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# Effect of genotype and concentrate supplementation on dairy product mix and the value of milk produced by grazing dairy cows during an extended lactation

S-A. TURNER[1], C.V.C. PHYN[1], E.S. KOLVER[1, 3], P.W. ASPIN[1] and N. LOPEZ-VILLALOBOS[2]

[1]DairyNZ, Private Bag 3221, Hamilton, New Zealand
[2]Institute of Veterinary, Animal and Biomedical Sciences, Massey University, Private Bag 11-222,
Palmerston North, New Zealand
[3]Present address: Synlait Ltd., Waikato Innovation Park, P.O. Box 9466, Hamilton, New Zealand

## ABSTRACT

Dairy product mix and milk value were investigated in Holstein-Friesian cows of New Zealand or overseas origin that grazed pasture and were supplemented with 0, 3 or 6 kg DM concentrate/cow/day during a 600-day extended lactation. A dairy product supply chain model was used to predict relative changes in dairy product mix and milk value during the "extended period" (300 to 600 days in milk) compared with the "normal period" (0 to 300 days in milk). Cow genotype and level of concentrate supplement affected dairy product yields, with little consistency of effect between "normal" and "extended" periods. Milk produced during the "extended period" resulted in more cheese, butter, butter milk powder, casein, and whey protein concentrate, but less whole milk powder, skim milk powder and whey milk powder compared to the "normal period". The overseas strain and those cows receiving higher levels of concentrates had less of a decline in whole milk powder yields associated with the "extended period". Milk value ($/L), was predicted to be 20.8% higher during the "extended period" compared with the "normal period". These results indicate that extended lactations may improve the dairy product mix and milk value following processing.

**Keywords:** extended lactation; dairy product mix; milk value; genotype; concentrate supplementation.

## INTRODUCTION

In New Zealand (NZ), more than 95% of milk supplied to dairy processors is manufactured into dairy products for export. Milk from cows with different fat and protein concentrations results in changes to the yields and relative mix of dairy products and subsequently the value of milk for processing (Garrick & Villalobos, 2000). Differences in milk composition for fat and protein occur between different genetic strains of dairy cow, with diet and stage of lactation (Auldist *et al*., 1998; Kolver *et al*., 2005; Turner *et al*., 2006). Recent studies have reported that high milksolids (MS; fat + protein) concentrations are obtained during lactations of over 300 days in milk (DIM) (Auldist *et al*., 2007; Kolver *et al*., 2007).

Extended lactation (increasing the days in milk by increasing the interval between calvings) is a management option for dairy farmers to decrease costs associated with getting cows in calf, reduce post-partum metabolic diseases, cow replacement costs and increase lactation days within a cow's lifetime. During a 600-day extended lactation, Kolver *et al,* (2006; 2007) reported that Holstein-Friesian (HF) cows of overseas (OS) origin produced more milk with lower milk fat, but similar protein contents to NZ HF cows. Cows of divergent genetic strains respond differently to extended lactation and there is a strong interaction with dietary level of concentrates (Kolver *et al.,* 2006; 2007). This study uses a supply chain model to examine the effect of cow genotype and concentrate supplementation on the predicted dairy product mix and milk value following processing of milk from the "extended period" (300 - 600 DIM) compared with the "normal period" (0 - 300 DIM) of an extended lactation.

## MATERIALS AND METHODS

### Experimental design

This study was conducted as part of a larger experiment investigating the feasibility of extended lactations in pastoral systems (Kolver *et al.,* 2006; 2007). Data were collected over a 24-month calving interval from 27 OS HF cows and 29 NZ HF cows that grazed pasture and were individually fed 0, 3 or 6 kg DM/d of a pelleted concentrate at milking, twice daily. This resulted in six feeding treatments (NZ0, NZ3, NZ6, OS0, OS3, OS6). Milk yields were recorded at each milking (Westfalia Surge, Oelde, Germany). Milk samples were collected weekly to determine milk composition (fat, protein, casein, lactose) using an infrared milk analyser (Fourier transform infrared spectroscopy: FT120, Foss Electric, Hillerød, Denmark).

### Modelling dairy product mix and product value

The extended lactation was divided into two stages. The "normal period" was defined as the period from calving to a theoretical dry-off date for a 12-month calving interval system (mean 296 ± 23.6 DIM; nominally 0 - 300 DIM). The "extended

**TABLE 1**: Milk yield and composition data for New Zealand (NZ) and overseas (OS) Holstein-Friesians grazing pasture and fed 0, 3 or 6 kg of concentrate DM/cow/d, resulting in six feeding treatments (NZ0, NZ3, NZ6, OS0, OS3, OS6), during normal[1] and extended[2] lactation. SED = Standard error of difference.

| Component | Treatment | | | | | | SED | Significance level (P value[3]) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | NZ0 | NZ3 | NZ6 | OS0 | OS3 | OS6 | | Genotype | Diet$_L$ | Diet$_Q$ | G x D$_L$ |
| Normal lactation | | | | | | | | | | | |
| Milk yield (kg/cow) | 5,936 | 6,912 | 6,996 | 6,398 | 7,481 | 8,738 | 474 | 0.002 | <0.001 | 0.596 | 0.047 |
| Fat (%) | 4.69 | 4.45 | 4.04 | 4.31 | 3.98 | 3.68 | 0.24 | 0.017 | <0.001 | 0.825 | 0.924 |
| Protein (%) | 3.61 | 3.59 | 3.58 | 3.48 | 3.44 | 3.45 | 0.10 | 0.057 | 0.620 | 0.799 | 0.972 |
| Lactose (%) | 4.76 | 4.93 | 4.80 | 4.85 | 4.87 | 4.86 | 0.08 | 0.699 | 0.432 | 0.132 | 0.797 |
| Casein (%) | 2.60 | 2.52 | 2.57 | 2.44 | 2.38 | 2.44 | 0.10 | 0.012 | 0.785 | 0.274 | 0.847 |
| Milksolids (kg/cow) | 489 | 551 | 530 | 494 | 556 | 625 | 38 | 0.150 | 0.003 | 0.510 | 0.085 |
| Protein:Fat ratio | 0.77 | 0.81 | 0.91 | 0.81 | 0.87 | 0.95 | 0.05 | 0.127 | <0.001 | 0.465 | 0.987 |
| Extended lactation | | | | | | | | | | | |
| Milk yield (kg/cow) | 2,899 | 4,034 | 2,957 | 4,446 | 6,515 | 6,761 | 824 | <0.001 | 0.063 | 0.064 | 0.047 |
| Fat (%) | 5.16 | 4.90 | 4.59 | 4.67 | 4.49 | 4.24 | 0.32 | 0.061 | 0.010 | 0.905 | 0.733 |
| Protein (%) | 4.24 | 4.14 | 3.95 | 4.12 | 4.09 | 3.97 | 0.17 | 0.704 | 0.031 | 0.662 | 0.503 |
| Lactose (%) | 4.29 | 4.58 | 4.21 | 4.67 | 4.65 | 4.71 | 0.16 | 0.004 | 0.983 | 0.170 | 0.534 |
| Casein (%) | 3.20 | 3.13 | 2.97 | 3.15 | 3.13 | 3.05 | 0.13 | 0.909 | 0.033 | 0.656 | 0.458 |
| Milksolids (kg/cow) | 274 | 368 | 259 | 387 | 554 | 556 | 69 | <0.001 | 0.156 | 0.045 | 0.056 |
| Protein:Fat ratio | 0.83 | 0.85 | 0.88 | 0.89 | 0.92 | 0.94 | 0.04 | 0.015 | 0.044 | 0.973 | 0.980 |

[1] The period from calving to the theoretical dry-off date (0 to 300 days in milk).

[2] The period from the theoretical dry-off date to actual dry-off date following an extended lactation (300 to 600 days in milk).

[3] L = linear contrast; Q = quadratic contrast; G x D$_L$ = genotype x diet$_L$ interaction; no significant interactions of G x D$_Q$ were apparent

**TABLE 2:** Predicted yields of dairy products (kg product/1,000 L milk) and milk value from Holstein-Friesian cows of New Zealand (NZ) and overseas (OS) origin, grazing pasture and fed 0, 3 or 6 kg of concentrate DM/cow/d, resulting in six feeding treatments (NZ0, NZ3, NZ6, OS0, OS3, OS6), during normal[1] and extended[2] lactation. The model was used to simulated milk being processed into: 30% whole milk powder (WMP), 20% skim milk powder (SMP), 25% cheese, 25% casein/butter, with the associated by-products[3]. SED = Standard error of difference.

| Component | Genotype | | SED | Diet | | | SED | Significance level (*P* value[4]) | |
|---|---|---|---|---|---|---|---|---|---|
| | NZ | OS | | 0 kg | 3 kg | 6 kg | | Genotype | Diet$_L$ |
| Normal lactation | | | | | | | | | |
| WMP | 32.3 | 33.4 | 0.7 | 32.0 | 33.4 | 33.2 | 0.8 | 0.160 | 0.113 |
| SMP | 14.9 | 15.5 | 0.6 | 14.3 | 14.9 | 16.4 | 0.7 | 0.323 | 0.005 |
| Cheese | 26.1 | 24.6 | 0.7 | 26.0 | 25.5 | 24.5 | 0.9 | 0.046 | 0.061 |
| Butter | 30.2 | 25.8 | 1.9 | 31.6 | 28.0 | 24.3 | 1.7 | 0.020 | <0.001 |
| Butter milk powder | 3.4 | 2.8 | 0.2 | 3.5 | 3.1 | 2.7 | 0.2 | 0.018 | <0.001 |
| Casein | 11.0 | 9.7 | 0.5 | 10.7 | 10.0 | 10.4 | 0.6 | 0.023 | 0.634 |
| WP$_{cheese}$[5] | 16.4 | 16.5 | 0.3 | 16.6 | 17.1 | 15.8 | 0.4 | 0.848 | 0.033 |
| WPC$_{casein}$[6] | 19.3 | 18.9 | 0.4 | 19.0 | 19.2 | 19.0 | 0.4 | 0.347 | 0.932 |
| Value of milk ($/L) | 0.36 | 0.33 | 0.01 | 0.36 | 0.34 | 0.34 | 0.01 | 0.008 | 0.059 |
| Extended lactation | | | | | | | | | |
| WMP | 24.4 | 28.3 | 1.3 | 25.1 | 27.0 | 27.0 | 1.3 | 0.006 | 0.135 |
| SMP | 11.5 | 15.0 | 1.0 | 12.0 | 13.6 | 14.0 | 0.9 | 0.001 | 0.031 |
| Cheese | 31.4 | 29.5 | 1.3 | 31.9 | 30.5 | 28.9 | 1.2 | 0.128 | 0.011 |
| Butter | 36.3 | 30.8 | 2.3 | 36.2 | 33.5 | 30.9 | 2.0 | 0.020 | 0.008 |
| Butter milk powder | 4.1 | 3.6 | 0.3 | 4.1 | 3.8 | 3.5 | 0.3 | 0.086 | 0.008 |
| Casein | 17.1 | 15.8 | 0.9 | 17.4 | 16.4 | 15.5 | 0.8 | 0.194 | 0.013 |
| WP$_{cheese}$[5] | 15.0 | 14.7 | 0.4 | 15.1 | 15.0 | 14.5 | 0.5 | 0.471 | 0.157 |
| WPC$_{casein}$[6] | 20.8 | 20.7 | 0.5 | 21.1 | 21.0 | 20.3 | 0.5 | 0.854 | 0.065 |
| Value of milk ($/L) | 0.42 | 0.41 | 0.02 | 0.43 | 0.42 | 0.40 | 0.01 | 0.369 | 0.012 |

[1] The period from calving to the theoretical dry-off date (0 to 300 days in milk).

[2] The period from the theoretical dry-off date to actual dry-off date following an extended lactation (300 to 600 days in milk).

[3] By products of processing include butter milk powder, WP$_{cheese}$, WPC$_{casein}$

[4] L= linear contrast; no significant interactions of G x D$_L$ were apparent.

[5] Whey milk powder from cheese production.

[6] Whey protein concentrate from casein production.

period" was defined as the period from the theoretical dry-off date to the actual dry-off date achieved in the 24-month calving interval (mean 604 ± 59 DIM; nominally 300 - 600 DIM). Data (milk yield and composition) were averaged for individual cows across the "normal" and "extended" periods, and used, along with a standard mineral composition (0.7%), as input data (Table 1) into the simulation model described by Garrick and Lopez-Villalobos (2000), for the following milk processing scenario: 20% skim milk powder (SMP); 30% whole milk powder (WMP); 25% casein/butter; 25% cheese. Milk value (NZ$/L) was calculated assuming that milk was processed into the above product mix (with associated by-products) and sold at international prices (US$/tonne), which were representative of the 2004/05 season (Foreign Agricultural Service, USDA: http://www.fas.usda.gov/dpl/dairy/dairy.asp): WMP $2,250, SMP $2,200, cheese $2,775, butter $2,020, butter milk powder (BMP) $2,200, casein $8,000, whey milk powder from cheese production ($WP_{cheese}$) $1,760, and whey protein concentrate from casein production ($WPC_{casein}$) $1,760. Prices for $WP_{cheese}$ and $WPC_{casein}$ were taken as 80% of the SMP value. An average exchange rate between the NZ and American dollar was calculated at NZ$0.689 (Statistics New Zealand, www.stats.govt.nz).

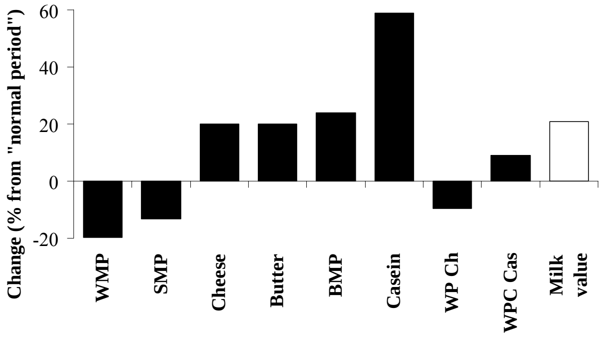
### Statistical analyses

Data were analysed for each of the "normal" and "extended" periods as a mixed model with genotype (G), linear and quadratic contrasts of diet (D), and the G x D interactions as fixed effects with cow, and the cow's sire as random effects using REML in GenStat (Payne *et al.,* 2007). Unless specifically reported, no G x $D_{Quadratic}$ effects were found for the milk composition data, and no $D_{Quadratic}$, G x $D_{Linear}$ or G x $D_{Quadratic}$ were apparent for dairy product yields and milk value.

## RESULTS

Effect of cow genotype and diet on milk production and composition during the "normal" and "extended" periods are presented in Table 1. During the "normal period" OS HF cows had greater milk production, but lower milk fat, casein and protein concentrations compared with NZ HF. During the "extended period" OS HF cows had greater milk and MS yields, protein:fat ratios and lactose contents, but lower milk fat contents, than NZ HF cows. Increasing levels of concentrates produced a linear increase in milk and MS yields during the "normal period", and a trend (P <0.10) for a quadratic increase during the "extended period". Linear decreases in milk fat content and increases in protein:fat ratio were apparent with increasing levels of concentrates during both periods, and protein and casein contents were also linearly reduced in the "extended period". The G x $D_{Linear}$ interactions indicated that differences between OS HF and NZ HF cows in milk yields were greatest at the highest concentrate level. In general, concentrations of fat, protein and casein were higher, and concentrations of lactose lower, in milk from the "extended period" compared with the "normal period".

**FIGURE 1**: Predicted average % changes in dairy product outputs (black bars) and milk value ($/L; white bar) following the processing of milk from the "extended period" (300 to 600 days in milk), compared with the "normal period" (0 to 300 days in milk) of a 600-day extended lactation. WMP, whole milk powder; SMP, skim milk powder; BMP, butter milk powder; WP Ch, whey milk powder from cheese production; WPC Cas, whey protein concentrate from casein production.



During the "normal period" the predicted yields (kg product/1,000L milk) of cheese, butter, BMP and casein were greater for the milk from NZ HF compared with OS HF cows (Table 2). Increased supplementary feeding reduced yields of cheese, butter, BMP and $WP_{cheese}$ while SMP yields increased. During the "extended period", milk from NZ HF cows also produced more butter, but less WMP and SMP than milk from OS HF. SMP yields increased and cheese, butter, BMP and casein yields decreased with increasing concentrate level. Milk value ($/L) was predicted to be higher for NZ HF cows during the "normal period" and decreased with increasing concentrate supplementation during the "extended period". There was an apparent advantage of the "extended period" over the "normal period" (Figure 1) for cheese, butter, BMP, casein and $WPC_{casein}$ production. In contrast, more $WP_{cheese}$, WMP and SMP were produced from milk during the "normal period". Milk from OS HF cows showing greater gains in BMP, casein and $WPC_{casein}$, and appeared to be better at overcoming the decline in WMP and SMP yields than NZ HF cows. The advantage of the "extended period" over the "normal period" was also greater in cows receiving more concentrates, for butter and BMP yields. Milk value during the "extended period" was predicted to be 20.8% higher than the "normal period" (Figure 1), with the advantage greater for OS HF, and slightly better for those cows receiving lower levels of concentrates.

## DISCUSSION

Predictions of the yields of dairy products, and the value of the milk, following dairy processing were made for cows of divergent genotypes fed increasing levels of concentrate supplements. Extending lactations to 600 days has clear effects on dairy product yield and value. Compositional changes in milk due to the cow genotype and the level of concentrate supplement were found that varied between "normal" and "extended" periods of lactation, and that resulted in differences in the dairy product output and milk value.

Variations in the composition of milk alter the quality and yield of dairy products produced. Auldist *et al.* (2004) found that yield of cheddar cheese is influenced by total solids concentration of milk, while Guinee *et al.* (2007) reported that altering the protein:fat ratio of milk influences cheese yield. During the "normal period", the predicted yields of cheese, butter, BMP and casein produced were greater from NZ HF cows compared with OS HF, and were likely due to the higher concentrations of fat, casein and protein in the milk of the NZ HF. Using the same dairy supply chain model, Lopez-Villalobos *et al.* (2002) and Back & Lopez-Villalobos (2004) also predicted that milk with higher fat concentration had greater yields of cheese, butter and BMP. It would appear that casein yield is influenced by the protein:fat ratio, as Back & Lopez-Villalobos (2004) also showed that milk from cows with a higher protein:fat ratio resulted in a greater predicted yield of casein along with WMP and SMP. In the current study, higher yields of SMP were predicted during the "normal period" for cows receiving higher levels of supplements, consistent with the increased protein:fat ratio. Cows receiving lower levels of supplements were found not only to have greater milk fat concentrations, but were predicted to yield greater quantities of butter, BMP and cheese.

This is the first time the yields of dairy products have been predicted from milk from cows during an extended lactation. The greater yields of WMP and SMP from the milk of OS HF likely results from the higher protein:fat ratio of these cows compared with the NZ HF. This is supported by Paul (1985) who reported that higher product yields were apparent from herds with higher protein:fat ratios. During the "extended period", increasing levels of supplementation resulted in greater yields of SMP, but lower yields of cheese, butter, BMP and casein. The increase in SMP yields was associated with an increase in the protein:fat ration, in agreement the "normal period" and Back & Lopez-Villalobos (2004) who also found that a higher protein:fat ratio results in greater predicted yields of SMP. Similarly, the lower yields of cheese, butter and BMP with the higher levels of concentrate supplement can be explained by the lower concentrations of fat in the milk of these cows and is supported by the similar findings of Lopez-Villalobos *et al.* (2002) and Back & Lopez-Villalobos (2004). The effects of diet and genotype during the "extended period" were often different to those apparent during the normal period, probably due to the differing composition of the milks between the periods. Compared to the "normal period", milk collected during the "extended period" resulted in lower yields of WMP and SMP, but greater yields of the other products. This result is not unexpected as milk collected during the extended period was characterized by higher fat and protein concentrations. Thus, although extended lactation can improve casein $\text{WPC}_{\text{casein}}$, BMP, butter and cheese production, it may not be suitable for dairy processors that produce predominately whole milk powders. Indeed when the current data were used as input to a 100% milk powder scenario, under the same conditions as described, for the product mix reported here, the results confirm this observation (Turner, 2008; unpublished data). The advantage of the "extended period" over the "normal period" was influenced by both genotype and diet. OS HF were better at overcoming the decline in WMP and SMP production during the "extended period", while predicted yields of BMP and casein were even greater for these cows. There was also an advantage of the "extended period" for cows on decreased supplement levels with greater production of cheese, casein and $\text{WPC}_{\text{casein}}$, while cows on increased supplements responded to the "extended period" with increased yields of butter and BMP, and less of a decline in WMP yields. It should be noted that the detailed composition of milk affects its processability and that the higher milk fat and protein concentrations apparent during the extended period may not result in the same quality of product as anticipated due to predicted changes in these minor components. These have yet to be examined.

Both genotype and level of concentrate supplements affected the processing value of milk. It was greater for the NZ HF during the "normal period", but no different between genotypes during the "extended period". This is likely to be due to the solids content of the milk as both fat and protein in the milk of the NZ HF were higher than that of the

OS HF during the "normal period", while only fat concentrations were higher during the extended period. Indeed, Thomson *et al.* (2005) reported that milk from NZ HF cows is of higher value than that from OS HF cows and that there were positive correlations between milk value and fat %, protein % and MS %. Milk value decreased with increasing concentrate supplementation during both the "normal" and "extended" periods. While only fat concentrations decreased with increasing supplementation during the "normal period", both fat and protein concentrations decreased with increasing supplementation during the "extended period". Milk collected during the "extended period", was of greater value than that collected during the "normal period". This can be explained by the increased yields of the more valuable products such as cheese and casein. In particular, the 59% increase in casein yields during the "extended period" compared with the "normal period" would have been the greatest driver of changes in milk value, countering the small declines in the less valuable powders.

Modelling the dairy product output and milk value provides a valuable tool to measure the impact of various farm management practices on dairy processing. This study shows that cow genotype and level of concentrate supplementation can have a substantial impact on the yield of dairy products and the value of milk, depending upon calving interval. Extended lactations may improve dairy product mix and milk value for processors in favour of casein, butter and cheese production but not for WMP or SMP production.

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