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Future global, EU and UK markets for milk and milk products – *implications for the UK dairy industry*

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8 Responding to future market requirements: implications for breeding strategies

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INTRODUCTION

Genetic improvement is one of the most effective strategies available for altering the performance of farm animals. It is relatively slow compared to some other methods, such as improved feeding, but it is permanent and cumulative, and it is usually highly cost-effective and sustainable. Effective genetic improvement programmes contribute greatly to the efficiency and competitiveness of livestock industries, and to the cost and quality of food produced for human consumption.

Over the last few decades genetic selection of dairy cattle has had a dramatic effect on the productivity of cows in most temperate dairying countries. Sustained high rates of genetic progress have been achieved in several countries since the 1960s, especially the United States (US), Canada and New Zealand (see Figure 1 for US results).

In many more countries, rates of improvement have increased only recently; often aided by importations of genetic material, especially from North America (see Figure 2). In this paper we briefly review some of the evidence on the effect of genetic improvement of yield on economic performance, and we outline some recent and likely future developments in breeding which could help dairy farmers to respond more effectively to future market requirements. These include the development of more comprehensive breeding goals and indexes, improved systems of testing and genetic evaluation, and the possible future role of molecular genetic techniques.

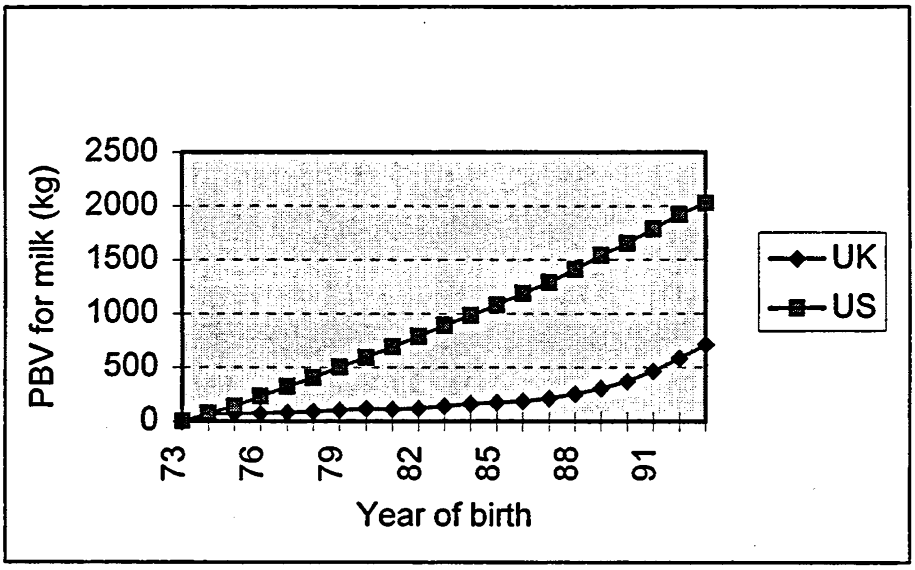
THE EFFECT OF SELECTION FOR YIELD ON ECONOMIC PERFORMANCE

In theory, the breeding goal of most dairy producers is to increase the profitability of their animals. However, in practice, most selection in the past has been for increased yield of milk or milk solids, with some producers paying additional attention to type classification or physical appearance of cows.

Research at the University of Edinburgh/Scottish Agricultural College (SAC) Langhill Dairy Cattle Research Centre and elsewhere has demonstrated that selection for higher solids yields has an important effect on economic performance in both relatively high and relatively low input feeding systems (see Table 1). However, there are opportunities to increase the benefits from selection still further by tailoring the emphasis on milk components more closely to their likely future value, and by including other economically important traits in selection. Both of these aims are best achieved through the development of more comprehensive breeding goals and selection indexes, as described below.

Figure 1

Cumulative change in cows' predicted breeding values (PBVs)[1] (i.e. 2x PTAs) for milk production, in milk-recorded Holstein Friesian cows in the UK and the US over a 20-year period.



Note: [1] PVB=2xPredicted transmitting ability (PBA)
[2] US PVBs have been converted from pounds to kg (by multiplying by 0.4536).
[3] N.B. the graph shows *cumulative change* in PBV since 1973, and does not allow comparison of the *average merit* of cows in the two countries.

Source: ADC; Dr G R Wiggans, personal communication, after Simm, 1998.

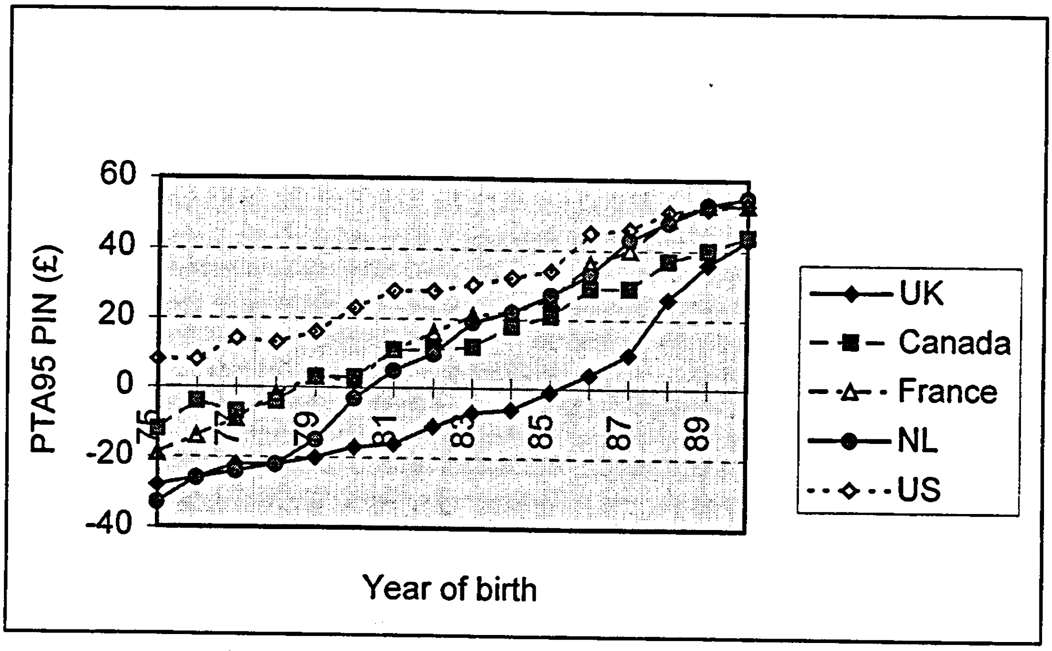
Table 1

Performance and efficiency of selection (high genetic merit) and control line (average genetic merit) Holstein Friesian cows over the first 38 weeks of lactation, during 4 years of the Langhill feed intake trial.

	Low Forage		High Forage	
	Selection	**Control**	**Selection**	**Control**
Milk yield (kg)	7569	6537	6372	5360
Fat %	4.19	4.20	4.54	4.37
Protein %	3.09	3.19	3.07	3.09
Fat plus protein yield (kg)	550	481	482	398
Dry matter intake (kg)	4803	4603	4149	3948
Gross energetic efficiency (MJ milk/MJ feed)	0.418	0.377	0.440	0.374
Live weight (kg)	610	610	601	590
Condition score (5 point scale)	2.55	2.70	2.45	2.59
Margin overall feed costs (£)	1008	825	914	712

Source: SAC/University of Edinburgh (1994).

Figure 2
Trends in genetic merit of bulls in some major dairying countries.



Note: Trends are shown in terms of the UK production index PIN, which is based on PTAs for kg milk, kg fat and kg protein. This graph *does* allow direct comparison of estimated genetic merit of bulls among countries, since the data came from INTERBULL international evaluations. All the bulls used in a country and included in the evaluation, i.e. including foreign bulls, contribute to the mean PTA for that country.

Source: ADC; INTERBULL, after Simm, 1998.

MORE COMPREHENSIVE BREEDING GOALS AND INDICES

New Breeding tools

In many dairying countries selection indices have been developed recently to help balance selection for yield and solids content and, importantly, to account for some of the costs of production rather than just returns. (Selection for reduced costs of production is likely to become even more important in future, if milk prices fall in relation to costs.) Most UK producers are familiar with the PIN index introduced a few years ago for this purpose. The current version of PIN (PIN95) is based on the estimated genetic merit of bulls and cows (predicted transmitting abilities, or PTAs) for kg milk, kg fat and kg protein, each weighted by their expected future economic value. The weightings take into account the expected higher value of protein compared to fat (relative values of 1.5:1 are assumed), the extra feed costs resulting from increased production, the extra transport and cooling costs of high volume, low solids milk, and the cost of leasing extra quota to match the higher production of daughters of high genetic merit bulls. (It seems sensible to include quota leasing costs for extra production until the timescale over which quotas will remain is known. Since these costs are set against increases in fat yield, their effect is to 'tilt' the selection emphasis further towards protein, at the expense of fat, compared to a possible future version of PIN ignoring quota costs.) Economic selection indices provide a direct route for farmers to breed for future market requirements, providing that there are reasonably accurate predictions of what these requirements will be.

More recently, research at SAC and the University of Edinburgh has produced a related index, called ITEM (index of total economic merit), which includes some additional costs of production. ITEM is based on exactly the same principles as PIN, and still includes PTAs for kg milk, fat and protein. However, the initial version of ITEM also includes breeding values for four linear type traits which are associated with cow longevity - udder depth, teat length, angularity and foot angle. Table 2 shows the expected changes in production form selection on PIN95 and ITEM. Selection on either of these indices is expected to increase solids yields, whilst maintaining fat and protein % at about their current levels. Selection on ITEM is expected to produce slightly smaller changes in yield compared to selection on PIN, but improved cow longevity, which results in a higher overall change in margin.

Table 2
Estimated responses following selection on ITEM and PIN95

Index on which selection is based:	**ITEM**	**PIN**
Estimated annual response		
Margin (£ per cow)	15.6	15.3
Longevity (%)	0.14	0.00
Milk (kg per cow)	117	119
Fat (kg per cow)	4.9	5.0
Protein (kg per cow)	3.9	3.9

Note: Longevity is defined as the % of cows not involuntarily culled in the first 4 lactations, after correcting for genetic differences in yield.

Source: Veerkamp *et al* (1995a).

Whilst the expected economic benefits of selection on the initial version of ITEM are modest (about 2%) compared to selection on PIN, the index is an important step towards more comprehensive breeding goals for dairy cattle. In the future, new versions of ITEM are expected which will include: (i) updated estimates of the correlations between linear type traits and longevity, to reflect changes in the breed type of the UK herd; and (ii) PTAs for lifespan which are predicted from type traits together with actual herdlife measures of individual cows (rather than from type traits alone, as in the current version of ITEM. In the longer term, ITEM is likely to include predictors of liveweight, feed intake, reproductive performance and resistance to common diseases, to help breed healthier and more profitable cows. (Much of our current research in Edinburgh is geared towards identifying useful predictors.) These changes will lead to higher overall returns from selection on ITEM compared to selection on PIN, and bigger differences in rankings of animals on the two indexes. Similar indexes are being developed in several other major dairying nations. Evaluations on broader indexes such as these, together with improved reproductive technologies, may lead to renewed interest in crossbreeding.

GENOTYPE X ENVIRONMENT INTERACTIONS

The long-running debate on the importance of genotype x environment interactions (whether you need to breed 'horses for courses') has been refuelled by the massive importation of North American Holstein semen into Europe and elsewhere over the last couple of decades. In the past most experimental studies have indicated that, in temperate dairying systems, breed or strain x feeding system interactions are of little or no importance, at least for production per cow. However, recent research at Langhill suggests that genotype x environment interactions may becoming important, at least in relatively low input systems. Whilst the Langhill results in Table 1 show no evidence of a major genotype x feeding system interaction, comparing the average production of the four groups of animals is a fairly crude test. Table 3 shows the results of a more recent analysis of the changes in production in relation to pedigree index for fat plus protein. These show that responses to selection on the low input system tend to be lower than those in the high input system. This may indicate the beginning of a genotype x feeding system interaction. It appears that high merit cows may be unable to eat enough high forage diet to keep pace with their potential extra yield, especially of protein. Despite mobilising more body tissue, they are still unable to match the increase in yield seen in their contemporaries on a higher concentrate diet. Some would argue that the problem could be surmounted by modifying management of the high merit cows. This may be necessary in the short term, but in the long term it may be more sustainable and profitable to breed cows more suited to high forage systems. So, research at Langhill will continue to monitor the potential development of an interaction, and to investigate new breeding strategies which increase emphasis on feed intake, rather than tissue loss, to 'fuel' future increases in yield. Recent analyses have shown that several linear type traits are useful predictors of liveweight, feed intake and condition score, and so these could have a valuable role in future indices. Research is now in progress to refine estimates of genetic parameters and economic values of the relevant traits.

Use of these broader indexes to select bulls, both nationally and internationally, should help breed animals more suited to local systems, especially if traits like feed intake, health and reproduction are affected by interactions. Also, when there are important differences in ranking of bulls between countries, the new methods for international evaluation of bulls outlined below should allow more accurate selection of bulls.

METHODS OF SELECTION

Systems of testing

For the last forty years or so progeny testing of dairy bulls, and their subsequent widespread use through Artificial Insemination (AI), has been central to the genetic improvement of dairy cattle in most major dairy industries. The main benefit of progeny testing is that it can produce very accurate predictions of genetic merit. The main disadvantages are the cost and time it takes to get an accurate test. In the early 1980s the use of multiple ovulation and embryo transfer (MOET), to create large full sister families in nucleus herds, was proposed as an alternative to progeny testing. Although selection of bulls on the basis of their sisters' performance is less accurate than selection on progeny performance, the results are available a lot sooner, and so the annual rate of improvement can be greater. Testing in a nucleus herd also allows a wider range of traits to be recorded, and reduces the impact of preferential treatment which can occur in progeny testing. However, if nucleus animals are managed in an atypical way, the risk of genotype x environment interactions is increased. Nucleus herds need to be kept open to imports in order to keep inbreeding at acceptable levels, and to ensure that sires being used are of the highest genetic merit internationally. As a result the MOET schemes initiated by breeding companies in several countries are now geared more towards improving progeny testing schemes than replacing them. They do so largely by providing more accurate, unbiased assessment of elite females, which helps in the selection of bull mothers, and by providing earlier more accurate predictions of genetic merit on young bulls which are candidates for progeny testing. It seems likely that this interdependence of MOET nucleus schemes and progeny testing will continue in future, though sib-tested bulls may become more widely used as sires in nucleus herds as they reach similar levels of genetic merit to that of the top progeny tested bulls available internationally.

Table 3
Changes in performance of Langhill cows in two feeding systems per kg increase in pedigree index for fat plus protein

	Change in performance per kg increase in pedigree index for fat plus protein (regression coefficients with standard errors in brackets)	
	Low Forage	**High Forage**
Milk yield (kg/day)	0.20 (0.03)	0.13 (0.03)
Fat %	0.001 (0.004)	0.000 (0.004)
Protein %	-0.002 (0.001)	-0.005 (0.001)
Fat yield (kg/day)	7.8 (1.1)	5.4 (1.2)
Protein yield (kg/day)	5.6 (0.8)	2.9 (0.9)
Dry matter intake (kg/day)	0.04 (0.01)	0.01 (0.01)
Liveweight (kg)	0.1 (0.3)	0.0 (0.3)
Condition score (5 point scale)	-0.008 (0.002)	-0.009 (0.002)

Source: Veerkamp *et al* (1995b).

Genetic evaluation
In the last few years there have been several improvements in the methods of genetic evaluation of dairy cattle in Britain. In 1992 animal model BLUP evaluations were introduced for the first time. These produce predictions of genetic merit for both bulls and cows using information on all available relatives, resulting in greater accuracy. At the same time, evaluations were extended to include up to five lactation records on cows. Since 1995, evaluations have also included 'records in progress' (incomplete lactation results) from heifers. This shortens the time taken to get a reasonably accurate prediction of merit for young bulls being progeny tested. Further improvements are likely in this area through the use of more sophisticated methods of using individual test-day records of production in evaluations.

The range of traits evaluated in many countries is likely to increase in the future. In the UK the ADC recently introduced national evaluations for somatic cell counts and evaluations of lifespan are expected soon. National evaluations for other traits of direct or indirect economic importance, such as fertility, disease resistance, and possibly condition score, would be desirable too. Recent analyses of UK data has shown unfavourable genetic associations between yield and reproduction and between yield and some common diseases (see Table 4). Only by evaluating these traits, and giving them proper emphasis in breeding programmes, will we be able to slow the rate of decline in, or hopefully improve performance in, these important characteristics. Although the heritabilities of health and fertility traits are relatively low, the variation in these traits is reasonably high (Table 4), so genetic differences between the best and worst animals are substantial, making improvement though selection possible. Furthermore, public concern over animal welfare and methods of production means that these traits probably have even higher value than a direct economic analysis might suggest. The Scandinavian countries are among the few countries that have successfully incorporated health and fertility into their breeding programmes. This has been possible as all veterinary treatments are compulsorily recorded and stored in central databases in Scandinavia. Inclusion of health and fertility traits elsewhere in the world has often been limited by a lack of reliable data.

Table 4

Phenotypic standard deviations (σ_p), heritabilities (along the diagonal), genetic correlations (below the diagonal) and phenotypic correlations (above the diagonal) for 305 day milk, fat and protein yields, calving interval, mastitis and lameness obtained from analysis of data from UK Livestock Services and National Milk Record's Dairy Information System (DAISY).

Trait	σ_p	1	2	3	4	5	6
1. Milk yield	1075	0.33	0.69	0.71	0.20	-0.01	0.04
2. Fat yield	45	0.92	0.27	0.73	0.16	-0.02	0.01
3. Protein yield	36	0.99	0.96	0.27	0.16	0.02	-0.01
4. Calving interval	45	0.39	0.53	0.36	0.025	0.04	0.04
5. Mastitis	0.28	0.26	0.27	0.29	0.11	0.057	0.05
6. Lameness	0.28	0.17	0.12	0.13	0.20	0.33	0.036

Source: Pryce *et al* (1998).

With increasing numbers of traits evaluated, it will become particularly important to use selection indices to rank animals, in order to put the appropriate emphasis on each individual trait, based on its economic value, and its genetic association with profitability. Where economic values differ widely between herds, there may be benefits from customising indices to individual herd circumstances.

Dairy cattle breeding has become an increasingly international business over the past few decades, and much effort has gone into developing procedures to allow breeders in one country to make use of genetic evaluations of bulls in other countries (under the guidance of INTERBULL). International comparisons provide all countries with the opportunity to increase selection differentials. In the past this has been achieved by deriving formulae to convert foreign PTAs to equivalent local PTAs. Conversion formulae are based on sires' proofs in two countries - the foreign and the importing country. As a result, they have to be derived separately for each foreign country of interest. Also, when conversion formulae are used, the ranking of sires will be identical in the foreign and the importing countries. In practice many sires have proofs in several countries, and their rankings may differ between countries. To surmount these problems, and make better use of the international information available on a sire, a procedure was developed recently to allow international evaluations. The procedure, called multi-trait across country evaluation, or MACE, treats records (average daughter yield deviations) on the same trait from different countries as if they were different traits. This allows for differences amongst countries in the heritability of the trait of interest (eg milk production), and allows for different genetic correlations between this trait recorded in different countries. There are several potential benefits from the use of MACE. First, it produces separate PTAs for sires for each country involved in the evaluation, and these are expressed on the local scale and are ready to use; second, these evaluations are more accurate than the conversions they replace; third, because MACE allows different values for genetic correlations between a trait in different countries, the rankings of sires evaluated can differ amongst countries. This is particularly useful where there is a genotype x environment interaction (eg for the same milk production trait in countries with very different management systems), or where the traits being recorded in different countries are similar, but not identical (eg some linear type traits). These benefits are also seen in cows, when MACE evaluations on male relatives are used in calculating cow PTAs. MACE evaluations are now produced routinely by INTERBULL for milk, fat and protein yields. Evaluations of Holstein Friesians in February 1997 were based on data from 19 countries, including the UK (Wickham and Banos, 1998) and included data on over 50 000 Holstein Friesian sires with progeny tests. It is clear that as MACE evolves further, and the results are more widely used, it will improve the accuracy of selection of dairy bulls internationally, for a wide range of traits.

MOLECULAR GENETICS

Recent advances in molecular biology are allowing the identification and location of individual genes, or other sequences of DNA, on the chromosomes. In the short to medium term, the main benefit of these new techniques is likely to be in assisting conventional selection programmes. If we have a test to identify which version of a gene of interest animals are carrying, or we have a test for alternative versions of a neighbouring sequence of DNA (a 'marker'), then we may be able to select animals more effectively than on performance records alone. For example, there may be interest in introducing a single gene controlling polledness or resistance to a disease into a different breed, cross, or family. Molecular markers may be useful in identifying animals carrying the favoured allele. Alternatively, markers may help to accelerate selection for traits, like milk production, which are influenced by many genes. In this case the aim of using markers is simply to boost the improvement made by conventional means, by using associations between the marker and genes affecting production which already present in the breed concerned. The most likely role of markers in dairy cattle breeding will be in pre-selecting young bulls for progeny testing. Research is in progress in several countries, including the UK, to identify useful markers. In the longer term the transfer of genes between strains, breeds or species may be used for agricultural applications. This will depend both on technical and ethical issues. The technique is already being used in the production of novel pharmaceutical proteins in milk. This is partly because it appears to be relatively simple to identify the genes concerned, and feasible to transfer them without running into problems of gene expression and regulation. Also, providing there are no serious side effects for the animals, producing transgenics to cure human disease stands a better chance of public acceptance than creating transgenics to improve agricultural productivity. However, agricultural applications which are of direct benefit to animals as well as humans, such as improving the disease resistance of animals, may be publicly acceptable also.

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