Across breed evaluation of dairy cattle

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ABSTRACT

Genetic analysis of dairy cattle has been undertaken using an animal model including pedigree records since 1940 and performance records since 1986. The animal model analyses all breeds and breed crosses simultaneously allowing accurate estimation of hybrid vigour effects for milk production, liveweight, four survival traits and 16 linear type traits. The animal model allows the effects of induction, age at calving and herd- year-season to be taken into account when estimating an animal's breeding and production values. The breeding value estimates of all animals regardless of breed are on the same scale allowing direct comparison of Holsteins and Jerseys, for example. The results of the animal model analysis are expressed in terms of individual animal performance, eg. kg of milk fat per cow.

Three selection indices have been developed to identify the most economically efficient animals under New Zealand pasture based farming systems. To identify the best animals for breeding herd replacements in the future the breeding worth index is used. To rank cows on lifetime profitability the production worth index is used and to rank cows on current lactation profitability the lactation worth index is used. The indices have been developed using a whole farm model which takes into account the future revenue and cost streams to rank the animals on net income per unit of feed.

INTRODUCTION

An animal evaluation project responsible for developing an appropriate animal evaluation system for use in New Zealand has been researching for 3 years and will implement a new system nationally in March 1996 for sires and June 1996 for cows. Since the introduction of the current sire evaluation system over 20 years ago there have been a number of developments which together justify a thorough review of the entire system used for providing genetic evaluations of dairy cattle in New Zealand. The developments include statistical methods which allow simultaneous evaluation of cows and sires using all known relationships known as the animal model. Further changes in the structure of the national dairy herd with increases in the number of crossbred cows and mixed breed herds require the national evaluation system to be able to compare animals nationally and within herd regardless of breed to allow farmers to select the most profitable animals for the future. This paper provides an overview of the new genetic evaluation system along with the current results for the national dairy herd.

METHODS

Best Linear Unbiased Prediction under an animal model has been used to evaluate New Zealand dairy cattle for breeding and production. There are a large number of possible animal models depending upon the characteristics of the data being analysed (Henderson 1988). The animal model allows simultaneous sire and cow evaluation which can prevent certain classes of selection bias and can increase the accuracy of prediction (Misztal and Gianola 1987). The statistical and genetic properties of animal models have been reported by Henderson (1973), Henderson (1988) and Kennedy et al., (1988). Methods for solving animal models have been discussed by Quaas and Pollack (1981), Schaeffer and Kennedy (1986), Misztal and Gianola (1987) and Westell et al., (1988).

The animal models used for production and liveweight are repeated records, single trait, additive genetic effects repeatability models (Henderson 1988). The statistical model for analysis of a cow with production yields included effects for a herd-season-age contemporary group, period of calving relative to the mean calving date of the contemporary group, induced lactation, heterosis class, age at calving class in months nested within breed class, genetic group, genetic merit of the animal, random non-additive genetic and permanent environment effects and random residual effects. The statistical model for liveweight was the same as for production except the effects for induction and period of calving were replaced with an effect for stage of lactation when weighed nested within age. The models for the linear type traits and survival are single record, single trait, additive genetic effects models (Henderson 1988). The statistical model for analysis of a cow with linear type scores included effects for herd-season contemporary group, stage of lactation class when scored and age at first calving class in months nested within breed, heterosis, genetic group, random animal genetic merit and the random residual. The statistical model for survival was the same as for linear type except there were no effects for stage of lactation or age at calving. The herd-season-age for survival was assigned as the herd-season-age immediately prior to the survival record.

The production animal model uses records based on partial lactation information and records based on complete lactation information for genetic evaluation. The records based on partial lactation information have less genetic and phenotypic variance than completed records. Weights are used in the animal model equations to account for the differences in the variances (Johnson, 1996).

A grouping strategy developed by Westell et al., (1988) in which a genetic group for each animal is derived from the genetic group effect of the animal's ancestors is used. For each animal with unknown ancestors, phantom parents without records are created. The phantom parents are assigned to appropriate genetic groups. The genetic group effects represent the average genetic contribution of the phantom parents. Genetic groups were assigned by sex (male or female missing parent), birth year, country of origin and breed.

Provision within the animal model has been made to include foreign information for sires for the production traits. This is achieved by creating phantom daughters with the level of performance which is equivalent to the value of the foreign information in New Zealand with the number of phantom daughters being based on the reliability of the foreign information in New Zealand.

The genetic merit of the animals is defined as the breeding value which is the sum of the additive animal genetic effect and the genetic group effect. The productive merit is defined as a production value which is the sum of the breeding value, non-additive genetic, permanent environment and average heterosis effects. The animal model results for the breeding and production values for individual traits are expressed in the units in which the trait is measured. To compare individual animals on net farm profitability for breeding and production two indices were developed: Breeding Worth (**BW**) and Production Worth (**PW**), respectively. The BW index is the sum of the breeding values for fat, protein, milk volume, liveweight and survival each weighted by an economic weight. The BW economic weights for each trait represent the net income per unit of feed from breeding replacements. The PW index is the sum of the production values for fat, protein, milk volume and liveweight each weighted by an economic weight. The PW economic weights represent the net income per unit feed from milking cows. The economic weights were calculated from a farm model (Harris 1995) using economic methods to value technological change (Ladd 1982). The economic farm model included income streams from production, cull cows and bobby calf sales and cost streams associated with maintaining cows and replacements, the food required for production and dairy cash expenses such as breeding and animal health. Predictions of future average and marginal milk production prices were taken into account. The economic weights are partial derivatives of the net income function with respect to the trait measure (eg., fat breeding value) and represent the marginal net income per unit improvement.

RESULTS AND DISCUSSION

Model Results

The animal model methods were applied to the national dairy herd at three weekly intervals from October 1995 to February 1996. The data included 15.5 million lactation records from 1986 to 1995, 309,314 linear type records, 381,813 liveweight records and 4.5 million survival records on 8.9 million animals. There were 496,748 contemporary groups with an average of 31 animals per contemporary group for the production traits.

Five percent of lactations were recorded as induced prior to the normal calving date. The estimates of the effects of induction on 240 day milk production given by age of cow are given in Table 1. On average the milk yield depression from inducing cows is close to 4-5% of the annual yield. Estimates for the effect of average heterosis in crossbred animals for the milk production traits, liveweight and survival are given in Table 2. The estimates for production are consistent with previous estimates reported by Ahlborn and Hohenboken (1991).

TABLE 1: Effects of induction on milk production yield (kg).

Age	Fat	Protein	Milk
2 yr	5.6	3.6	163
3yr	7.8	4.9	219
4 yr	6.4	4.2	180
5-8yr	5.2	3.5	142
>8 yr	4.5	3.1	122

TABLE 2: Heterosis estimates

	HF x J	HF x A	J x A
Fat (kg)	6.8	2.7	7.6
Protein (kg)	5.0	2.4	5.5
Volume (l)	129	64	146
Liveweight (kg)	7.2	3.8	12.5
Survival[1] %	4.7	2.6	4.7

[1]Survival from first to second lactation

The heterosis estimates for linear type were low in value and for most traits and breed crosses close to zero.

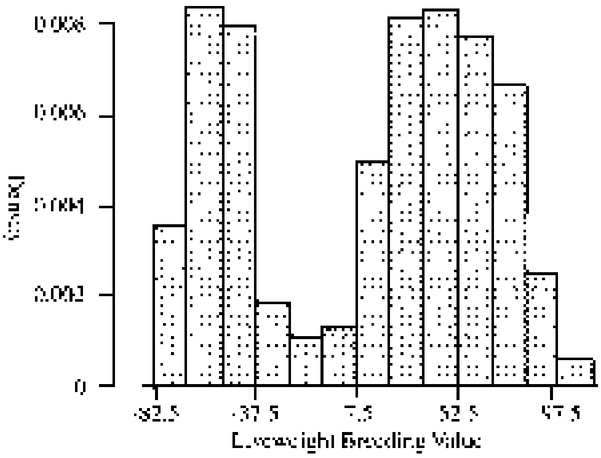
The estimates of the age in months at calving within breed effects indicated that on average cows which calve at a younger age relative to their contemporaries produce or weigh less than and cows which calve at a older age relative to their contemporaries produce or weigh more. The size of the effect diminishes as the average age of the contemporaries increases. The rate of decline in the effects with age is greater for the Jersey breed than other breeds suggesting that Jersey cattle mature at a faster rate.

The average breeding and production values for milk production, liveweight and survival for cows lactating in 1995-96 season are given in Table 3. The breeding and production values are expressed relative to a 1985 cow base, a group of 30,000 cows born in 1985 with all traits measured. The average breeding value of the base cows is zero for all traits. The averages for the different breeds are directly comparable, for example the average genetic merit difference for milk volume of Jersey and Holstein Friesian cows is 908 litres. This direct comparison among the breeds can also been seen in Figure 1 which illustrates the distribution of sire liveweight breeding values. The shape of the distribution is bimodal with the Jersey sires clus-

TABLE 3: Average breeding and production values for current lactating cows by breed.

	Holstein	Jersey	Ayrshire	HF x J
Fat BV	16.1	4.7	0.3	12.8
Fat PV	17.3	6.1	1.6	18.7
Protein BV	15.1	-3.9	6.6	8.3
Protein PV	15.9	-3.1	7.5	12.4
Volume BV	554	-354	273	219
Volume PV	575	-304	295	325
Liveweight BV	37.4	-43.6	2.5	4.4
Liveweight PV	37.7	-43.5	2.7	9.3
Survival BV	0.6	0.1	-0.6	0.5

FIGURE 1: Distribution of sire liveweight breeding values.



tered at the left of the distribution and the Holstein Friesian clustered at the right. The average production values are greater than the average breeding values which represents the effects of culling in the purebred cows, and culling and the contribution of heterosis in the crossbred cows. The column headed HFxJ represents all Jersey x Holstein Friesian crossbred cows, in which the largest group are 4/3HF x 1/4J animals.

Comparison with the current system

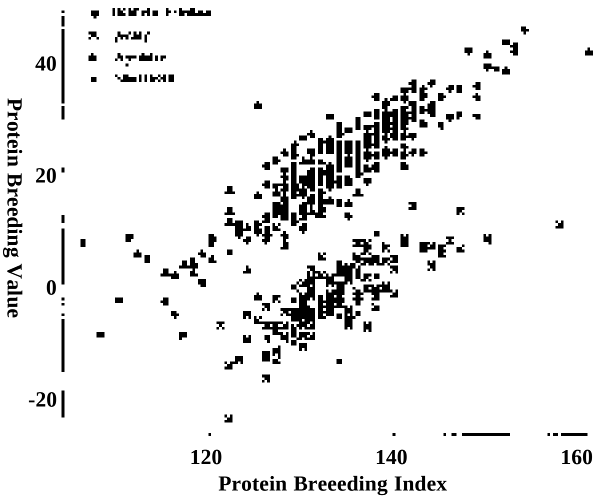
The animal model evaluations for sires born since 1989 with at least 30 milking daughters were compared with the current system within breed. Table 4 provides the correlations between the current system breeding indexes (BI) and breeding values for production traits by breed. The correlations are lower than those report by Wiggans et al., (1988) when the animal model was compared with the modified contemporary comparison in the USA. However, this is not unexpected since the animal model analysis uses all known relationships which better accounts for selective matings by the using genetic merit of a progeny's dam. The animal model also uses 270 day yields accounting for the genetic variance of partial records (Johnson 1996) whereas, the current system uses accumulating yields unadjusted for lactation length. Furthermore, the animal model results contain yields from daughters in the 1995/96 season whereas the results from the current system do not.

Figure 2 illustrates the across breed comparison for protein yield. Under the current within breed system the

TABLE 4: Correlations between current system and animal model evaluations for sires with at least 30 daughters born after 1988.

Breed	N	Fat	Protein	Volume
Holstein	304	0.87	0.88	0.92
Jersey	160	0.78	0.78	0.86
Ayrshire	30	0.78	0.76	0.86

FIGURE 2: Comparison of current and animal model sire evaluations for protein yield .



sires of each breed have similar BIs for protein even though their respective daughter average productions are considerably different. The breeding values in Figure 2 more closely represent the daughter average productions.

Continuous Evaluation

The animal model analysis has been carried out at three weekly intervals for the production traits. The use of partial lactation yields allows, in particular, sires of high genetic merit to be identified earlier in the season. Provided that the early season breeding values are good predictors of the end of season breeding values younger sires could be used for generating cows and future sires thus reducing the generation interval and increasing the rate of genetic gain. The correlations among breeding values and average root mean square error over successive months for sires receiving their first evaluation based on progeny this season are given in Table 5. The evaluations in October would be based on largely 1 herd test on a limited number of daughters, those in November on 1 to 2 herd tests, December 2 herd tests and February 3 herd tests. The correlations and mean square errors indicate that early season proofs are good predictors of proofs based on more herd-test information from large numbers of daughters.

Selection for productive efficiency

Computing the animal model across breed evaluations is the first step in providing New Zealand farmers with tools to select the most profitable animals. The second step is to combine the individual trait evaluations into indexes for the selection of animals for breeding and culling of cows within herd. The breed averages for indi-

TABLE 5: Comparisons of breeding values for first proof sires as the number of herd-tests increase across the 1995/6 season.

		Correlations			
Comparison	N	Fat BV	Protein BV	Milk BV	Lwt BV
Oct - Nov	447	0.97	0.99	0.99	0.99
Nov - Dec	561	0.99	0.99	0.99	0.99
Dec - Jan	585	0.99	0.99	0.99	0.99
Jan - Feb	595	0.99	0.99	0.99	0.99
Oct - Feb	447	0.94	0.98	0.93	0.98
		Root Mean Square Error			
Comparison	N	Fat BV	Protein BV	Milk BV	Lwt BV
Oct - Nov	447	4.18	2.92	85.1	2.63
Nov - Dec	561	2.07	1.47	53.6	6.52
Dec - Jan	585	1.85	1.40	40.8	4.59
Jan - Feb	595	0.68	0.55	17.1	0.35
Oct - Feb	447	5.86	4.14	121.2	10.1

vidual trait evaluations in Table 6 show considerable variation among the productive abilities of the different breeds as well as considerable variation in the liveweight evaluations. Animals with low production can be as efficient at converting feed into income as animals with high production provided the difference in maintenance costs is in proportion to the difference in production income. The BW and PW indexes provide the mechanism for comparing animals for breeding or productive ability in terms of net efficiency irrespective of breed. The breed averages for the economic indexes for cows lactating in the 1995/96 season are given in Table 6. The breed averages for economic indexes are consistent with farm trials reported by Bryant et al. (1985) and Ahlborn and Byrant (1992) suggest that there is little difference in the profitability of Jersey and Holstein-Friesian.

CONCLUSIONS

TABLE 6: Average economic indexes for current lactating cows by breed.

	Holstein	Jersey	Ayrshire	HF x J
BW	20.0	23.1	8.7	24.5
PW	24.3	31.8	13.1	40.3

The new animal evaluation system provides considerable improvements over the current systems. The use of all known relationships among animals and the statistical removal of nuisance effects such as induction will increase the accuracy of evaluations. The ability to implement continuous evaluation will provide more accurate information at an earlier time within a season allowing farmers and artificial breeding companies to make earlier selection decisions. Moving from selection on gross income to net income per unit feed should maintain or enhance New Zealand's competitive advantage as a low cost dairy exporter.

The system has been tested with 200 clients to date. The next challenge will be the considerable extension effort required to inform the remaining 14,000 dairy farmers of the new system prior to full implementation in June 1996.

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