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Replacing ground corn with incremental amounts of liquid molasses does not change milk enterolactone but decreases production in dairy cows fed flaxseed meal

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ABSTRACT

We investigated the effects of replacing ground corn (GRC) with incremental amounts of liquid molasses (LM) on milk enterolactone concentration, antioxidant enzymes activity in plasma, production, milk fatty acid (FA) profile, and nutrient utilization in Jersey cows fed flaxseed meal and low-starch diets. Sixteen multiparous organically certified Jersey cows averaging (mean ± standard deviation) 101 ± 45 d in milk, 462 ± 38 kg of body weight, and 19.8 ± 3.90 kg/d of milk in the beginning of the study were randomly assigned to treatment sequences in a replicated 4 × 4 Latin square design, with 14 d for diet adaptation and 7 d for data and sample collection. Diets were fed as total mixed rations consisting (dry matter basis) of 52% grass-legume baleage, 8% grass hay, 8.5% soyhulls, 2.5% roasted soybean, 15% flaxseed meal, and 2% minerals-vitamins premix. The GRC-to-LM dietary ratios (dry matter basis) were 12:0, 8:4, 4:8, and 0:12. Orthogonal polynomials were used to test linear, quadratic, and cubic effects using the MIXED procedure of SAS (SAS Institute Inc., Cary, NC). The milk concentration of enterolactone tended to respond cubically, thus suggesting that replacing GRC with LM did not affect this lignan in milk. The plasma activities of the antioxidant enzymes glutathione peroxidase and catalase did not differ, but superoxide dismutase activity tended to respond cubically with feeding increasing amounts of LM. Dry matter intake and yields of milk and milk fat, true protein, and lactose decreased linearly with substituting GRC for LM. Whereas the concentrations of milk fat and milk true protein did not differ across treatments, milk lactose content decreased linearly. Feeding incremental levels of LM reduced linearly the milk concentration of urea N and the amount of N excreted in urine, and tended to decrease linearly the concentration of plasma urea N. Apparent total-tract digestibilities of dry matter, organic matter, and neutral and acid detergent fiber did not differ across treatments, whereas digestibility of crude protein decreased linearly. Digestibility of starch responded linearly and quadratically, but the actual differences between treatments were too small to be biologically significant. Milk FA profile was substantially changed most notably by linear increases in *cis*-9,*trans*-11 18:2, *cis*-9,*cis*-12,*cis*-15 18:3, Σ odd-chain FA, and the *trans*-11-to-*trans*-10 ratio, and linear decreases in *cis*-9 18:1 and *cis*-9,*cis*-12 18:2 when replacing GRC by incremental amounts of LM.
Key words: antioxidant, lignan, organic dairy, public health

INTRODUCTION

Lignans are polyphenolic, phytoestrogenic compounds known to elicit a wide range of biological activities, including weak estrogenic and cardioprotective effects, as well as antiestrogenic, antioxidant, anti-inflammatory, and anticarcinogenic properties (Adolphe et al., 2010; Högger, 2013; Imran et al., 2015). Flaxseed (*Linum usitatissimum* L.) is the richest source of the lignan secoisolariciresinol diglucoside (**SDG**), which is a precursor for the synthesis of the mammalian lignans enterolactone (**EL**) and enterodiol by the gut microbiota of humans (Thompson et al., 1991; Gaya et al., 2016) and ruminants (Gagnon et al., 2009; Zhou et al., 2009). Feeding incremental amounts of flaxseed meal (**FM**) to dairy cows increased linearly the milk concentration of EL, whereas no enterodiol was detected in milk (Petit and Gagnon, 2009). Recently, we reported that the concentration of EL in milk was modified by the type of NSC source supplemented to dairy cows fed diets containing (DM basis) 15% FM, with liquid molasses (**LM**) leading to greater milk EL than ground corn (**GRC**; Brito et al., 2015). This suggests that, compared with GRC, LM may select for ruminal mi-

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croorganisms with better capacity to convert FM-SDG to EL. However, we are not aware of any study to date that has investigated whether milk EL concentration behaves in a linear or curvilinear fashion in response to incremental amounts of LM in cows offered FM. There is also lack of information regarding whether LM could interact synergistically with GRC to maximize the concentration of EL in milk.

There has been a continuous interest in the use of sugarcane molasses in both conventional (Broderick and Radloff, 2004; Martel et al., 2011; Siverson et al., 2014) and organic (Soder et al., 2012; Brito et al., 2015, 2017) dairy systems in the United States. Whereas conventional dairy cows have been fed dried molasses or LM accompanied by other NSC supplements and corn silage (Broderick and Radloff, 2004; Martel et al., 2011; Siverson et al., 2014), organically certified dairy cows are typically fed LM as the sole NSC supplemental source to grass hay (Brito et al., 2015) or mixed grass-legume pasture (Soder et al., 2012; Brito et al., 2017). Previous dose-response studies resulted in inconsistent responses on DMI, milk yield and composition, and nutrient digestibility when dried or LM partially replaced high-moisture corn (Broderick and Radloff, 2004; Baurhoo and Mustafa, 2014) or GRC (Martel et al., 2011) in moderate- to high-starch diets. However, research addressing the effect of completely replacing GRC with incremental amounts of LM on production, milk composition, and nutrient utilization in dairy cows fed mixed grass-legume baleage and low-starch diets is lacking.

We hypothesized that (1) the concentration of EL in milk would be modulated by expected changes in DM and SDG intakes when replacing GRC with incremental amounts of LM in cows fed FM. We also hypothesized that replacing GRC with LM would lead to (2) increased milk yield and milk N efficiency (i.e., milk N/N intake) due to improved balance between RDP and fermentable energy supply, as sucrose from LM is more rapidly degraded in the rumen than starch from GRC; and (3) marked changes in milk fatty acid (**FA**) profile in response to expected differences in 18C FA intake between GRC and LM. The objective of our study was to evaluate the effects of replacing GRC with incremental amounts of LM on milk EL concentration, antioxidant enzymes activity in plasma, production, milk FA profile, and apparent total-tract digestibility of nutrients in Jersey cows fed FM and low-starch diets.

MATERIALS AND METHODS

This 84-d long study was conducted at the University of New Hampshire Burley-Demeritt Organic Dairy Research Farm (43°10′N, 70°99′W; Lee, NH) from December 3, 2014, to February 24, 2015. Care and handling of cows used in our study were conducted as outlined in the guidelines of the University of New Hampshire Institutional Animal Care and Use Committee (IACUC Protocol #140901).

Cows, Experimental Design, and Diets

Sixteen multiparous organically certified Jersey cows averaging (mean ± SD) 101 ± 45 DIM, 462 ± 38 kg of BW, and 19.8 ± 3.90 kg/d of milk in the beginning of the study were used. Distribution of cows to squares was done to balance for differences in DIM (square 1 = 163 ± 10 DIM; square 2 = 112 ± 16 DIM; square 3 = 78 ± 7 DIM; square 4 = 50 ± 10 DIM). Within each square, cows were randomly assigned to treatment sequences in a replicated 4 × 4 Latin square design. Each experimental period lasted 21 d, with 14 d for diet adaptation and 7 d for data and sample collection. The experimental diets were fed as TMR consisting (DM basis) of 31.2% mixed-mostly grass baleage, 20.8% mixed-mostly legume baleage, 8% grass hay, 8.5% soyhulls, 2.5% roasted soybean, 15% FM, and 2% minerals-vitamins premix. The GRC-to-LM dietary ratios (DM basis) were 12:0, 8:4, 4:8, and 0:12. Sugarcane LM was purchased from Buffalo Molasses LCC (North Java, NY). The nutritional composition of the feedstuffs used in this study is presented in Table 1, and the ingredient and nutritional composition of the experimental diets are reported in Table 2.

Cows were housed in a bedded-pack barn with dried pine shavings as bedding and kept in a pen separated from the remaining lactating cows in the herd. The bedding area (132 m^2) opens to a 478-m^2 concrete-floor outdoor lot (total pen area = 610 m^2), allowing cows to walk freely in compliance with the USDA National Organic Program "Livestock living conditions" (USDA, 2010), which calls for year-round access to the outdoors for all ruminants among other regulations. Cows had access to a roof-covered feeding station equipped with electronic recognition Calan doors system (American Calan Inc., Northwood, NH) located at the end of the pen facing the bedding area.

Feeding Management and Feed Sampling and Analyses

All bales used in this study were sampled before feeding using a Hilti model TE 7-A drill (Hilti North America, Tulsa, OK) fitted with a 40-cm long metal core sampler. Throughout the study, approximately 150-g forage samples were obtained after 3 to 4 core