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Response of Milk Fatty Acid Composition to Dietary Supplementation of Soy Oil, Conjugated Linoleic Acid, or Both[1]

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ABSTRACT

Thirty-six Holstein cows were blocked by parity and allotted by stage of lactation to 6 treatments to evaluate the effects of dietary soy oil, conjugated linoleic acid (CLA; free acid or calcium salt), or both, on CLA content of milk. Diets were fed for 4 wk and are as follows: (1) control, (2) control + 5% soy oil, (3) control + 1% CLA, (4) control + 1% $Ca(CLA)_2$, (5) control + 1% CLA + 4% soy oil, and (6) control + 1% $Ca(CLA)_2$ + 4% soy oil. Rumen volatile fatty acid concentrations, blood fatty acid concentrations, milk yield, and milk composition were measured weekly or biweekly. Dry matter intake and milk yield were recorded daily. Dietary supplementation of soy oil or CLA had no effect on daily milk yield, milk protein concentration and production, or milk lactose concentration and production. Supplementation of unsaturated fatty acids as soy oil, CLA, or $Ca(CLA)_2$ increased total fatty acid concentration in plasma, decreased milk fat concentration and production, and had no effect on rumen volatile fatty acid concentrations. The weight percentage of CLA in milk was increased from 0.4 to 0.7% with supplementation of 1% CLA, to 1.2% with supplementation of soy oil, and to 1.3% with supplementation of 1% CLA plus soy oil. Supplementation with $Ca(CLA)_2$ or $Ca(CLA)_2$ + soy oil increased the CLA content of milk fat to 0.9 and 1.4%, respectively. In summary, adding 5% soy oil was as effective as supplementing CLA, $Ca(CLA)_2$, or a combination of 1% CLA (free acid or calcium salt) + 4% soy oil at increasing CLA concentrations in milk fat. Feeding CLA as the calcium salt resulted in greater concentrations of CLA in milk fat than did feeding CLA as the free acid. Dietary supplementation of 5% soy oil or 4% soy oil + 1% CLA as the free acid or the calcium salt increased the yield of CLA in milk.
Key words: calcium, conjugated linoleic acid, rumen, volatile fatty acid

INTRODUCTION

Conjugated linoleic acid (**CLA**) has been reported to have a wide range of beneficial effects including anticarcinogenic (Parodi, 1994), antiatherogenic (Lee et al., 1994), and antiobesity activities (Pariza et al., 1996) as well as the ability to stimulate immune function (Miller et al., 1994). Ruminant meat, milk, and dairy products are the predominant sources of CLA in the human diet (Lawson et al., 2001). Total CLA content in milk or dairy products ranges from 0.34 to 1.07% of total fat, and it is currently estimated that the average adult consumes only one-third to one-half of the amount of CLA that has been shown to decrease cancer incidence in animal studies (Dhiman et al., 2005). For this reason, increasing the CLA content of milk has the potential to raise the nutritive and therapeutic values of dairy products.

Conjugated linoleic acid originates from either incomplete biohydrogenation of linoleic or linolenic acid to stearic acid in the rumen (Fellner et al., 1995) or from endogenous synthesis in the mammary gland or adipose tissue. Endogenously, *cis*-9, *trans*-11 CLA (the primary isomer found in milk) is synthesized from *trans* vaccenic acid, another intermediate of ruminal biohydrogenation, via Δ^9-desaturase in tissues (Corl et al., 2001). The CLA content of milk and meat is affected by several factors including the animals breed, age, and diet. Providing plant (soybean, sunflower, corn, canola, flaxseed) and marine oils in the diet (Dhiman et al., 2000; Ramaswamy et al., 2001; Abu-Ghazaleh et al., 2003), pasture feeding (Dhiman et al., 1999), decreasing the forage-to-concentrate ratio (Kelly and Bauman, 1996), and supplementing diets with ionophores such as monensin (Fellner et al., 1997) all increase ruminal production of CLA and its secretion into milk fat. Protecting supplemental CLA from ruminal biohydrogenation may be an additional strategy to increase the CLA content of milk.

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Calcium salts of long-chain fatty acids have been utilized extensively as an energy source in diets of lactating dairy cows. The salts remain relatively inert in the rumen under normal pH conditions and do not inhibit ruminal bacteria as do free long-chain fatty acids; the calcium salts then dissociate in the acidic conditions of the abomasum (Jenkins and Palmquist, 1984). Feeding calcium salts of CLA has been reported to increase CLA and decrease monounsaturated fatty acids in sheep tissues (Wynn et al., 2006), beef tissues (Gillis et al., 2004), and milk fat of early-lactation cows (Castaneda-Gutierrez et al., 2005) and midlactation cows (Giesy et al., 2002) but not cows in established lactation (Perfield et al., 2002).We hypothesize that supplementing dairy diets with the calcium salt of CLA, because they are less subject to ruminal biohydrogenation, will increase the CLA content in milk to a greater extent than supplementing the diet with the free acid of CLA or with soy oil. Thus, the objective of this study was to determine the effect of different dietary fat sources on milk fatty acid content.

MATERIALS AND METHODS

Experimental Design

Twelve primiparous and 24 multiparous Holstein cows in midlactation were used in a completely randomized block design experiment to evaluate the effects of dietary soy oil or CLA (free acid or calcium salt) on CLA content of milk. Cows were blocked by parity and were randomly assigned to 1 of 6 treatments. Diets were fed for 4 wk, and cows were managed in accordance with guidelines provided by the Iowa State University Committee on Animal Care. The 6 different diets were as follows: (1) control, (2) control + 5% soy oil, (3) control + 1% CLA, (4) control + 1% $Ca(CLA)_2$, (5) control + 1% CLA + 4% soy oil, and (6) control + 1% $Ca(CLA)_2$ + 4% soy oil. All diets were formulated to meet NRC (1989) requirements and were fed as TMR (Table 1). Supplemental CLA was included in the diet as an oil (provided courtesy of Conlinco Inc., Detroit Lakes, MN). The oil contained 67% CLA (Table 2) by weight and was added to the diet at 1.67% (DM basis) to provide 1% CLA in the diet. The $Ca(CLA)_2$ was prepared (courtesy of Eiler Frederiksen of Bioproducts Inc., Las Vegas, NV) by combining 18.09 g of CaO, 17.79 g of water, and 100.4 g of CLA-containing oil (FFA form, see above) and was added to the diet at 1.91% to provide 1% CLA in the diet. Dry matter content was approximately 60% for all 6 diets. Diets containing added soy oil or CLA had an increased concentration of total fatty acids, an increased percentage of $C_{18:0}$, and a decreased percentage of $C_{16:0}$, $C_{18:1}$, $C_{18:2}$, and $C_{18:3}$ compared with the control diet (Table 2).

Table 1. Ingredients and chemical composition of diets[1]

Composition	Control diet[2]	Soy-oil diets[2]
Ingredient, % of DM		
Alfalfa haylage	7.4	7.0
Corn silage	31.3	29.8
Alfalfa hay	9.6	9.1
High-moisture corn	24.2	23.0
Corn gluten feed	13.0	12.3
Soybean meal	11.0	10.5
Vitamin-mineral supplement[3]	3.5	3.3
Soybean oil	0.0	5.0
Chemical composition		
CP	16.8	15.9
ADF	17.9	16.9
NDF	30.5	29.0
Lipid	3.0	8.0
Ash	6.9	6.6
NE_L,[4] Mcal/kg	1.67	1.87
NFC[5]	42.8	40.5

[1]Dry matter on an as-fed basis = 62.4%.

[2]To provide 1% conjugated linoleic acid (CLA) in the CLA-containing diets, CLA-containing oil was added at 1.67% of the diet (DM basis) for the free acid diets and 1.91% (DM basis) for the $Ca(CLA)_2$ diets.

[3]Contained 13.83% Ca, 3.66% P, 3.14% Mg, 0.07% K, 7.70% Na, 5.42% Cl, 0.22% S, 8.03 mg/kg of Co, 451.41 mg/kg of Cu, 6,327.41 mg/kg of Fe, 21.58 mg/kg of I, 1,855.15 mg/kg of Mn, 16.20 mg/kg of Se, 2,535.57 mg/kg of Zn, 152.03 kIU/kg of vitamin A, 33.05 kIU/kg of vitamin D, and 1,316.54 kIU/kg of vitamin E. The mineral supplement was prepared by The Heart of Iowa Cooperative (Gilbert, IA).

[4]Calculated using NRC (2001) values.

[5]Calculated as 100 – (CP + NDF + lipid + ash).

Sample Collection and Measurements

The TMR samples were collected at wk 0, 2, and 4. Milk samples, from the a.m. and p.m. milkings, were collected, and equal volumes were combined for each cow during wk 0, 1, 2, 3, and 4. Rumen fluid was collected via an esophageal tube from each cow during wk 0 and 4. Blood was collected from coccygeal veins during wk 0, 2, and 4, and plasma was prepared from heparinized blood samples by centrifugation at 800 × g for 10 min at 4°C. All samples were stored at –20°C until analysis. Milk production was recorded daily. A duplicate set of milk samples was stored at 4°C until analysis of fat, protein, and lactose content by midinfrared spectrophotometry (MilkoScan 203, Foss Food Technology Corp., Eden Prairie, MN; AOAC, 1991). Milk samples were analyzed by Dairy Lab Services (Dubuque, IA). Dry matter in feed was quantified by drying feed at 65°C for 48 h (AOAC, 1991) in a forced-air oven. Nitrogen in feed samples was quantified by Kjeldahl analysis (AOAC, 1991). Lipid content of feed was determined gravimetrically by the procedure of