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Effects of selection and crossbreeding on industry returns from whole milk powder, butter and casein in the New Zealand dairy industry

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ABSTRACT

The effects of selection and crossbreeding on New Zealand dairy industry return were evaluated with a deterministic simulation model over 25 years. Several crossbreeding strategies involving Holstein-Friesian (F), Jersey (J) and Ayrshire (A) cattle were evaluated. These strategies were straightbreeding, upgrading to F (UPGF), upgrading to J (UPGJ), upgrading to A, and two- and three-breed rotational crosses. Total production of milk, fat, protein, lactose and ash were calculated assuming that 12,000 kg dry matter/ha was eaten for 1,224,911 ha. Yields of standardised whole milk powder (WMP), casein and butter were calculated. For the base year all the protein was utilised in WMP and for subsequent years, some increases in protein were sold in the form of casein. Casein and WMP were valued at $6.00 and $3.31 per kg respectively over the 25 years, whereas butter was valued at $3.00 per kg for base year production levels and $0.45 per kg for marginal increases in production.

Production for the base year was 9,874 million l milk, 467 million kg fat, 359 million kg protein and 464 million kg lactose which yielded 1,263 million kg WMP and 157 million kg butter for an industry return of $4,646 million. Relative to the base year, UPGF resulted in the largest increase in WMP (128 million kg, 10%), the lowest increase in casein (36 million kg) and increased returns by $639 million (14%). UPGJ resulted in the lowest increase in WMP (73 million kg, 6.0%), the largest increases in butter (67 million kg, 43%), casein (65 million kg) and returns ($662 million, 14%). Two-breed rotational (F,J) resulted in product flows for WMP and butter that were above the intermediate between UPGF and UPGJ but return that was equal to UPGJ.

Selection within-breed in combination with crossbreeding can increase industry returns. However, the net financial outcome of all changes must be assessed taking into account farm expenses, income from culled stock and factory costs in processing milk with different composition in order to determine optimum crossbreeding strategies.

Keywords: selection; crossbreeding; industry returns; whole milk powder; butter; casein.

INTRODUCTION

The New Zealand dairy industry comprises 3.1 million cows distributed in 14,741 herds. The breed structure of the national herd is 57% Holstein-Friesian (F), 16% Jersey (J), 18% crossbred FxJ, 2% Ayrshire (A) and 7% other dairy breeds and their crosses (Livestock Improvement, 1997). The average dairy farm is 86 hectares with 208 lactating cows grazing on mainly ryegrass-clover pastures, at 2.41 cows/ha. About 90% of the milk is processed into semi-dry products mainly butter, cheese, casein, whole milk powder (WMP), skim milk powder and butter milk powder which are exported to a number of countries.

There is considerable variation in milk composition between and within breeds of dairy cattle (Gibson, 1989). This variation, in turn, causes variation in the yields of dairy products (Paul, 1985) from a given quantity of liquid milk.

Selection within-breed and breed crossing or breed substitution will impact the mix of products that can be achieved. Selection for protein only compared to selection for fat only would have resulted in more skim milk powder and milk and less butter (Fenwick and Marshall, 1991) and would have also increased industry returns by $22 million each season (Parker, 1991).

Few studies have dealt with a breed comparison for production of dairy products and returns. Campbell (1966) demonstrated, on the basis of production per acre, that Jerseys had an advantage for butter, combination of butter and casein, and cheese production but Friesians tended to favour the production of milk powder. A simulation study showed that net returns (gross income minus production costs) were similar for the two breeds when milks were processed into WMP and butter (Wiles, 1987). However, net returns for Jersey were higher than for Friesian when milks were processed into cheese (Wiles, 1988).

A model comprising four pathways of selection accounting for overlapping generations and crossbreeding strategies has been developed to calculate the annual rate of genetic gain (Lopez-Villalobos and Garrick, 1997) and increases in industry production of milk, fat and protein (Lopez-Villalobos *et al*., 1998). The objective of this study was to extend that model to evaluate the effects of selection and crossbreeding strategies on industry return from WMP, butter and casein over the next 25 years.

METHODS

The model developed by Lopez-Villalobos and Garrick (1997) and Lopez-Villalobos *et al*. (1998) was extended to calculate yields of WMP, butter and casein from milks produced by the dairy cattle population under different breeding strategies. The cow population was assumed to be 3,064,526 cows with a representative breed composition and age structure for the season 1996-97 (Livestock Improvement, 1997). Starting sizes of F, J and A active populations (bull mothers) were assumed to be 239,959, 134,640 and 12,492 cows, respectively (Dr. B. L. Harris, personal communication). Selection of cows to breed female replacements was assumed negligible. For each young bull to be progeny tested, 4.2 bull mothers were selected per year. Bulls to breed cows were selected from live 5, 6 and 7 year old progeny tested bulls. Numbers of bulls selected per breed depended on anticipated future demand for semen. Within-breed, three bulls to breed bulls were selected from 5 and 6 year old bulls.

Selection of cows and bulls was based on breeding worth (BW) calculated as $BW=\Sigma v_j EBV_j$ where vj is the economic value in dollars of trait j (Table 1) and EBV_j is the estimated breeding value of the individual for trait j. Traits contained in BW were cow live weight and 270-day lactation yields of milk volume, fat and protein. This is a simplification of the industry BW as the contribution of survival was ignored. Estimates of genetic and phenotypic parameters used in the selection index were as in Spelman and Garrick (1997).

TABLE 1: Estimates of additive breed and heterosis effects, and economic values for milk traits and live weight for New Zealand dairy cattle (Livestock Improvement, unpublished data).

	Trait			
	Milk Yeild (*l*)	Milkfat Yeild (kg)	Protein Yeild (kg)	Live-Weight (kg)
Additive breed effects				
Holstein-Friesian (F)	3,896	176	138	492
Jersey (J)	3,064	166	121	407
Ayrshire (A)	3,614	161	130	454
First cross heterosis effects				
F x J	137	7.1	5.2	7.7
F x A	77	3.5	2.8	0.3
J x A	156	8.4	5.9	9.9
Economic values ($)	-0.051	0.470	4.054	-0.427

Breeding strategies evaluated were straightbreeding, upgrading to F (UPGF), upgrading to J (UPGJ), upgrading to A (UPGA), and two- and three-breed rotational crosses. In all strategies, a fraction (10% to 50%) of straightbred cows were mated to bulls of the same breed to produce replacements and maintain a source of bull mothers. Further details are in Lopez-Villalobos and Garrick (1997).

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 (Table 1) were added. Concentration of lactose and ash were calculated at 4.7% and 0.7% of milk volume, respectively. Multiplicative age adjustment factors for milk and milk component yields per cow were 0.75, 0.87, 0.95, 1.0, and 0.97 and 0.92 for lactations 1, 2, 3, 4-7, 8 and 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 (AFRC, 1993) and assuming an energy density of 10.5 MJ ME per kg pasture DM. It was assumed that 12,000 kg pasture DM was eaten per hectare per year and that increases in DM requirements per cow as a result of genetic improvement for production traits were achieved by reducing the stocking rates.

Industry outputs of milk, fat, protein, lactose and ash were calculated assuming that 1,224,911 ha were available for dairying. Yields of WMP, casein and butter were calculated assuming that WMP was standardised to contain 26.5% fat and 28.4% protein. Quantities of fat and protein extracted were calculated as the difference between the contents in milk minus the contents in WMP. Yield of butter was calculated as fat extracted x 1.19 (Wiles, 1987) and the yield of casein was calculated as protein extracted x 0.87 (Creamer and McGillivray, 1972).

Industry returns were derived from the sale of the processed dairy products. Casein and WMP were valued at \$6.00 and \$3.31 per kg respectively over the 25 years, whereas butter was valued at \$3.00 per kg for base year production levels and \$0.45 per kg (vegetable oil equivalent) for marginal production. Therefore, the value of butter per kg for year t (vb_t) was calculated as: $vb_t = \{[z_0 \times vb_0] + [(z_t - z_0) \times 0.45]\}/z_t$, where, z_0 is initial volume of butter produced, z_t is volume of butter in year t and vb_0 is base value of butter.

RESULTS

Long-term effects of 25 years of selection and breeding on total industry production of milk and its components from the fixed amount of DM and numbers of cows are shown in Table 2. Compared to the productivity for the base season, 25 years of selection within-breed (straightbreeding) increased the yields of milk (891 million *l*; 9.0%), fat (44 million kg; 9.0%), protein (81 million kg; 22.5%), lactose (42 million kg; 9.0%) and ash (6.2 million kg; 9.0%) and decreased the number of cows (264, 000; 8.6%). Upgrading the population to J caused the smallest increase in milk volume (570 million *l*; 5.8%), lactose (27 million kg; 5.8%) and ash (4 million kg; 5.8%), the largest increase in fat (75 million kg; 16.1%) and protein (96 million kg; 26.7%) and the smallest decrease in number of cows (34,547; 1.1%). Upgrading the population to F caused the largest increase in milk volume (1,001 million *l*; 10.1%), lactose (47 million kg; 10.1%) and ash (7 million kg; 10.1%), an increase in fat by 36 million kg (7.7%) and protein by 78 million kg (21.7%) and the largest decrease in number of cows (338,182; 11.0%). Effects of rotational crossbreeding strategies were only slightly different from the intermediate between the effects caused by UPGF, UPGJ and UPGA.

The average cow live weight of the national herd for the base year was 460 kg (Table 2). Upgrading the population to Friesian for 25 years increased live weight by 24 kg whereas UPGJ decreased live weight by 41 kg. Other

TABLE 2: Predicted changes in industry outputs of milk and its components, average cow live weight (LW) and number of cows for the New Zealand dairy industry with different breeding strategies comprising of Holstein-Friesian (F), Jersey (J) and Ayrshire (A) breeds from 1,224,911 hectares in all cases.

	Milk (l x 10^6)	Fat (kg x 10^6)	Protein (kg x 10^6)	Lactose (kg x 10^6)	Cow LW (kg)	Cows (x 10^3)
Base 1996-97	9,874	467	359	464	460	3,064
Predicted changes after 25 years of breeding						
Strategy						
Straightbreeding	891	44	81	42	8	– 264
Upgrading to F	1,001	36	78	47	24	– 338
Upgrading to J	570	75	96	27	– 41	– 35
Upgrading to A	949	28	76	45	– 3	– 162
Two-breed rotation (F,J)	821	58	87	39	– 5	– 222
Two-breed rotation (F,A)	919	37	79	43	– 1	– 201
Two-breed rotation (J,A)	822	50	85	39	– 11	– 166
Three-breed rotation (F,J,A)	888	48	84	42	– 4	– 207

strategies had intermediate effects between UPGF and UPGJ.

Total industry production of milk products after 25 years of selection and breeding are shown in Table 3. Relative to the base year, straightbreeding resulted in an increase in WMP (114 million kg; 9.0%), butter (16 million kg; 10.2%) and casein (42 million kg). Upgrading to F resulted in the largest increase in WMP (128 million kg; 10.3%) and the lowest increase in casein (36 million kg) whereas UPGJ resulted in the lowest increase in WMP (73 million kg; 5.8%) and the largest increase in butter (67 million kg; 42.7%) and casein (65 million kg). Upgrading to A decreased butter by 4 million kg. Two-breed rotation (F,J) increased butter and casein by values which were intermediate between those achieved by UPGF and UPGJ, but the increase in WMP was higher than the intermediate increases.

TABLE 3: Predicted changes in industry outputs of whole milk powder (WMP), butter and casein, value of butter and industry returns for the New Zealand dairy industry with different breeding strategies comprising of Holstein-Friesian (F), Jersey (J) and Ayrshire (A) breeds from 1,224,911 hectares in all cases.

	WMP yield (kg x 10^6)	Butter yield (kg x 10^6)	Casein yield (kg x 10^6)	Value of butter ($/kg)	Industry returns[a] ($ x 10^6)
Base 1996-97	1,263	157	0	3.00	4,646
Predicted changes after 25 years of breeding					
Strategy					
Straightbreeding	114	16	42	– 0.24	638
Upgrading to F	128	2	36	– 0.04	639
Upgrading to J	73	67	65	– 0.76	662
Upgrading to A	121	– 4	36	0.00	604
Two-breed rotation (F,J)	105	36	50	– 0.48	662
Two-breed rotation (F,A)	118	7	39	– 0.12	629
Two-breed rotation (J,A)	105	27	48	– 0.37	646
Three-breed rotation (F,J,A)	114	22	45	– 0.31	654

[a] Industry returns were calculated as: (WMP yield x value per kg WMP) + (butter yield x value per kg butter) + (casein yield x value per kg casein).

Changes in industry returns and the value of butter after 25 years are shown in Table 3. Values of butter in the year 25 can be derived from values in the Table 3 as $3.00 plus the change in the base value. Relative to the base year, straightbreeding increased industry returns by $638 million (13.7%). UPGJ and two-breed rotation (F,J) resulted in the largest increase in industry returns ($662 million; 14.2%) with butter valued at $2.24 and $2.52 per kg, respectively. The UPGF and UPGA strategies increased industry returns by $639 million (13.8%) and $604 million (13.0%) with butter valued about the same value as in the base year.

DISCUSSION

This study predicted total yields for the industry in the average year and did not consider random differences between years, although these can be important as a source of variation for milk production (van Bebber *et al*., 1997). The yields of milk components predicted for the 1996-97 season were lower than the actual yields, because 1996-97 was a very favourable year for dairy production (Livestock Improvement, 1997).

Variation within- and between breeds for milk production can be exploited through selection and crossbreeding (Gibson, 1989). Results obtained in this study show that from a fixed amount of feed utilised for dairying, selection of animals based on BW caused increases in the quantities of milk, its components and the resultant dairy products being produced from a decreased number of cows.

Live weight of cows is important because it impacts the stocking rate through feed requirements for maintenance. Average cow live weight of the national herd was reduced by UPGJ but increased by UPGF (Table 2). The live weight changes, along with productivity increases from genetic progress lead to reduction in stocking rate of 1% and 11% by UPGJ and UPGF, respectively.

Upgrading the cow population to F caused the largest increase in WMP, whereas UPGJ caused the largest increase in butter and casein. These differences were directly related to the differences in the quantities of the various milk constituents produced by cows of different breeds and they agree with the predictions of Wiles (1987, 1988).

The average value of butter depended on the amount of butter sold. Upgrading the cow population to J for 25 years resulted in 67 million kg butter being sold at the marginal value of $0.45 per kg whereas UPGF increased butter by only 2 million kg. Accordingly, the average values of butter in the year 25 were $2.24 and $2.96 per kg for UPGJ and UPGF, respectively. Therefore, industry returns will be sensitive to the amount of dairy products and their value for each of the breeding strategies. Two-breed rotation (F,J) and UPGJ resulted in different yields of dairy products and values of butter, but in equal increases in total industry returns.

Wiles (1988) pointed out that if milk is processed into WMP and butter (i.e. WMP not standardised for protein and therefore protein not extracted), all the protein will be part of the WMP. This would favour the F breed as the superior protein gain in UPGJ (Table 2) is not given a higher monetary value as casein. A sensitivity analysis showed that when WMP was not standardised for protein, UPGJ and UPGF were equal in industry returns and two-breed rotation (F,J) was superior to both by $10 million (results not shown).

Results from this study confirm results obtained by Campbell (1966) and Wiles (1988) suggesting that for a combination of WMP, butter and casein, industry returns would be increased more by upgrading toward the Jersey breed rather than towards the Holstein-Friesian breed. However, the net financial outcome of all these changes must be assessed carefully, taking into account farm expenses, income from culled stock and factory costs in processing milk with different composition.

CONCLUSIONS

Results from this study suggest that selection within-breed in combination with crossbreeding can be used to modify the mixture of dairy products which can increase industry returns in the New Zealand dairy industry. However, the nature of the increase in milk components depends on the crossbreeding strategy adopted and the total financial implications of different strategies are considerably different. These impacts on industry returns are sufficiently large that industry adoption of crossbreeding strategy should not be left to chance.

ACKNOWLEDGMENTS

The senior author wishes to acknowledge financial support of Consejo Nacional de Ciencia y Tecnología (CONACYT) and Universidad Autünoma Chapingo, México.

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