
THE PROCEEDINGS OF THE
NEW ZEALAND SOCIETY
OF
ANIMAL PRODUCTION
VOLUME 62 2002

ISSN 0370-2731/2002 *Proceedings of the New Zealand Society of Animal Production 62:* 90-94

Genetic opportunities to improve milk value in New Zealand

N. LOPEZ-VILLALOBOS, D. J. GARRICK AND C. W. HOLMES

Institute of Veterinary, Animal and Biomedical Sciences, Massey University, Private Bag 11222, Palmerston North, New Zealand.

ABSTRACT

The value of milk in New Zealand can be improved by altering its composition by genetic means (crossbreeding, selection, and biotechnology). Breed changes and crossbreeding influence the value of milk, but the choice of breed is usually dominated by attributes other than milk composition. Responses to within-breed selection are influenced by the emphasis placed on milk components relative to other animal attributes. The relative economic emphasis among the traits in the objective, and the genetic and environmental relationships between measured performance attributes will influence the rate of progress in milk quality, milk value and farm profit. Transgenic modification of the bovine genome offers the possibility of quantum shifts in milk characteristics but requires further research, education and testing in order to gain consumer acceptance. The manufacture of high-value dairy products for specific markets will likely require the segregation of milks from different farms. The long-term nature of genetic improvement dictates that today's vision shared by producers, processors and AB companies must be in concert with future needs of consumers if real opportunities are to be realised.

Keywords: selection; crossbreeding; biotechnology; milk value.

INTRODUCTION

The joint effects of genetic change and improved management have enabled continuous lifts in the productivity of New Zealand dairy farms. Today's average dairy cow has resulted from the identification and selection of previous generations of cows that fit into the grazing system. In contrast to the makeup of cows that have developed in systems of milk production using high levels of concentrates, the New Zealand cow has lighter live weight and higher fertility, lives longer, and produces milk with higher concentration of milk solids. Farm profit has been achieved from efficient conversion of pasture into milk with a low production cost.

The value of milk to the producers is dependent on the world prices for dairy products and exchange rates between the US and NZ dollar, because 95% of milk produced is processed into dairy products and exported around the world. The milk prices paid to New Zealand producers increased significantly from $3.77/kg milk solids in 1999 to $5.01/kg milk solids in 2001. This large change was caused by simultaneous increase in the international price of dairy products and a devaluation of the New Zealand currency against the US dollar. However, long-term trends indicate that the price of milk solids is likely to decrease steadily (Livestock Improvement, 2000). Dairy farmers have responded in various ways to the historical reduction of milk price, but most notably by increasing farm size while concurrently lifting productivity per cow and per hectare (Garrick *et al*., 2001). The production of "commodity milk" has increased and it has been manufactured into cheeses, milk powders, casein and butter for export.

The prediction for declining commodity prices can be offset by increasing the value of dairy products sold. For example, specialist market for high-calcium milk in Asia earns the New Zealand dairy industry $200 million/year (Mackle, 2001). The development of milk with particular processing or nutritional properties requires knowledge about the manipulation of milk composition. Changes in milk composition can be achieved by nutritional management (Fearon, 2001; Beever *et al*., 2001) or through genetic manipulation (Gibson, 1989, Goddard, 2001). The objective of this paper is to discuss some aspects relating to the genetic improvement of the value of milk.

Changing milk value by crossbreeding

Alternative breeds of cattle produce different yields of milk that vary in the concentrations of particular components. The nature of the fat and protein fractions may vary between breeds (MacGibbon, 1996; Townsend *et al*., 1997; Ng-Kwai-Hang, 1998). Breeds of cattle differ in many other attributes, such as coat colour, temperament, reproductive performance, meat and carcass attributes, size, weight, stature and feed intake. The choice of breed by producers includes many aspects other than their revenue from milk. Producers have opportunities to alter milk composition by changing breeds or by crossbreeding. Changing breeds and crossbreeding will not be successful in practice if it focuses on only one aspect of animal performance, such as milk composition, without considering the aggregate performance as influenced by the entire spectrum of attributes associated with the breed or cross. Complementarity of characteristics from two or more breeds may favour crossbreds, but producers in many countries have a marked preference for purebred breeds of dairy cattle. Average productive performance and cow mature live weight (Livestock Improvement, 2000) of the main breed groups of New Zealand dairy cattle are in Table 1. Crossbred Holstein-Friesian x Jersey cows represent all cows having up to ³/₄ Holstein-Friesian or up to ³/₄ Jersey genes. Yields of dairy products and the value of milk (Table 1) were calculated assuming that milk was processed into whole milk powder (30%), skim milk powder (25%), cheese (22%) and butter/casein (23%) as shown in Garrick & Lopez-Villalobos (2000). Values

TABLE 1: Productive performance, value of milk and farm profit for different breeds[1] in New Zealand.

	HF	J	HFxJ	A
Production per cow, kg				
Milk	3,803	2,791	3,445	3,452
Fat	166 (4.4%)	161 (5.8%)	170 (4.9%)	151 (4.4%)
Protein	131 (3.4%)	113 (4.0%)	127 (3.7%)	122 (3.5%)
Mature live weight	450	355	420	417
Days in milk	215	220	217	218
DM requirements[2], kg/cow/year	4,774	4,042	4,577	4,430
Milk value[3], $/kg	0.468	0.557	0.504	0.478
Income per cow, $				
Milk	1,781	1,554	1,737	1,649
Cull cows	85	64	78	78
Total income	1,866	1,618	1,815	1,727
Costs per cow, $				
Marginal costs	220	220	220	220
Feed costs	240	203	230	223
Total costs	460	423	450	443
Net income per cow, $	1,406	1,195	1,365	1,284
Farm profit, $/tonne DM	294	296	298	290

[1] Breeds are HF=Holstein-Friesian; J=Jersey; HFxJ=crossbred HFxJ; A=Ayrshire.
[2] Includes requirements for maintenance, production, pregnancy and growth of replacements.
[3] Milk was processed into a channel mix of whole milk powder 30%, skim milk powder 25%, cheese 22% and casein/butter 23%.

of dairy products (Anonymous, 2001) were US$2,020/tonne whole milk powder, US$2,075/tonne skim milk, US$1,325/tonne butter, US$2,075/tonne butter milk powder, US$5,200/tonne casein, US$2,100/tonne Cheddar cheese and US$872/tonne whey powder, at an exchange rate of US$0.42 per NZ$1.00. Compared to the previous year these product values were higher and the US exchange rate was lower. The combination between these two favourable effects led to a very high value of milk calculated in this study.

Farm profit (Table 1) was calculated as explained by Lopez-Villalobos *et al*. (2000a), the difference between income (sale of milk and salvage value of animals) and costs (marginal and feed costs per cow). Marginal costs per cow were assumed at $220 and included animal health, breeding and herd testing, farm dairy expenses, electricity, and freight. Feed costs were 5 cents per kg of pasture dry matter. Dry matter requirements were calculated for maintenance, production, pregnancy and growing of the required proportion of replacements.

Jersey cows had the lowest requirements for dry matter, due mainly to their small size (Table 1). When the milks from these breeds were processed into a typical New Zealand mix of dairy products, Jersey milk resulted in the highest yield of butter whereas Holstein-Friesian milk resulted in the highest yield of whole milk powder and cheese. The crossbred Holstein-Friesian x Jersey and Ayrshire milks had intermediate yields between the Holstein-Friesian and Jersey milks. Jersey milk had the highest value per kg of milk but the lowest milk income per cow, mainly because they produced the lowest amount of milk. On the contrary, the Holstein-Friesians had the highest income per cow from milk, resulting from large volumes of milk overcoming their low milk value. The crossbred Holstein-Friesian x Jersey cows had the highest farm income ($298/tonne dry matter). These results show that the value of milk and farm profit are influenced by breed changes and crossbreeding. Differences in profit between breeds are large when expressed per cow but are small when expressed per tonne of dry matter required.

Changing milk value by selection

Significant changes in the composition of milk in New Zealand dairy cattle have been achieved through selection. In the early years of the industry, selection of cows and bulls was based on a Breeding Index for lactation yield of fat. Effects of continuous within-breed selection among Jerseys for fat yield over 30 years increased the lactation yield of milk (475 litres), fat (32 kg) and protein (18 kg) resulting in increased fat concentration (0.19 %) and small changes in protein (Bryant, 1986). Similar changes were reported in Friesian cows (Grainger *et al*., 1985).

In 1996 across-breed genetic evaluation was implemented and the selection criterion changed to Breeding Worth (BW). This index expresses profit per unit of dry matter and accounts for incomes from milk and beef and feed costs of maintenance and lactation. The unit of dry matter is 4.5 tonne, which is about the quantity eaten by an "average" cow born in 1985 and her proportion of replacements. BW is calculated as the sum of estimated breeding values for mature cow live weight, longevity, and lactation yields of milk, fat and protein weighted by their respective relative economic values.

The effects of two selection strategies on the value of milk and farm profit were evaluated using the genetic model developed by Lopez-Villalobos *et al*., (2000b). The first strategy was selection for milk solids (fat and protein) yield per cow and the second was selection for profit (net income per 4.5 tonne DM). In the latter, a simplified profit index was calculated considering mature cow live weight and lactation yields of milk, fat and protein but ignoring longevity. Correlated responses (Table 2) were calculated assuming current selection practices on the traditional four selection pathways. Selection to increase the yield of milk solids resulted in higher responses for lactation yields of milk, fat and protein and mature cow live weight than selection for profit.

TABLE 2: Annual correlated responses for different selection strategies.

	Strategy[1]	
	Yield	Profit
Rates of genetic gain, kg/year		
Lactation yield of milk	53.50	30.50
Lactation yield of fat	1.85	1.13
Lactation yield of protein	2.09	1.89
Cow mature live weight	1.78	0.03

[1] Selection strategies were: Yield=selection to increase fat and protein yields with relative economic values 1:4; and Profit=index selection to increase farm profit ($/4.5 tonne dry matter) with relative economic values –$0.049/kg milk, $0.123/kg fat, $5.00/kg protein, and –$0.651/kg mature cow live weight.

Changes in productive performance, value of milk and farm profit after 10 years of continuous selection under the different selection strategies were evaluated following Lopez-Villalobos *et al*., (2000a) (Table 3). Ten years of selection for profit did not change the average live weight of the cows, increased the concentration of protein, slightly reduced the concentration of fat and increased the value of milk. Selection for yield caused higher increases in milk yield, live weight and dry matter requirements, relative to selection for profit. Compared to selection for milk solids yield, selection for profit resulted in faster gain in net income per tonne of dry matter. The selection strategies increased net income from $31 to $34/tonne DM relative to the base situation earning $277/tonne DM, representing an annual improvement of over 1% per year.

TABLE 3: Changes in productive performance, value of milk and farm profit after 10 years for different selection strategies.

		Strategy[1]	
	Base	Yield	Profit
Production per cow, kg			
Milk	3,423	3,958	3,728
Fat	160 (4.7%)	179 (4.5%)	171 (4.6%)
Protein	121 (3.5%)	142 (3.6%)	140 (3.8%)
Mature live weight	450	468	450
DM requirements[2], kg/cow/year	4,645	5,002	4,827
Milk value[3] $/kg	0.484	0.486	0.505
Income per cow, $			
Milk	1,656	1,922	1,881
Cull cows	85	89	85
Total income	1,740	2,011	1,966
Costs per cow, $			
Marginal costs	220	220	220
Feed costs	234	252	243
Total costs	454	472	463
Net income per cow, $	1,287	1,539	1,503
Farm profit, $/tonne DM	277	308	311

[1]Selection strategies were: Yield=selection to increase fat and protein yield with relative economic values 1:4; and Profit=selection to increase farm profit ($/4.5 tonne dry matter) with relative economic values –$0.049/kg milk, $0.123/kg fat, $5.00/kg protein, and –$0.651/kg mature cow live weight.

[2]Includes requirements for maintenance, production, pregnancy and growth of replacements.

[3]Milk was processed into a channel mix of whole milk powder 30%, skim milk powder 25%, cheese 22% and casein/butter 23%.

Changing milk value by gene transfer

There are many alterations that could usefully be made by gene transfer to improve the value of milk (Bremel *et al*., 1989; Martin & Grosclaude, 1993; Karatzas & Turner, 1997; Wall *et al*., 1997; Goddard, 2001). These include, altering proteins to change the manufacturing properties of milk, increasing the antimicrobial activity of milk, altering the type and amount of fatty acids in milk, changing the amino acid composition of milk to improve human nutrition, and increasing overall protein content of milk (Murray & Maga, 1999). However such changes are likely to have more than one effect on the animal, some of which may be unfavourable; all effects must be considered. The use of modified animals is unlikely to be immediately adopted for many reasons. Nevertheless it is beneficial to consider the theoretical economic impact of such a quantum change, while ignoring the practicalities.

The farm (Lopez-Villalobos *et al.*, 2000a) and processing (Garrick & Lopez-Villalobos, 2000) models were used to illustrate some effects of gene transfer on the value of milk. The first scenario assumed that casein concentration in protein was increased from 78 to 80% without changing total protein concentration of milk, and the milk was processed into cheese. The second scenario assumed that the concentration of fat was reduced from 4.7 to 3.0%, and the milk was processed into a typical New Zealand mix of dairy products.

Improving the concentration of casein in protein increased the yield of cheese by 2.5% (Table 4). This occurred because more fat could be used in cheese production rather than for butter. The value of milk was increased by 1.1% and farm profit increased by 1.3%. Assuming that 22% of the total milk produced in New Zealand is used for cheese production, the industry benefit of increasing the concentration of casein in protein from 78 to 80% is $13.6 million per year (about $4.00 per cow).

Effects of changing fat concentration on yields of dairy products, value of milk and farm profit are in Table 4. Cows producing milk with 3% fat required less dry matter for milk production than cows producing 4.7% fat. The milk with 3.0% fat produced lower yields of butter and cheese, higher yields of whole milk powder, skim milk powder and casein and had lower value. Nevertheless, cows producing milk with 3% fat had 1% higher farm profit. Assuming 1.2 million ha for dairying and 12 tonne pasture dry matter utilised per hectare for milk production, the industry benefit from reducing fat concentrations from 4.7 to 3.0% is about $38.9 million per year (about $12.00 per cow).

Obstacles for achieving increased value of milk

The milk payment system is one of the major drivers that can stimulate selection to modify the value of milk. Producers will typically overlook milk characteristics that influence the true value of the milk, but are not part of the payment system. For example, the colour or hardness of the milk fat can contribute to the value of the resulting dairy products manufactured from the milk. However, neither colour nor hardness are part of the current payment system. Colour and hardness differ markedly between Friesian and Jersey cattle (Winkelman *et al.*, 1999; MacGibbon, 1996). Recent evidence suggests the concentration of CLA (conjugated linoleic acid) in milk

TABLE 4: Effect of changing the concentration of casein in protein (scenario I) and fat in milk (scenario II) on the yield of dairy products, value of milk, and farm productivity and farm profit.

	Scenario I		Scenario II	
	Casein 78%	**Casein 80%**	**Fat 4.7%**	**Fat 3.0%**
Production				
Fat, kg	160	160	160	103
Fat percentage in milk	4.7	4.7	4.7	3.0
Protein	121	121	121	121
Casein percentage in protein	78	80	78	78
Milk production	3,423	3,423	3,423	3,423
Live weight	450	450	450	450
DM Requirements, kg/cow/year				
Milk production	1,812	1,812	1,812	1,481
Total per cow	4,645	4,645	4,645	4,296
Use of milk	Cheese and butter		New Zealand mix[1]	
Yield of dairy products, kg				
Whole milk powder			112	115
Skim milk powder			65	67
Butter	17.3	12.5	116	58
Butter milk powder	1.8	1.3	12.3	6.1
Casein			35	43
Casein whey powder			55	70
Cheese	387	397	85	60
Cheese whey powder	211	209	46	33
Cheese yield, kg cheese/100 kg milk	11.41	11.69	11.41	11.23
Value of milk, $/kg milk	0.537	0.543	0.484	0.454
Income per cow, $				
Milk	1,839	1,859	1,656	1,553
Cull cows	85	85	85	85
Total income	1,924	1,944	1,741	1,638
Costs per cow, $				
Marginal costs	220	220	220	220
Feed costs	234	234	234	216
Total costs	454	454	454	436
Net income per cow, $	1,470	1,490	1,287	1,202
Farm profit, $/tonne DM	317	321	277	280

[1] Milk was processed into a channel mix of whole milk powder 30%, skim milk powder 25%, cheese 22% and casein/butter 23%.

influences its nutritional value for human consumption (Kelly and Bauman, 1996). The level of CLA could therefore influence the value of the milk in the marketplace. Concentrations of CLA are not currently accounted for in evaluating the value of milk. Traits to be included in the payment system have to be economically important such that the costs of measurement must be less than the value of the expected benefits.

Preference for a particular breed involves many attributes, with coat colour, size and temperament all playing significant roles in addition to production, reproduction, longevity and milk quality. Producers are often reluctant to change to breeds that are not already accepted by their neighbours. Most of the developed world's dairy industry is now based on a Holstein monoculture with the exception of New Zealand. Non-traditional breeds with favourable milk characteristics will seldom be adopted in these circumstances.

The recent Holsteinisation of the world dairy cow population appears to have been driven by their undisputed superiority in producing high volumes of milk per cow. However, their typically lower concentrations of fat and protein, and their higher maintenance requirements erodes their apparent advantage when comparison is based on profitability per unit of feed, particularly in payment systems that penalise volume, such as occurs in New Zealand. In these perhaps unique circumstances, the most profitable cows can represent a range of breeds and their crosses, providing opportunities to exploit breed differences in milk quality that may not exist in other parts of the world.

The best ways to use economic incentives in order to encourage genetic change in milk composition are not clear. For example, changes in fat composition that would improve the quality of one milk product would often be detrimental to other milk products. Such changes would best work where subpopulations of cows produce milk for specific end products, but segregation of the industry would be difficult to organise and might impede existing improvement programmes.

A dairy industry requires the definition of a clear selection objective. To achieve this, concordance of activities between the main sectors of the industry is required. Producers, processing companies, marketing and breeding organisations must contribute to the definition of the selection objective of the industry. In practice, market failure often occurs, most notably when simplified payment systems are adopted. Consequently, the producers do not receive true market signals about the components that influence their long-term returns. Accordingly, these components will not be appropriately represented in the economic indexes of aggregate merit used to rank candidates for selection as parents of the next generation. The entire chain from consumer preference to animal ranking and selection decisions must be coherently integrated in order to optimise the advance in milk value and farm profit.

CONCLUSIONS

The development of the dairy industry has largely occurred through the production of milk from pasture at low production cost, and the processing and export of commodity manufactured products, such as butter, cheese, whole and skim milk powders. Continued increases in efficiency, including overall economic and feed conversion efficiency in the cow, will be mandatory if the industry maintains its reliance on these strategies. Inclusion of fertility and health traits in the breeding objective are likely to become increasingly important in order to enhance farm profit.

Increasing the value of milk will contribute favourably to farm profit. There are genetic opportunities to increase the value of milk by modifying the composition of fat and protein to improve the quality and the yields of current and future dairy products. Implementation of genetic strategies to achieve these changes will require the modification of current selection strategies to include biotechnology for the production of "designer milks". Segregation of such milk from different herds will be required in order to facilitate the development of niche market milks, customised for "designer milk products". Selection for customised milk characteristics will require a change in the payment system and processing systems, and in industry attitudes.

REFERENCES

Anonymous. 2001: Price trends. *AGBRIEF 1(21)*: 1.

Beever, D. E.; Sutton, J. D.; Reynolds, C. 2001: Increasing the protein content of cow's milk. *Australian journal of dairy technology 56*: 138-149.

Bremel, R. D.; Yom, H. -C.; Bleck, G. T. 1989: Alteration of milk composition using molecular genetics. *Journal of dairy science 72*: 2826-2833.

Bryant, A. M. 1986: Major determinants of milk production from grazed pasture in New Zealand. *Bulletin No. 19. International Dairy Federation* pp. 3-6.

Fearon, A. M. 2001: Optimising milkfat composition and processing properties. *Australian journal of dairy technology 56*: 104-108.

Garrick, D.J.; Lopez-Villalobos, N. 2000: Potential for economic benefits to the producer from altering the composition of milk. *In:* Agnew, R. E.; Agnew, K. W.; Fearon, A. M. *ed*. Milk composition. Occasional Publication No. 25, British Society of Animal Science. pp. 93-108.

Garrick, D. J.; Lopez-Villalobos, N.; Holmes, C. W. 2001: Recent pre- and post-farm gate developments in the New Zealand dairy industry. *Advances in dairy technology 13*: 369-378.

Gibson, J. P. 1989: Altering milk composition through genetic selection. *Journal of dairy science 72*: 2815-2825.

Goddard, M. E. 2001: Genetics to improve milk quality. *Australian journal of dairy technology 56*: 166-170.

Grainger, C.; Davey, A. W. F.; Holmes, C. W. 1985: Performance of Friesian cows with high and low breeding indexes. 1. Stall feeding and grazing experiments and performance during the whole lactation. *Animal production 40*: 379-388.

Karatzas, C. N.; Turner, J. D. 1997: Toward altering milk composition by genetic manipulation: current status and challenges. *Journal of dairy science 80*: 2225-2232.

Kelly, M. L.; Bauman, D. E. 1996: Conjugated linoleic acid: a potent anticarcinogen found in milk fat. *Proceedings of the Cornell nutrition conference for feed manufacturers.* pp 68-74.

Livestock Improvement. 2000: Dairy statistics 1999-2000. Livestock Improvement Corporation Ltd. Hamilton, New Zealand.

Lopez-Villalobos, N.; Garrick, D. J.; Holmes, C. W.; Blair, H. T.; Spelman, R. J. 2000a: Profitabilities of some mating systems for dairy herds in New Zealand. *Journal of dairy science 83*: 144-153.

Lopez-Villalobos, N.; Garrick, D. J.; Holmes, C. W.; Blair, H. T.; Spelman, R. J. 2000b: Effects of selection and crossbreeding strategies on industry profit in the New Zealand Dairy Industry. *Journal of dairy science 83*: 164-172.

Martin, P.; Grosclaude, F. 1993: Improvement of milk protein quality by gene technology. *Livestock production science 35*: 95-115.

MacGibbon, A. K. H. 1996: Herd-to-herd variations in the properties of milk fat. *Proceedings of the New Zealand society of animal production 56*: 224-227.

Mackle, T. 2001: Milk technology and research – an overview. *Westpac Trust dairy conference: The magic of milk*.

Ng-Kwai-Hang, K. F. 1998: Genetic polymorphism of milk proteins: relationships with production traits, milk composition and technological properties. *Canadian journal of animal science 78 (Suppl.)*: 131-147.

Murray, J. D.; Maga, E. A. 1999: Changing the composition and properties of milk. *In:* Murray, J. D.; Anderson, G. B.; Oberbauer, A. M.; McGloughlin, M. M. *ed.* Transgenic animals in agriculture. CABI Publishing, Wallingford, Oxon, UK. pp 193-208.

Townsend, S. J.; Siebert, B. D.; Pitchford, W. S. 1997: Variation in milk fat content and fatty acid composition of Jersey and Friesian cattle. *Proceedings of the association for the advancement of animal breeding and genetics 12*: 283-286.

Wall, R. J.; Kerr, D. E.; Bondioli, K. R. 1997: Transgenic dairy cattle: genetic engineering on a large scale. *Journal of dairy science 80*: 2213-2224.

Winkelman, A. M., Johnson, D. L.; MacGibbon, A. K. H. 1999: Estimation of heritabilities and correlations associated with milk color traits. *Journal of dairy science 82*: 215-224.