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Effects of urea formaldehyde condensation polymer treatment of flaxseed on ruminal digestion and lactation in dairy cows

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ABSTRACT

Flaxseed is a potent source of the n-3 fatty acid α-linolenic acid (ALA), yet most ALA is lost during ruminal biohydrogenation when ground flaxseed is fed to ruminants. Heat processing and urea formaldehyde condensation polymer (UFCP) treatment of flaxseed were investigated as possible means of protecting ALA from ruminal degradation. Ground flaxseed (GF), heated ground flaxseed (HGF), or UFCP-treated ground flaxseed (UFCPGF) were incubated for 0, 4, 8, and 12 h in 4 ruminally cannulated multiparous lactating Holstein cows. Compared with GF, HGF and UFCPGF decreased ruminal disappearance of dry matter, crude protein, and ALA. Pepsin-digestible protein remaining after 12 h of ruminal incubation was greater for UFCPGF and HGF than for GF. Twenty-four lactating Holstein cows (207 ± 37 d in milk, 668 ± 66 kg of body weight, and 1.33 ± 0.56 lactations) were then used in a randomized complete block design experiment with a basal feeding period to assess effects of flaxseed treatment on ALA enrichment of plasma and milk as well as lactational performance. No evidence existed that supplementation of HGF and UFCPGF affected dry matter intake, milk fat content, milk protein content, or energy-corrected milk yield, but UFCPGF marginally decreased milk yield compared with HGF. Plasma concentration of ALA was not affected by treatment. Concentrations of n-3 fatty acids and conjugated linoleic acids in milk fat were increased by UFCPGF relative to HGF, but ALA yield was not affected. Taken together, in situ results suggest that heat-treated flaxseed, with or without UFCP treatment, slowed ruminal disappearance of ALA. Feeding UFCP-treated flaxseed failed to alter ALA content of plasma or milk ALA yield relative to heating alone.

Key words: flaxseed, milk fatty acid, dairy cow

INTRODUCTION

The n-3 FA are essential for the normal physiological functions and health of humans and domestic animals (Palmquist, 2009). Dietary supplementation with α-linolenic acid (**ALA**), a type of n-3 FA, has been shown to prevent cardiovascular diseases in humans (Bloedon and Szapary, 2004). In dairy cows, dietary supplementation of whole flaxseed, an oilseed rich in ALA, during the dry period decreased liver triacylglycerol accumulation after calving (Petit et al., 2007). In addition, feeding whole flaxseed, compared with feeding calcium salts of palm oil or micronized soybeans, decreased embryo mortality for cows that conceived within 120 d postpartum (Petit and Twagiramungu, 2006). Furthermore, whole flaxseed supplementation increased serum n-3 FA concentration and transiently reduced lymphocyte proliferation in postparturient cows, suggesting a role of flaxseed in modifying immune function in dairy cows (Lessard et al., 2003). Perhaps more interestingly, dietary supplementation of flaxseed to cattle has been investigated as a method to increase n-3 FA content in milk fat, for the purpose of improving human health (Petit, 2002, 2003; Côrtes et al., 2010). However, because flaxseed oil is extensively modified by ruminal biohydrogenation (**BH**), only small percentages of PUFA innate to flaxseed oil are absorbed by cattle and incorporated into milk (Lock and Bauman, 2004; Palmquist, 2009).

Chemical or physical (or both) treatments of oilseeds have been shown to slow ruminal BH of dietary PUFA (Palmquist, 2009) and protein degradation (Broderick and Craig, 1980). Both fat and protein constituents in lipid supplements treated with formaldehyde are highly protected from ruminal metabolism and are readily digested in the small intestine (Gulati et al., 2005). Tymchuk et al. (1998) reported that cattle consuming ground canola seed treated with formaldehyde had increased milk concentrations of PUFA, possibly as a result of reduced ruminal BH. However, the optimum treatment levels of formaldehyde vary considerably,

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depending on the passage rate of the feed through the rumen, making it difficult to use formaldehyde effectively (Lebo and Winowiski, 2008). Recently, Lebo and Winowiski (2008) reported that treatment with a urea formaldehyde condensation polymer (**UFCP**) reduced in vitro ruminal degradation, but not intestinal digestibility, of protein from oilseeds. It is possible that UFCP treatment may provide superior protection of PUFA relative to existing technologies.

Two experiments were conducted with the objectives to (1) evaluate the effects of heating and UFCP treatment on nutrient digestion from flaxseed, (2) assess plasma and milk enrichment of n-3 FA in response to UFCP treatment versus heating of flaxseed, and (3) assess effects of UFCP treatment versus heating of flaxseed on lactational performance. We hypothesized that compared with heating alone, treating flaxseed with UFCP could better protect ALA from ruminal BH and subsequently increase plasma and milk concentrations of these bioactive lipids.

MATERIALS AND METHODS

The Kansas State University Institutional Animal Care and Use Committee (Manhattan) approved all experimental procedures.

Ruminal Disappearance Experiment

Four ruminally cannulated multiparous lactating Holstein cows (120 ± 10 DIM, mean ± SD) were housed in individual tiestalls and fed a diet with no added fat (basal diet; Table 1) beginning 10 d before measures of ruminal nutrient disappearance.

Ground flaxseed (**GF**), heated ground flaxseed (**HGF**), and UFCP-treated ground flaxseed (**UFCPGF**; LignoTech USA, Rothschild, WI) were manufactured from a common flaxseed source. The composition of UFCP was reported in Lebo and Winowiski (2008). All flaxseed was coarsely ground; one aliquot was then heated to 100°C by direct addition of steam over a 4-min period and held at temperature for 16 min to produce the HGF. Another aliquot was used to manufacture UFCPGF using a 1:99 ratio of UFCP to GF with the same heating conditions as used for HGF. Samples (1 g) of GF, HGF, and UFCPGF were weighed into Dacron bags (5 × 10 cm, 50-μm pore size; Ankom Technology, Macedon, NY), placed in weighted mesh bags (36 × 42 cm), and ruminally incubated in each of the 4 cannulated cows. Quadruplicate samples of GF, HGF, and UFCPGF were removed from each cow after 0 (5 min of soaking), 4, 8, or 12 h of ruminal incubation (Hussein et al., 1995), and placed in an ice bath until being rinsed (1-min agitation and 2-min spin, for 5 cycles) in a washing machine (Series 80 washing machine; Kenmore, Hoffman Estates, IL) with warm water (30°C). Rinsed samples were subsequently dried (55°C) in a forced-air oven for 72 h. The N content of residue samples was determined by oxidation and detection of N_2 (Midwest Laboratories Inc., Omaha, NE). In addition, pepsin-digestible protein content was determined in samples removed after 12 h of ruminal incubation (AOAC International, 1995; method 971.09).

Lactation Experiment

Twenty-four lactating Holstein cows (207 ± 37 DIM, 668 ± 66 kg of BW, and 1.33 ± 0.56 lactations) were blocked by milk yield and randomly assigned to 1 of 2 diets. Prior to receiving dietary treatments, cows were fed a common basal diet with no added fat (basal diet; Table 1) for 21 d. During this time, cows were housed in a group pen for 14 d and were moved to tiestalls on d 15 for the remainder of the experiment. Cows were milked 3 times daily (0300, 1100, and 1900 h) in a milking parlor and fed twice daily (0930 and 1800 h) for ad libitum intake, targeting 5 to 15% daily refusals. Milk was sampled using in-line samplers and yields recorded at each milking on d 19 to 21. Blood samples were collected before feeding on d 21 (0930 h) from the coccygeal vein or artery into 10-mL evacuated tubes containing K_3-EDTA (Vacutainer; Becton Dickinson, Franklin Lakes, NJ). Blood samples were centrifuged at 2,000 × *g* for 15 min immediately after collection; plasma was harvested and frozen (−20°C) until analysis.

Treating flaxseed with UFCP requires heating, and heating was shown in the ruminal experiment to alter the loss of ALA from flaxseed. Therefore, to carefully assess the effect of UFCP treatment per se, UFCPGF was compared with HGF in the lactation experiment. Cows were fed dietary treatments containing either HGF or UFCPGF (Table 1) for 21 d immediately following the 21-d basal feeding period. Feed offered and refused were measured daily, and feed ingredient and TMR samples were collected throughout the experimental period. Milk samples were collected at each milking on d 18 to 19, and blood samples were collected on d 21 as described for the basal period.

Sample Analyses

Milk samples were analyzed for concentration of fat, true protein, lactose (B-2000 Infrared Analyzer; Bentley Instruments Inc., Chaska, MN), MUN (MUN spectrophotometer; Bentley Instruments Inc.), and somatic cells (SCC 500; Bentley Instruments Inc.) by Heart of America DHIA (Manhattan, KS). Diet ingredients and