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On-farm management to modify milkfat composition – a review of experiments undertaken at Dexcel to produce a spreadable butter directly from the cow.

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ABSTRACT

For many years it has been known from overseas studies that the composition and physical characteristics of milkfat are influenced by diet. The feeding of oilseeds had been shown to reduce the concentration in milkfat of short- and medium-chain-length fatty acids and to increase the concentration of long-chain unsaturated fatty acids. It was also reported that these changes resulted in softer milkfat and butter with improved spreadability at low temperatures. With this knowledge, a six-year collaborative research programme between the New Zealand Dairy Research Institute and Dexcel was undertaken to investigate the economic feasibility of producing a spreadable butter directly from the cow. The programme investigated the influence of each component in pastoral dairying that may possibly influence milkfat composition. These were: pasture, (location, defoliation interval, and species effects) on pasture lipid composition, grazed pasture effects (species and grazing rotation), supplementary feed effects (ruminally and non-ruminally protected oilseeds), frequency of feeding, and milking management. Following the study of each component the various components will be combined to develop a total farm management system to achieve the programme's goals. The goal of producing a spreadable butter directly from the cow has been achieved, but the programme has yet to develop a profitable farm system to produce the product under existing returns for milksolids.

Keywords: milkfat composition; pasture lipid composition; oilseed supplementation.

INTRODUCTION

Milkfat contains a relatively high level of saturated fat, and it contains cholesterol. This has led to a poor perception of its healthiness (Ney 1991). Fats containing high levels of saturated fatty acids are harder and if manufactured into a spread such as butter, the product is difficult to spread at low temperature, for example when removed directly from the refrigerator. These negative associations directed towards saturated fats, including milkfat, have resulted in a decline in butter consumption while "fat-free" dairy products have emerged and maintained or increased market share.

The softness and spreadability of butter is influenced by its fatty acid composition. MacGibbon (1996) reported strong correlations among the proportion of individual fatty acids, solid fat content (SFC) and sectility hardness. Mackle *et al.,* (1997) reported that increasing SFC at 10°C (SFC_{10}) was associated (r^2=0.91) with increasing proportions of saturated fatty acids, especially palmitic, $C_{16:0}$, and decreasing proportions of mono- and poly-unsaturated fatty acids (MUFA and PUFA respectively). The composition of the fatty acids which influence spreadability are influenced by cow effects (MacGibbon 1996 & Mackle *et al.,* 1997), stage of lactation and time of year (Auldist *et al.,* 1998) and feed effects (Ashes *et al.,* 1992; Murphy *et al.,* 1995).

Differences between cows, stages of lactation, times of year and feeding regimes in the composition and characteristics of milkfat, provide opportunities to develop management systems to change the relative levels of saturated and unsaturated fatty acids and the physical characteristics of milkfat. The objective of the research programme was to produce a butter that was spreadable from the refrigerator. This goal was to be achieved through a small increase in PUFAs and a large increase in MUFAs.

The programme covered a period of six years and ranged from investigations into pasture, oilseed supplements and cow effects, to experiments that combined some of these components with the aim of developing the most cost-effective system that achieved the programme's goal. Information on the spreadability of the butter produced in this programme is presented by MacGibbon *et al.,* (2002).

Pasture effects

New Zealand – Ireland comparison:–Seasonal variation in the composition and characteristics of milkfat has been observed in bulk milk supplied to processing plants in New Zealand (MacGibbon & McLennan, 1987) and Ireland (Cullinane *et al.,* 1984). Irish cows grazing pasture in Ireland produced milkfat that was softer with higher concentrations of unsaturated fatty acids than the milkfat produced by New Zealand cows grazing New Zealand pasture (Murphy *et al.,* 1995; Thomson & MacGibbon 2000). Auldist *et al.,* (1998) reported effects of both stage of lactation and time of year on milkfat characteristics. Milkfat was softer in spring and autumn and harder in summer irrespective of stage of lactation. This suggested that pasture might be affecting milkfat characteristics.

Hawke (1963) reported marked differences in the type and amount of lipid in ryegrass pasture at different stages of maturity. McDowell & McGillivray (1963a;1963b) reported that pasture species and stage of maturity of ryegrass leaf both influenced the characteristics of milkfat suggesting that seasonal effects on milkfat characteristics were in part due to seasonal changes in the lipid characteristics of pasture. From all these reports it was hypothesised that different lipid composition of New Zealand and Irish pastures was the reason for the different characteristics of milkfat in New Zealand and Ireland. To determine if this was the case a project was initiated to

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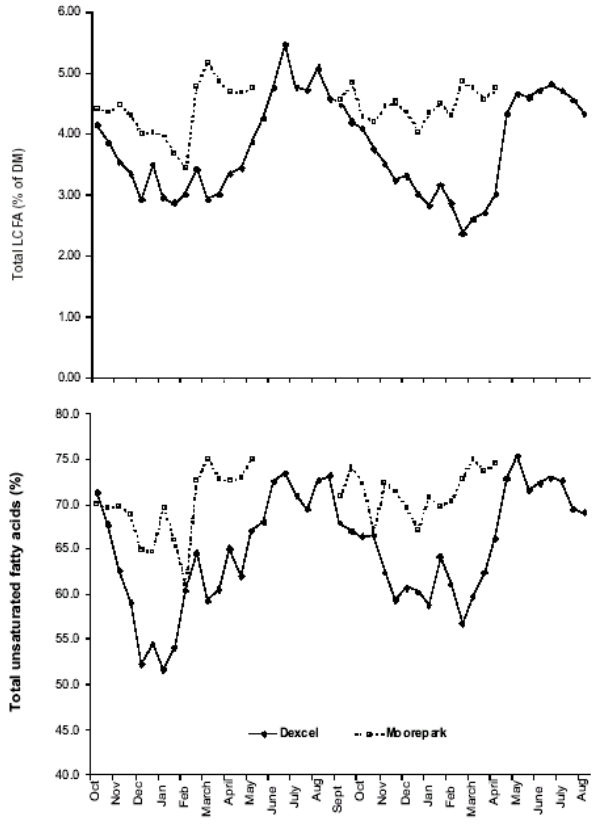
FIGURE 1. Seasonal variation in the average lipid composition (total long-chain fatty acids, C_{12}-C_{20}, (LCFA) and unsaturated fatty acid composition) of perennial ryegrass dominant pastures in New Zealand (Dexcel) and Ireland (Moorepark) defoliated at intervals of 14, 28 and 42 days. The data from Ireland has been offset by six months to bring the seasons in line with New Zealand.



study the total long-chain fatty acids, C_{12}-C_{20} (LCFA) fat and the fatty acid composition of ryegrass-dominant pasture in the two countries (New Zealand, all year; Ireland, April-October) at different stages of maturity (14, 28-, and 42-day regrowth periods). In addition, a short-term study (spring, summer and autumn 1998/99) was undertaken at Dexcel to determine the lipid composition of a range of different pasture species collected from the grazing trial described by Thom *et al.*, (2001).

The seasonal variation of total LCFA and the proportion of unsaturated fatty acids in pasture in New Zealand and Ireland are presented in Figure 1. These data show that the lipid characteristics of Irish pasture maintained higher and less variable concentrations of total LCFA and unsaturated fatty acids throughout the grazing season than the lipid in New Zealand pasture. During similar seasons at the two locations, mid-spring to mid-autumn, the climate in the Waikato was drier (470 mm vs. 560 mm rainfall) and warmer (16.6°C vs. 12.9°C) than at Moorepark in Ireland. At both locations, the 42-day regrowth pasture contained less ($P<0.01$) total fat (3.9% vs. 4.2% of DM: 42 vs. 14 days) and lower ($P<0.01$) concentration of linolenic acid (47.6% vs. 51.0%: 42 vs. 14 days) than the 14-day regrowth pasture. Of the pasture species investigated, timothy, red clover and white clover consistently contained more total LCFA ($P<0.05$) than perennial ryegrass, and tall fescue contained less total LCFA ($P<0.01$) than perennial ryegrass. The concentration of total unsaturated fatty acids was similar for timothy, red and white clover, but higher than perennial ryegrass or tall fescue ($P<0.05$).

Effect of pasture species:

The differences reported between species and defoliation frequency may be of sufficient magnitude to influence the characteristics of milkfat. To examine this a grazing trial was established and conducted during the 2000/2001 season. The trial compared the milkfat characteristics of cows grazing ryegrass/white clover pasture on rotations of 10, 20 and 30 days, and timothy/white clover pastures on a 20-day grazing rotation in November 2000 and March 2001. Rotation length and pasture species both had small effects on milkfat characteristics (Table 1). Cows grazing timothy pastures in spring produced milkfat that was higher in total unsaturated fatty acids ($P<0.001$) than cows grazing ryegrass pasture. In autumn milkfat was more unsaturated than in spring and more unsaturated from ryegrass than Timothy pastures ($P<0.001$). Grazing rotation also had a variable effect depending on season. Rotation length had little effect in spring but in autumn the 30-day rotation produced milkfat that contained lower concentrations of unsaturated fatty acids than either the 10- or 20-day rotations ($P<0.01$).

Supplementary feed effects

Feeding oilseeds in a grazed-pasture system will modify the composition and physical characteristics of milkfat (Murphy *et al.*, 1995). The level and type of modification to milkfat will depend on the type of oilseed and the degree of ruminal protection. The dominant fatty acids in pasture, linoleic and linolenic ($C_{18:2}$ and $C_{18:3}$), are hydrogenated by the action of rumen micro-organisms to produce less-unsaturated acids oleic, ($C_{18:1}$) and stearic, ($C_{18:0}$). The ruminal hydrogenation process is incomplete and feeding oilseeds, either ruminally protected or non-protected will cause an increase in the concentration of unsaturated fatty acids in milkfat, a decline in fatty acids synthesised endogenously (C_4 to C_{15}) and an increase in preformed fatty acids (mainly C_{18}). The amount of unsaturated fatty acids escaping ruminal biohydrogenation will increase with the effectiveness of ruminal protection of the oilseed. Work at Dexcel has examined the effect on the characteristics of milkfat of feeding unprotected oilseed and oilseed protected against ruminal biohydrogenation by different processes (Table 2). Feeding the same amount of canola (2 kg oilseed/cow/day), with different levels of ruminal protection, produced milkfat with different fatty acid compositions. A moderate level of ruminal protection (canola 2) caused the maximum levels of MUFAs and a higher level of ruminal protection (canola 3) increased PUFAs.

Trials were conducted investigating feeding 4 rates of ruminally protected canola (0, 1, 2, and 3 kg/cow/day) at early, mid and late lactation. The degree of change in the fatty acid composition of milkfat with amount of oilseed fed, declined as the daily amount of feed increased. Feeding in mid and late lactation was more effective at

TABLE 1: Yield and characteristics of milkfat produced by cows grazing timothy/white clover on a 20-day rotation or ryegrass/white clover pastures on rotations of 10, 20 or 30 days.

	Ryegrass			Timothy		
	10-day	20-day	30-day	20-day	s.e.d.	Significance
Spring 2000						
Milkfat yield (kg/c/d)	0.76 [ab]	0.85 [b]	0.71 [a]	0.94 [bc]	0.05	***
Mono-unsat. (%)	22.7 [a]	22.8 [a]	22.4 [a]	24.9 [b]	0.51	***
Poly-unsat. (%)	4.0 [a]	3.9 [a]	4.0 [a]	4.6 [b]	0.17	***
Total unsat. (%)	26.7 [a]	26.7 [a]	26.4 [a]	29.5 [b]	0.61	***
Autumn 2001						
Milkfat yield (kg/c/d)	0.45 [b]	0.52 [ab]	0.56 [bc]	0.48 [a]	0.04	*
Mono-unsat. (%)	29.7 [b]	30.8 [c]	27.7 [a]	28.9 [b]	0.54	***
Poly-unsat. (%)	6.5 [ab]	6.9 [b]	6.1 [a]	6.1 [a]	0.36	*
Total unsat. (%)	36.2 [b]	37.7 [c]	33.7 [a]	35.1 [b]	0.63	***

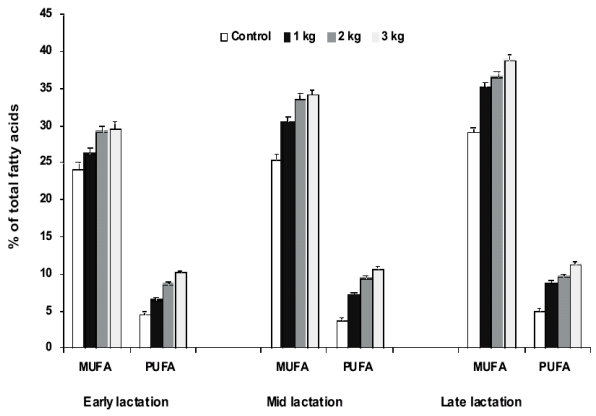
[abc] Means within rows having superscripts with common letters are not significantly different (level of significance specified for each row)

TABLE 2: Yield and characteristics of milkfat produced by cows fed 2 kg oilseed per cow per day which was not protected or protected against ruminal biohydrogenation by two different processes.

	Control	Canola 1	Canola 2	Canola 3	s.e.d.
Milkfat yield (kg/c/d)	0.53[a]	0.56[a]	0.50[a]	0.58[a]	0.04
Mono unsat. (%)	32.4[a]	38.4[b]	42.0[c]	39.5[b]	1.1
Poly unsat. (%)	6.3[a]	6.1[a]	6.8[a]	10.6[b]	1.3
Total unsat. (%)	38.7[a]	44.5[b]	49.0[c]	50.0[c]	1.2

Canola 1, Crushed canola seed – non-ruminally protected
Canola 2, Ruminally protected; method 1
Canola 3, Ruminally protected; method 2
[abc] Means within fatty acid groups having superscripts with common letters are not significantly different (P<0.001)

FIGURE 2: The concentration of mono unsaturated fatty acids (MUFA) and poly unsaturated fatty acids (PUFA) in the milkfat of cows fed 0, 1, 2 and 3 kg/cow/day of ruminally protected oilseed in early, mid and late lactation.



increasing MUFAs than feeding in early lactation (Figure 2). In comparison, the effect of feeding increasing amounts of ruminally protected oilseed on PUFAs was more linear and less affected by stage of lactation. These results show that a particular target for increased unsaturated fatty acid content in milkfat would be achieved in late lactation by feeding less ruminally protected oilseed than would occur in early lactation.

Feeding of oilseed, in the studies conducted at Dexcel, took place after milking at 0730hrs and 1500 hrs. A study conducted to determine the effect on milkfat characteristics of milking time or feeding 2 kg ruminally protected oilseed/cow/day either once or twice daily showed that both milking time and feeding frequency had an effect (Table 3). The afternoon milk (after an 8-hour interval) contained higher concentrations of unsaturated fatty acids than milk collected from the morning milking (after a 16-hour milking interval) (P<0.001). Feeding 2 kg/cow/day of ruminally protected oilseed once a day had a more marked effect on the fatty acid composition and characteristics of milkfat than feeding it twice a day (P<0.001). Once-daily feeding almost eliminated the effects of time of milking or milking interval on the concentration of unsaturated fatty acids in milkfat (P<0.01). The greater effect on milkfat composition from feeding once a day was most likely due to a greater proportion of the unsaturated fatty acids in the oilseed supplement escaping biohydrogenation. Ruminal protection of the canola seed used in these studies was 60-70% effective.

Across all trials the average milksolids response to feeding 2 kg/cow/day of ruminally protected oilseed was 0.15 kg/cow/day. The feed cost was greater than $900/tonne and at present milksolids returns the modification of milkfat solely by feeding oilseed irrespective of time of year or stage of lactation would be uneconomic.

CONCLUSIONS

Changes in the lipid composition of the diet of dairy cows will result in significant alterations to the composition of milkfat. In particular, in a pasture system, seasonal changes and selection of pasture species can increase the concentration of unsaturated fatty acids to 35% of the total. Further modifications to the fatty acid composition of milkfat will require the feeding of oilseed supplements. With this, the concentration of unsaturated fatty acids can reach as high as 50%. With present returns for milksolids at around $5.00/kg, feeding of oilseeds alone will be uneconomic. A combination of pasture type and season may however enable the desired level of modification to milkfat to be achieved with a reduced amount of oilseed supplement.

TABLE 3: The fatty acid composition of morning and afternoon milk, collected under a 16 hour (PM to AM) and an 8 hour (AM to PM) milking regime, from cows fed 2 kg/cow/day of ruminally protected oilseed either once (1x) or twice (2x) a day.

		Frequency of feeding oilseed			Significance		
		0	1 x day	2 x day	Time	Freq.	Time x Freq.
Mono-unsat.(%)	PM	26.6	32.7	31.0			
	AM	22.5	30.8	28.3	***	***	NS
Poly-unsat.(%)	PM	3.4	7.5	7.4			
	AM	3.0	7.7	6.9	***	***	**
Total unsat. (%)	PM	39.8	40.5	38.3			
	AM	25.3	38.7	35.1	***	***	*

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