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Improving the fatty acid profile of winter milk from housed cows with contrasting feeding regimes by oilseed supplementation

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ABSTRACT

Many studies show concentrations of nutritionally desirable fatty acids in bovine milk are lower when cows have no access to grazing, leading to seasonal fluctuations in milk quality if cows are housed for part of the year. This study investigated the potential to improve the fatty acid profiles of bovine milk by oilseed supplementation (rolled linseed and rapeseed) during a period of indoor feeding in both organic and conventional production systems. Both linseed and rapeseed increased the concentrations of total monounsaturated fatty acids, vaccenic acid, oleic acid and rumenic acid in milk, but decreased the concentration of the total and certain individual saturated fatty acids. Linseed resulted in greater changes than rapeseed, and also significantly increased the concentrations of α-linolenic acid, total polyunsaturated fatty acids and total omega-3 fatty acids. The response to oilseed supplementation, with respect to increasing concentrations of vaccenic acid and omega-3 fatty acids, appeared more efficient for organic compared with conventional diets.

1. Introduction

Milk and dairy products are important sources of fatty acids (FA) in the human diet (Haug, Hostmark, & Harstad, 2007; Mills, Ross, Hill, Fitzgerald, & Stanton, 2011), with up to 36% of infant fat intake being from dairy products in some countries (Food Standards Agency, 2009). However, there are health concerns about the high concentrations of saturated fatty acids (SFA) in milk fat. Most importantly, lauric acid (C12:0), myristic acid (C14:0) and palmitic acid (C16:0) have all been linked to negative effects on human health, especially an increased risk of cardiovascular disease, although more recent reviews recommend the main target of improving milk quality should be a decrease in C16:0, due to its relatively high concentrations in milk fat (Haug et al., 2007).

A number of recent studies show that the concentrations of total and specific monounsaturated (MUFA) and polyunsaturated fatty acids (PUFA) increase when cows consume high fresh grass or grass/clover (and to a lesser extent conserved) forage and low concentrate diets (Butler et al., 2008; Stergiadis et al., 2012). This included increases in PUFA, such as omega-3 fatty acids (n-3) and rumenic acid (RA, c9t11 C18:2), and the MUFA oleic acid (OA, c9 C18:1), which have been linked to health benefits (Haug et al., 2007; Mills et al., 2011). High fresh forage intake also improved the ratio of omega-3:omega-6 fatty acids (n-3/n-6) in milk (Butler et al., 2008; Stergiadis et al., 2012) in line with dietary recommendations (European Food Safety Authority, 2010). However, when cows are housed, the milk concentrations of desirable MUFA and PUFA are known to decrease, due to lack of fresh forage in the diet. Seasonal changes in dairy diets on many farms have been shown to result in variable milk fat composition throughout the year with differences being more marked in organic systems where high intakes of grazed forage in summer are replaced with conserved forage based diets in winter (Butler, Stergiadis, Seal, Eyre, & Leifert, 2011; Stergiadis et al., 2012). Therefore, there is a need to develop strategies to improve winter milk quality in both conventional and organic production systems.

One approach to increase the MUFA and PUFA content in milk and reduce concentrations of the main undesirable SFA is to supplement winter dairy diets with vegetable oils or oilseeds (Chilliard et al., 2007; Glasser, Ferlay, & Chilliard, 2008). However, the efficiency of this approach to raise the MUFA and PUFA concentrations in milk is relatively poor. For example, Chilliard et al. (2007) reported only 7% of α-linolenic acid (ALA, c9c12c15 C18:3) and 15% of linoleic acid (LA, c9c12 C18:2) consumed by cows was transferred into milk with the balance lost through

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hydrolysis, isomerisation and biohydrogenation (RBH) in the rumen. This is even more marked for longer chain n-3, such as eicosapentaenoic acid (EPA, c6c9c12c15c18 C20:5), docosapentaenoic acid (DPA, c7c10c13c16c19 C22:5) and docosahexaenoic acid (DHA, c4c7c10c13c16c19 C22:6) (Chilliard et al., 2007). Transfer rates are also reported to depend on the type of oilseed supplement used, the proportion and composition of FA in the diet, productivity of the cows and the proportion of concentrate in the diet (Chilliard et al., 2007; Zachut et al., 2010). The metabolism of dietary MUFA and PUFA in the rumen involves hydrogenation to SFA; in addition, SFA leaving the rumen can be further transformed in the mammary gland before being secreted into milk. For example, Δ9-desaturase enzymes convert SFA (e.g. C14:0 C16:0 and C18:0) and MUFA (e.g. vaccenic acid; t11 C18:1) into MUFA and PUFA, respectively, although the latter will be dominated by the conversion of VA to RA (Chilliard et al., 2007; Destaillats, Trottier, Galvez, & Angers, 2005). Supplementation of dairy diets with oilseeds has shown variant results on milk yield mainly due to contrasting basal diets between the studies (Glasser et al., 2008).

To our knowledge there are no studies reporting both the impact of oilseed supplementation on milk fat profiles and the relative efficiency of this practice under contrasting feeding regimes and management practices (organic, conventional) for housed dairy cows. Provided the main nutritional differences between commonly used organic and conventional dairy regimes (higher forage:concentrate ratio and clover inclusion in the organic silages) influence rumen kinetics and lipid metabolism (Dewhurst et al., 2003), responses in milk FA profiles after oilseed supplementation may differ between the two systems. This study therefore aimed to (a) quantify the effect of dietary linseed and rapeseed supplementation of 'winter indoor diets' and (b) identify the impact of this oilseed supplementation in organic and conventional dairy systems under identical environmental conditions and stockmanship. The overall goal was to provide protocols for dairy producers to improve the nutritional quality of winter milk.

2. Materials and methods

2.1. Experimental design

This study was based on two experiments carried out in two separate winter feeding seasons (2007 and 2010). Each experiment was carried out over a six week period using animals in two parallel herds of Holstein–Friesian cows at Newcastle University's Nafferton farm. The herds, established in 2006, are treated as independent units although under common supervision; one herd managed to organic standards (Soil Association, 2010), which allowed a system comparison without the bias of differing stockmanship and environmental conditions. Nafferton farm dairy herds are run along the lines of typical commercial production systems; management, including feeding, reflect practice on many comparable conventional and organic units. Each experiment consisted of two separate but simultaneous trials, one performed in the conventional and one in the organic herd, resulting in four different trials: (a) year 1, conventional herd (trial C1), (b) year 1, organic herd (trial O1), (c) year 2, conventional herd (trial C2) and (d) year 2, organic herd (trial O2). Both experiments were of a nested design with cows in each herd randomly allocated to treatment groups, blocked for lactation number, days in milk, milk yield, gross milk composition (fat, protein and lactose) and somatic cell count (SCC) based on the last recording prior to selection. In both experiments, milk samples proportionate to yield were taken from individual cows twice in 24 h (morning and afternoon milking) during weeks 1, 3 and 6, with samples mixed before being stored at −20 °C until analysis. Cows from both herds were loose housed with fresh straw bedding added daily and feed offered once a day as a mixed ration, with additional concentrate feed provided in the milking parlour twice per day. The organic herds received a mixed ration based on silage made from organically managed ryegrass/white clover and red clover swards, and conventional cows were fed a diet based on silage made from pure ryegrass swards. Table 1 lists the quantities of silage and other ingredients included in the

Table 1
Ingredients and composition of concentrate diets and conserved forage intake in both experiments (kg DM/cow/day). Diets were planned to be iso-nitrogenous within management systems (conventional, organic) for each experiment.

	Experiment 1						Experiment 2			
	Conventional (C1)			Organic (O1)			Conventional (C2)		Organic (O2)	
	Control	Linseed	Rapeseed	Control	Linseed	Rapeseed	Control	Linseed	Control	Linseed
Silage[a]	12.8	13.0	11.9	13.3	14.1	12.4	10.7	9.9	14.0	15.4
Straw[b]	–	–	–	–	–	–	0.3	0.4	0.3	0.6
Concentrates										
Wheat	3.5	3.0	2.9	2.9	2.9	2.6	2.7	2.3	2.3	2.2
Extracted rapeseed meal: extracted soyabean meal	1.8	1.4	1.4	–	–	–	0.8	1.0	–	–
Beans	–	–	–	1.2	–	0.2	1.6	–	1.6	0.3
Molasses	0.5	0.6	0.5	–	–	–	0.7	0.7	–	–
Rolled rapeseed	–	–	1.2	–	–	1.0	–	–	–	–
Rolled linseed	–	1.5	–	–	1.4	–	–	2.0	–	2.0
Minerals/vitamins[c]	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	–	–
Compound feed	2.5	2.5	2.5	2.5	2.5	2.5	3.3	3.3	3.7	3.7
Estimated intakes[d]										
Dry matter (kg)	21.2	22.0	20.4	20.2	21.1	18.8	20.1	19.7	21.9	24.1
Metabolisable energy (MJ/kg DM)	10.3	10.8	10.7	9.9	10.2	10.1	9.7	10.2	9.7	10.3
Neutral detergent fibre (% of DMI)	30.4	29.8	29.4	29.9	29.9	29.9	26.7	25.4	28.1	28.2
Crude protein (% of DMI)	15.0	15.0	14.9	14.7	14.3	14.4	13.7	13.7	12.9	12.9
Lipid intake (kg/cow/day)	0.8	1.3	1.2	0.6	1.1	1.0	0.8	1.4	0.7	1.4
Concentrates (% of DMI)	39.7	41.3	42.1	34.2	33.3	34.5	45.5	47.6	34.7	33.9

[a] Conventional silage was made of grass while organic silage was a mixture of organically grown grass and clover.
[b] Straw was not included in the diet in trial 1 but cows bedded daily on fresh straw.
[c] Organic supplements excluded vitamins.
[d] Based on weighed feed dispensed in each group.