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Effect of flaxseed physical form on digestibility of lactation diets fed to Holstein steers

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ABSTRACT

Four multicannulated (rumen, duodenum, and ileum) Holstein steers (459.7 ± 46.4 kg of initial body weight) were used in a 4 × 4 Latin square design to determine the effect of flaxseed processing method on ruminal fermentation and digestibility. Treatments were based on inclusion of (1) 7.5% linseed meal (control), (2) 10% whole flaxseed, (3) 10% rolled flaxseed, or (4) 10% ground flaxseed on a dry matter (DM) basis, and were formulated to mimic typical high-producing dairy cow lactation diets. The control diet contained linseed meal in a proportion to provide crude protein (CP) equal to the amount of CP contributed by the flaxseed in the other treatments. Diets were fed for ad libitum intake and contained 30% corn silage, 17% chopped alfalfa hay, 6% sugar beet pulp, and 47% concentrate (comprising ground corn, supplemental protein, trace minerals and vitamins, and either flaxseed or linseed meal (DM basis). Diets were formulated to contain 17% CP, 34% neutral detergent fiber, 21% acid detergent fiber, and 4% fatty acid (DM basis). Periods were 14 d long and consisted of 7 d of adaptation and 7 d of sample collection. Dry matter intake (as a % of body weight) was similar (2.41 ± 0.17) for all treatments. The inclusion of flaxseed, regardless of processing method, tended to decrease total-tract organic matter digestibility relative to the linseed control, but no differences in CP intake, duodenal CP flow (bacterial, apparent feed, or total), ileal CP flow, fecal CP output, microbial efficiency, or CP digestibility (apparent ruminal, true ruminal, small intestine, large intestine, or total tract) were observed between treatments. Method of processing did not alter ruminal pH, ammonia, or volatile fatty acids production. The ground flaxseed treatment had the fastest rate of in situ DM degradation (11.25%/h), followed by the control (7.46%/h), rolled flaxseed (4.53%/h), and whole flaxseed (0.57%/h) treatments. Degradability of CP and fat followed the same pattern as DM degradability for processed flaxseed. In situ degradation rates of alfalfa hay neutral detergent fiber and acid detergent fiber tended to be fastest for the ground flaxseed treatment. Taken together, the digestibility, fermentation, and in situ data indicate that rolling and grinding are both acceptable methods of processing flaxseed. The in situ data strongly support the need for processing flaxseed before inclusion in lactation diets.

Key words: dairy steer, digestibility, flaxseed, physical form

INTRODUCTION

Flaxseed can be used as a source of supplemental fat and protein for dairy cows (Mustafa et al., 2003). Nonetheless, supplementation of nonprotected fat in excess of 7% of dietary DM can decrease DMI and reduce digestibility in ruminants (Merchen, 1988; Doreau et al., 1991; Jenkins, 1993). Lipids can reduce fiber digestibility but the degree depends on the type and nature of the lipid (Ward et al., 2002). The reduction in DMI is associated with changes in ruminal fermentation, gut motility, palatability, release of gut hormones, and the oxidation of fat in the liver (Allen, 2000). Processing oil seeds increases ruminally unprotected PUFA, which can have detrimental effects on ruminal fermentation, including altering the microbial population or hindering microbial fiber digestion (Palmquist and Jenkins, 1980; Moore et al., 1986); however, processing methods such as rolling or grinding also generally increase the availability of nutrients to the animal. Gonthier et al. (2004) concluded that flaxseed supplementation (12.6% of DM) improved total-tract digestibility with no detrimental effects on rumen function. Those authors also concluded that micronization increased RUP for flaxseed. Previous studies recommend the processing of flaxseed in beef finishing diets (Maddock et al., 2006) and lactating dairy cow diets (da Silva et al., 2007) compared with whole flaxseed but have not measured the effects of processing on digestion. Therefore, the objective of this study was to evaluate the effects of physical form of flaxseed on the site and extent of digestion, ruminal fermentation, and in situ degradation.

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Our focus was to assess relative differences of processing and method from altering the physical form of flaxseed.

MATERIALS AND METHODS

Animals and Diets

All procedures were approved by the North Dakota State University (NDSU) Animal Care and Use Committee. Four Holstein steers (459.7 ± 46.4 kg of initial BW) with ruminal, duodenal, and ileal cannulas were used in a 4 × 4 Latin square design to determine the effect of flaxseed processing (whole, rolled, or ground) on ruminal fermentation and digestibility of nutrients. Steers were housed in individual pens (3.0 × 3.7 m) at the NDSU Animal Nutrition and Physiology Center (Fargo). During the sample collection periods, steers were kept in individual metabolism stalls (1.0 × 2.2 m). Steers were fed completely mixed diets at 0700 and 1900 h daily and were allowed unlimited access to water. Diets were offered for ad libitum intake to ensure an approximate daily 5% rate of feed refusals.

All diets (Table 1) were formulated to meet NRC (2001) requirements for a lactating dairy cow. Steers were fed basal diets of 47% concentrate, 30% corn silage, 17% alfalfa hay, and 6% beet pulp shreds (DM basis). Alfalfa hay was chopped in a tub-grinder (HayBuster, model H1100 Tilt, DuraTech Industries International Inc., Jamestown, ND) with a 3.8-cm screen. Corn silage and alfalfa hay used for the study were from the same harvest. The concentrate portion of the diets containing the flaxseed or linseed meal was mixed before the initiation of the study by the NDSU Northern Crops Institute Feed Mill (Fargo, ND). Dietary treatments included (1) 7.5% linseed meal (control), (2) 10% whole flaxseed, (3) 10% rolled flaxseed, or (4) 10% ground flaxseed. The control diet contained solvent-extracted linseed meal (Cargill, West Fargo, ND) at proportions equal to the amount of protein contributed by the flaxseed in the other treatments. The rolled flaxseed was processed using a roller-grinder (2-pair stacked rollers, 23 × 30.5 cm, top pair = 0.42 corrugations/cm, bottom pair = 0.84 corrugations/cm; differential drive reduction of 1.5:1, fast to slow; motor size = 25 hp; model K, Roskamp Champion, Waterloo, IA). The ground flaxseed was processed using a hammermill (96.5 cm diameter, split-screen design, down-swing side = 4.8-mm screen hole, up-swing side = 5.6-mm screen hole; motor size = 50 hp; model E-38095 TF, Bliss Industries, Ponca City, OK). Chromic oxide was included in the diets as an external marker from d 4 to 14 at 0.25% of the DM to determine digesta flows at the duodenum. Chromic oxide was premixed into the concentrate by using a Hobart mixer (model H-600, Hobart Manufacturing Co., Troy, OH).

Diets were mixed in advance using a Davis paddle mixer (model S-20, H. C. Davis Sons Mfg. Co. Inc., Bonner Springs, KS) in sufficient quantities to last 3 to 4 d. The total mixed diets were stored in barrels in a walk-in freezer (−20°C), with each day's rations moved to a walk-in cooler (4°C) for 12 h before feeding twice daily at 0700 and 1900 h. Diet intakes were recorded and amounts were adjusted daily for fluctuations in DMI to include 5% daily refusal.

Sample and Data Collection

Each experimental period was 14 d long including 7 d for adaptation to the diet and 7 d for sample collection. For each animal, orts were collected on d 8 to 14, weighed, composited, and mixed by hand. Samples of duodenal (200 g) and ileal (100 g) chyme were collected on d 11 to 13 in a manner to achieve a sampling point in time of every other hour between the feedings (0700 and 1900 h). Samples were composited within steer and period for the experiment. Fecal trays were placed behind the steers for total fecal collection from d 10 through 14. Fecal output was weighed and subsampled (10% of wet weight), and composited across days within steer and stored at −20°C. Composite samples were mixed in a rotary mixer (model H-600, Hobart Manufacturing Co.) and subsampled. Fecal samples were dried in a forced-air oven for 48 h (50°C; model SB-350, Grieve Corp., Round Lake, IL). Chyme samples were freeze-dried and stored at −20°C.

On d 14, ruminal fluid samples were collected at −2, 0, 2, 4, 6, 8, 10, and 12 h relative to the morning feeding. After the collection at −2 h, the rumen was dosed with 200 mL of a CoEDTA solution (20 g of Co/L) via a catheter-tipped, 50-mL syringe with a tube attached, to determine the ruminal liquid dilution rate (Uden et al., 1980). Ruminal fluid samples (200 mL) were drawn using a suction strainer, and pH was recorded using a pH meter and combination electrode (model 2000, Beckman Instruments Inc., Fullerton, CA). A 3-mL sample of ruminal fluid was retained, and 1 mL of 25% (wt/vol) HPO_3 was added to the sample in a 12- × 75-mm culture tube. Samples were stored at −20°C until analysis for NH_3 and VFA.

In situ bags were incubated from d 8 to 13. Dacron bags (10 × 20 cm, 50 ± 15 μm pore size, Ankom, Fairport, NY) containing 5-g samples of ground alfalfa hay were incubated in the rumen to determine the effect of flax processing on rate and extent of forage digestion. The same kind of bags containing 5-g samples of flaxseed and linseed meal (physical form equal to