Relationship between milk fatty acid composition and dietary roughage source in dairy cows

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Abstract According to a 2×2 crossover design, 14 Holstein dairy cows were fed two isoenergetic diets based on either grass hay (GH) or maize silage (MS). Milk samples were collected during the third week of each period, and fatty acid (FA) profiles were analyzed using gas chromatography. The data obtained were subjected to ANOVA. Dietary treatment had no effect on either dry matter intake or milk yield. Milk from animals fed the GH-diet contained lower concentrations of saturated FAs (61.9 vs. 63.4% of total FAs; $P<0.05$) and higher levels of polyunsaturated FAs (PUFAs) (6.1 vs. 5.8; $P<0.01$). Feeding additional hay also increased conjugated linoleic acid and n-3 FA levels and decreased C16:0 levels. Increases in both PUFAs and n-3 FAs resulted in lower ($P<0.01$) atherogenic and thrombogenic indices in milk from animals fed the GH diet compared with those fed the MS diet. A complete substitution of GH for MS appeared to improve milk FA profiles, even using different types of concentrates to provide a balanced diet.

Keywords Dairy cow · Roughage source · Fatty acids · Conjugated linoleic acid

Abbreviations

CLA	conjugated linoleic acid
FA	fatty acid
GH	grass hay
MS	maize silage
SFA	saturated fatty acid
MUFA	monounsaturated fatty acid
PUFA	polyunsaturated fatty acid

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Introduction

In dairy cows, the source of roughage affects the organoleptic and nutritional quality of milk, particularly the fatty acid (FA) profile (Shingfield et al. 2005; Egger et al. 2007). Differences between grass hay (GH) and maize silage (MS) are evident in single FA contents. The storage system used could affect FA availability (Chilliard et al. 2001). For example, oxidation during haying decreases the polyunsaturated fatty acid (PUFA) content in grass (Dewhurst et al. 2002). The dietary inclusion of GH enhances the content of monounsaturated fatty acids (MUFA), PUFA, and conjugated linoleic acid (CLA) in milk (Shingfield et al. 2005; Bauman et al. 2006). The increase of unsaturated FAs leads to a reduction of the ratio between saturated fatty acids (SFA) and PUFAs, thus improving milk nutritional quality (Williams 2000). Finally, recent studies *in vitro* and *in vivo* with laboratory animals (Wahale et al. 2004) showed that CLA had a positive effect against cancer and obesity. The aim of the present study was to assess the influence of the roughage source, MS or GH, on milk FA profiles of dairy cows.

Materials and methods

According to a 2×2 (2 diets×2 periods) cross-over design, 14 Holstein Friesian dairy cows (212±99 days in milk; 26.7±5.9 kg milk/d) were fed two isoenergetic (0.94 *Unité Fourragère Lait* per kg of dry matter), isonitrogenous and isofibrous, diets based on MS or GH and balanced by using protein and starch blends. The approximate composition of diets (Table 1) was assed by NIRS technology (Berzaghi et al. 2000). After a 3-week adaptation period, milk samples were analyzed by gas chromatography to obtain FA profiles. Aliquots of 10 mL were centrifuged for 10 min at 4000 × *g*. One-hundred milligrams of surfaced fat was mixed with 4 mL methanol and 4 mL *n*-heptane and centrifuged for 5 min at 4000 × *g* (Novelli et al. 2004). Two milliliters of the upper phase containing the ether extract was trans-esterified with sodium methoxide and oxalic acid. Fatty acid methyl esters were quantified by gas chromatography (Shimatzu GC17A) equipped with an Omegawax 250 capillary column (30 m×0.25 mm×0.25 µm; Supelco, Bellefonte, PA, USA). Data were reported as the percentage of total detected FA and were used to calculate atherogenic and thrombogenic indexes (Ulbricht and Southgate 1991) according to a linear model. Data were subjected to analysis of variance (SAS 2002) using diet and period as fixed effects and cows as the random effect.

Table 1 Ingredients (g/kg dry matter) and approximate composition (%) of diets

	MS diet	GH diet
Maize silage	356	—
Permanent meadow hay	192	398
Dehydrated alfalfa	40	40
Maize and barley meal	163	314
Sugar beet pulps	23	47
Proteic and mineral blend	226	201
Crude protein	14.5	15.0
Ether extract	4.5	3.9
Crude ash	6.9	7.6
Neutral-detergent fibre	35.8	36.2
Non-fibrous carbohydrates	38.3	37.3

Results

Feed intake, milk production, and milk quality traits were not affected by the dietary treatment (data not shown). As shown in Table 2, the partial substitution of MS with GH led to a change in the milk FA profile, resulting in a significant reduction of SFA. This change was characterized by a relevant decrease of C16:0 and by an opposite trend of C18:0 which resulted in an increase.

The GH diet affected the increase of MUFA and PUFA, with particular regard to C18:1 n-9 and C18:3 n-3. The greater the inclusion of hay in GH diets the greater the CLA content was in the milk. The nutritional values of GH-milk were improved by the increase of MUFA and PUFA and by a reduction of the n-6/n-3 ratio resulting in a significant decrease of atherogenic and thrombogenic indexes.

Discussion

In dairy cows, diet fodder can be considered the main source of FA, but feed storage systems can affect the FA availability (Chilliard et al. 2001). In accordance with the

Table 2 Effect of diet on fatty acid profile (% of the total detected FA) of milk

	MS diet	GH diet	P	SEM
C4:0	2.2	2.2	ns	0.1
C6:0	1.8	1.8	ns	0.1
C8:0	1.2	1.2	ns	0.1
C10:0	2.1	2.0	ns	0.1
C12:0	3.6	3.6	ns	0.2
C14:0	10.9	10.9	ns	0.3
C14:1	0.9	1.0	ns	0.1
C15:0	1.1	1.1	ns	0.1
C16:0	27.7	25.9	**	0.6
C18:0	11.2	12.0	**	0.5
C18:1 n-9	19.7	20.7	**	0.5
C18:1 n-7	2.3	2.3	ns	0.2
C18:2 n-6	4.1	4.2	ns	0.1
C18:3 n-6	0.1	0.2	*	0.1
C18:3 n-3	0.6	0.8	*	0.1
CLA	0.7	0.9	*	0.1
C20:0	0.2	0.2	ns	0.1
C20:4 n-6	0.2	0.2	ns	0.1
Σ SFA	63.4	61.9	*	0.7
Σ MUFA	24.4	25.7	*	0.6
Σ PUFA	5.8	6.1	**	0.2
n-6/n-3	6.05	5.60	**	0.07
Atherogenic index	2.55	2.37	**	0.09
Thrombogenic index	1.48	1.38	**	0.04

* $P < 0.05$, ** $P < 0.01$

literature (Shingfield et al. 2005), the present study showed that milk from GH-fed cows was characterized by an increase in MUFA and PUFA, even if the increases of C18:3 n-6 and C18:3 n-3 were rather low. Due to the physical and chemical form of PUFA in the hay and to the possible oxidation during storage, part of this FA is saturated through rumen biohydrogenation, and the remaining amount is transferred to milk (Dewhurst et al. 2002). The higher CLA content is related to desaturation at the mammary gland level of C18:1 n-7, which is one of the terminal products of rumen biohydrogenation (Leiber et al. 2005). The results of this trial showed that GH-milk was characterized by higher contents of C18:3 n-3 and C18:0, whereas C18:1 n-7 was similar in both diets. These differences are the consequence of higher levels of C18:3 n-3 in GH diets and of rumen FA biohydrogenation, respectively. The FA profiles could also have been partially affected by the blends used to balance the diets. Taking into account the higher unsaturated/saturated ratios and the lower n-6/n-3 ratios, as well as the higher CLA concentration, the GH diet led to improved milk nutritional traits (Williams 2000; Wahale et al. 2004). PUFAs however are susceptible to auto-oxidation causing the development of off-flavors affecting milk rheological traits. The haying process reduces the amount of natural antioxidant compounds, such as α -tocopherol, β -carotene, and ascorbic acid that could support the oxidation process. In conclusion, the partial substitution of maize silage with grass hay in isofibrous diets, improved milk acidic profiles, thus enhancing the human intake of beneficial FAs.

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