J. Dairy Sci. 95:5276–5284
http://dx.doi.org/10.3168/jds.2012-5415

Transfer rate of α-linolenic acid from abomasally infused flaxseed oil into milk fat and the effects on milk fatty acid composition in dairy cows

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ABSTRACT

The objectives of the present study were to evaluate the transfer efficiency of α-linolenic acid (ALA) from the abomasum into milk fat, its interaction with milk fat content and yield, and the relationship between ALA and C16:0 in milk fat. Three rumen-fistulated multiparous Holstein cows at midlactation were used in a 3 × 3 Latin square design. Treatments consisted of abomasal infusion of (1) 110 mL of water/d (control), (2) 110 mL of flaxseed oil/d (low flaxseed oil, LFO), and (3) 220 mL of flaxseed oil/d (high flaxseed oil, HFO). Experimental periods were continued for 2 wk and fat supplements were infused abomasally during the last 7 d of each period. Average dry matter intake and milk yield were not affected by oil infusion. Milk fat and lactose content tended to be greater with flaxseed infusion compared with the control. Plasma ALA was 2.9- and 4.0-fold greater with LFO and HFO, respectively. The apparent transfer efficiency of ALA to milk was 44.8 and 45.7% with LFO and HFO, respectively. The C16:0 content in milk fat was decreased by 3.59 and 5.25 percentage units, whereas the ALA content was increased by 1.68 and 3.09 percentage units with LFO and HFO, respectively. Similarly, C18:2n-6 was increased by 0.95 and 1.31 percentage units with LFA and HFO, respectively, without changes in other fatty acids (FA). Total polyunsaturated FA was 4.4 and 2.7% lower in the HFO and LFO, respectively, than in the control. Furthermore, C16:0 content in the milk fat was reduced to a greater extent than the increase in ALA content, as a 1.68 and 3.09 percentage unit increase occurred in ALA compared with a 3.6 and 5.25 percentage unit decrease in C16:0 for LFO and HFO, respectively, such that a negative correlation existed between ALA and C16:0 ($r = -0.72$). In conclusion, abomasal infusion of flaxseed oil dramatically increased the ALA content in plasma and milk fat. Because the replacement of C16:0 with ALA and C18:2n-6 occurred without changes in other FA presumed to be synthesized de novo in the mammary gland, this suggests that the preformed C16:0 was replaced, rather than being caused, by an overall suppression of de novo FA synthesis in the mammary gland.
Key words: α-linolenic acid, flaxseed oil

INTRODUCTION

Omega-3 FA plays significant roles in several biological pathways (Deckelbaum et al., 2006). The chain length and the position of the double bonds provide distinct characteristics to these FA that confer them unique biological capabilities that are beneficial to human health; for example, they have been shown to decrease the incidence of cardiovascular diseases, hypertension, and arthritis (Simopoulos, 2002). Therefore, a growing interest exists in enhancing the proportion of these FA in milk fat.

Flaxseed is a rich source of n-3 FA, containing approximately 50% α-linolenic acid (**ALA**). Studies on feeding flaxseed to dairy cows resulted in an increased n-3 FA content and a decreased n-6/n-3 ratio in milk fat. Several studies investigated the effect of feeding a variety of flaxseed forms to test the magnitude of transfer of ALA into milk fat and the results were inconsistent. The rate of increase of ALA in milk fat ranged from 1.8 to 3 fold (Petit et al., 2004; Ambrose et al., 2006). Differences in the apparent transfer rate between studies may be ascribed to the difference in the proportion of ALA in the control groups and to the form of flaxseed fed.

In a recent study (Zachut et al., 2010), feeding high rates of extruded flaxseed (9.2% of diet, providing 402.5 g of ALA/d per cow) to dairy cows increased the proportion of ALA in milk by up to 2 percentage points. However, enrichment of ALA in milk fat was also negatively correlated with milk fat percentage. Although no change in de novo synthesized FA of less than 16 carbons was found, C16:0 yields were markedly decreased. Furthermore, the yield of C16:0 was nega-

Received February 7, 2012.
Accepted June 3, 2012.
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tively correlated with ALA content in milk fat (Zachut et al., 2010).

We hypothesized that ALA per se suppresses de novo synthesis of C16:0 in the mammary gland without impairing the synthesis of short-chain FA. Direct feeding of fat sources containing high concentrations of ALA such as flaxseed would likely alter production of rumen biohydrogenation end products such *trans*-10,*cis*-12 conjugated linoleic acid (**CLA**) and other C18:1 and C18:2 *trans* isomers, which are responsible for depressing milk fat synthesis and altering milk FA composition; indeed, several studies reported higher concentrations of CLA and C18:1 *trans* isomers in milk fat of cows supplemented with extruded flaxseed (Mustafa et al., 2003; Gonthier et al., 2005; Chilliard et al., 2009). Therefore, abomasal infusion of flaxseed oil allows for study of the effects of ALA on milk fat synthesis and composition without the confounding effects of changes in rumen biohydrogenation. The objectives of the present experiment were to evaluate the transfer efficiency of postruminal ALA from flaxseed oil to milk fat, the interaction of ALA with milk fat content and yield, and the relationship between ALA and C16:0 in milk fat.

MATERIALS AND METHODS

The experimental protocol and procedures were approved by the University of Maryland Institutional Animal Care and Use Committee (College Park). Three rumen-fistulated multiparous Holstein cows in midlactation (49 ± 20 DIM; mean ± SD) were used in a 3 × 3 Latin square design, with 14-d experimental periods. Treatments consisted of twice-daily (0630 and 1900 h) abomasal infusion of the following: (1) 110 mL of water/d (control), (2) 110 mL of flaxseed oil/d (low flaxseed oil, **LFO**), and (3) 220 mL of flaxseed oil/d (high flaxseed oil, **HFO**). Cows were not infused during d 1 to 7 of each experimental period to reduce carryover effects of the previous treatment. Abomasal infusion of different treatments was from d 8 to 14 of each period. Oil was filled in syringes and was infused via Tygon tubing (0.48-cm i.d., 0.64- cm o.d.; VWR Scientific Inc., Bridgeport, NJ) as described by Kadegowda et al. (2008). The daily amounts of infused flaxseed oil or water were split into 2 equal portions and manually infused twice daily, at 0630 and 1900 h. Patency and location of the infusion line inside the cow were checked on alternate days.

Cows were housed in individual tie-stalls and were fed a basal diet containing 55% forage and 45% concentrate (DM basis) to meet NRC (2001) nutrient specifications for a 650-kg cow producing 40 kg of milk containing 3.7% milk fat and 3.1% milk protein. Ingredients and chemical composition of the basal diet are shown in Table 1. Diets were fed as TMR once daily at 0800 h. Corn silage DM was determined weekly, and the TMR was adjusted accordingly to maintain a constant forage-to-concentrate ratio on a DM basis. Amounts of feed offered and refused were recorded once daily. Cows were milked twice per day at 0600 and 1600 h, and milk production was recorded electronically at each milking.

Samples for milk composition and FA analysis were collected from 2 consecutive milkings on d 7 of each period, before infusion, and from 6 consecutive milkings on d 12 to 14 of each experimental period. Milk fat, CP, and SCC were determined by infrared analysis (MilkoScan; Foss Food Technology Corp., Eden Prairie, MN) on fresh samples from individual milkings. A subset of samples from each milking was composited and frozen at −20°C for subsequent analysis of FA profile in milk fat.

Table 1. Ingredient and chemical composition of the basal diet

Composition	Value
Ingredient, % of DM	
Corn silage	55.04
Corn grain, ground	22.01
Soybean meal	19.19
Corn gluten meal	0.45
Limestone	0.62
BioPhos[1]	0.43
Magnesium oxide	0.16
Sodium bicarbonate	0.57
Dynamate[2]	0.13
Salt	0.38
Trace minerals and vitamins[3]	0.46
Megalac[4]	0.56
Chemical composition (DM basis; % of DM unless noted)	
DM, %	58.16
CP	16.39
RUP	42.63[5]
ADF	15.19
NDF	26.22
NE_L, Mcal/kg	1.56[5]
Ca	0.75
P	0.43
Mg	0.26
K	1.36
S	0.23
Na	0.29
Cl	0.39
DCAD, mEq/100 g of DM	21.78

[1]IMC-Agrico, Bannockburn, IL.

[2]The Mosaic Co. (Plymouth, MN).

[3]Trace mineral and vitamin mix combined (per kilogram of mix): 1,732 mg of Co, 2,207 mg of Cu, 1,196 mg of Fe, 141 mg of I, 980 mg of Mn, 8,153 mg of Zn, 75 mg of Se, 819,000 IU of vitamin A, 273,000 of vitamin D, and 4,880 IU of vitamin E.

[4]Church and Dwight Co. Inc., Princeton, NJ.

[5]Calculated value.