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Production, milk and plasma fatty acid profile, and nutrient utilization in Jersey cows fed flaxseed oil and corn grain with different particle size

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ABSTRACT

We aimed to compare the effects of ground (GC) or cracked corn (CC), with or without flaxseed oil (FSO), on milk yield, milk and plasma fatty acid (FA) profile, and nutrient digestibility in Jersey cows fed diets formulated to contain similar starch concentrations. Twelve multiparous organic-certified Jersey cows averaging (mean ± standard deviation) 455 ± 41.9 kg of body weight and 152 ± 34 d in milk and 4 primiparous organic-certified Jersey cows averaging (mean ± standard deviation) 356 ± 2.41 kg of body weight and 174 ± 30 d in milk in the beginning of the experiment were used. Cows were randomly assigned to treatment sequences in a replicated 4 × 4 Latin square design with a 2 × 2 factorial arrangement of treatments. Each period lasted 24 d with 18 d for diet adaptation and 6 d for data and sample collection. Treatments were fed as total mixed rations consisting of (dry matter basis): (1) 0% FSO + 27.1% GC, (2) 0% FSO + 28.3% CC, (3) 3% FSO + 27.1% GC, and (4) 3% FSO + 28.3% CC. All cows were offered 55% of the total diet dry matter as mixed grass-legume baleage and treatments averaged 20% starch. Significant FSO × corn grain particle size interactions were observed for some variables including milk concentration of lactose and proportions of *cis*-9,*cis*-12,*cis*-15 18:3 in milk and plasma. The proportion of *cis*-9,*cis*-12,*cis*-15 18:3 in milk and plasma decreased slightly when comparing GC versus CC in 0% FSO cows, but a larger reduction was observed in 3% FSO cows. Dry matter intake did not differ and averaged 16.1 kg/d across diets. Feeding 3% FSO increased yields of milk and milk fat and lactose and feed and milk N efficiencies, but decreased fat, true protein, and MUN concentrations and apparent total-tract digestibility of fiber. The Σ branched-chain, Σ<16C, Σ16C, and Σn-6 FA decreased, whereas Σ18C, Σ*cis*-18:1, and Σ*trans*-18:1 FA increased in 3% versus 0% FSO cows. No effect of corn particle size was observed for production and milk components. However, the apparent total-tract digestibility of starch was greater in GC than CC cows. Compared with CC, GC increased Σ branched-chain, Σ<16C, Σ16C, Σn-6 FA, and decreased Σ18C and Σ *cis*-18:1 FA in milk fat. Overall, results of this study are more directly applicable to dairy cows fed low starch, mixed grass-legume baleage-based diets.
Key words: milk yield, organic dairy farm, starch, vegetable oil

INTRODUCTION

Flaxseed oil (**FSO**) is the richest source of the essential n-3 fatty acid (**FA**) α-linolenic acid (**ALA**; *cis*-9,*cis*-12,*cis*-15 18:3) as ALA comprises approximately 50 to 55% of its total FA (Glasser et al., 2008; Benchaar et al., 2012). In organic-certified dairies in the United States, heifers and cows must have year-round access to the outdoors to be in compliance with the USDA National Organic Program "Livestock living conditions" regulations (section 205.239 https://www.ecfr.gov/cgi-bin/text-idx?SID=38fb700cb79331adaec0a1e05477134f&mc=true&node=se7.3.205_1239&rgn=div8; accessed September 20, 2017). As a result of this federally mandated rule, cows may be susceptible to cold stress during the winter months due to exposure to outside freezing temperatures, wind, snow, mud, and wet conditions, which can ultimately depress DMI and milk yield. Flaxseed oil appears to be an attractive strategy to increase energy intake and mitigate potential milk yield losses during the winter months in organic-certified dairy farms or dairies where animals are exposed to similar management conditions. However, inconsistent results have been reported in the literature in response to FSO supplementation as milk yield decreased (Chilliard et al., 2009), did not change (Loor et al., 2005; Benchaar et al., 2015), or increased (Benchaar et al., 2012, 2014). In these previous studies, cows were fed hay (Loor et

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al., 2005) or silage (Chilliard et al., 2009; Benchaar et al., 2012, 2014, 2015), but no information is available about the effect of FSO on production in dairy cows fed mixed grass-legume baleage. Oil from flaxseed may interact with the forage source in the basal diet to modulate ruminal fermentation processes, as well as DMI and milk yield responses (Glasser et al., 2008; Petit, 2010; Meignan et al., 2017), thereby reinforcing the need for research with baleage-based diets. It is important to note that mixed grass-legume baleage and haylage are more extensively used in northeastern (Hafla et al., 2016) and midwestern (Hardie et al., 2014) organic dairies than corn silage. In addition, Coblentz et al. (2016) stated that baleage is an attractive option to small- or mid-sized dairy farms because it offers several advantages when compared with dry hay, most notably reduced risk of rain damage due to less wilting time in the field.

We are also not aware of any published research that has simultaneously evaluated the effects of FSO and corn grain particle size (**PS**) on production, milk composition, and nutrient utilization in dairy cows. Neveu et al. (2014) reported that feeding extruded flaxseed to dairy cows increased the proportions of ALA and *cis*-9,*trans*-11 18:2 in milk by 60 and 29%, respectively, but the effect of cereal grain sources on these 2 FA was not consistent. Compared with rolled barley, high-moisture corn increased milk *cis*-9,*trans*-11 18:2 by 29%, but did not affect ALA (Neveu et al., 2014). Recently, Lascano et al. (2016) fed soybean oil and corn grain with different starch degradability to continuous culture fermentors and observed that enhanced intake of UFA increased the accumulation of biohydrogenation intermediates (e.g., *trans*-10 18:1, *trans*-11 18:1, *cis*-9,*trans*-11 18:2, *trans*-10,*cis*-12 18:2). In addition, Lascano et al. (2016) reported elevated production of *trans* FA intermediates (e.g., *trans*-10 18:1, *trans*-10,*cis*-12 18:2) associated with milk fat depression when starch degradability was increased from low to high. Results from these 2 studies (Neveu et al., 2014; Lascano et al., 2016) suggest that further research is needed to better understand the potential interactions between oil and cereal grain PS on production and milk FA profile.

We hypothesized that (1) FSO would improve yields of milk and milk components, as well as feed efficiency due to increased energy intake, (2) compared with cracked corn (**CC**), ground corn (**GC**) would be more extensively fermented in the rumen, leading to a greater proportion of *trans* FA intermediates in milk fat and improved milk N efficiency (i.e., milk N/N intake), and (3) FSO would interact with corn grain PS to affect production, milk and plasma FA profile, and nutrient utilization. The objective of the current study was to examine the potential interactions of FSO and corn grain PS on production, milk and plasma FA profile, and nutrient utilization in dairy cows fed diets formulated to contain similar starch concentrations.

MATERIALS AND METHODS

Care and handling of the animals used in the current study were conducted as outlined in the guidelines of the University of New Hampshire Institutional Animal Care and Use Committee (#160107). The 96-d-long experiment was conducted at the University of New Hampshire Burley-Demeritt Organic Dairy Research Farm (43°10′N, 70°99′W; Lee, NH) from February 12 to May 17, 2016.

Animals, Experimental Design, and Treatments

Twelve multiparous organic-certified Jersey cows averaging (mean ± SD) 455 ± 41.9 kg of BW, 152 ± 34 DIM, and 22.6 ± 3.89 kg/d of milk and 4 primiparous organic-certified Jersey cows averaging (mean ± SD) 356 ± 2.41 kg of BW, 174 ± 30 DIM, and 17.9 ± 2.46 kg/d of milk in the beginning of the experiment were used. Cows were randomly assigned to treatment sequences in a replicated 4 × 4 Latin square design with a 2 × 2 factorial arrangement of treatments. Distribution of animals to squares was done to balance for differences in DIM and parity, resulting in 3 squares of multiparous cows (square 1 = 124 ± 38 DIM; square 2 = 149 ± 1 DIM; square 3 = 184 ± 23 DIM) and 1 square of primiparous cows (square 4 = 174 ± 30 DIM). Squares were also balanced for potential first-order carryover effects in subsequent periods as each treatment immediately preceded and followed every other exactly once in each square (Williams, 1949; Kim and Stein, 2009). Each period lasted 24 d with 18 d for diet adaptation and 6 d for data and sample collection. The following dietary treatments were fed (DM basis): (1) 0% FSO + 27.1% GC, (2) 0% FSO + 28.3% CC, (3) 3% FSO + 27.1% GC, and (4) 3% FSO + 28.3% CC. Inclusion of corn grain sources and soyhulls in the diets varied to obtain treatments with similar concentrations of starch. The 2 types of corn grain used in the present study were purchased from the same mill (Green Mountain Feeds, Bethel, VT), but they were not from the same batch of corn. Treatments were fed as TMR (55:45 forage-to-concentrate ratio) formulated according to the NRC (2001) and balanced to meet or exceed the nutritional requirement of a Jersey cow producing 19 kg of milk/d, 4.5% milk fat, and 3.5% milk true protein. A generic mineral and vitamin lactation dairy premix (97.6% DM) fed at 1.98% of the diet DM consisting of (as-fed basis) Ca (32.7%), Mn (1.0%), Zn (1.7%), Cu (2,501 mg/kg), Co (282 mg/kg), I (332 mg/