Supply and demand for lactose in the New Zealand dairy industry

NW Sneddon[a]*, N Lopez-Villalobos[a], RE Hickson[a], L Shalloo[b], DJ Garrick[a] and U Geary[b]

[a]*Institute of Veterinary, Animal and Biomedical Sciences, Massey University, Private Bag 11-222, Palmerston North, New Zealand;* [b]*Dairy Production Department, Teagasc, Moorepark Production Research Centre, Fermoy, Co. Cork, Cork, Ireland*
**Corresponding author. Email: N.W.Sneddon@massey.ac.nz*

Abstract

Global milk product demand has been rapidly growing in the past decade, which is reflected in an increased demand for milk powders. The New Zealand dairy industry is capitalising on this by shifting its product portfolio towards milk powders. However, current international product specifications in combination with New Zealand milk composition and an industry objective to maximise farm profitability makes the industry deficient in milk lactose. This study aimed to determine how lactose deficit or surplus is influenced by changes in the product portfolio. In order to quantify this lactose balance, a computer simulation model was used (Moorepark Processing Sector Model). The 2012 New Zealand milk production (19.129 billion litres, milkfat concentration (4.99%), protein concentration (3.82%) and lactose concentration (4.70%, anhydrate)) was used within the analysis. Four manufacturing portfolio scenarios were investigated with different proportions of milk diverted to whole milk powder production (80%, 60% (current proportion), 30% and 10%). The model simulated the total production of whole milk powder, skim milk powder, casein, whey powder, buttermilk powder, butter and cheese. Whole milk powder production varied from 2,292,000 tonnes for the 80% scenario to 286,000 tonnes for the 10% scenario. Lactose mass balance varied from 214,000 tonnes in deficit for the 80% scenario to 510,000 tonnes in surplus for the 10% scenario. These analyses indicate that as more whole milk powder is produced, milk from current New Zealand cows results in an increased deficit of milk lactose. The national breeding objective could be adjusted to reflect changes in the future product portfolios to better align the composition of milk with the likely product mix.

Keywords: Lactose; processing model

Introduction

Global demand for milk products has been increasing rapidly in the past decade (Fonterra 2003; Fonterra 2012a), and the amount of milk powder (whole, skim and, butter milk powders) traded by New Zealand on the world market has increased from 687,900 tonnes in 2002 to 2,413,000 tonnes in 2012 (Fonterra 2003; Fonterra 2012a). Over the last decade, the New Zealand dairy industry has moved to capitalise on this increased demand through shifting its manufacturing towards milk powders. This shift in the product portfolio of the New Zealand dairy industry has created an imbalance within current milk lactose constituents. When the objective is to maximise industry profitability within the context of the international codex requirements for milk powder production. Currently the composition of New Zealand milk is reported as 4.99% milkfat, 3.82% protein (Livestock Improvement Corporation 2013) and 4.70% lactose (anhydrate). If this milk was processed directly into milk powder, the composition of the resulting powder would be 36.9% fat, 28.3% protein and 34.8% lactose. This shows excess fat and protein and a deficit of lactose compared to the codex of 26.5% fat, 25.1% protein and 39.8% lactose reported by Geary et al. (2010). In order to maximise industry profitability based on current costs and prices it makes more sense to buy in lactose and add it to the powder than removing protein and fat; That would result in an increase in the production of products like anhydrous milk fat or milk protein concentrates (MPC) produced through ultrafiltration.

Selection of cows on breeding worth has seen an increase in milkfat and protein concentrations since 1996 (Livestock Improvement Corporation 2013) with no reported changes in lactose concentrations. This increase in milkfat and protein production has led to the current industry practise to incorporate additional lactose into milk, however, the test used to determine lactose in the raw milk for whole milk powder (WMP) production is not reported by milk processors. Lactose concentration can be determined by an infrared milk analyser (Fourier Transform Infrared Spectroscopy [FT120], Foss Electric, Hillerød, Denmark), and is usually reported as lactose monohydrate which produces a higher lactose concentration than lactose anhydrate.

Lactose demand in New Zealand can be linked to the export product portfolio. Between 2002 and 2012 the New Zealand dairy industry shifted from being a mass exporter to a mass importer of lactose (Fonterra 2003; Fonterra 2012a). The aim of this study was to determine how the deficit or surplus for lactose may change in the future through simulating different product portfolio scenarios.

Materials and methods

Model description

A mass-balance processing-sector model that accounts for all inputs, outputs, and losses involved in dairy processing, developed by Geary et al. (2010), was used to simulate the total production of various products in each of the investigated scenarios. Within this model, the production of each of the dairy products is simulated (WMP, skim milk powder (SMP), cheese, butter, fluid milk). Key inputs for the model are milk volume and composition, and the product portfolio and its composition. The quantities of products and by-products that can be produced from the available milk pool are calculated by the model (Geary et al. 2010), which is set to minimise by-products and maximise product output.

Data

Data on milk production for the 2011/12 dairy season were obtained from NZ dairy statistics (LIC 2013). This provided milk volume (billions of litres, BL), milk fat and protein yields, and milk fat and protein concentrations (19.129BL, 4.99% fat, 3.82% protein). Lactose yield and concentration is not reported in NZ dairy statistics, so the concentration was estimated using a national dataset obtained from LIC's sire-proving scheme (where fat and protein percentage are similar to the national average, 4.97% milkfat and 3.86% protein). Lactose monohydrate concentration of 4.95% was obtained and converted to lactose anhydrate using a conversion factor of 342/360 to give a lactose anhydrate concentration of 4.70%, which was used in the model, this also compares relatively well with values used by Lopez-Villalobos et al. (2000). The milk production per cow, hectare and for the overall industry used in the model is shown in Table 1.

Four scenarios were evaluated in this study; the base New Zealand product portfolio obtained by combining data available in the Fonterra 2012 annual report (Fonterra 2012c), Fonterra farm gate milk price statement (Fonterra 2012a) and the Fonterra milk price – the facts (Fonterra 2012b), the product portfolios used in this study are summarised in Table 2, and included a current product mix (60% WMP) (60%), a historical mix (30% WMP) (30%), an extreme high mix (80% WMP) (80%) and an extreme low mix (10% WMP) (10%).

Whey protein concentrate (WPC) was produced in this model by removing 75% of the lactose from whey powder (WP; 80% lactose, 5.8% fat, 12.8% protein, 5.8% minerals, 2.4% water). The lactose is then used to partially offset the lactose requirements for WMP and SMP production. A conservative value of 75% was chosen, with up to 80% recovery possible (Archer 1998, Mollea et al. 2013). The model calculated lactose deficit by balancing output on fat and protein contents.

Results

Results of all four scenarios are detailed in Table 3. The 60% scenario resulted in a product portfolio split of 56% WMP, 15.5% SMP, 10.9% cheese and 13.5% of butter. The lactose deficit was estimated at 129,000 tonnes with lactose recovery from whey powder, and this would result in a cost of US$260 million at market value of US$2,000/ton (GlobalDairyTrade). The 80% scenario produced a product portfolio of 73.7% WMP, 6.7% SMP, 6.2% cheese and 9.9% butter. The lactose deficit under this scenario was 214,000 tonnes and would result in a cost of US$430 million. The 30% scenario produced a portfolio of 27.9% WMP, 23.2% SMP, 23.4% cheese and 16.0% butter. Due to decreased production of WMP and increased production of cheese, this scenario had a surplus of 19,000 tonnes of lactose with a market value of US$38 million. The 10% scenario production produced a portfolio of 8.3% WMP, 7.2% SMP, 52.5% cheese and 6.1% butter. Under this scenario there was a surplus of 510,000 tonnes of lactose (representing 14.8% of the total production) generated with an estimated market value of US$1,020 million.

As the proportion of milk production used to produce WMP increases, the lactose mass balance can change from surplus to deficit. This is shown in the

Table 1 Milk and milk component production per cow, per hectare, and overall dairy industry for the 2011/2012 dairy season used for the simulations.

Production	Per cow	Per hectare	Industry ($\times 10^6$)
Milk yield (kg)	4,128	11,663	19,129
Milkfat yield (kg)	206	582	939
Protein yield (kg)	158	446	719
Lactose yield (kg)	194	548	899
Live weight (kg)	443	1,250	
Stocking rate (cows/ha)		2.83	
Effective hectares (ha)			1,638,546
Number of cows			4,634,226

Table 2 Proportions of milk used for each product under the four investigated product portfolios in study as input values for the Moorepark processing sector model (Geary et al. 2010).

Product[1]	80% WMP	Base (60% WMP)	30% WMP	10% WMP
WMP	80.0	60.0	30.0	10.0
SMP	10.0	23.5	30.0	10.0
Cheese	8.0	14.0	30.0	75.0
Butter	0.5	0.5	6.0	2.5
Casein	1.5	2.0	4.0	2.5

[1]WMP = Whole milk powder, SMP = Skim milk Powder, WPC = Whey protein concentrate, BMP = Butter milk powder.

Table 3 Industry production of dairy products ($\times 10^3$ tonnes) from milk produced during the 2011/2012 season and processed under four different manufacturing portfolio scenarios. Proportion of total production is within brackets.

Product[1]	80% WMP	Base (60% WMP)	30% WMP	10% WMP
WMP	2,292 (73.7)	1,719 (56.0)	859 (27.9)	286 (8.3)
SMP	208 (6.7)	476 (15.5)	714 (23.2)	248 (7.2)
Cheese	192 (6.2)	336 (10.9)	720 (23.4)	1,800 (52.5)
Butter	308 (9.9)	416 (13.5)	491 (16.0)	209 (6.1)
Casein	9 (0.3)	12 (0.4)	24 (0.8)	15 (0.4)
WPC	68 (2.8)	63 (5.0)	327 (6.3)	333 (23.9)
BMP	34 (1.1)	50 (1.6)	54 (1.8)	25 (0.7)
Total	3,111	3,071	3,075	3,426
Lactose	-214(-6.9)	-129(-4.2)	19 (0.6)	510 (14.8)

[1]WMP = Whole milk powder, SMP = Skim milk Powder, WPC = Whey protein concentrate, BMP = Butter milk powder.

comparison between 10% and 80% where lactose goes from 510,000 tonnes in surplus to 214,000 tonnes in deficit. Total milk product exports were 3,111,000 tonnes, 3,071,000 tonnes, 3,075,000 tonnes and 3,426,000 tonnes for the 80% WMP, 60% WMP, 30% WMP and 10% WMP scenarios, respectively. The difference is due to different product mixes and the composition of those products, for example cheese has 35% moisture compare to 2-4% for WMP and SMP. Using the model, the industry neutral point for lactose is estimated as 32% WMP, 30% SMP, and 28% cheese.

Discussion

Changes in milk product demand have seen New Zealand increase production of WMP in the last ten years; however, the composition of the milk from the cows being milked has not changed as quickly or dramatically under genetic selection. From a system in which there was an even split between WMP, SMP and cheese (Fonterra 2003), to one dominated by WMP and SMP production (Fonterra 2012c), it is becoming evident that while cows in New Zealand produce milk well suited for cheese or butter production, they require the removal of protein or fat or the addition of lactose in order to maximise the returns from WMP production given the current costs and prices compared to North American type animals (White et al. 2001; Miglior et al. 2006; Miglior et al 2007; Sneddon et al. 2012). Since New Zealand was a butter-producing market up until the 1980s, New Zealand cows were selected for high milkfat yield, with subsequent emphasis put on protein. This led to more highly concentrated milk, from 4.86 to 4.99% milkfat and from 3.62 to 3.82% protein between 1996 and 2012 (Livestock Improvement Corporation 2013), from New Zealand cows compared to that produced from sires generated in breeding programmes in other countries. Lactose concentrations have not increased over the same period as lactose monohydrate as measured by an infrared milk analyser remaining between 4.80 and 5.10 (Mackle 1996; Johnson et al. 2000; Sneddon et al 2012). This is not unexpected, since lactose is an important osmotic regulator of milk yield and its concentration exhibits much less variation than does fat or protein.

It is important to note that New Zealand milk is not low in lactose with average monohydrate values between 4.80 and 5.10% compared to 4.45% to 4.56% in Ireland (Prendiville et al. 2000) and 4.42% to 4.86% in USA (White et al. 2001; Miglior et al. 2006; Miglior et al 2007). The disparity is caused by the higher protein content: 3.82% in New Zealand vs 3.30% in

USA and 3.39% in Ireland (Prendiville et al. 2000; White et al. 2001; Miglior et al. 2006; Miglior et al 2007); which results in the ratio of protein to lactose being unbalanced for direct production of WMP. This disparity is highlighted when comparing the 30% scenario with the 60% and 80% scenarios, in which the industry moves from a surplus of almost 20,000 tonnes of lactose to a deficit of 214,000 tonnes of lactose. In the 10% scenario cheese production increases to 1,800,000 tonnes, this is five times higher than current production levels, and may result in an inability to sell such an increase in product supply. The neutral point for lactose (point at which there is neither deficit nor surplus) is when 32% of the industry milk was processed into WMP, which is half of the current industry practice.

The demand for lactose for production of milk powders in New Zealand has been increasing and has led to lactose imports rising from NZ$300 to NZ$600 million from 2010 to 2012 (Fonterra 2012a) representing an increase in lactose imports of 150,000 tonnes to around 300,000 tonnes currently. This increased lactose costs from 22 to 42 cents per kilogram of milksolids (Fonterra 2012a). In this time, WMP production has increased from 1,401,000 tonnes to 1,768,000 tonnes, which is comparable with the production estimated by the Moorepark processing model. The actual production of different milk products and their composition is also not known. If the WMP is made to a different codex standard this would also alter the final demands for lactose.

From this analysis, it can be estimated that future lactose deficits will continue to rise if the manufacturing portfolio continues to shift to higher milk powder production and the relative values of protein and milkfat remain the same. If demand continues to rise, there could be further increases in lactose value, making the incorporation of imported lactose into WMP less economically viable; however, the economic analysis of this was not a focus of this study.

This study shows the potential importance of linking the processing sector to the national breeding program to breed for a cow which is better suited to potential future product portfolios. These analyses have highlighted, that as more WMP is produced, milk from current New Zealand cows results in an increased deficit of milk lactose. Linking analysis of probable future scenarios with the national breeding objective could see the deficit reduced over time, highlighting a potential future focus for the New Zealand dairy industry. This could allow for a breeding strategy to reduce the need for imported lactose to fill the deficit and allow for reduced costs for WMP production, thus maximising overall industry profitability.

Acknowledgements

The primary author is funded by the Livestock Improvement Corporation Pat Shannon scholarship.

References

Archer RH 1998. Whey Products. New Zealand Institute of Chemistry. http://nzic.org.nz/ChemProcesses/dairy/3G.pdf [accessed 22/9/2013]

Fonterra 2003. Annual Report 2002/03. https://www.fonterra.com/wps/wcm/connect/080a0d21-6591-4f93-ad8b-7ba594e40da1/Annual+Report+FY03.pdf?MOD=AJPERES [accessed 15/9/2013]

Fonterra 2012a. Farmgate milk price statement http://www.fonterra.com/wps/wcm/connect/faa17736-5668-4643-8f70-bbafd4394ec6/Farmgate+Milk+Price+Statement+FY2012.pdf?MOD=AJPERES [accessed 15/9/2013]

Fonterra 2012b. Fonterras milk price - the facts. http://www.fonterra.com/wps/wcm/connect/1f30c6e8-4407-4464-986e-32b24ea5c39a/Milk%2BPrice%2BQuestions%2Band%2BAnswers%2B1%2BAug%2B2011.pdf?MOD=AJPERES [accessed 15/9/13]

Fonterra 2012c. Fonterra annual report 2012. http://www.fonterra.com/wps/wcm/connect/9cde8aac-960f-4b23-8158-01192b22ab13/Annual+Review+FINAL.pdf?MOD=AJPERES [accessed 15/9/2013]

Geary U, Lopez-Villalobos N, Garrick DJ, Shalloo L 2010. Development and application of a processing model for the Irish dairy industry. Journal of Dairy Science 93: 5091-5100.

Johnson DL, Petch SF, Winkelman AM, Bryant M 2000. Genetics of milk characteristics in New Zealand dairy cattle. Proceedings of the New Zealand Society of Animal Production 60: 318-319.

Livestock Improvement Corporation 2013. Dairy Statistics 2012-13. Livestock Improvement Corporation, Hamilton, New Zealand.

Lopez-Villalobos N, Garrick DJ, Holmes CW, Blair HT, Spelman RJ 2000. Effects of selection and crossbreeding strategies on industry profit in the New Zealand dairy industry. Journal of Dairy Science 83: 164-172.

Mackle TR, Parr CR, Stakelum GK, Bryant AM, Macmillan KL 1996. Feed conversion efficiency, daily pasture intake, and milk production of primiparous Friesian and Jersey cows calved at two different liveweights. New Zealand Journal of Agricultural Research 39: 357-370.

Miglior F, Sewalem A, Jamrozik J, Lefebvre DM, Moore RK 2006. Analysis of milk urea nitrogen and lactose and their effect on longevity in Canadian dairy cattle. Journal of Dairy Science 89: 4886-4894.

Miglior F, Sewalem A, Jamrozik J, Bohmanova J, Lefebvre DM, Moore RK 2007. Genetic analysis of milk urea nitrogen and lactose and their relationships with other production traits in

Canadian Holstein cattle. Journal of Dairy Science 90: 2468-79.

Mollea C, Marmo L, Bosco F 2013. Valorisation of cheese whey, a by-product from the dairy industry. In Food Industries editor Innocenzo Muzzalupo http://www.intechopen.com/books/food-industry/valorisation-of-cheese-whey-a-by-product-from-the-dairy-industry [accessed 22/9/2013]

Murray Goulburn ingredients 2013. http://www.globaldairytrade.info/download.aspx?p=0&f=/Public/English/MG/MG-LAC-Edbl-AU-120725.pdf [accessed 15/9/2013]

Prendiville R, Lewis E, Pierce KM, Buckley F 2010. Comparative grazing behavior of lactating Holstein-Friesian, Jersey, and Jersey x Holstein-Friesian dairy cows and its association with intake capacity and production efficiency. Journal of Dairy Science 93: 764-774.

Sneddon NW, Lopez-Villalobos N, Hickson RE, Shalloo L 2012. Genetic parameters for lactose and its relationship with concentrations and ratios of other milk components. Proceedings of the New Zealand Society of Animal Production 72: 76-80.

White SL, Bertrand JA, Wade MR, Washburn SP, Green Jr JT, Jenkins TC 2001. Comparison of fatty acid content of milk from Jersey and Holstein cows consuming pasture or a total mixed ration. Journal of Dairy Science 84: 2295-2301.