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Effect of lactation stage and breed on the concentration of unsaturated fatty acids in milkfat of New Zealand dairy cattle

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ABSTRACT

Milkfat composition influences the nutritional value and manufacturing characteristics of milk. This research studied the influence of: 1) stage of lactation on the concentration of unsaturated fatty acids (UFA) in milkfat of Holstein-Friesian, Jersey and Crossbred cows, 2) segregation of cows according to their UFA concentration in milkfat. The concentration of UFA in milkfat was predicted with a calibration equation using Fourier transform infrared spectroscopy. The data (21,757 test-day records) were analysed using a mixed model with a third-order orthogonal polynomial. In the three breeds studied, after early lactation the concentration of UFA in milkfat decreased steadily as the lactation progressed, but in Holstein-Friesian cows it increased slightly at the end of lactation. Throughout lactation, Holstein-Friesian cows produced milkfat with a higher concentration of UFA than Jersey and Crossbred cows. In each herd, cows were split into a high and a low group according to the average UFA concentration of the herd. The high UFA group had higher ($P < 0.001$) milk yield, but lower ($P < 0.001$) yields and concentrations of fat and protein than the low UFA group. This study indicates that concentration of UFA in milkfat is affected by breed and stage of lactation in New Zealand dairy cattle.

Keywords: unsaturated fatty acids; breed; lactation stage.

INTRODUCTION

In New Zealand, milkfat is one of the milk components for which farmers are paid. However, in addition to the quantity of milkfat produced, the composition of milkfat is also important because it influences the nutritional value and manufacturing characteristics of milk (Arsic *et al.*, 2009; Bobe *et al.*, 2007).

In recent years there has been a shift in consumer preferences towards low-fat and functional dairy products (Wiley, 2007). In developed countries, dairy products are one of the main sources of saturated fat. In an Australian study dairy products accounted for 35% of saturated fat intake in a population of older people (Flood *et al.*, 2007). Thus, the nutritional value of milk and dairy products can be improved by increasing the concentration of unsaturated fatty acids (UFA) and decreasing the concentration of saturated fatty acids (SFA), in milkfat. An additional benefit of increasing the concentration of UFA in milkfat is the increase in the concentration of conjugated linoleic acid (CLA) in milkfat, which is a fatty acid with anticarcinogenic and anti-atherogenic properties (Lock & Bauman, 2004).

Milkfat composition is influenced by season, diet, breed, strains within a breed, genetics, stage of lactation and energy status of the cow (Auldist *et al.*, 1998; Stoop *et al.*, 2009; Thomson *et al.*, 2002; Wales *et al.*, 2009). New Zealand and overseas studies reported a higher concentration of UFA in milkfat of Holstein-Friesian cows than in milkfat of Jersey cows (MacGibbon, 1996; Palladino *et al.*, 2010).

There are few studies about the changes in milkfat composition during lactation. In the study by Auldist *et al.* (1998) the concentration of UFA in milkfat was higher in early and late lactation than in mid lactation. The concentration of SFA in milkfat followed a pattern opposite to the one of UFA, and was higher in mid lactation than in early and late lactation. Similar variations in the concentrations of UFA and SFA in milkfat during the lactation have been reported in overseas studies (Arnould *et al.*, 2010; Stoop *et al.*, 2009). A sound knowledge of the changes in the concentration of UFA in milkfat during lactation can help in the development of strategies to select animals and segregate milk with a desirable fat composition at the farm level.

The objectives of this study were to determine the influence of stage of lactation on the concentration of UFA in milkfat of Holstein-Friesian cows, Jersey cows and Crossbred cows, and to study the effect of segregating animals according to the concentration of UFA in their milkfat.

MATERIALS AND METHODS

Data

The dataset used in this study corresponded to the 2007/08 dairy season and comprised 21,756 test-day records from 5,370 Holstein-Friesian cows, Jersey cows and Holstein-Friesian x Jersey crossbred cows, in their first to tenth lactations (parity). On average, there were four test-day records per animal, but some cows had up to six test-day records. Milk yield (L/day) was extracted from production records. Fat and protein percentages were determined by Infrared Spectroscopy (FT120™, Foss, Hillerød, Denmark). The concentration of UFA in milkfat was estimated with a calibration equation based on partial least squares using Fourier transform infrared spectroscopy derived externally from the FT120^{TM} machine. The validation of the calibration equation was done using 297 independent milk samples analysed by gas chromatography. These samples corresponded to second-parity Crossbred cows in late lactation in the 2003/04 dairy season. The concordance correlation coefficient of the calibration equation was estimated at 0.96. Similar estimations of UFA concentration in milkfat using infrared spectroscopy have been done overseas using equations with cross-validation correlation coefficients of 0.90-0.92 (Coppa *et al.*, 2010), 0.77 (Soyeurt *et al.*, 2006) and 0.69-0.87 (Rutten *et al.*, 2009).

The dataset studied represented five regions with 307 to 2101 cows/region) and 150 herds (3 to 199 cows tested per herd) with a calving period between 15 July and 10 October (50 to 2971 cows calved/month) and between three and 270 days in milk (DIM) (16 to 126 samples per day). Means and standard deviations across lactation for traits analysed were: milk yield 17.2 L/day (standard deviation (SD) = 6.6), fat yield 0.81 kg/day (SD = 0.27), protein yield 0.64 kg/day (SD = 0.21), fat percentage 4.88% (SD = 0.90), protein percentage 3.78% (SD = 0.42) and UFA concentration 28.64 g/100g milkfat (SD = 2.44).

TABLE 1: Parameters used to estimate the concentration of unsaturated fatty acids in milkfat (g/100g of milkfat) of Holstein-Friesian, Jersey and Crossbred cows (based on third-degree orthogonal polynomials of days in milk: 1 to 270 days in milk). SEM = Standard error of the mean.

Regression coefficients	Holstein-Friesian		Crossbred		Jersey		P value
	Mean	SEM	Mean	SEM	Mean	SEM	
α_0	28.85^{a}	0.35	27.90^{ab}	0.35	27.07^{b}	0.35	<0.05
α_1	-0.94^{a}	0.04	-1.25^{b}	0.04	-1.38^{b}	0.05	<0.05
α_2	-0.47^{a}	0.05	-0.83^{b}	0.05	-0.58^{ab}	0.07	<0.05
α_3	0.46^{a}	0.06	-0.05^{b}	0.06	0.37^{ab}	0.08	<0.05

[a,b,c]Means in the same row with different superscript letters are significantly different (P <0.05).

TABLE 2: Lactation average ± standard error of the mean for milk production and milk composition within a subsample of 29 herds. Cows in each herd were split into high and low unsaturated fatty acids (UFA) groups according to the average UFA concentration of their herd.

Measurement	UFA Group		P value
	High	Low	
Number of cows	1,449	1,444	
Test-day records	5,965	5,881	
Milk yield (L/cow/day)	18.41 ± 0.08	17.59 ± 0.08	<0.001
Fat yield (kg/cow/day)	0.822 ± 0.003	0.895 ± 0.003	<0.001
Protein yield (kg/cow/day)	0. 660 ± 0.003	0.678 ± 0.003	<0.001
% Fat	4.62 ± 0.01	5.27 ± 0.01	<0.001
% Protein	3.66 ± 0.01	3.95 ± 0.01	<0.001
UFA (g/100g milkfat)	29.68 ± 0.03	27.15 ± 0.03	<0.001
% of Holstein-Friesian cows	24.7%	16.8%	<0.001

Statistical analysis

A mixed model using restricted maximum likelihood (REML) procedures (Gilmour *et al.*, 2006) was used to analyse the concentration of UFA in milkfat during the lactation across breed groups. The model included the fixed effects of herd, lactation number, calving month and DIM within each breed group and the random effect of cow. The effect of days in milk within breed on the concentration of UFA was expressed as a third order orthogonal polynomial.

For Holstein-Friesian, Jersey and Crossbred cows the coefficients of variation for UFA concentration in milkfat were 6.81%, 8.66% and 7.93%, respectively. A sample of 29 herds, with at least 60 cows per herd, was selected to investigate the effect of segregating cows according to their concentration of UFA in milkfat. Cows in each herd were split into two groups: the high UFA group for each herd was formed by cows with an average UFA concentration in their milkfat during their lactation, above the herd average. Cows with an UFA concentration below the herd average formed the low UFA group. Comparisons of means between high and low UFA groups were conducted using the PROC GLM (Tukey-Kramer tests) procedure of SAS. The model used was:

$$y_{ijkl} = H_i + U_j + D_k + UD_{jk} + e_{ijkl}$$

where y_{ijkL} is the concentration (g/100g of milkfat) of UFA of sample l, for group j on day k of dairy season of herd i, H_i is the random effect of herd on UFA concentration (g/100g of milkfat), U_i is the fixed effect of the UFA group (high or low), D_k is the fixed effect of day k of the dairy season (15 July (Day 0) – 10 May (Day 310)), UD_{jk} is the fixed effect of the interaction between UFA group j and day of dairy season k, and e_{ijk} is the random residual error.

RESULTS

The concentration of UFA in milkfat was significantly influenced by herd (P <0.001), parity (P <0.001), calving month (P <0.001) and DIM (P <0.001).

Breed had a significant (P <0.001) influence on the concentration of UFA in milkfat. The intercept (α_0) and linear (α_1) coefficients for the estimation of UFA concentration in milkfat during the lactation were higher for Holstein-Friesian cows than for Jersey cows, but the quadratic (α_2) and cubic (α_3) coefficients were not significantly different between these breeds (Table 1). Crossbred cows had an intercept coefficient intermediate to those of Holstein-Friesian and Jersey cows. The linear (α_1), quadratic (α_2) and cubic (α_3) coefficients for UFA concentration in milkfat of Crossbred cows were significantly different from those of Holstein-Friesian cows, but they were not significantly different from those of Jersey cows (Table 1).

Holstein-Friesian cows had a higher concentration of UFA in milkfat (29.87%, standard error of the mean (SEM) = 0.02) than Jersey (27.24%, SEM = 0.02) and Crossbred (28.40%, SEM = 0.03) cows (lactation average). There was a significant breed x DIM interaction for the concentration of UFA in milkfat during the lactation. Throughout the lactation Holstein-Friesian cows had significantly higher UFA concentrations in milkfat than Jersey cows (Figure 1). In Crossbred cows the concentrations of UFA in milkfat during the lactation were intermediate to those of Holstein-Friesian and Jersey cows, but not significantly different from them (Figure 1). The range of difference in UFA concentration in milkfat between Holstein-Friesian and Jersey was 4.97%-9.52% (at different stages of lactation).

During the dairy season (15 July-10 May), the high UFA group had significantly higher (8.0% to 12.7% more) concentration of UFA in milkfat than the low UFA group (Figure 2). There was a significant interaction between UFA group and day of dairy season on the concentration of UFA in milkfat. There were larger differences between groups in late lactation.

The lactation average for milk yield which was higher, and the lactation averages for milkfat and milk protein yields and concentrations were lower in the high UFA group than in the low UFA group (Table 2).

FIGURE 1: Concentration of unsaturated fatty acids in the milkfat of Holstein-Friesian, Jersey and Crossbred cows during lactation between Day 0 (Calving) and Day 270 (Drying-off). SEM = Standard error of the mean; HFxJ = Holstein-Friesian and Jersey crossbred.

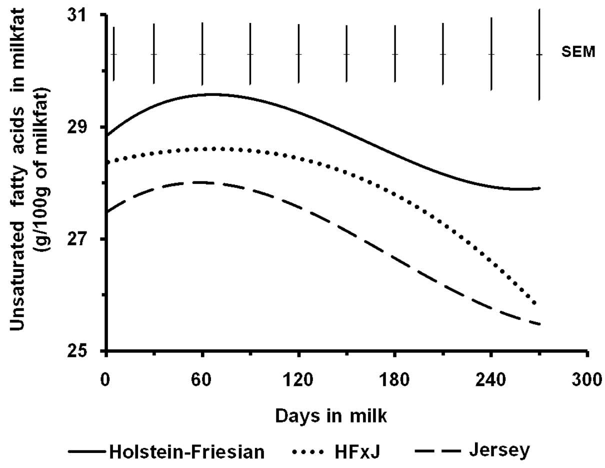
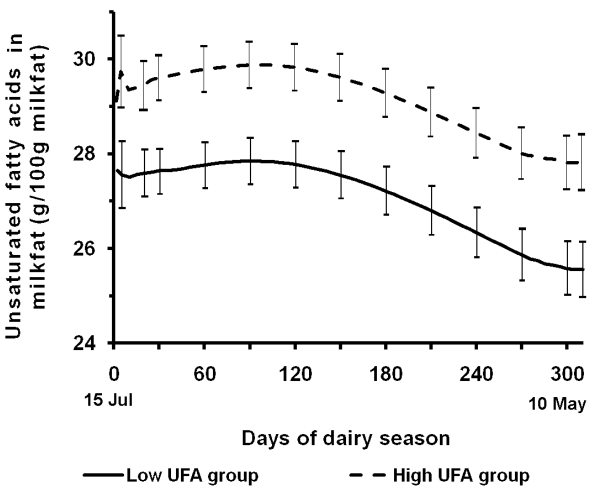


FIGURE 2: Effect of segregation of cows into high (1449 cows) and low (1444 cows) UFA groups within a subsample of 29 herds according to the average UFA concentration within each herd, on the concentration of unsaturated fatty acids in milkfat (UFA) during the dairy season: from Day0 (15 July) to Day310 (10 May).



DISCUSSION

The influence of herd, calving month, DIM and parity on the concentration of UFA in milkfat found in this study agrees with previous studies (Auldist *et al.*, 1998; Back & Thomson, 2005; Thomson & Van der Poel, 2000; Wales *et al.*, 2009). Region, herd and calving month influence the type and composition of feed supplied to the herd, and diet is known to influence milk fat composition (Thomson *et al.*, 2002). For New Zealand seasonal pastoral systems these factors are particularly important since pasture and supplement type and composition can vary between regions and farms during the year.

In the present study the milkfat of Holstein-Friesian cows had a higher concentration of UFA than the milkfat of Jersey cows. Similar differences between these breeds were reported by Back and Thomson (2005). Back and Thomson (2005) also reported an intermediate value for the concentration of UFA in milkfat of crossbreed cows in late lactation, which is in agreement with the results of the present study. Nevertheless, it is not possible to compare values of concentrations between studies due to differences in methodology and measurement of fatty acids in milkfat. Although the differences between breeds found in the present study also agreed with the results of overseas studies (Carroll *et al.*, 2006; Palladino *et al.*, 2010), it is difficult to compare the results of the present study with the overseas studies due to differences in farming systems and the influence of strain within breeds on milkfat composition (Wales *et al.*, 2009).

Soyeurt and Gengler (2008) reported that the activity of the enzyme Stearoyl-CoA desaturase-1 (SCD) can vary during lactation and it is lower in Jersey cows than in Holstein-Friesian cows. Since SCD plays an important role in the desaturation of fatty acids, it is possible that differences in the activity of this enzyme can partly explain the differences in the concentration of UFA in milkfat between breeds in this study.

Differences between breeds in regression coefficients for the prediction of UFA concentration in milkfat also indicated that there were differences between breeds in the way the UFA concentration in milkfat changed during the lactation. This is further confirmed by the interaction between breed and DIM for the concentration of UFA in milkfat.

Studies done in New Zealand (Auldist *et al.*, 1998; Back & Thomson, 2005; Thomson & Van-der-Poel, 2000) and overseas (Stoop *et al.*, 2009) reported that the concentration of UFA in milkfat was lower in mid-lactation than in early- and late-lactation. In contrast to those studies, the present study showed that the concentration of UFA in milkfat did not increase significantly in late-lactation. The rate of decrease in the concentration of UFA in milkfat in Holstein-Friesian cows was however, less than in Jersey and Crossbred cows. Since the three breeds studied were represented across the five regions, 10 parity groups and four calving months, it is possible that factors related to nutrition and diet, such as changes in pasture composition during the period of study, could have also influenced these results.

The coefficients of variation indicated that, within each breed, there was a significant variation in the concentration of UFA in milkfat. Given the moderate heritability of 0.09 to 0.28 for the concentration of major UFA in milkfat (Soyeurt *et al.*, 2007), the selection and segregation of animals with high UFA concentrations in milkfat, and manipulation of the diet, have been suggested in some studies as a means to increase the UFA concentration in milkfat produced by a herd (Lock & Bauman, 2004; Soyeurt *et al.*, 2007; Thomson *et al.*, 2002). The split of the animals in high and low UFA groups indicated that it is possible to alter the concentration of UFA in milkfat by means of animal segregation within herds. The negative effects associated with a higher concentration of UFA in milkfat of a decrease in yields and percentages of fat and protein, have also been reported in the literature (Soyeurt & Gengler, 2008). In New Zealand, under the current payment system this can negatively affect farm profit.

More studies are needed before implementing a programme for animal segregation. These studies should consider the implications on technology to achieve within-herd milk segregation, milk collection and the development of a payment system that rewards the concentration of unsaturated fatty acids in milkfat.

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REFERENCES

Arnould, V.M.R.; Hammami, H.; Soyeurt, H.; Gengler, N. 2010: Short communication: Genetic variation of saturated fatty acids in Holsteins in the Walloon region of Belgium. *Journal of Dairy Science* **93**: 4391-4397.

Auldist, M.J.; Walsh, B.J.; Thomson, N.A. 1998: Seasonal and lactational influences on bovine milk composition in New Zealand. *Journal of Dairy Research* **65**: 401-411.

Back, P.J.; Thomson, N.A. 2005: Exploiting cow genotype to increase milk value through production of minor milk components. *Proceedings of the New Zealand Society of Animal Production* **65**: 53-58.

Carroll, S.M.; DePeters, E.J.; Taylor, S.J.; Rosenberg, M.; Perez-Monti, H.; Capps, V. 2006: Milk composition of Holstein, Jersey, and Brown Swiss cows in response to increasing levels of dietary fat. *Animal Feed Science and Technology* **131**: 451-473.

Coppa, M.; Ferlay, A.; Leroux, C.; Jestin, M.; Chilliard, Y.; Martin, B.; Andueza, D. 2010: Prediction of milk fatty acid composition by near infrared reflectance spectroscopy. *International Dairy Journal* **20**: 182-189.

Flood, V.M.; Webb, K.L.; Rochtchina, E.; Kelly, B.; Mitchell, P. 2007: Fatty acid intakes and food sources in a population of older Australians. *Asia Pacific Journal of Clinical Nutrition* **16**: 322-330.

Gilmour, A.R.; Gogel, B.J.; Cullis, B.R.; Thompson, R. 2006: ASReml User Guide. Release 2.0. VSN International Ltd., Hemel Hempstead, Hertfordshire, UK. 320 pp.

Lock, A.L.; Bauman, D.E. 2004: Modifying milk fat composition of dairy cows to enhance fatty acids beneficial to human health. *Lipids* **39**: 1197-1206.

MacGibbon, A.K.H. 1996: Herd-to-herd variations in the properties of milkfat. *Proceedings of the New Zealand Society of Animal Production* **56**: 224-227.

Palladino, R.A.; Buckley, F.; Prendiville, R.; Murphy, J.J.; Callan, J.; Kenny, D.A. 2010: A comparison between Holstein-Friesian and Jersey dairy cows and their F-1 hybrid on milk fatty acid composition under grazing conditions. *Journal of Dairy Science* **93**: 2176-2184.

Rutten, M.J.M.; Bovenhuis, H.; Hettinga, K.A.; van Valenberg, H.J.F.; van Arendonk, J.A. M. 2009: Predicting bovine milk fat composition using infrared spectroscopy based on milk samples collected in winter and summer. *Journal of Dairy Science* **92**: 6202-6209.

Soyeurt, H.; Dardenne, P.; Dehareng, F.; Lognay, G.; Veselko, D.; Marlier, M.; Bertozzi, C.; Mayeres, P.; Gengler, N. 2006: Estimating fatty acid content in cow milk using mid-infrared spectrometry. *Journal of Dairy Science* **89**: 3690-3695.

Soyeurt, H.; Gengler, N. 2008: Genetic variability of fatty acids in bovine milk. *Biotechnologie Agronomie Societe Et Environnement* **12**: 203-210.

Soyeurt, H.; Gillon, A.; Vanderick, S.; Mayeres, P.; Bertozzi, C.; Gengler, N. 2007: Estimation of heritability and genetic correlations for the major fatty acids in bovine milk. *Journal of Dairy Science* **90**: 4435-4442.

Stoop, W.M.; Bovenhuis, H.; Heck, J.M.L.; van Arendonk, J.A.M. 2009: Effect of lactation stage and energy status on milk fat composition of Holstein-Friesian cows. *Journal of Dairy Science* **92**: 1469-1478.

Thomson, N.A.; Auldist, M.J.; Kay, J.K.; MacGibbon, A.K.H.; Murphy, J.J. 2002: On-farm management to modify milkfat composition - a review of experiments undertaken at Dexcel to produce a spreadable butter directly from the cow. *Proceedings of the New Zealand Society of Animal Production* **62**: 100-103.

Thomson, N.A.; Van-der-Poel, W. 2000: Seasonal variation of the fatty acid composition of milkfat from Friesian cows grazing pasture. *Proceedings of fhe New Zealand Society of Animal Production* **60**: 314-317.

Wales, W.J.; Kolver, E.S.; Egan, A.R.; Roche, J.R. 2009: Effects of strain of Holstein-Friesian and concentrate supplementation on the fatty acid composition of milk fat of dairy cows grazing pasture in early lactation. *Journal of Dairy Science* **92**: 247-255.