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RESEARCH ARTICLE

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Effect of breed and stage of lactation on the solid fat content of milk from cows milked once a day or twice a day

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ABSTRACT

Solid fat content at 10°C (SFC_{10}) is an important parameter of milk fat that influences the spreadability of butter. This study aimed to evaluate the effect of breed and stage of lactation on SFC_{10} of milk fat from cows milked once a day (OAD) or twice a day (TAD). Milk was collected from 39 Holstein-Friesian (F), 27 Jersey (J), and 34 Holstein-Friesian × Jersey (F × J) cows from a OAD herd and 104 F and 83 F × J cows from a TAD herd in early, mid and late lactation. The SFC_{10} was predicted using a regression model using milk fatty acid composition. The lower the SFC_{10}, the higher the spreadability of butter. The SFC_{10} was lower ($P < 0.05$) for F cows compared with J cows milked OAD. The SFC_{10} was lower ($P < 0.05$) for F cows compared with F × J cows milked TAD. The SFC_{10} was lower in early lactation compared with mid- and late lactation in both milking frequencies. This study revealed that F cow milk and early lactation milk would be suitable for making more easily spreadable butter in OAD and TAD milking. These results could be applicable in the New Zealand dairy industry if consumer preference for more easily spreadable butter increases.

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Breed; dairy cow; fatty acids; milking frequency; solid fat content; stage of lactation

Introduction

Solid fat content is considered an important parameter in the dairy industry as it is a good indicator of the functional properties of milk fat. Solid fat content is the proportion of fat that has crystallized at a given temperature and is generally expressed in the percentage of total fat. The solid fat content of the milk fat is usually measured in the temperature range from 10–20°C, as substantial changes occur in this temperature range (Meagher et al. 2007). Solid fat content at 10°C (SFC_{10}) has a relationship with hardness and spreadability, both functional properties (MacGibbon 1996). Lower SFC_{10} of milk fat increases the spreadability of butter, which is the ability to spread the butter, for example on bread.

The majority of the variation in the functional properties of butter can be explained by the variation in fatty acid composition. Among 400 fatty acids detected, 16 fatty acids

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were present in sufficiently large quantities to affect the physical properties of butter including melting point, spreadability, and solidification temperature (Chen et al. 2004). The proportions of C16:0 and C18:1 *cis*-9 in milk are considered important as they influence the SFC_{10} of milk fat (MacGibbon 1996; Mackle et al. 1997). The lower the C16:0/C18:1 ratio in milk higher the spreadability of the butter (Couvreur et al. 2006). Milk fatty acid composition is affected by several factors including breed (Soyeurt et al. 2006; Sanjayaranj et al. 2022a), stages of lactation (Kgwatalala et al. 2009; Sanjayaranj et al. 2022b), diet (Palmquist et al. 1993; Dewhurst et al. 2006) and genetic variation (Stoop et al. 2008; Lopez-Villalobos et al. 2014).

One of the other factors affecting milk fatty acid composition is milking frequency. Dairy farming in New Zealand predominantly involves twice-a-day (TAD) milking. However, recently farmers have adopted once-a-day (OAD) milking for a full season or part of the season. Once-a-day milking reduces the milk volume and modifies the milk composition (Tong et al. 2002; Clark et al. 2006). Recent studies reported that OAD milking affects the fatty acid composition of milk (Delamaire and Guinard-Flament 2006; Sanjayaranj et al. 2022b). Therefore, there is the possibility that OAD milking could affect the SFC_{10}. Previous studies also reported the effect of breed (MacGibbon 1996) and stages of lactation (Auldist et al. 1998) on SFC_{10} in cows milked TAD. There have been no studies on the effect of breed and stage of lactation on the SFC_{10} in OAD milking. Therefore, this study aimed to explore the effect of breed and stage of lactation on SFC_{10} of milk fat from cows milked OAD and TAD as separate experiments.

Materials and methods

Experiment 1

Experiment 1 was conducted on the No. 1 Dairy farm at Massey University, New Zealand. The No.1 Dairy farm is managed as a low-input system with cows milked OAD. The cows are fed ryegrass (*Lolium perenne*)/white clover (*Trifolium repens*) pasture and herb mix crops containing chicory (*Cichorium intybus*), plantain (*Plantago lanceolata*), and red clover (*Trifolium pratense*) with lower supplements. The supplements included maize silage, dried distillers grains, tapioca pellets, grain-based concentrate, and baleage. The stocking rate of the No.1 Dairy was 2.4 cows/ha. Milk samples were collected from the OAD herd containing 39 Holstein-Friesian (F), 27 Jersey (J), and 34 Holstein-Friesian × Jersey (F × J) cows in early, mid, and late lactation. The herd consisted of 1st and 2nd parity cows.

Experiment 2

Experiment 2 was conducted on the No. 4 Dairy farm at Massey University, New Zealand. The No.4 Dairy farm is managed as a high input system with cows milked TAD. The cows are mainly fed ryegrass/white clover pasture with higher supplements. The supplements included maize silage, dried distillers grains, grain-based concentrate, dry roughages, and baleage. The stocking rate of the No.4 Dairy was 2.6 cows/ha. Milk samples were collected from 104 and 83 F × J cows in early, mid-, and late lactation. The herd consisted of 1st and 2nd parity cows.

Sample collection

Morning milk samples were collected from the OAD herd in experiment 1 and morning and afternoon milk samples were collected from the TAD herd in experiment 2. Composite milk samples were collected using Waikato milk flow metres. Milk samples were stored at 0–4°C until analysis which was carried out within two days of sample collection.

Determination of fatty acid composition

The fatty acid composition was analysed using a Milkoscan FT1 (Foss Analytical, Hillerød, Denmark). Calibration equations for individual fatty acids were developed using FTIR calibrator software (Foss Analytical, Hillerød, Denmark) using a data set with mid-infrared spectral data and gas chromatography reference values.

Determination of solid fat content at 10°C

Solid fat content at 10°C was predicted using PROC REG in SAS version 9.4 (SAS Institute Inc., Cary, NC, USA), using the fatty acid composition and SFC_{10} data from the study of MacGibbon (1996). In this study, the fatty acids C4:0 C6:0 C8:0 C10:0 C12:0 C14:0 C16:0 C18:0 C18:1 *cis*-9 were tested for their prediction for SFC_{10}. A stepwise regression was used to find the good predictors of SFC_{10}. The final multiple regression model was the following:

$$\begin{aligned} SFC_{10} = {} & -2.72 \times C12{:}0 + 3.33 \times C14{:}0 + 0.97 \times C16{:}0 + 1.61 \times C18{:}0 - 0.82 \\ & \times C18{:}1\mathit{cis} - 9 \end{aligned}$$

Statistical analysis

A linear model was developed to estimate the effect of breed and stage of lactation for milk fatty acids and SFC_{10}. The least-squares means and standard errors were estimated using a PROC MIXED procedure in SAS version 9.4 (SAS Institute Inc., Cary, NC, USA) for each milking frequency separately (different data sets for OAD and TAD farms).

$$y_{ijkm} = \mu + B_i + L_j + S_k + \beta_1 d_{ijkm} + C_m + e_{ijkm}$$

Y_{ijkm} is the observation for composition traits and SFC_{10} for breed group i, lactation number j, stage of lactation k, and cow m.

μ is the population mean.

B_i is the fixed effect of breed i (i = F, F × J, and J in OAD herd and F and F × J in TAD herd).

L_j is the fixed effect of lactation number j (j = 1st and 2nd lactation).

S_k is the fixed effect of stages of lactation k (k = early, mid, and late).

β_1 is the regression coefficient associated with the linear effect of deviation from the median calving date (d) of cow m.

C_m is the random effect of cow m (m = 1, 2, … 100 in OAD herd and 1, 2, … 187 in TAD herd) assumed with mean zero and variance σ_c^2.

e_{ijkm} is the residual random error assumed with mean zero and variance σ_e^2.

Results

Descriptive statistics of milk fatty acids and SFC$_{10}$ for cows milked OAD (experiment 1) and TAD (experiment 2) are presented in Table 1.

Table 2 shows the least squares means and standard errors for milk fatty acids and SFC$_{10}$ in F, F × J, and J cows milked OAD (experiment 1).

The only fatty acid that showed a significant difference ($P < 0.05$) between breeds was C18:0 in OAD milking frequency. The proportion of C18:0 was lower in F cows compared with J cows. Similarly, the SFC$_{10}$ was lower in F cows compared with J cows milked OAD.

Table 3 shows the least squares means and standard errors for milk fatty acids and SFC$_{10}$ in F and F × J cows milked TAD (experiment 2). The proportion of C18:0 was lower in F cows compared with F × J cows. The SFC$_{10}$ was lower in F cows compared with F × J cows milked TAD.

Figure 1 shows the proportions of C16:0, C18:0, C18:1 *cis*-9 and SFC$_{10}$ in early, mid- and late lactation in cows milked OAD (experiment 1) and cows milked TAD (experiment 2). In cows milked OAD, the proportions of C16:0 and C18:0 were lower and the proportion of C18:1 *cis*-9 was higher in early lactation compared with mid- and late lactation. The SFC$_{10}$ was lower in early lactation compared with mid- and late lactation.

Table 1. Descriptive statistics of milk fatty acids and solid fat content at 10°C (SFC$_{10}$) of cows milked once a day (experiment 1[†]) and twice a day (experiment 2[‡]) during the 2020–2021 production season.

	N	Mean	SD	CV	Min	Max
Once-a-day (experiment 1)						
Fat	296	5.21	0.88	16.9	3.29	8.53
C16:0	296	31.47	2.6	8.3	22.86	38.69
C18:0	296	12.66	1.75	13.8	7.87	22.23
C18:1 *cis*-9	296	19.57	2.75	14	11.81	33.6
SFC$_{10}$	296	67.13	8.14	12.1	33.41	89.57
Twice-a-day (experiment 2)						
Fat	543	3.98	0.85	21.4	1.27	6.89
C16:0	543	32.1	2.47	7.7	25.17	39.81
C18:0	543	13.28	1.22	9.2	9.94	21.37
C18:1 *cis*-9	543	20.54	2.69	13.1	14.75	31.99
SFC$_{10}$	543	67.44	7.13	10.6	41.03	86.96

[†] The farm was managed as a low-input system.

[‡] The farm was managed as a high-input system.

The proportions of individual fatty acids are expressed as a percentage of total fatty acids.

Fat content and SFC$_{10}$ are expressed in percentage.

Table 2. Least squares means and standard errors of fatty acids and solid fat content at 10°C (SFC$_{10}$) of milk from Holstein-Friesian, Holstein-Friesian × Jersey and Jersey cows milked once a day (experiment 1[†]) in the 2020–2021 production season.

	Holstein-Friesian	Holstein-Friesian × Jersey	Jersey
Fat	4.84 ± 0.10^{c}	5.23 ± 0.10^{b}	5.75 ± 0.11^{a}
C16:0	31.57 ± 0.24	31.31 ± 0.26	31.83 ± 0.29
C18:0	12.17 ± 0.19^{b}	12.87 ± 0.20^{a}	13.07 ± 0.22^{a}
C18:1 *cis*-9	19.72 ± 0.24	19.59 ± 0.25	19.09 ± 0.28
SFC$_{10}$	66.29 ± 0.66^{b}	67.00 ± 0.71^{b}	69.28 ± 0.79^{a}

[†] The farm was managed as a low-input system.

The proportions of individual fatty acids are expressed as a percentage of total fatty acids. Fat content and SFC$_{10}$ are expressed in percentage.

^{abc}means with different superscripts are significantly different $P < 0.05$.

Table 3. Least squares means and standard errors of fatty acids and solid fat content at 10°C (SFC_{10}) of milk from Holstein-Friesian and Holstein-Friesian × Jersey cows milked twice a day (experiment 2[‡]) in the 2020–2021 production season.

	Holstein-Friesian	Holstein-Friesian × Jersey
Fat	3.85 ± 0.07^{b}	4.14 ± 0.07^{a}
C16:0	32.08 ± 0.15	32.51 ± 0.16
C18:0	13.03 ± 0.09^{b}	13.53 ± 0.10^{a}
C18:1 *cis*-9	20.50 ± 0.14	20.23 ± 0.16
SFC_{10}	67.11 ± 0.41^{b}	68.85 ± 0.44^{a}

[‡] The farm was managed as a high-input system.
The proportions of individual fatty acids are expressed as a percentage of total fatty acids.
Fat content and SFC_{10} are expressed in percentage.
[ab] means with different superscripts are significantly different $P < 0.05$.

Similar trends were reported for the fatty acid in cows milked TAD except for the proportions of C18:0. The proportion of C18:0 was higher in early lactation compared with mid- and late lactation. However, the SFC_{10} was lower in early lactation.

Discussion

In this study, the analysis was carried out separately and the results were interpreted separately for each milking frequency as OAD and TAD cows were fed mainly pasture with different levels of supplements. The SFC_{10} of milk fat is generally used to measure the spreadability of butter. A significant proportion of variation in SFC_{10} is explained by breed (MacGibbon 1996). In experiment 1, the lower SFC_{10} in F cows milked OAD compared with J cows was in agreement with MacGibbon (1996). Lower SFC_{10} in F cows could be due to a lower proportion of C18:0 compared with J cows milked OAD. MacGibbon (1996) reported that higher melting point long-chain saturated fatty acids contribute to higher SFC_{10}. Although, the proportions of C16:0, and C18:1 *cis*-9 were not significantly different between breeds the combination of these fatty acids could also affect the SFC_{10}. MacGibbon (1996) reported that cows producing higher fat content tend to produce higher SFC_{10}. In experiment 1, J cows milked OAD produced higher fat content compared with F cows. Overall, the lower SFC_{10} in F cows could be due to the lower proportion of C18:0 and lower fat content compared with J cows. Lower SFC_{10} would result in F cows producing more easily spreadable butter compared with J cows when milked OAD.

In experiment 2, lower SFC_{10} in F cows could be due to a lower proportion of C18:0 and lower fat content compared with F × J cows milked TAD. Holstein-Friesian cows would be expected to produce more easily spreadable butter compared with F × J cows.

The SFC_{10} was associated with milk fatty acid composition. Solid fat content at 10°C was positively correlated with fatty acids C8:0 – C14:0 (MacGibbon 1996) and C16:0 (Mackle et al. 1997) and negatively associated with C18:1 and C18:2 fatty acids (MacGibbon 1996; Mackle et al. 1997). Similarly, Bobe et al. (2003) and Couvreur et al. (2006) reported that increasing unsaturated fatty acids in the diet decreased the SFC_{10} in butter fat. In general, milk containing higher unsaturated fatty acids and lower long-chain saturated fatty acids tends to reduce the SFC_{10} and therefore increase the spreadability of butter. Auldist et al. (2004) reported J cows had higher proportions of long-chain saturated fatty acids and lower proportions of long-chain unsaturated fatty acids

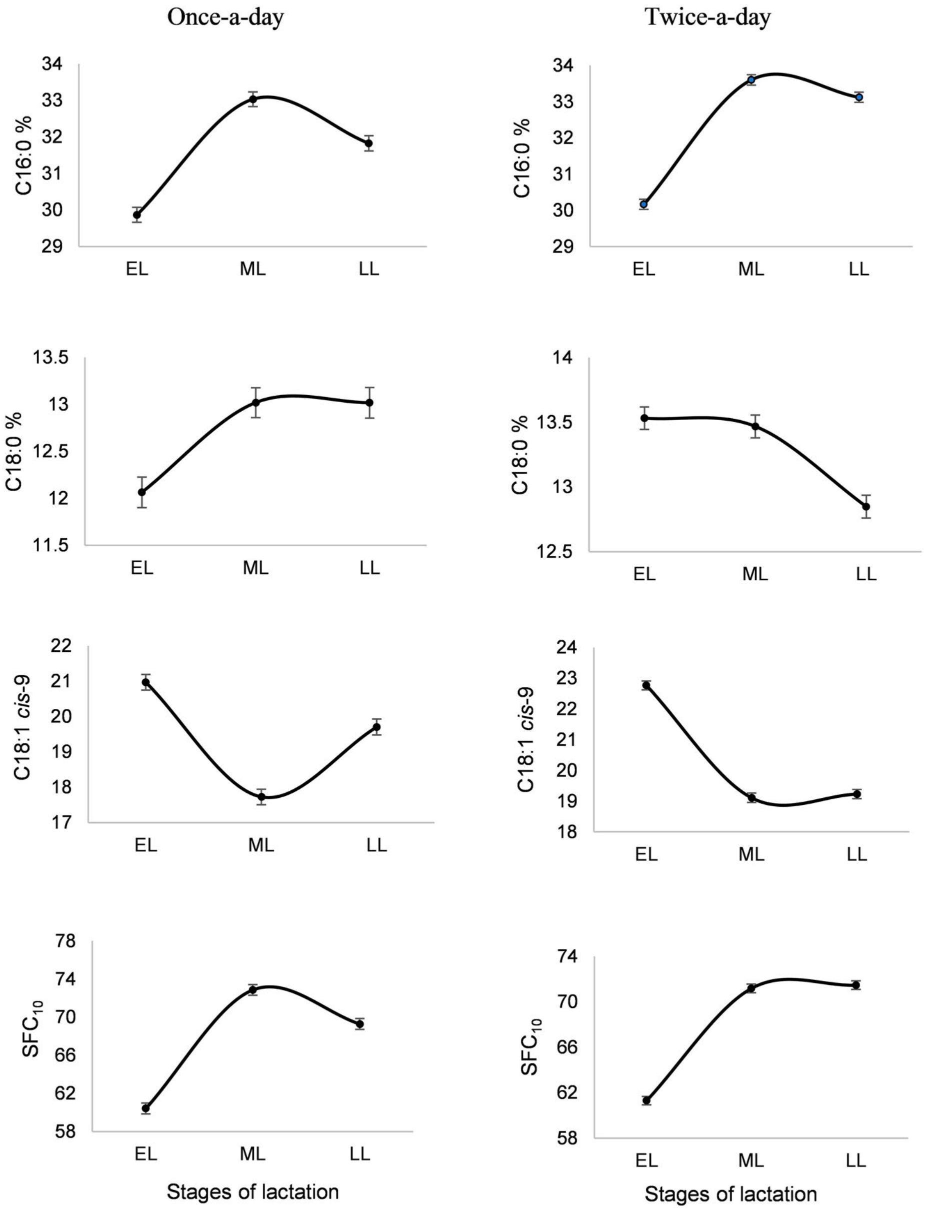

Figure 1. Proportions of C16:0, C18:0, C18:1 *cis*-9 and solid fat content at 10°C (SFC_{10}) in cows milked once a day (experiment 1[†]) and twice a day (experiment 2[‡]) during the production season 2020–2021. [†] The farm was managed as a low-input system; [‡] The farm was managed as a high-input system. EL = early lactation (<90 days); ML = mid lactation (90–180 days); LL = late lactation (>180 days). The vertical bars show the standard errors.

compared with F cows. This could be a reason that J cows showed higher SFC_{10} in this study and this was also explained by the proportion of higher C18:0 in J cows compared with F cows milked OAD. Similar results were reported for F × J cows compared with F cows milked TAD. Shukla et al. (1994) reported that high melting point milk fat can be potentially used in bakery, chocolate, and confectionary industries where harder fat is desirable. Jersey milk could be used in these industries. In both milking frequencies, F cows produced milk with lower SFC_{10}, which could be useful in producing more easily spreadable butter.

The SFC_{10} is also affected by stages of lactation. In both experiments, butter produced from early lactation milk is expected to be more easily spreadable due to lower SFC_{10} in early lactation compared with mid- and late lactation. This is in agreement with Auldist et al. (1998) and Thomson and Van Der Poel (2000) that the SFC_{10} was lower in early lactation. In experiment 1, the lower SFC_{10} in early lactation in cows milked OAD may be due to lower proportions of C16:0 and C18:0 and higher proportion of C18:1 *cis*-9 in early lactation. In experiment 2, the lower SFC_{10} in early lactation in cows milked TAD could be due to lower proportion of C16:0 and higher proportion of C18: 1 *cis*-9 in early lactation. The higher proportion of C18:0 in early lactation in cows milked TAD could increase the SFC_{10} but this effect may be reduce due to lower proportions of C16:0 and higher proportion of C18:1 *cis*-9. These fatty acids occur in higher proportions in milk compared with C18:0. Overall, in both miking frequencies, milk from early lactation would be more suitable for making more easily spreadable butter.

In this study, the effect of the stage of lactation on SFC_{10} and milk fatty acids was significant for cows milked OAD and TAD. However, the SFC_{10} is also influenced by the seasons of the year. MacGibbon (1996), Auldist et al. (1998), and Meagher et al. (2007) reported that the effect of the season of the year on SFC_{10} was more prominent than the effect of stages of lactation. In New Zealand, stages of lactation are synchronised with the season and pasture growth. Therefore, finding the actual effect of stages of lactation is complicated.

In summary, in OAD milking, F cows would more suitable for producing more easily spreadable butter compared with J cows and early lactation milk is expected to be producing more easily spreadable butter compared with mid- and late lactation. In TAD milking, F cows would more suitable for producing more easily spreadable butter compared with F × J cows and early lactation milk is expected to produce more easily spreadable butter compared with mid- and late lactation.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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