EFFECT OF SELECTION AND CROSSBREEDING ON RATE OF GENETIC GAIN AND INDUSTRY FLOWS OF MILK, FAT AND PROTEIN IN THE NEW ZEALAND DAIRY INDUSTRY

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SUMMARY

A model for four pathways of selection accounting for overlapping generations and crossbreeding strategies was developed to evaluate the effects of selection and crossbreeding on advancing the progress in genetic merit of bulls, total production of milk, fat and protein and total feed requirements of the New Zealand dairy industry over the next 25 years.

Rotational crossbreeding strategies reduced the sizes of active populations (bull mothers) with only minor changes in the annual genetic gain of bulls. Assuming a fixed area (985,000 ha) for grazing the national herd and calculating feed intake per head based on current productivity and assumed genetic gains, 25 years of upgrading to Jersey (J) caused the smallest decrease in cow number (15,000), the largest decrease in milk volume (33 million *l*) and the largest increases in fat (62 million kg) and protein (75 million kg) compared to the values for the season 1995/96. Upgrading to Holstein-Friesian (F) had opposite effects causing the largest decrease in cow number (240,000), the largest increase in milk volume (702 million *l*) and the smallest increase in fat (27 million kg) and protein (59 million kg). Effects of rotational crossbreeding strategies were intermediate between the effects caused by upgrading to J and upgrading to F. The overall net financial outcome of all these changes must be assessed carefully.

Keywords: dairy cattle, crossbreeding, selection, industry production.

INTRODUCTION

The New Zealand dairy cow population comprises 2.9 million cows distributed in 14,736 herds. The breed structure of the national herd is 57% Holstein-Friesian (F), 17% Jersey (J), 17% FxJ, 2% Ayrshire (A) and 7% other dairy breeds and their crosses (Livestock Improvement Corporation Limited, 1996). The majority of milk solids (85%) are processed and exported. The payment system for dairy farmers rewards protein and fat and penalizes milk volume, reflecting average export market value adjusted for processing and marketing costs.

The selection objective of the New Zealand dairy industry is to increase farm profit ($/ha) and includes five traits: milk, fat, protein, liveweight and survival. Economic values for fat and protein depend largely on the predicted future world demand for milk products.

Crossbreeding can increase farm profit (Lopez-Villalobos and Garrick 1996). This may encourage greater use of crossbred cows thereby eroding the number of potential bull mothers (active cows) and reducing genetic progress. The objective of this study was to investigate the effects of selection and crossbreeding strategies on increases in the genetic merit of bulls and production of milk, fat and protein and corresponding feed requirements by the dairy industry.

METHODS

Population structure. There were three straightbred F, J and A and several crossbred cow populations. Starting values were 2.6 million cows with a representative 1990's breed composition and age structure. Cows were classified into groups according to the number of generations for which male ancestors were artificial breeding sires. Numbers of animals were updated each year using a herd-growth model (Upton, 1989).

Selection of animals to be parents of the next generation was undertaken by truncation across age classes following Ducrocq and Quaas (1988). The best 90% of cows were selected to breed female replacements. Active cows were those with at least 3 generations of artificial breeding and with ≥7/8 of genes of one breed. Starting sizes of F, J and A active populations were assumed at 255,469, 157,900 and 8,493 cows, respectively. For each young bull to be progeny tested, 4.2 bull mothers were selected. Results of progeny tests were obtained when bulls were five years old. Bulls to breed cows were selected from live 5, 6 and 7 year old bulls. Numbers of bulls selected depended on anticipated future demand for semen. Within-breed, three bulls to breed bulls were selected from 5 and 6 year old bulls.

Selection Index. Selection of cows and bulls was on an index (breeding worth, BW) which is calculated as $BW=\Sigma v_j EBV_j$ where v_j is the economic value in dollars of trait j and EBV_j is the estimated breeding value of the individual for trait j. Traits and economic values (in brackets) contained in BW were cow liveweight (-0.419 $/kg) and 270-day lactation yields of milk volume (-0.056 $/*l*), fat (0.425 $/kg) and protein (3.913 $/kg). Estimates of genetic and phenotypic parameters used in the selection index were as in Spelman and Garrick (1997). The standard deviation of true BW was calculated as $25. Reliabilities of genetic evaluations (the squared correlation between true and estimated BW) were based on the number of lactation records for individual cows and information from the 60 to 85 first crop daughters for bulls.

Breeding strategies. Several strategies were evaluated: straightbreeding, upgrading to F, upgrading to J, two-breed rotation FxJ and three-breed rotation FxJxA. In all strategies, a fraction of straightbred cows was kept to maintain a source of bull mothers. For rotational crossbreeding 60% of cows with ≥7/8 genes of one breed were mated to bulls of the same breed.

Expected performance. Correlated responses for milk, fat, protein and live weight were calculated from the regression of the trait values on the selection index, and, in the case of crossbred cows, heterosis effects (Harris *et al.* 1996) were added. Age adjustment factors for milk and milk component yields per cow were 0.75, 0.88, 0.95, 1.0, and 0.90 for lactations 1, 2, 3, 4-7, and 8-9, respectively. Dry matter (DM) intake of dairy cows including replacements was calculated by summing the metabolisable energy (ME) requirements for maintenance, live weight gain, pregnancy and lactation (Holmes *et al.* 1987) and assuming a energy density of 10.5 MJ ME per kg pasture DM. It was assumed that 12,000 kg pasture DM were eaten per hectare per year.

RESULTS AND DISCUSSION

Genetic gain. Average annual rates of genetic gain were calculated as the average change in BWs of the bull teams over time and asymptotic annual genetic gains were taken as the increase in BW of the bull teams in the last year of simulation. Results are shown in Table 1. After 25 years of upgrading to F the number of active F and J cows were 1,219,000 and 47,000, respectively. The average annual genetic gains of F and J bull teams were 7.0 and 5.9 $BW and approached an asymptotic rate of 8.3 and 5.6 $BW. Upgrading to J had an opposite effect on growth in active cow numbers and corresponding effects on genetic gain of bull teams. Rotational crossbreeding strategies did reduce the size of active populations but caused only minor reductions in the gain in BWs of the bull teams.

Table 1. Number of active cows and average and asymptotic annual genetic gain in the bull team after 25 years under different breeding strategies comprising Holstein-Friesian (F), Jersey (J) and Ayrshire (A) breeds

		Active cows	Genetic gain ($BW[a]/year)	
Strategy	Breed	(000s)	Average	Asymptotic
Straightbreeding	F	964	6.7	8.1
	J	338	6.3	7.2
	A	29	5.5	6.0
Upgrading to F	F	1,219	7.0	8.3
	J	47	5.9	5.6
Upgrading to J	F	76	6.3	6.0
	J	1,105	6.8	7.9
Two-breed rotation FxJ	F	76	6.4	7.0
	J	24	6.0	6.4
Three-breed rotation FxJxA	F	76	6.4	6.9
	J	24	6.0	6.4
	A	17	5.6	6.8

[a] BW = breeding worth

Industry flows. Long-term effects of selection and crossbreeding on total production of milk, fat and protein, protein:fat ratio and total requirements for dry matter by the industry are shown in Table 2. If feed (number of hectares) remains constant, then the number of cows (stocking rate) will decrease by 0.6% for Jersey upgrading and 9.1% for Friesian upgrading in order to satisfy the higher feed requirements of the improved cows. Upgrading to J caused the smallest decrease in cow number, the largest decrease in milk volume, and the largest increases in fat and protein from fixed feed.

Table 2. Predicted changes in total milk, fat and protein yield, protein:fat ratio and cow number for the New Zealand dairy industry with different breeding strategies comprising of Holstein-Friesian (F), Jersey (J) and Ayrshire (A) breeds from 985,000 hectares in all cases

	Milk (million, *l*)	Fat (million, kg)	Protein (million, kg)	Protein:Fat ratio	Cows (000s)
Base 1995/96	8,694	404	317	0.785	2,633
	Predicted changes after 25 years of breeding				
Strategy					
Straightbreeding	526	34	63	0.081	-184
Upgrading to F	702	27	59	0.088	-240
Upgrading to J	-33	62	75	0.058	-15
Two-breed rotation FxJ	393	46	68	0.071	-156
Three-breed rotation FxJxA	543	40	68	0.083	-162

CONCLUSION

Upgrading to Jersey appears to produce the largest quantity of milk solids in the smallest volume of milk from the fixed quantity of feed. This would probably require the smallest increases in manufacturing capacity, but the overall net financial consequences must be evaluated fully.

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