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Future genetic progress of dairy cattle in New Zealand

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ABSTRACT

For about fifty years New Zealand dairy farmers have relied on the traditional methods of population genetics, with intensive selection on three of the four genetic selection pathways, to improve the genetic ability of their cows to convert grazed pasture into milksolids. They have complemented selection within breeds with selection across breeds and crossbreeding. These methods have delivered predictable improvements in the profit-related traits of their cows. The rate of genetic improvement in converting feed into net income is increasing as breeding goals are more precisely specified, more data to support trait selection becomes available, genetic evaluation techniques improve, and new reproductive technologies have an impact on selection intensities. In future improved genetic evaluation techniques will be available to control any associated tendency for functional traits to deteriorate as a consequence of genetic selection for higher milksolids yields. Over the next ten years it is expected that new techniques in biotechnology will supplement rather than replace the traditional methods of genetically improving dairy cattle on commercial dairy farms in New Zealand. Accelerating rates of genetic gain in the milkfat and protein traits result in increased feed demand at the individual cow level, so increased feed supply per-cow needs to proceed in tandem with genetic improvement.

Keywords: dairy cattle; selection; crossbreeding; genetic trend.

INTRODUCTION

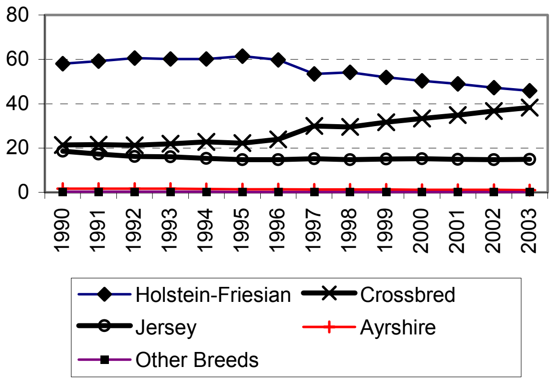
New Zealand dairy farmers seek progressive improvement in the ability of their cows to convert high forage diets into valued milk products. These high forage diets incorporate high proportions of grazed pasture throughout the lactation period. The national breeding goal is to identify animals whose progeny will be the most efficient converters of feed into farmer profit. A total merit index for breeding purposes was formulated in the 1987-88 dairy season. This index, known as Total Breeding Index, was designed to rank sires within breeds. In 1996 new genetic evaluation techniques were adopted which allowed bulls and cows of all breeds and crosses to be compared in terms of their expected ability to convert feed into farmer profit. The index adopted at that time is known as Breeding Worth (BW). Both of these selection indexes have featured positive relative economic values for milkfat and protein yield. Some restraint on the increased body size and milk volume yield associated with selection for increased milksolids has been achieved by incorporating negative relative economic values for these traits. The negative relative economic value for liveweight arises because, for a given milksolids yield, additional liveweight diverts feed resources to lowly valued farm outputs. Genetic improvement of dairy cattle occurs in response to selection between breeds, selection within breeds, and crossbreeding with appropriate parent breeds. The objective of this paper is to discuss some ways in which selection will be used over the next ten years to maintain progress consistent with the breeding goal.

Selection between breeds and crossbreeding

Crossbreeding, particularly with Holstein-Friesian and Jersey parent lines, is an important genetic improvement strategy in New Zealand. Crossbreeding was initially undertaken in the 1960s primarily with a view to upgrading from Jersey to Holstein-Friesian. In 1985 the previously rising trend in percentage of Holstein-Friesian bull semen used for artificial breeding stopped (Livestock Improvement, 2003). Since then crossbreeding has been a strategy widely adopted for its own sake, and not simply as a stage in changing from one breed to an alternative. New Zealand's dairy cattle population is unlike the populations in comparable countries such as Australia and Ireland. In those countries the international Holstein strain has effectively replaced the local black and white strain of dairy cattle; breeds other than Holstein are maintained in very small proportions; and crossbreeding is very uncommon (International Committee for Animal Recording, 2004).

In New Zealand, existing trends show that there will be more crossbred replacements reared in 2006 than replacements of the largest single breed group (defining crossbreds as cows with less than fourteen sixteenths of single breed ancestry). Simple extrapolation of current trends indicates that over half of all replacements in ten years time will be crossbred, while straightbred Holstein-Friesian will comprise about a third of all replacements. Trends in percentage of replacements by breed are shown in Figure 1.

FIGURE 1: Trends in percentage of dairy replacements by breed reared in New Zealand 1990-2003[1].



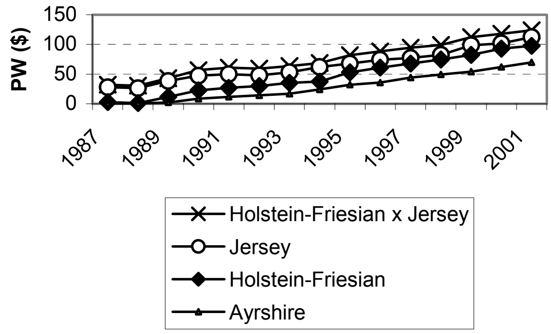
[1]Source: Animal Evaluation statistics 12 March 2004

The trend towards increasing numbers of crossbred cows is driven by extensive evidence for average superiority of the crossbred cows compared to either of the parent lines (Ahlborn-Breier & Hohenboken, 1991; Lopez-Villalobos, 1998; Lopez-Villalobos & Garrick, 2002). The superiority arises as a consequence of (i) existence of parent lines with similar total merit for converting feed into net farm income, (ii) significant biological and economic heterosis between these breeds, and (iii) evidence for retention of a substantial proportion of the heterosis benefits in advanced generations of the crossbred cattle.

The Production Worth (PW) index is designed to compare cows for their comparative ability to convert feed into farm profit over their lifetime. It is based on the milkfat, protein, milk volume and liveweight traits. It includes additive genetic effects on performance, genetic effects other than those transmitted additively, and non-genetic effects that remain with the cow for her lifetime (sometimes called permanent environment effects). The measure is comparable across age groups and farms because management effects such as the herd-year-season-age contemporary group effects are accounted for in the estimation procedure, and are not summed into the production value estimates that underlie the index. The methods for calculating economic weights for the index are described by Harris *et al.* (1996). The average PW for Holstein-Friesian x Jersey crossbred cows (including all backcrosses as well as first crosses) is the highest of all breed groups for each year of birth for the last fifteen years 1987-2001 (Figure 2).

In addition to the feed conversion efficiency effects captured in the PW index, crossbreeding helps to address farmer concerns about survival and reproduction traits that are not included in the PW index. Holstein-Friesian x Jersey first cross cows, Holstein-Friesian x Ayrshire first cross cows, and Jersey x Ayrshire first cross cows all exceed the average herd life of their parent breeds in New Zealand. These heterosis advantages are 222, 93, and 201 days respectively (Garrick, 2002). Heterosis estimates for first cross cows for fertility, measured as percentage likelihood of calving to artificial insemination (AI), have been reported as +6.8%, +10.1%, and 3.3% for NZ Holstein-Friesian x Jersey, Overseas Holstein-Friesian x Jersey, and NZ Holstein-Friesian x Overseas Holstein-Friesian respectively (Harris & Kolver, 2001).

FIGURE 2: Trends in Production Worth index for four breed groups in New Zealand 1987-2001[1].



[1]Source: Animal Evaluation statistics 12 March 2004

The artificial breeding (AB) organizations have responded to the interest of farmers in cows with mixed breed ancestry by progeny testing crossbred sires. Around 15% of bulls currently selected by AB companies to be progeny tested are themselves crossbred (pre-dominantly with close to half Holstein-Friesian, half Jersey ancestry, but including some with Ayrshire ancestry). These sires have not yet graduated from the progeny testing schemes. As they do so, the presence of highly ranked proven crossbred sires will add a significant new dimension to the pool of elite crossbred parents. Motivation for progeny testing crossbred sires includes the maintenance of high selection intensity on the cow to breed bulls selection pathway. Selection on this pathway accounts for around 34% of genetic improvement in New Zealand dairy cattle (Lopez-Villalobos, 1998), and arbitrarily confining selection of dams of sires to straightbred cows would reduce selection intensity as proportions of straightbred cows in the national population decline.

Three foreseeable possibilities might halt the tendency for New Zealand farmers to choose to work with cows with mixed breed ancestry. A marked shock that increased the marginal cost of increased stocking rate to harvest a given feed supply would favour a shift towards the Holstein-Friesian breed. Conversely, changes in production circumstances that encouraged widespread adoption of once-a-day milking practices would favour a shift towards the Jersey breed, at least while farmers awaited effective selection for Holstein-Friesian or crossbred sires evaluated for this management practice.

Dramatic changes in demand for different dairy commodities might affect relative prices for major components of milk, with important consequences for suitability of the breeds. Very dramatic shift factors appear unlikely to affect all farms simultaneously over the next ten years. Consequently, genetic progress in New Zealand dairy cattle is unlikely to feature a sudden trend reversal towards domination of the population by a single breed within this time.

Selection within breeds

Genetic selection is currently based on six breeding objective traits: milkfat, protein, milk volume, liveweight, cow fertility, and longevity. The cow fertility trait is defined as the comparative percentage likelihood to calve in the herd's AI calving period. The longevity trait is called Residual Survival - and is defined as herd life, after accounting for the genetic effects of production, liveweight and fertility on herd life. Selection within breeds on the four traditional selection pathways has resulted in annual additive genetic change. For the current breeding objective traits the rates of annual genetic change for the cows born from 1985 to 2002 were estimated by linear regression, using the Animal Evaluation statistics for May 2003. Rates of gain within breed for cows born from 1997 to 2002 were compared with those for the cows born from 1985 to 1996. The cows born in the earlier period were selected prior to the introduction of the more accurate animal model genetic evaluation techniques that were adopted at the same time as the introduction of the BW index. For the two main parent breeds the analysis reveals accelerating genetic gain for the milksolids traits in recent years. For the Holstein-Friesian breed the trends have been significantly higher in the more recent period for milkfat ($P < 0.05$) and for protein ($P < 0.10$), while trends for milk volume, livewight, and cow fertility have not been significantly different. For the Jersey breed the trends have been significantly higher in the more recent period for milkfat ($P < 0.01$), protein ($P < 0.01$), milk volume ($P < 0.05$), and liveweight ($P < 0.05$). The Jersey trend for cow fertility was significantly lower in the more recent period ($P < 0.05$), although this reduction was off a higher base compared to Holstein-Friesian cows.

Future cows

For the purposes of looking to the future the annual average genetic change for cows of all breeds and crosses analysed together is instructive (Table 1). These trends reflect not only selection within breed but also selection between breeds. For all cows analysed together the trends have been significantly higher in the more recent period for milkfat ($P < 0.01$) and protein ($P < 0.10$). There is no significant difference in trends for milk volume or for cow fertility. The trend for liveweight is positive but lower than in the earlier period ($P < 0.05$). The trend for residual survival is higher in the more recent period ($P < 0.05$), possibly reflecting improvement in some traits associated with ease of management in recent times.

TABLE 1: Linear trends for annual additive genetic change of New Zealand dairy cows born 1985-2002[1].

	1985-1996	**1997-2002**
Milkfat (kg)	1.37	2.19
	(0.05)[2]	(0.15)
Protein (kg)	1.33	1.62
	(0.07)	(0.08)
Milk Volume (litres)	37.2	35.8
	(2.0)	(4.9)
Liveweight (kg)	1.51	0.76
	(0.11)	(0.15)
Cow Fertility (%)	-0.02	-0.03
	(0.01)	(0.07)
Residual Survival (days)	-3.79	1.71
	(0.50)	(2.01)

[1] Source: Animal Evaluation statistics 12 May 2003
[2] Standard errors of the regression coefficients in brackets

Extrapolating from recent trends, and comparing the cows born in 2010 with the cows born in 2001, the future cows will have an enhanced genetic ability to produce milksolids of at least 35 kg per lactation. The future cows will be heavier, but most likely by no more than 8 kilograms – implying a noticeably enhanced feed conversion ability if measured by milksolids per kilogram of metabolic liveweight. The cows will produce more volume, but the trend analysis suggests that the increase in volume will proportionately be lower than the increase in milksolids – implying a reduction in the proportion of farm feed diverted to volume and lactose.

The extra yield and body size will be associated with a greater feed demand of around 250 kilograms of pasture dry matter per-cow annually. Farmers planning to take advantage of the genetically improved cows of the future will need to meet this additional feed demand per-cow by reducing the number of cows in the herd if they do not plan to increase the total feed supply on the farm.

The trend analysis suggests that improvements in feed conversion efficiency will be accompanied by some decline in cow fertility. However, commencing in 2002, cow fertility was introduced as a new trait in the BW index. Under BW selection, genetic decline in cow fertility within breed will be arrested (Anonymous, 2002). Prior to this development, farmers made use of non-additive genetic effects such as heterosis between breeds and heterosis between strains within breeds to assist in achieving acceptable genetic levels of fertility in their herds. Some natural selection for fertility can be presumed to have occurred over a long period, associated with long established management practices such as culling of late calving cows and retention of replacement calves only from early calving cows. The effect of this natural selection over a long period, in the absence of planned selection for fertility, has not been quantified.

Industry level data does not suggest that the current genetic profile of the national herd has undermined the ability of cows to survive and reproduce in recent years. There has been very rapid expansion of the national herd from 3.22 million cows in the 1997/98 season to 3.74 million cows in the 2002/03 season. Percentage rates of survival as cows age from one season to the next have been stable across this time. Average calving intervals have been 368.1 days and 368.3 days in 2001 and 2002 respectively (Livestock Improvement, 2003; International Committee for Animal Recording, 2004). Given that genetic change is effected in small increments across time, future industry level data for survival rates and for calving intervals should only be marginally affected as a consequence of breeding decisions.

The parents of the cows to be born in ten years time will have been selected on the basis of broader knowledge about important functional traits than we have currently. Assistance for genetic selection against high somatic cell counts in milk and against excessive periods of negative energy balance will have been in place for some time (Winkelman, 2002; Harris 2002). Selection for persistency in lactation will have been facilitated by adoption of new test day genetic evaluation techniques.

It is possible that sire breeding values estimated for "response to environment" will be available within ten years, if important genotype x environment interactions are identified. The range of dairy production environments within New Zealand is small compared to a country such as Australia, and the conclusion of a recent Australian study was that change to the Australian national genetic evaluation system to recognize these interactions was not necessary (Hayes *et al*., 2003). This conclusion indicates a low probability that accounting for genotype x environment interactions to breed the future New Zealand cows will be necessary. However, it is possible that once a day milking might be adopted by large numbers of New Zealand farmers. In that case the alternative environment represented by that management practice might well be sufficiently distinct to justify breeding cows specifically for once a day milking, as well as breeding cows for twice a day milking.

Biotechnology

Advancing knowledge on the molecular basis of inheritance and new techniques in reproductive technology offer the prospect for more rapid genetic changes to be effected in the future than we have been accustomed to in the past. It is easy to envisage that customized milks could be produced in quantities and localities designed to suit milk processors seeking to manufacture specialty products or to take advantage of particular processing attributes of particular milks. Current plans for such procedures do not involve large quantities of milk. Uptake of such technologies over the next ten years is difficult to predict.

In the biotechnology area the immediate search for genetic markers will concentrate on markers associated with economically important traits, the subject of discussion by other authors. There is another potential benefit from increasing knowledge of the bovine genome. Genetic progress in dairy cattle involves a trade-off between intensive use of a small number of elite animals to drive improvement in important profit-related traits and the desirability of maintaining genetic diversity. Maintaining diversity has important consequences for minimizing inbreeding, which is associated with depression of performance particularly in fitness traits. Also a more genetically diverse population has a better chance of responding to future changes in management practices or market demands. Identification of markers to maintain genetic diversity is potentially important for small populations, such as the New Zealand Jersey population.

CONCLUSIONS

Over the next ten years the genetic improvement of New Zealand dairy cattle for milksolids yield per kilogram of metabolic liveweight will proceed more rapidly than has been the experience over the average of the last twenty years. Research is in progress to address associated challenges to ensure that functional traits do not deteriorate as a consequence.

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