Ten Years Experience of Multi-Breed Evaluations and Crossbreeding in New Zealand

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Introduction

National genetic evaluation centres exist to provide the genetic information their farmers need. New Zealand dairy farmers select primarily from Jersey and Holstein-Friesian parent breeds. In New Zealand farm production systems the overall efficiency is very similar for converting feed into profit for the elite animals of these breeds, even though the breeds differ markedly in many inherited characteristics such as milk volume yield and body size. Some of the elite animals of the Ayrshire breed match the elite animals of the two major breeds for overall feed conversion efficiency. Favourable heterosis effects for important profit-related traits are well understood, and crossbreeding is common practice.

Farmers demand evaluation procedures that enable them to compare cows of all breeds and crosses in their own herds for predicted ability to convert the farm feed profitably. They also require a genetic evaluation system that enables them to compare bulls and cows of different breeds and crosses when making breeding decisions. The breeding goal is to identify animals whose progeny will be the most efficient converters of feed into farm profit. This paper describes the evaluation system developed for this goal.

National herd

Improvement of dairy cattle occurs in response to selection between breeds, selection within breeds, and crossbreeding. Farmers have limited control over genetic change within breeds, where the important selection decisions are made by Artificial Insemination (AI) companies. However, farmers have immediate control over the breeds of AI sires used in their herds, constrained only by lack of choice if AI companies offer only single breed product.

From a base of predominantly Jersey cows New Zealand farmers began to crossbreed in the 1960s, primarily with a view to upgrading from Jersey to Holstein-Friesian. However, in 1985 the previously rising trend in percentage of Holstein-Friesian bull semen used for artificial breeding leveled out. Since then crossbreeding has been a strategy adopted for its own sake, rather than as a stage in changing from one breed to an alternative. Crossbreds (defined as cows with less than fourteen sixteenths of single breed ancestry) are an increasing proportion of replacements reared for the national herd (Figure 1).

Figure 1. Trends in percentage of dairy replacements reared in New Zealand by breed 1985-2004.

Multi-breeding trait evaluations

The methods for multi-breeding trait evaluation were reported to Interbull (Harris, 1994). In summary, features of the development that addressed the multi-breeding dimension of the evaluation were: nesting of fixed effects for age-at-calving within breed classes to account for differing rates of maturity between breeds; fitting fixed effects for coefficients of heterosis; and assigning genetic groups by breed. In the case of an animal that is ¾ breed A and ¼ breed B with a known single breed
parent, the phantom parent is assigned as $\frac{1}{2}A \times \frac{1}{2}B$ crossbred.

Contemporary groups containing cows of different breeds and crosses are widespread, establishing extensive linkages between cows of different breeds and crosses in common management groups.

The trait evaluation methods adopted in 1996 for the production and liveweight traits have remained substantially in place. New models have been developed since 2000 for milk somatic cells, cow fertility, and longevity. Recombination coefficients have been fitted for the models developed in 2004/05, and will be fitted for new models.

The average heterosis effects for the first crosses, expressed in genetic standard deviation units, are given in Table 1.

<table>
<thead>
<tr>
<th>Breed Combination</th>
<th>Milkfat</th>
<th>Protein</th>
<th>Volume</th>
<th>Liveweight</th>
<th>Cow fertility</th>
<th>Somatic cell score</th>
<th>Longevity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hol-Fries x Jersey</td>
<td>0.70</td>
<td>0.33</td>
<td>0.46</td>
<td>0.33</td>
<td>0.60</td>
<td>-0.14</td>
<td>0.96</td>
</tr>
<tr>
<td>Hol-Fries x Ayrshire</td>
<td>0.33</td>
<td>0.67</td>
<td>0.29</td>
<td>0.003</td>
<td>0.59</td>
<td>-0.37</td>
<td>0.58</td>
</tr>
<tr>
<td>Jersey x Ayrshire</td>
<td>0.73</td>
<td>0.69</td>
<td>0.49</td>
<td>0.48</td>
<td>0.38</td>
<td>-0.11</td>
<td>0.55</td>
</tr>
</tbody>
</table>

**Breeding objective**

Evidence in the 1990s indicated that experimental farms stocked with Jerseys with lower milksolids yields per-cow were at least as profitable as experimental farms with equal feed supply but stocked with fewer, substantially larger, higher yielding Holstein-Friesian cows when the stocking rates were optimized for profit. These findings accorded with farm survey data. (Holmes et al., 2002). Net income per cow is transparently inadequate for comparing profitability of cows of different breeds in these farm production circumstances.

The principal resource for the pasture-based dairy farmer is the farm’s feed supply, including pasture and any supplements introduced as a normal part of the production system. Therefore, genetic changes in the breeding objective traits are appropriately valued as marginal net revenue per unit of feed, as long as proper account is taken of the impact on farm costs (feed supply held constant) of any change in required stock numbers to harvest the feed accompanying the genetic changes.

To enable farmers to compare bulls and cows of all breeds and crosses in terms of the expected ability of their progeny to convert feed into farmer profit the Breeding Worth (BW) index was developed. Abstracting from gene flow and time discounting features, the bio-economic model associated with the index assesses the total annual utilised feed for a base herd of cows (typical of the current national herd). A breeding objective trait is modified by one unit, holding other traits unchanged. The number of modified cows that can be supported by the initial total annualised feed after the change in the trait is calculated. The difference in net dairy cash income per 4.5 tonnes of feed between the initial state and the genetically modified state is the economic weight of the trait for the BW index (Harris et al., 1996). The index features positive economic weights for milksolids traits, and negative economic weights for milk volume and liveweight. The negative value in the index of increased liveweight arises because, for a given milksolids yield, additional liveweight diverts feed resources primarily to valueless annual body maintenance, which was an important factor in the lower overall efficiency of feed conversion into milksolids on Holstein-Friesian experimental farms. Income streams from cull cows and surplus calves do not outweigh this diversion of feed. The negative value for milk volume arises partly from the milk payment system penalty, and partly because additional volume effectively wastes feed that could have been diverted to milksolids. By expressing the economic weights in terms of marginal net revenue for a given feed unit, cows of different breeds with markedly different feed intakes can be compared.
For calculating the impact on farm costs of a change in the number of cows needed to harvest the feed an econometric cost function is fitted to farm data. The cost function fits costs-per-ha as a function of cows-per-ha, feed-supply-per-ha, and farm-size. Specified in natural logarithms, the coefficient on cows-per-ha represents the elasticity of farm costs with respect to a change in stocking rate.

Across breed cow productivity index

The Production Worth (PW) index is designed to compare cows for their expected ability to convert feed into farm profit over a typical lifetime, 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. The measure is comparable across age groups and farms because management effects are accounted for in the estimation, but are not included in the production value estimates that underlie the index.

Provision of the PW index for cows recognizes the heterosis affecting individual cow performance and assists farmers in making culling and cow purchase decisions. It is also a powerful tool for answering farmers’ questions when a highly productive cow has a modest total merit index for breeding purposes, by demonstrating that her superiority as an individual is recognized as part of the overall evaluation system. 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 years 1985-2002 (Figure 2).

Figure 2. Trends in Production Worth index for four breed groups in New Zealand 1985-2002.

Additive genetic trends

The trends for additive genetic change are usually reported within breeds. However, the annual average genetic change for cows of all breeds and crosses analysed together is instructive (Table 2). These trends reflect not only selection within breed but also selection between breeds. In New Zealand breeding of cows born before 1997 was based on breed specific evaluations. Cows born from 1997 onwards were bred using the multi-breed evaluation system. The rates of annual genetic change for the females born from 1985 to 2004 were estimated by linear regression, using the Animal Evaluation statistics for April 2005. Rates of gain for females born from 1997 to 2004 were compared with those born from 1985 to 1996. For all New Zealand females analysed together the trends have been significantly higher in the more recent period for milkfat (P < 0.05) and for protein (P < 0.05). The accelerating trend in the milksolids traits is associated with larger investments by the breeding companies in breeding schemes in
more recent times. It is noticeable that the genetic trend for milk volume has not accelerated in recent times even though the milksolids trends have accelerated. This difference arises partly from the trend in farmers’ breed choices at mating time, which have enabled them to restrain the rate of increase in volume without restraining the rate of increase in milksolids. The genetic trend for liveweight has remained positive in the recent period when multi-breed evaluations have been available – but is increasing at a slower rate than previously (P < 0.05). The restraint on the rate of increase in liveweight in the national herd has arisen entirely as a response to a lower proportion of Holstein-Friesian genes in replacements reared in the more recent period. Farmers make the choice to restrain growth in body size of their cows, knowing that unrestrained increases in body size impose larger marginal costs than benefits.

Table 2. Annual genetic changes for the New Zealand dairy cow population 1985-1996 and 1997-2004 in genetic standard deviation units

<table>
<thead>
<tr>
<th></th>
<th>1985-1996</th>
<th>1996-2004</th>
<th>Significance of difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milkfat</td>
<td>0.12</td>
<td>0.17</td>
<td>P &lt; 0.05</td>
</tr>
<tr>
<td>Protein</td>
<td>0.16</td>
<td>0.21</td>
<td>P &lt; 0.05</td>
</tr>
<tr>
<td>Volume</td>
<td>0.12</td>
<td>0.12</td>
<td>NS</td>
</tr>
<tr>
<td>Liveweight</td>
<td>0.05</td>
<td>0.03</td>
<td>P &lt; 0.05</td>
</tr>
<tr>
<td>Cow fertility</td>
<td>-0.02</td>
<td>0.01</td>
<td>NS</td>
</tr>
<tr>
<td>Somatic cell score</td>
<td>0.04</td>
<td>0.01</td>
<td>P &lt; 0.05</td>
</tr>
<tr>
<td>Longevity</td>
<td>0.03</td>
<td>0.04</td>
<td>NS</td>
</tr>
</tbody>
</table>

1 Positive trend desirable
2 Positive trend undesirable

Crossbred AI sires

Around 15% of bulls currently selected by AI companies in New Zealand to be progeny tested are themselves crossbred (predominantly with close to half Holstein-Friesian, half Jersey ancestry, but including some with Ayrshire ancestry). Motivation for progeny testing crossbred sires includes the maintenance of high selection intensity on the cows to breed bulls selection pathway, which accounts for around 34% of genetic improvement in New Zealand dairy cattle (Lopez-Villalobos, 1998). Confining selection of dams of sires to straightbred cows would reduce selection intensity on this pathway. The first intake of the crossbred sires graduated from the progeny testing schemes in the 2004/05 dairy season. In April the top 20 active AI sires ranked by BW comprised 1 Ayrshire, 3 Crossbred, 6 Holstein-Friesian, and 10 Jersey sires.

Discussion

Foreseeable challenges for Interbull’s MACE evaluations include: (i) developing appropriate procedures for allocation of crossbred sires to breed evaluations; (ii) specification of genetic groups for maternal grandams for these sires; and (iii) implications for assignment of sire standard deviations in the MACE equations.

References


