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Effect of replacing calcium salts of palm oil with camelina seed at 2 dietary ether extract levels on digestion, ruminal fermentation, and nutrient flow in a dual-flow continuous culture system

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ABSTRACT

Camelina is a drought- and salt-tolerant oil seed, which in total ether extract (EE) contains up to 74% polyunsaturated fatty acids. The objective of this study was to assess the effects of replacing calcium salts of palm oil (Megalac, Church & Dwight Co. Inc., Princeton, NJ) with camelina seed (CS) on ruminal fermentation, digestion, and flows of fatty acids (FA) and AA in a dual-flow continuous culture system when supplemented at 5 or 8% dietary EE. Diets were randomly assigned to 8 fermentors in a 2 × 2 factorial arrangement of treatments in a replicated 4 × 4 Latin square design, with four 10-d experimental periods consisting of 7 d for diet adaptation and 3 d for sample collection. Treatments were (1) calcium salts of palm oil supplementation at 5% EE (MEG5); (2) calcium salts of palm oil supplementation at 8% EE (MEG8); (3) 7.7% CS supplementation at 5% EE (CS5); and (4) 17.7% CS supplementation at 8% EE (CS8). Diets contained 55% orchardgrass hay, and fermentors were fed 72 g of dry matter/d. On d 8, 9, and 10 of each period, digesta effluent samples were taken for ruminal NH_3, volatile fatty acids, nitrogen metabolism analysis, and long-chain FA and AA flows. Statistical analysis was performed using the MIXED procedure (SAS Institute Inc., Cary, NC). We detected an interaction between FA source and dietary EE level for acetate, where MEG8 had the greatest molar proportion of acetate. Molar proportions of propionate were greater and total volatile fatty acids were lower on CS diets. Supplementation of CS decreased overall ruminal nutrient true digestibility, but dietary EE level did not affect it. Diets containing CS had greater biohydrogenation of 18:2 and 18:3; however, biohydrogenation of 18:1 was greater in MEG diets. Additionally, CS diets had greater ruminal concentrations of *trans*-10/11 18:1 and *cis*-9,*trans*-11 conjugated linoleic acid. Dietary EE level at 8% negatively affected flows of NH_3-N (g/d), nonammonia N, and bacterial N as well as the overall AA outflow. However, treatments had minor effects on individual ruminal AA digestibility. The shift from acetate to propionate observed on diets containing CS may be advantageous from an energetic standpoint. Moreover, CS diets had greater ruminal outflow of *trans*-10/11 18:1 and *cis*-9,*trans*-11 conjugated linoleic acid than MEG diets, suggesting a better FA profile available for postruminal absorption. However, dietary EE at 8% was deleterious to overall N metabolism and AA outflow, indicating that CS can be fed at 5% EE without compromising N metabolism.

Key words: amino acid, biohydrogenation, fatty acid, in vitro fermentation

INTRODUCTION

Camelina sativa is an oil seed crop from the mustard family (Brassicaceae), which is salt- and drought-tolerant. It is adapted to a variety of climate and soil conditions (Zubr, 1997), including dry regions such as the western United States (Keske et al., 2013). Camelina seed (**CS**) contains, in total ether extract (**EE**), up to 74% PUFA, of which 46% is linolenic acid (Hurtaud and Peyraud, 2007). Another feature of CS is its high protein content and good AA profile (Zubr, 2003), primarily Arg (Miller et al., 1962; Zubr, 2003). Therefore, feeding CS may be advantageous because of its energy content, as well as its FA and AA profiles. However, CS contains antinutritional factors such as glucosinolates and erucic acid (Kramer et al., 1990; Mawson et al., 1994) that may affect digestion.

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Although UFA (notably PUFA, when expressed in % of total FA) are predominant in commonly used ruminant feedstuffs, milk and milk products are relatively low in PUFA content. This is due to extensive biohydrogenation (**BH**) by the ruminal microbial population (Morimoto et al., 2005). Therefore, extent as well as type of BH determine the quantity and structures of FA leaving the rumen (Fievez et al., 2007) and ultimately found in milk. However, it is possible to increase PUFA concentration in milk through dietary PUFA supplementation (Theurer et al., 2009; Moate et al., 2013) using oil seeds such as CS. Yet diets excessively high in UFA may have deleterious effects on nutrient digestibility, microbial population, and digestion. Typically, UFA have greater negative effects on ruminal fermentation than calcium salts of palm oil, due to the calcium salts of palm oil partial protection from ruminal fermentation.

Thus, CS may be a promising source of UFA and capable of providing supplementary EAA as well. However, to our knowledge, the literature lacks reports on the effects of CS supplementation on ruminal fermentation as well as its effects on ruminal FA and AA outflows. The objective of this study was to assess the effects of replacing calcium salts of palm oil with CS on ruminal fermentation, digestion, and flows of FA and AA in a dual-flow continuous culture system when supplemented at 5 or 8% dietary EE. Therefore, our hypotheses were that (1) when replacing calcium salts of palm oil at a level of 5% dietary EE, CS would not negatively affect ruminal fermentation; and (2) CS and calcium salts of palm oil would have different ruminal fermentation patterns.

MATERIALS AND METHODS

Animal care and handling were approved by the University of Nevada–Reno Institutional Animal Care and Use Committee (IACUC protocol # 00588).

Experimental Design and Diets

This study was conducted in a replicated 4 × 4 Latin square design with four 10-d experimental periods, consisting of 7 d of diet adaptation followed by 3 d of sampling. Each fermentor unit was randomly assigned within Latin square to receive each diet once over the 4 periods. Treatments were arranged in a factorial 2 × 2, where factor A consisted of CS as supplement versus calcium salts of palm oil supplement, and factor B consisted of 2 dietary EE levels (5 vs. 8%). Therefore, the treatments were (1) calcium salts of palm oil (Megalac, Church & Dwight Co. Inc., Princeton, NJ) supplementation at 5% EE (**MEG5**); (2) calcium salts of palm oil supplementation at 8% EE (**MEG8**); (3) 7.7% CS supplementation at 5% EE (**CS5**); and (4) 17.7% CS supplementation at 8% EE (**CS8**).

Fermentors were manually fed 72 g of DM/d, equally distributed twice daily at 0800 and 2000 h. Experimental diets were fed on a DM basis and were formulated to meet or exceed NRC recommendations (NRC, 2001) for a Holstein dairy cow, with 660 kg of BW and producing 35 kg of milk/d, with 3.5% fat and 3.2% protein. Diets were formulated to have 16% CP and approximately 35% NDF (Table 1). Diets consisted of orchardgrass hay, ground corn, canola meal, and either ground CS or calcium salts of palm oil fatty acids. Treatments CS5 and CS8 contained 83.4 and 85.4% UFA, respectively, and MEG5 and MEG8 contained 42.4 and 47.7% SFA, respectively (Table 2).

Camelina seed, genotype Calena, was used in this experiment and contained 35.5% EE and 88.5% UFA; calcium salts of palm oil fatty acids contained 53% SFA. In addition, CS contained 29.4% CP, 19.8% NDF, and 9.4% ADF. All dietary ingredients were ground through a 2-mm screen in a Wiley mill (model #2, Arthur H. Thomas Co., Philadelphia, PA) and orchardgrass hay was pelleted. Dietary AA composition is presented in Table 3.

Dual-Flow Continuous Culture System

Diets were randomly assigned to 8 dual-flow continuous culture fermentors, with volume ranging from 1,200 to 1,250 mL (Omni-Culture Plus; Virtis Co. Inc., Gardiner, NY) similar to that originally described by Hoover et al. (1976), and recently modified by Benedeti et al. (2015), Silva et al. (2016), and Paula et al. (2017). Briefly, this system consists of a glass fermentation vessel, in which rumen fluid from donor animals is maintained at constant temperature and agitation. It has a dual-effluent removal system consisting of separate liquid and solid flows. Artificial saliva is continuously infused and feed is provided through an orifice located in the fermentation vessel lid. Fermentor contents are continuously stirred by a central propeller apparatus driven by magnets at the rate of 155 rpm, and N_2 is infused to maintain an anaerobic environment.

Ruminal fluid from 2 rumen-cannulated steers (average BW: 910.5 ± 34.5 kg) was collected approximately 2 h after morning feeding. Donor steers were fed (DM basis) the same forage:concentrate ratio established for the experimental diets, containing 55% alfalfa hay, 45% concentrate, and ad libitum mineral mixture. The ruminal fluid was manually collected from the ventral, central, and dorsal areas of the rumen of the donor