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The effect of genotype on milk composition, milk value, and dairy farm profitability

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ABSTRACT

This study was conducted to determine the effect of genotype on milk composition, milk value and economic farm surplus (EFS). The trial included two high breeding worth (\$BW) strains of either North American (OS90) or New Zealand (NZ) (NZ90) genetics, and one low \$BW strain of NZ genetics (NZ70). Each strain was farmed under systems designed to provide total feed allowances of 4.5 to 7.0 t DM/cow/year. For two years (2001/2002 & 2002/2003) monthly average milk yield and composition were determined for each of the 11 herds. A simulation model was used to calculate milk value using three product mixes. Using either the simulated values or actual values (paid by Fonterra 2002/2003) for milk and its components, milk value (\$/litre and \$/kg milksolids (MS)) and an EFS for each herd was determined. The OS90 strain produced milk with lower concentrations of fat and protein and higher protein:fat ratio than NZ70 or NZ90 strains. The effect of strain on milk price was unaffected by product mix. Milk value differed between strains irrespective of method of determination. Milk value expressed as \$/kg MS was lowest for the NZ70 and highest ($P < 0.001$) for the OS90 strain. When expressed as \$/litre milk value was highest ($P < 0.001$) for the NZ90 strain. Milk value expressed as \$/kg MS was positively associated with protein:fat ratio whereas milk value expressed as \$/litre was positively associated with MS concentration. Average EFS was greater for the NZ90 than the NZ70 strain and was least for the OS90 strain. The factors associated with EFS were MS production; milk value and milk composition had minimal impact. New Zealand's dairy cattle breeding programme has produced a strain of Holstein-Friesian with increased milk fat and protein concentration, an increased protein:fat ratio, and an associated increased milk value and increased EFS. In comparison, the OS90 strain which the current \$BW index ranks as high as the NZ90, produced milk with higher value (\$/kg MS) but resulted in lower EFS.

Key words: milk price; milk value; milk composition; economic farm surplus.

INTRODUCTION

The price paid for milk by processing companies is calculated from the yield and value of two of the major milk components (milk fat and crude protein) and a deduction is made for volume (Fonterra, 2004). The adoption of this milk pricing system in 1990 was designed to signal market trends in product prices and give the dairy industry a clearer signal for making strategic decisions on modifying factors affecting milk composition to better meet market trends and achieve a higher milk price (Paul, 1985). Since this milk pricing system has been in place, few if any on-farm management changes driven by differentially priced milk components have occurred. Recommendations made to farmers on ways to improve productivity have focused on increasing milksolids (MS) production (Macdonald & Penno 1998; Penno, 1998) and not on improving milk value by manipulating milk composition. Reports on the benefits of different management practices to dairy production and farm income have used a standard value for MS based on the national average MS price (Penno, 2001). Contrary to the trends in farm management practices, the national dairy cow breeding programme, has applied the different economic values of lactational yields for milk fat and protein to determine breeding worth for bull and cow selection (Spelman & Garrick, 1997).

The genetic composition of New Zealand's dairy herd in the last 30 years has changed. There has been a

shift from the Jersey to Holstein-Friesian breed and the national herd has become increasingly influenced by overseas (North America and Europe) Holstein-Friesian genetics (Harris & Kolver, 2001). It is predicted from this change in genetic structure of the national herd and from the data presented by Kolver *et al.* (2002) that an increase in milk yield/cow and a decrease in milk fat and protein concentration would be expected. These projected changes in milk composition however have not occurred. During this period the national average for milk yield per cow has increased by 31% but milk composition has remained constant (LIC, 1999; LIC, 2004). As the expected changes in milk composition have not occurred we therefore assume the national herd improvement programme (Spelman & Garrick, 1997) has counteracted the negative effect that changes in genotype would have had on milk composition.

To evaluate the likely effects of these changes on milk composition and milk value, a more detailed study was conducted using the Dexcel Strain Trial as a model. In 2001, Dexcel commenced an investigation into determining the effect of herd improvement and the introduction of overseas genetics on dairy cow performance and the profitability of farm systems developed to optimise performance of the different Holstein-Friesian genotypes. From the information produced in this study the effect of genotype on milk composition and milk value and the contribution of shifts in milk composition to economic farm surplus (EFS) was determined.

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METHOD

The study was based on yield and composition of milk assessed at approximately 4-weekly intervals from the Dexcel Strain Trial during the first two years of the study: the 2001/2002 and 2002/2003 dairying seasons. In the first season (2001/2002) 100% of the herds were heifers and in year two (2002/2003) each farmlet comprised 75% rising 3-year-olds and 25% heifers. The trial design has been fully described by Rossi *et al.* (2004). In brief, the trial comprised three strains of Holstein-Friesian dairy cows farmed on a range of feeding systems. The strains were high breeding worth Holstein-Friesian cows of overseas origin (OS90) and New Zealand origin (NZ90) and a 1970 New Zealand Friesian strain (NZ70). The strains were evaluated in farm systems designed to provide moderate to generous feed allowances ranging from 4.5 to 7.0 t DM/cow/year based on different stocking rates and supplementary feed inputs. Systems receiving 6 t DM/cow or greater were offered maize silage in the paddock during pasture deficit periods and those with a feed allowance of 7.0 t DM/cow or higher were also offered 2 kg/cow/day of maize grain during feed deficit periods.

Milk yield and composition were determined at approximately 4-weekly intervals on bulk milk samples collected from each herd. Individual cow milk yields were determined using in-line milk meters (Tru Test, Palmerston North, New Zealand). All milk in the individual cow milk meter sample was bulked for each herd at the evening and morning milking. These bulked herd samples were then thoroughly mixed to form a bulk composite sample for each herd. The bulk herd sample was then analysed for fat, crude protein, casein, and lactose concentration using a MilkoScan FT120 (Foss, Hillerød, Denmark) milk analyser. Additional milk samples were also analysed by reference procedures (fat by the Rose Gottlieb method, International Dairy Federation, 1987; total N by macro-Kjeldahl digestion, Barbano *et al.* 1991) to correct the FT120 results for matrix effects associated with strain of cow, level of feeding or stage of lactation.

Milk yield and composition (fat, protein, casein number, lactose and a standard mineral concentration (0.7%)) for each herd at each sampling time for each dairying season were used as input data to simulate three different milk processes: 1, 50% skim milk powder (SMP) + 50% casein and butter, 2, 100% cheese, and 3, a mix of dairy products; skim milk powder (SMP), cheese, butter, butter milk powder (BMP), casein, whey milk powder (WMP) from cheese processing, and whey protein concentrate (WPC) from casein processing, using the model described by Garrick and Lopez-Villalobos (2000) and Lopez-Villalobos *et al.* (2000). The part of the model that simulates the yield of dairy products and in-plant processing costs was used to calculate the value of MS from the milk yield and

composition for each herd at each 4-weekly herd test. The three product mixes were adopted to determine if milk price from a particular product mix was sensitive to milk composition or strain.

Average product prices for 2002/2003 were used in the model to determine the value of the individual milk components. Values for milk fat, protein, and volume (Fonterra, 2003) were also used to calculate the value of milk (\$/litre and \$/kg MS) produced for each herd at each milk-sampling period.

EFS was calculated for each farmlet in each season from total income (total milk income and income from sale of surplus animals and pasture supplements) and an estimate of actual farm operating costs and standard costs (Dexcel, 2004) using 2002/2003 values. Total milk income was determined from actual MS yield from each farmlet and the simulated and calculated values for MS for 2002/2003. EFS was also determined using the average milk price for 2002/2003 of 3.66/kg MS (LIC, 2003).

Herd means were calculated for each season and the data were statistically analysed using ANOVA (GenStat) with feed level as a covariate and strain as the fixed effect. The strain means presented in Table 1 are the estimated mean value for each strain at the mean feed allowance. Associations between milk components measured and milk value, milk income and EFS, were investigated.

RESULTS

The effects of strain on milk yield, milk composition and milk value for each season are presented in Table 1.

In the first season, strain had no effect on milk yield but in the second season there was a trend ($P < 0.11$) for milk yield from the NZ70 strain to be lower. Milk produced by the NZ90 strain had higher concentrations of milk fat, protein, MS and casein than the OS90 and the NZ70 strain. The composition of milk from the OS90 strain was lower in milk fat and higher in protein and casein than the NZ70 strain. The protein: fat ratio differed between strains with the NZ70 strain being lower and the OS90 strain higher than the NZ90 strain. Strain had little effect on milk lactose concentration. Irrespective of the method of determining milk value (expressed as \$/kg MS) in each year, the OS90 strain produced milk with the highest value and the NZ70 strain milk with the lowest value (Table 1).

Milk processed through the 100% cheese system had the highest value. The effect of strain on milk value was similar irrespective of product mix. Milk value expressed \$/kg MS was highest for the OS90 strain and expressed as \$/litre was highest for the NZ90 strain. Milk value was lowest for the NZ70 strain whether expressed as \$/kg MS or \$/litre (Table 1).

TABLE 1: The effect of Holstein-Friesian strain (low breeding worth and high breeding worth New Zealand and high breeding worth overseas Holstein-Friesian strains (NZ70, NZ90, and OS90 respectively) on milk composition and predicted milk value (\$/kg milk solids (MS) & \$/litre). Strain means are expressed as the average at the mean feed level across the three strains.

Variant	Year	Strain			SED	P value Strain
		NZ70	NZ90	OS90		
Milk yield (kg)	2001/02	14.4	15.0	15.2	0.37	0.187
	2002/03	17.2	19.2	19.6	0.91	0.101
Fat%	2001/02	4.42	4.64	4.16	0.085	0.002
	2002/03	4.42	4.70	4.21	0.110	0.006
Protein%	2001/02	3.16	3.49	3.38	0.023	<0.001
	2002/03	3.32	3.60	3.46	0.077	0.020
MS%	2001/02	7.58	8.14	7.54	0.105	0.011
	2002/03	7.74	8.30	7.67	0.179	0.013
Protein:fat	2001/02	0.72	0.76	0.82	0.011	<0.001
	2002/03	0.76	0.77	0.83	0.010	0.001
Casein%	2001/02	2.43	2.71	2.59	0.017	<0.001
	2002/03	2.53	2.80	2.65	0.067	0.011
Lactose%	2001/02	4.90	4.93	4.81	0.044	0.061
	2002/03	4.83	4.87	4.81	0.031	0.127
Milk value (\$/kg MS)						
SMP Ca-Bu ¹	2001/02	3.60	3.65	3.72	0.021	0.013
	2002/03	3.60	3.64	3.71	0.017	0.005
Cheese	2001/02	4.06	4.15	4.17	0.021	0.020
	2002/03	4.05	4.11	4.15	0.019	0.016
Product mix	2001/02	3.62	3.68	3.74	0.020	0.011
	2002/03	3.64	3.68	3.75	0.016	0.007
Fonterra	2001/02	3.49	3.57	3.61	0.009	0.000
	2002/03	3.55	3.59	3.62	0.014	0.005
Milk value (\$/litre)						
SMP Ca-Bu ¹	2001/02	0.27	0.29	0.28	0.003	<0.001
	2002/03	0.28	0.30	0.28	0.005	0.004
Cheese	2001/02	0.30	0.33	0.31	0.003	<0.001
	2002/03	0.31	0.34	0.32	0.006	0.004
Product mix	2001/02	0.27	0.30	0.28	0.003	<0.001
	2002/03	0.28	0.30	0.28	0.006	0.005

¹ 50% skim milk powder (SMP)-50% casein & butter

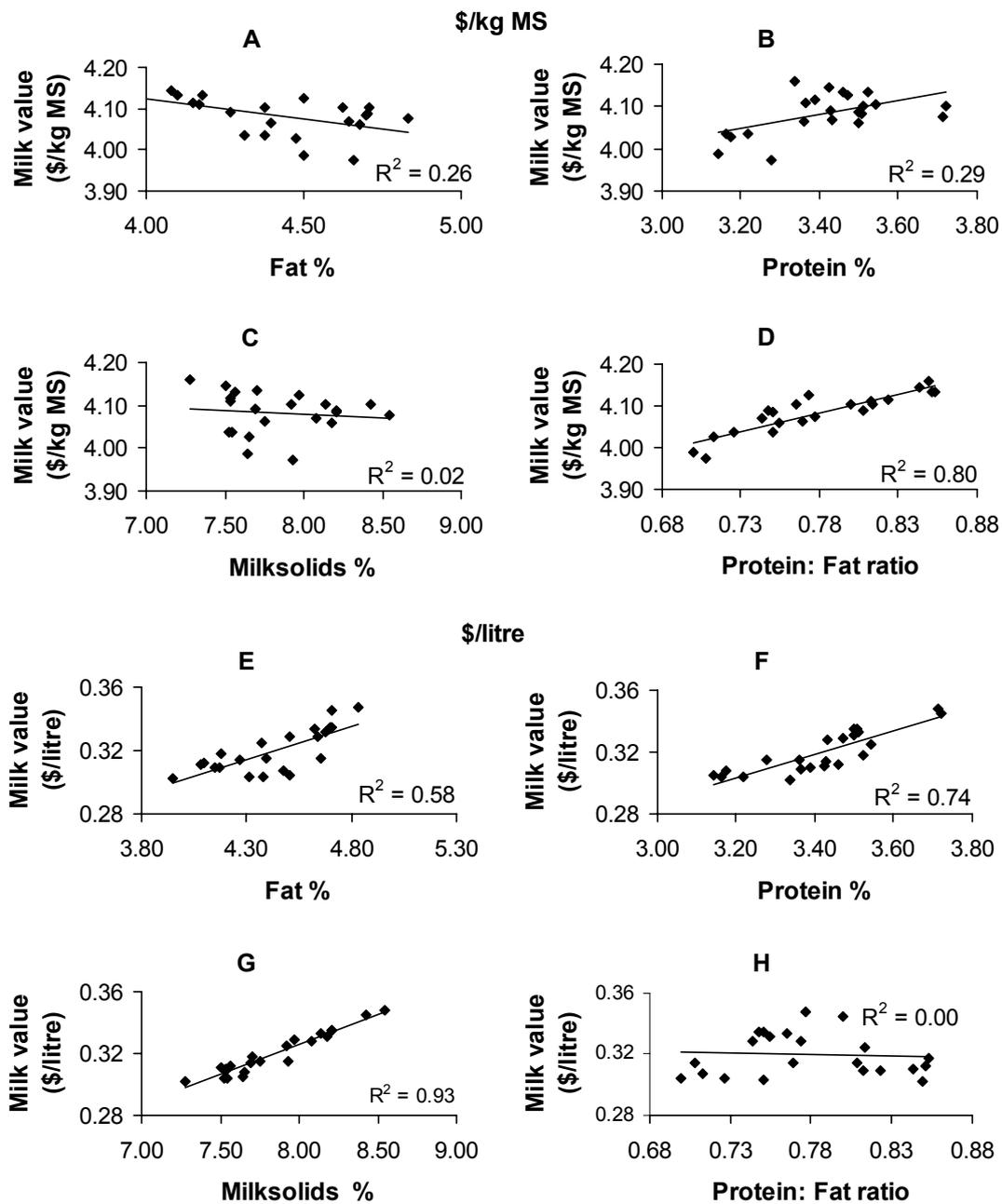
TABLE 2: Effect of strain of Holstein-Friesian (low breeding worth and high breeding worth New Zealand and high breeding worth overseas Holstein-Friesian strains, NZ70, NZ90, and OS90 respectively) on economic farm surplus (EFS \$/ha) calculated using simulated milk prices and the Fonterra 2002/2003 end of season milk price as either the average \$/kg MS or calculated using the sum of the values for fat and protein and an adjustment for volume.

Strain	Simulated milk values from different milk processing systems			Actual milk values	
	Mix of products	100% cheese	50% SMP 50% casein & butter	Standard ¹	Fonterra ²
NZ70	1610	2080	1490	1660	1440
NZ90	1910	2430	1780	1900	1750
OS90	1360	1800	1240	1250	1230

¹ The average milk price for 2002/2003 (LIC, 2003)

² Milk price using the milk price formula paid by Fonterra for the 2002/2003 season

FIGURE 1: Associations between average milk yield, milk composition and milk value as expressed as \$/kg milk solids (MS) and \$/litre for each farm system each year using milk value from the 100% cheese simulation.



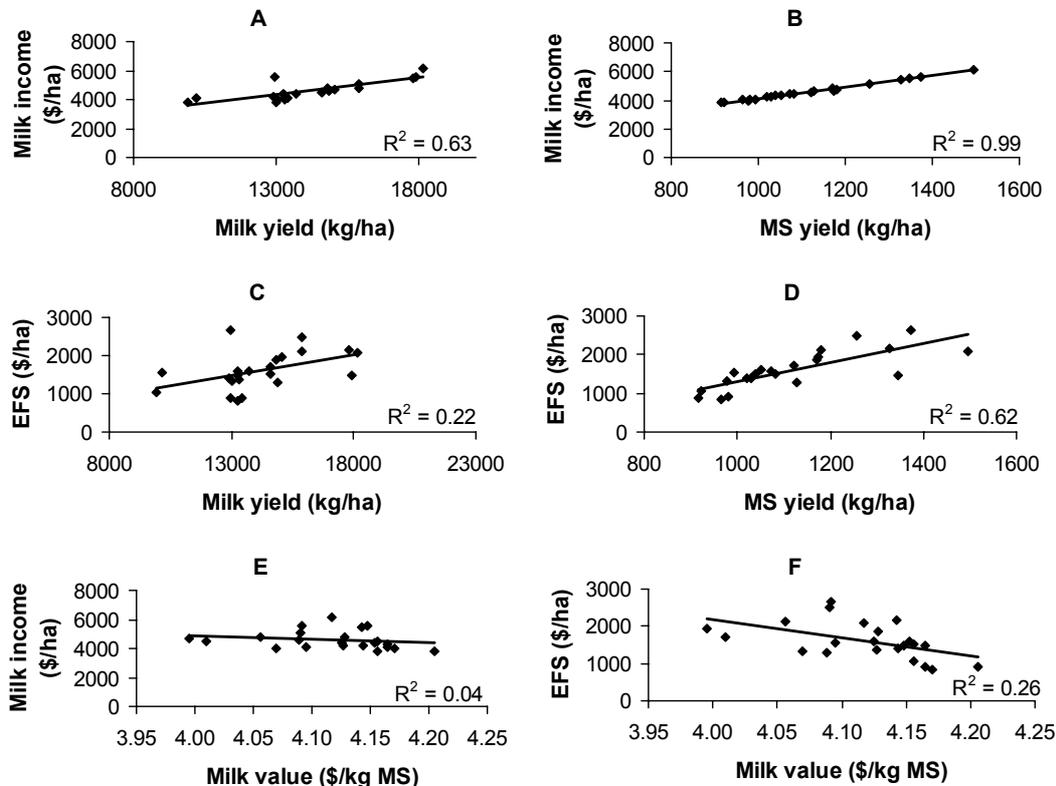
The graphs presented in Figure 1 show the associations between mean yearly herd values for the various milk components and milk value as expressed as \$/kg MS and \$/litre. Milk value expressed as \$/kg MS was associated with protein:fat ratio (Figure 1D) and as \$/litre was associated with MS concentration of milk (Figure 1G). For the purpose of this paper further calculations and discussion on these results will be based only on milk value expressed as \$/kg MS.

The relative effect of treatment on EFS did not differ between years (data not presented). As a result, only the average EFS for each strain for the two years are presented (Table 2). Irrespective of the product mix

used in the simulation model the relative rankings of EFS for each strain were similar. There was little difference in the ranking of strains for EFS whether calculated using the simulated milk price estimates, the actual milk pricing formula used by Fonterra for the 2002/2003 season, or, by using the 2002/2003 average price for MS.

Graphs of components that contribute to EFS (Figure 2) indicate that EFS was positively associated with total milk yield (Figure 2C) and MS production (Figure 2D), and negatively, (although weakly) associated with milk value (Figure 2F).

FIGURE 2: Associations between farmlet means for each season for milk yield, milk solids (MS) yield, milk value (\$/kg MS) and milk income and economic farm surplus (EFS) using the 100% cheese-processing model.



DISCUSSION

Since the inception of component pricing, the relative value of milk fat has declined and the value of protein increased. For example in the 1990/91 season, Marshall (1992) reported the ratio of milk fat to protein values to be 0.72. In 2004 this ratio had declined to 0.19 (Fonterra, 2004). The decline in relative value of milk fat has been dramatic and would suggest that such a shift in relative value would have resulted in the recognition that milk composition, especially milk protein, was an important factor affecting milk value and farm income. This however has not occurred and this paper attempts to identify the contribution of milk composition to milk value, farm income and EFS.

It was observed (Table 1) in the first two years of the Dexcel Strain Trial that milk composition was influenced by both breeding worth and strain of Holstein-Friesian dairy cow. The data presented, clearly demonstrated that between 1970 and 1990 the concentrations of fat and protein in milk from the New Zealand Friesian increased. The focus of the national breeding programme through the 1970s and up to the mid 1980s was on increasing milk fat yield. The selection of bulls on breeding index (BI) that involved selection for increased milk fat and protein concentration and against milk volume commenced in the late 1980s. This change in selection criteria possibly had insufficient time to have the impact on the increase

in milk fat and milk protein concentrations observed between the NZ70 and NZ90 Holstein-Friesian strains noted in this study. The change in milk protein concentration was most likely due to the selection pressure applied on milk fat yield and the positive genetic correlation between milk fat and protein concentration (Spelman & Garrick, 1997).

The strain of Holstein-Friesian cow influenced the value of the milk to the processing company and the changes in milk value were associated with changes in milk composition. Surprisingly, the concentration of the most valuable component in milk, protein, was only weakly associated with milk price, whereas milk price was negatively associated with milk fat concentration and positively associated with milk protein:fat ratio. This finding is supported by Paul (1985), who reported the protein:fat ratio in New Zealand milk to be the most important aspect of milk composition influencing product yield, the value of the mix of products processed, and the value of milk to the processor. Norman *et al.* (1991) also reported that end product price was favoured by milk with high protein:fat ratio and this should be reflected in a more equitable milk pricing scheme. These authors also found the protein:fat ratio was the major factor affecting the final milk price across five manufactured products and five different breeds of dairy cow. Therefore increasing protein:fat ratio of milk was the most important

component affecting the value of milk to the processing company.

The yield and quality of specific dairy products is affected by milk composition (Dalglish, 1992; Guinee *et al.*, 1998). From this it would be expected that milk value across the different product mixes would have been affected by strain. This however was not apparent, which indicates that the value of milk processed into different dairy products is insensitive to differences in milk composition. Auld *et al.* (2001) arrived at a similar conclusion when comparing the yield and quality of cheese made from Jersey and Friesian milk that differed in fat and protein concentration and protein:fat ratio.

The price paid for milk is only a component of farm income as total milk production is normally considered the dominant component affecting farm revenue. Sale of surplus animals and feed supplements will also affect total income. Production costs will be governed by stocking rate, feed inputs, animal health, etc., which will be influenced by \$BW and strain of Holstein-Friesian (Verkerk *et al.*, 2000; Kolver *et al.*, 2004). These factors are all taken into account in the EFS calculation, which provides a realistic means of assessing the benefits to the farmer by adopting a strain of dairy cow that increases the protein: fat ratio and therefore milk value.

Irrespective of pricing method, EFS was greatest for the farm systems running the NZ90 strain and least for the systems running the OS90 strain. The average EFS for each strain, calculated from the various methods of determining milk price, increased by \$300/ha between the NZ70 and the NZ90 strains and decreased by \$580/ha between the NZ90 and the OS90 strains. The advantage in EFS to the NZ90 strain over the NZ70 and OS90 strains is similar to that reported by Kolver *et al.* (2004) for the 2002/2003 dairy season. Milk price, irrespective of method of calculation, was not associated with EFS. The value of milk (\$/kg MS), increased with the impact of strain on the protein:fat ratio but this increase in milk value appeared to have little impact on EFS. This suggests there were costs associated with managing milk composition and increasing protein:fat ratio and milk price. For example, with the shift from NZ70 to NZ90 to OS90 genetics there was a decline in reproductive performance (Kolver *et al.* 2004). With the shift from NZ90 to OS90, lactation days declined and annual MS production was similar (Macdonald *et al.* 2005).

Farm operating costs differed between strains. In comparison with the NZ90 strain, farm operating costs for the OS90 strain were on average \$410/ha greater and sale of surplus animals and pasture silage \$180/ha less (data not presented). Whereas on average the NZ70 strain cost \$300/ha less in farm costs and produced \$60/ha more from animal and silage sales compared with the NZ90 strain. The low EFS from the NZ70 strain was associated more with reduced MS production (lower MS concentration in milk) than an increase in farm operating costs.

The data presented do not imply that an increase in milk fat and protein concentration or an increase in protein:fat ratio is of no benefit. The NZ90 strain produced milk with higher concentrations of milk fat, protein and MS, and had a higher protein:fat ratio, which resulted in a higher milk price and contributed to a higher EFS than the NZ70 strain. The OS90 strain had increased benefits in milk composition and milk price over the NZ90 strain but EFS was less than both the NZ90 and NZ70 strains. This suggests that the breeding programme adopted in New Zealand over the past 30 years enabled an increase in milk value to occur without associated increases in farm costs.

ACKNOWLEDGEMENTS

This work was funded by Dairy InSight.

REFERENCES

- Auld *et al.*, 2001: Effect of breed of cow on cheese yield. *The Australian journal of dairy technology* 56: 178
- Barbano, D.M., Lynch, J.M., Flemming, J.R. 1991: Direct and indirect determinations of true protein content of milk by Kjeldahl analysis: collaborative study. *Journal of the association of analytical chemists* 74: 281-288
- Dalglish, D.G. 1992: Bovine milk protein properties and the manufacturing quality of milk. *Livestock production science* 34: 75-93
- Dexcel 2004. www.Dexcel.co.nz. Farm Facts, Economic Farm Surplus 2003/2004
- Fonterra 2004. Final payments for 2003/04 production. *Farmlink July 2004*: 24-25
- Garrick, D.J, Lopez-Villalobos, N. 2000: Potential economic benefits to the producer from altering the composition of milk. In: Occasional Publication No 25 – *British Society of Animal Science ed.* RE Agnew, K.W Agnew & A.M. Feron: 93-108
- Guinee, T.P., Mulholland, E.O., Mullins, C., Cororan, C.O., Connolly, J.F., Beresford, T., Mehra, R., O'Brien, B.J., Murphy, J.J. Stakelum, G., Harrington D. 1998: Effect of altering daily herbage allowance to cows in mid-lactation on the composition, ripening and functionality of low-moisture, part skim Mozzarella cheese. *Journal of dairy research* 65: 23-30
- Harris, B.L., Kolver, E.S., 2001: Review of Holsteinization on intensive pastoral dairy farming in New Zealand. *Journal of dairy science* 84 (E. Suppl.): E56-61
- International Dairy Federation. 1987: Milk: Determination of fat content – Rose Gottlieb gravimetric method (reference method). IDF Standard FIL-IDF IC: International dairy Federation, Brussels, Belgium
- Kolver, E.S., Roche, J.R., DeVeth, M.J., Thorne, P.L., Napper, A.R. 2002: Total mixed rations versus pasture diets: Evidence for a phenotype x diet interaction in dairy cow performance. *Proceedings of the New Zealand Society of Animal Production* 62: 246-251
- Kolver, E., Thorrold, B., Macdonald, K., Glassey, C., Roche, J. 2004: Black and white answers on the modern dairy cow. *Proceedings of the South Island Dairy Event (SIDE) 2004*: 168-185
- LIC 1999: New Zealand Dairy Statistics 1998/1999. Livestock Improvement Corporation, Hamilton, New Zealand

- LIC 2003: New Zealand Dairy Statistics 2002/2003. Livestock Improvement Corporation, Hamilton, New Zealand
- LIC 2004: New Zealand Dairy Statistics 2003/2004. Livestock Improvement Corporation, Hamilton, New Zealand
- Macdonald, K.A., Penno, J. 1998: Management decision rules to optimise milksolids production on dairy farms. *Proceedings of the New Zealand Society of Animal Production* 58: 132-135
- Macdonald, K.A., Thorrold, B.S., Glassey, C.B. Holmes, C.W., Pryce, J.E. 2005: Impact of farm management decision rules on the production and profit of different strains of Holstein-Friesian dairy cows. *Proceedings of the New Zealand Society of Animal Production* 65: 40-45
- Marshall, K.R. 1992: The value of different components in 2002. *Dairyfarming annual* 44: 107-114
- Norman, H.D., Wright, J.R., Convington, C.B., Barton, E.P., Ernstrom, C.A. 1991: Potential for segregating milk: herd differences in milk value for fluid and five manufactured products. *Journal of dairy science* 74: 2353-2361
- Paul, K.J. 1985: A new direction for the payment of milk. *Proceedings of the Ruakura Farmers' Conference* 37: 77-85
- Penno, J.W. 1998: Principles of profitable dairying. *Proceedings of the Ruakura Farmers' Conference* 50: 1-14
- Penno, J.W. 2001: Changing farm systems in response to current market signals. *Proceedings of the Ruakura Farmers' Conference* 53: 1-8
- Rossi, J.L., Macdonald, K.A., Thorrold, B., Holmes, C.W., Matthew, C., Hodgson, J. 2004: Milk production and grazing behaviour during early lactation of three strains of Holstein-Friesian dairy cows managed in different feeding systems. *Proceedings of the New Zealand Society of Animal Production* 64: 232-236
- Spelman, R.J., Garrick, D.J. 1997: Effect of live weight and differing economic values on response to selection for milk fat, protein, volume and live weight. *Journal of dairy science* 80: 2567-2562
- Verkerk, G.A., Morgan, S. Kolver, E.S. 2000: Comparison of selected reproductive characteristics in overseas and New Zealand Holstein-Friesian cows grazing pasture or fed a total mixed ration. *Proceedings of the New Zealand Society of Animal Production* 60: 270-274