred types, and these are used in a wide range of climates and production systems, and all of these factors combine to complicate such issues as breeding objectives.

Most sheep breeds are assumed to have a conventional pyramid breeding structure, with a small number of elite pedigree breeders having a dominant say on the direction and rate of genetic change. Performance recording of sheep in the UK is a relatively recent development, with weight recording started by the MLC in the 1970s. This was targeted at these dominant breeders. A major fillip to recording occurred in the 1980s, with the introduction of ultrasonic scanning for fat and muscle depth.

A major handicap to effective genetic improvement in the industry was the small size of many of these pedigree flocks, with ewe numbers in registered flocks in most breeds in the "tens". Important steps to overcome this problem of limited numbers were the establishment of group breeding and sire referencing schemes. The latter in particular, using both AI and natural service sires, provided an effective means of linking flocks genetically, the calculation of cross flock predictions of genetic merit, and sizeable groups of rams for selection. The choice as superior rams as reference sires should in itself lead to genetic progress.

Provided rams are functionally sound, the advice then is to choose the best on breeding values. For the terminal sire breeds, this is in the form of an index, a Lean index (Table 1), combining information on growth and live animal carcass information (Simm and Dingwall, 1989).

Selection Goal	**Selection Index**
Increase carcass lean weight (+3)	Live weight (+)
Reduce weight of fat (-1)	Ultrasonic fat depth (-)
	Ultrasonic muscle depth (+)

Table 1: Lean growth selection index for terminal sire breeds

Results to date from a number of sire referencing schemes support this view, both for the Index, for growth and for muscle depth (Figures 1 and 2). The benefits of selection have been demonstrated in purebred and crossbred offspring, on a range of feeding regimes, and at various levels of maturity (see Simm, 1998).
The Lean Index is very much geared to the needs of terminal sire breeds. What is encouraging now about the UK sheep industry has been the development of indexes to specific breed groups (Table 2). With those making contributions to dam lines, these indexes are necessarily more complex.

In the sheep industry there are as yet, few concerns about the longer term effects of such selection strategies.

- Effective selection for increased performance is very recent, so the scale of the changes has not been great.

- The UK industry makes very extensive use of crossbreeding, which exploits both breed complementarity and heterosis. Adverse effects in a relatively small terminal sire population, for example, is thus likely to manifest itself in a commercial crossbred flock.

Whilst it is encouraging to see the uptake of recording in the sheep industry, and structural changes to both facilitate genetic evaluations and encourage progress, there are major challenges to the sheep industry to fully exploit the possibilities of genetic change. For example, recording needs to be broadened to include breeds other than those involved in terminal crossing. Here, especially when dealing with maternal characteristics, the debate on breeding objectives is likely to be rather protracted. It is encouraging to see how Sire Referencing Schemes have taken up testing for resistance to scrapie among potential reference sires. These schemes may also provide a conduit for adopting new technologies, such as CT scanning and, longer term, such potential aids as marker assisted selection. Individuals will generally lack the financial and technical resources to exploit such opportunities.

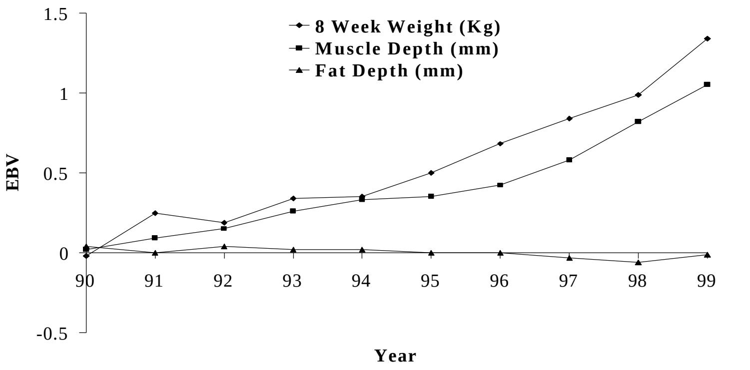

Figure 1: Genetic trends in Texel sire referencing schemes (Source: Signet)

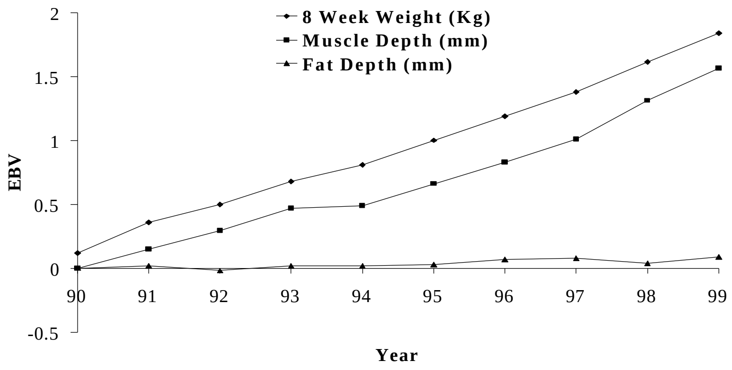

Figure 2: Genetic trends in Suffolk sire referencing schemes (Source: Signet)

Breed Type	**Emphasis on different goals (%)**					**Legend**	
	LS	**LG**	**MA**	**MS**	**LEAN**	**LS**	litter size
terminal sire	-	-	-	-	100	**LG**	lamb growth
lowland	66	17	17	-		**MA**	maternal ability
hill	11	40	40	9		**MS**	mature size

Table 2: Selection goals for different sheep breed types in the UK (Source: Signet)

Beef

Performance recording in UK beef breeds was started by the MLC in the 1970s, focussing initially on growth, but then incorporating ultrasonic scanning for backfat and muscle depth. In many respects these developments have paralleled those with the sheep breeds.

A major handicap to effective selection in the breeds is the small size of many herds (Table 3). This problem was overcome to some extent with the introduction of cross-herd BLUP predictions of genetic merit, analyses which exploit pedigree links between herds, together with planned inseminations in some breeds to improve links between herds.

Breed	**Number of herds**	**Average number of cows**
Aberdeen Angus	147	17
Blonde d'Aquitaine	57	13
Belgian Blue	20	7
Charolais	199	19
Hereford	36	27
Limousin	214	22
South Devon	68	27
Simmental	185	16

Table 3: Average size of UK recorded pedigree beef herds

A further major complication has been that many of the cows producing "premium" calves for slaughter were themselves crossbred animals derived from the dairy herd. While the Hereford in particular and the Angus to a lesser degree have held their position as natural service sirs on dairy cows, AI beef inseminations have come to be dominated by the larger continental breeds, such as the Limousin, Belgian Blue and Charolais.

Predictions of genetic merit (EBVs) are now produced for a range of traits, mostly related to an individuals own performance for growth and carcass traits, but also covering maternal contributions to growth. Evaluations for calving ease are rather more recent.

Information on these EBVs is then combined into two indexes, one for Beef Value, which is quite well-accepted by breeders, and a more recent one for Calving Value, combining information on gestation length and calving ease, which is still under debate.

Despite the limitations to progress that might be expected in beef breeds, with numerous breeders operating with small herds, and the ever-present need to maintain a balance between an animal's appearance and soundness, as well as his predicted genetic merit, there is now good evidence of genetic progress for growth and muscling in breeds such as the Charolais (Figure 3 and 4).

What of the future? If there are adverse effects of selection, then, as in the sheep industry, their impact will be mitigated by crossbreeding. Perhaps the biggest danger has been the temptation to focus on terminal sire features in all breeds, regardless of the role that a particular breed might play within the overall industry. In stressing growth and carcass traits in all breeds, some of the easy calving attributes of breeds such as the Angus and Hereford are thought to have been weakened (McGuirk et al, 1998). More generally, maternal attributes of other native breeds have not been recognised.

The recognition of these potential problems has been prompted in part by the change from Friesian to Holstein in the dairy herd, with the resulting cross now deemed less suitable as a suckler cow. Whether an alternative beef dam, not involving the Holstein, can be produced at a competitive price is still a moot point, but at least the debate has begun. One consequence of this ongoing debate will be more attention to maternal attributes in future selection strategies.

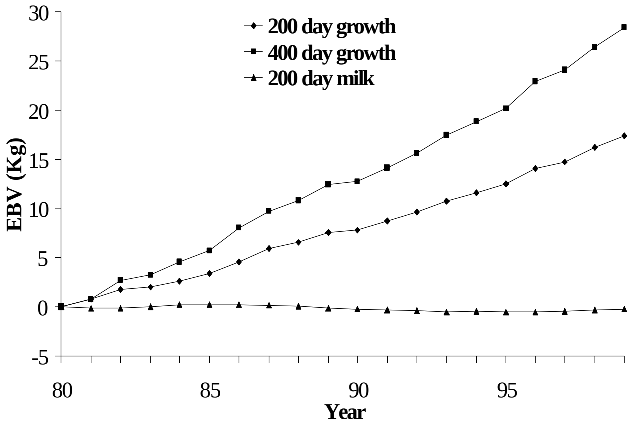

Figure 3: Genetic trends for growth traits in Charolais (Source: Signet)

While a more wide-ranging debate on breeding objectives is welcome, the size and structure of the pedigree beef industry in the UK does not lend itself to the adoption of more sophisticated breeding aids. For example, recent research has indicated either single gene or chromosomal (e.g. quantitative trait loci) effects on muscularity (e.g. myostatin) or on aspects of meat quality. Even if such effects were demonstrated in UK breeds, how would UK breeders exploit that knowledge? The relatively small size of herds, and the absence of technical and financial inputs into this sector will pose major handicaps to the application of such developments.

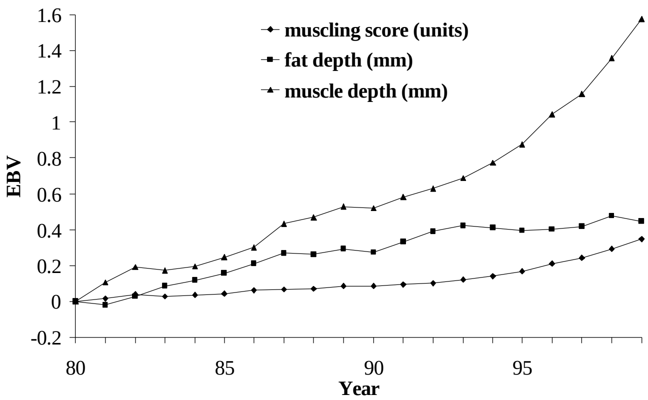

Figure 4: Genetic trends for carcass traits in Charolais (Source: Signet)

Dairy Cattle

Dairy cattle differ from the other two major ruminant industries in a number of important respects.

- The production traits of primary traits are sex-limited, hence the need for progeny testing of bulls, to identify bulls suitable for commercial use, and also those to breed the next generation of sons to be tested. Even in the early years of breeding programmes, this necessitated the use of substantial animal resources, with test daughters distributed across many herds. The evaluation of bulls for production traits, such as milk production, made use of the fact that farmers enrolled in milk recording schemes for management reasons. Since the early years of progeny testing we have seen the publication of bull progeny test results, or proofs, using increasingly sophisticated statistical procedures.

- After the development of frozen semen technology in the late 1950s, there has been the opportunity for extensive gene movement, initially just within countries, but now also between countries as well. There is now major international trade in dairy genetics, especially of the North American type Holstein, which has come to dominate dairying in most European countries, displacing more dual purpose breeds such as the British Friesian. The extent of the trade in dairy semen is illustrated by a list of currently (September 1999) available Holstein bulls in the UK (Table 4). Of the 752 available bulls, about 90 percent were born outside the UK, with the US and Canada still being dominant

Country	**Number of bulls**	**(%)**
USA	330	44
Canada	135	18
UK	71	9
France	71	9
Holland	54	7
Italy	46	6
Germany	25	3
New Zealand	18	2
Denmark	2	-
Total	752	

Table 4: Holstein bulls currently available in the UK by country of registration (Source: HUKI)

- Type or conformation information is also widely recorded on test daughters, be they in pedigree or non-pedigree herds, as this information has come to be seen as essential for marketing purposes. What good type means can vary, from show standards of excellence to emphasis on functional characteristics, generally of the mammary system or feet and legs.

Despite such differences in perceived excellence for type traits, there has been considerable progress in harmonising the recording of individual so-called linear traits across countries, using a standardised scoring system.

- We find much more variation among countries when we move to other **non-production traits,** such as fertility records, or information on disease occurrence. In some countries they are recorded systematically and comprehensively. In others, it is left to the farmers initiative to note such information, either through a formal recording scheme or for his own purposes.

- Another feature of dairy breeding has been the routine publication of bull proofs. This worked initially for bulls bred within a country, but was then applied to imported semen using conversion formulae. Finally, we now see the centralised publication of international proofs for both production and conformation (type) traits, using information from all member countries of Interbull. The extension of these procedures to non-production traits is of course limited by the extent such information is recorded on daughter groups in different countries.

- The Holstein breeding industry is now dominated by multinational breeding organisations. Such rationalisation was almost inevitable, given the high cost of testing a bull, the low proportion (5-10%) of bulls tested that are then marketed, the excessive number of bulls tested around the world, and low margins on semen. These breeding companies are now truly international, both because they vie to sell semen in many countries, but also because they will commonly source widely for their bull dams and sires. One consequence of these trends has been the notion of a “global product”, the pursuit of very similar breeding objectives by these companies, and very often the use of the same sires in different breeding programmes.

Evidence of Progress

Figures 5 and 6 illustrate the genetic changes which have been made for production and type traits in the US population. Similar results can be produced from many other countries, but these will include to some degree the influence of breed substitution.

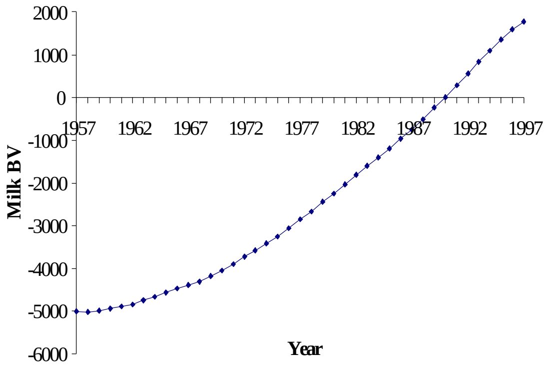

Figure 5: Genetic trend for Milk in US Holsteins

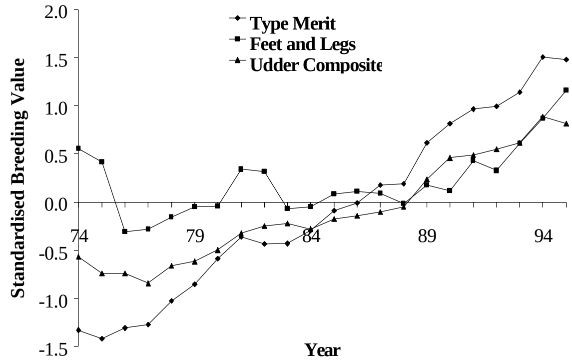

Figure 6: Genetic trend for Type traits in US Holsteins

It is not always clear to what extent the market drives breeding goals. However, if we look at Holstein currently marketed in the UK, we see a very high standard for both production, as measured in our current (September 1999) PIN index, and also for overall Type Merit. Most bulls have PIN values of £70 and over (Figure 7). The effective minimum standard for Type Merit is 1.0 (Figure 8), which means bulls have to be at least about one standard deviation above population average.

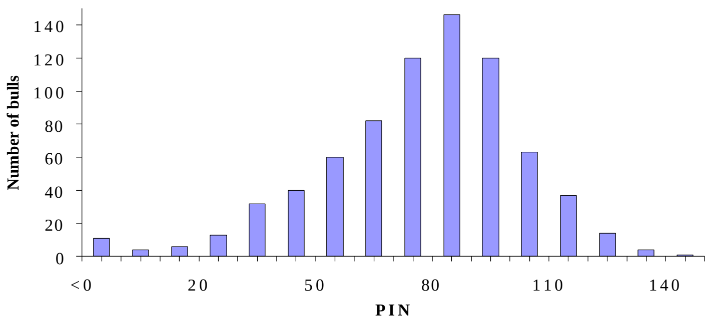

Figure 7: Distribution of PIN values for Holstein bulls currently marketed in the UK

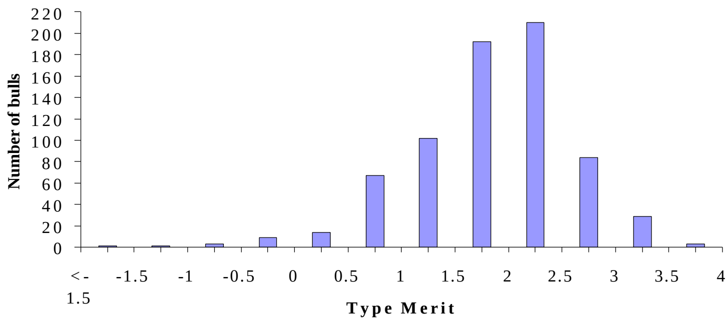

Figure 8: Distribution of Type Merit for Holstein bulls currently marketed in the UK

These figures need to be put into a national context of merit. Figure 9 shows the distribution of PIN values for bulls marketed in the UK, and for the UK cow population. The respective averages are **£64 and £28,** so that the use of currently available bulls will further lift the merit of the UK population.

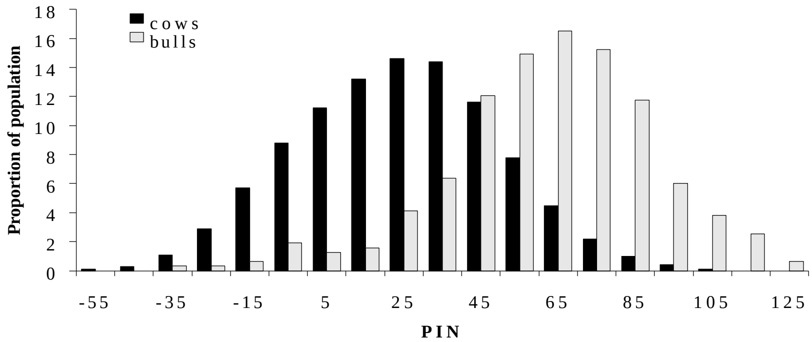

Figure 9: Distribution of PIN values for UK Holstein cows and bulls

Future Prospects

If breeding companies pursue similar goals to the present, then we are unlikely to see any slackening in the rate of genetic progress. With well-defined market "goal posts" for production and type, competing breeding companies will strive for operational efficiencies to achieve these goals. There is no evidence that past selection has led to a decline in genetic variation for such traits. Further, the size and technical resources of dairy breeding organisations are such that they are well-placed to exploit technical developments in reproductive and genetic biotechnology, such as cloning and marker assisted selection.

What direction should that genetic change take? The current emphasis on production and type is now coming under increased scrutiny, reflecting in part concerns about animal welfare and sustainability. High yielding cows are even less able to meet their feed needs in early lactation, so that animals are under more stress, their fertility suffers, and they may also be more susceptible to diseases such as mastitis. These concerns increase if we are to see a period of low milk prices, which will encourage farmers to look at low cost production systems, with reduced inputs generally and less reliance of concentrate feeds.

One unfortunate aspect of our current industry recording schemes is their inadequacies. For example, in the UK we have very incomplete inseminations, and effectively nothing on disease occurrence and why animals are culled. The UK is not alone in this situation – in many respects the situation in North America is worse. However, this situation makes it difficult to detect undesirable consequences of our past breeding efforts. Phenotypic trends (see for example Royal et al, 1999) can give a misleading impression of genetic change when a trait, such as somatic cell counts, can be strongly influenced by management.

Despite these reservations regarding data quality, I suggest we now have pretty compelling evidence to show that there has been decline in fertility in the UK herd, which probably has a genetic basis:

(1) Genetic correlation’s between production traits and fertility are consistently negative (Pryce et al, 1998).

(2) In the Langhill project, the Selected Line is poorer that the unselected Control both in days to first service, and in conceptions to first service (Pryce et al, 1999).
(3) Correlations between US bull proofs for production and type traits are unfavourably correlated with Scandinavian proofs for fertility and disease traits (Rogers et al, 1996, 1999).

What might breeding companies do in the face of such evidence? One overriding difficulty they have is in predicting market demand, when it takes perhaps 7-8 years between sourcing a bull (i.e. selecting his sire and dam), and when his proof emerges. Moving too quickly or too late risks losing market share. But doing nothing also looks an increasingly unacceptable option.

The available options are nicely illustrated by the recording and evaluation developments in various countries. A number have moved to evaluating daughter longevity, commonly combining functional type information with actual longevity records. In France and the Netherlands we have recently seen bull proofs for daughter fertility, based on actual insemination records. Of course, where such records are not collected nationally, proxy fertility traits such as intercalving interval are possible, although genetic information on this trait, as with longevity, will only be available some time after an initial production proof. And then we have the Scandinavian countries, where we see genetic evaluations for a more complete range of fertility and disease traits.

Breeding companies are caught in a difficult dilemma. They operate as global organisations effectively supplying a global product, semen from essentially the same bulls into all markets. At the same time, there are significant genotype*environement interactions in extreme situations, and increasing diversity among countries in the traits which are evaluated.

One factor restricting innovation in the industry in evaluation is the public ranking of bulls. One consequence of this is that any advantage one company has over its competitors is essentially a one generation affair, as all companies use the same top sires to breed the next generation of sons. This situation will certainly hinder the uptake of new breeding technologies, such as marker assisted selection. It also discourages investment in other areas, such as the organisation of breeding schemes (progeny testing) around herds that will record traits that the company deems to be essential for its commercial success. Perhaps the introduction of semen sexing will yield both the financial stability that companies need to encourage such investment, and possibly generate new products (e.g. crossbred heifers) that may avoid the consequences of our past breeding successes.

Acknowledgements

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