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Effect of dietary sugar concentration and sunflower seed supplementation on lactation performance, ruminal fermentation, milk fatty acid profile, and blood metabolites of dairy cows

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ABSTRACT

Previous research has shown that both sunflower seed (SF) and sucrose (SC) supplementation can result in variation in milk fat concentration and composition, possibly due to altered fermentation patterns and biohydrogenation of fatty acids in the rumen. The objective of this study was to determine the effects of different sugar concentrations with or without SF supplementation on lactation performance, ruminal fermentation, and milk fatty acid profile in lactating dairy cows. Eight multiparous Holstein dairy cows (body weight = 620 ± 15 kg, 60 ± 10 d in milk, mean ± standard deviation) were randomly assigned to treatments in a replicated 4 × 4 Latin square design with a 2 × 2 factorial arrangement of treatments. Each 21-d period consisted of a 14-d diet adaptation period and 7-d collection period. Dairy cows were fed 1 of the following 4 diets: (1) no additional SC without SF supplementation (NSC-SF), (2) no additional SC with SF supplementation (NSC+SF), (3) SC without SF supplementation (SC-SF), and (4) SC with SF supplementation (SC+SF). The diets contained the same amount of forages (corn silage and alfalfa hay). Four isonitrogenous and isoenergetic diets were formulated by replacing corn grain with SC and SF and balanced using change in proportions of canola meal and sugar beet pulp. No interaction was detected between SC and SF supplementation with respect to dry matter intake, milk yield, and composition. A tendency was found for an interaction between inclusion of SC and SF on energy-corrected milk with the highest amount in the SC-SF diet. Ruminal pH and the molar proportion of acetate were affected by SC inclusion, with an increase related to the SC-SF diet. Diets containing SF decreased the concentrations of short-chain fatty acids (4:0 to 10:0) and medium-chain fatty acids (12:0 to 16:0) in milk fat. The addition of SC tended to decrease the concentration of total *trans*-18:1. These data provide evidence that exchanging SC for corn at 4% of dietary dry matter influenced milk fat content and rumen pH, resulting in a tendency for decreased concentration of *trans*-18:1 in milk fat. Sucrose alone did not alter the milk fatty acid profile when cows were fed a combination of unsaturated fat and sugar, although several significant interactions between sugar and unsaturated fat were observed.
Key words: sucrose, sunflower seed, fatty acid profile, dairy cow

INTRODUCTION

It is well known that nutrition is a major factor determining the concentration and secretion of specific fatty acids in dairy cow milk (Chilliard et al., 2007; Shingfield et al., 2008). Although fat supplementation can increase the energy density of a ration, fat itself, particularly unsaturated fats, can have adverse effects on rumen fermentation. Incomplete biohydrogenation (**BH**) of UFA is a major cause of milk fat depression, which is defined as the decrease in milk fat synthesis mainly due to the formation of several *trans*-fatty acid isomers during ruminal BH, which exert anti-lipogenic effects (Shingfield et al., 2010). Thus, feeding vegetable oils or oilseeds to dairy cows may reduce the milk fat concentration and yield. Studies in ruminants have shown that inclusion of sunflower oil in the diet increases both *cis*-9,*trans*-11 18:2 and *trans*-11 18:1 content in milk (Roy et al., 2006) at the expense of the short- and medium-chain fatty acids (Glasser et al., 2008; Razzaghi et al., 2015).

Sugars can be used in a high-concentrate diet to replace a portion of corn grain. Indeed, replacing corn by sucrose (**SC**) or molasses has been shown in some

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instances to increase DMI, milk fat concentration, and alter milk fatty acid profile (Broderick et al., 2008; Penner and Oba, 2009; Martel et al., 2011). Feeding supplemental sugar to dairy cows has been shown in some instances to increase ruminal pH (Penner and Oba, 2009) and ruminal butyrate concentration (Martel et al., 2011), and decrease ruminal propionate (DeFrain et al., 2004). In the literature, the effect of sugars on milk yield is variable, with some studies reporting increases in milk yield (Broderick and Radloff, 2004) and others reporting no effect of sugar inclusion on milk yield (Broderick et al., 2008). As opposed to unsaturated fat supplementation, accumulating evidence indicates that sugar significantly decreases the proportions of both polyunsaturated (Mullins and Bradford, 2010) and *trans*-18:1 fatty acid (Penner and Oba, 2009) in milk fat and increases milk fat content (Broderick et al., 2008). Martel et al. (2011) reported that molasses may promote mammary de novo fatty acid synthesis in cows fed high-energy rations by moderating ruminal pH and altering ruminal fatty acid BH pathways. Complete BH of UFA eliminates potential negative effects of specific BH intermediates (*trans*-fatty acid) on milk fat synthesis (Shingfield et al., 2010); therefore, sugar may be capable of mitigating the potential adverse effects on milk fat synthesis. However, Razzaghi et al. (2015) failed to find enhancement of ruminal pH, milk fat concentration, and significant alterations in milk fatty acid profile when feeding SC (total sugar; 8.7% of DM) to dairy goats.

Some evidence has been found for interactions between sunflower oil and carbohydrates in the diet. Zened et al. (2013) observed that when sunflower oil, rich in *cis*-9,*cis*-12 18:2, was added to the diet, the ruminal pH did not change and the proportion of *trans*-11 BH intermediates in the rumen content greatly increased; however, the association of increasing starch level and adding sunflower oil to the diet of cows resulted in *trans*-10 fatty acid increasing at the expense of *trans*-11 fatty acid. In the current study, we hypothesized that PUFA and *trans*-fatty acid proportions in milk fat are lower when cows are fed SC compared with no supplemental SC diets. Furthermore, it is possible that the dietary sugar content and dietary *cis*-9,*cis*-12 18:2 supplementation interact to alter the pathways of rumen BH, resulting in changes in the specific fatty acid contents in milk fat. To confirm this hypothesis, we investigated the effects of feeding diets containing different total sugar contents (~4.7 vs. 8.9% of dietary DM) with or without ground sunflower seed (**SF**) supplementation (8 vs. 0% of dietary DM) to dairy cows on productivity, ruminal fermentation, and milk fatty acid profile.

MATERIALS AND METHODS

Cows, Experimental Design, and Treatments

The experiment was conducted at the Research Farm of the Faculty of Agriculture, Ferdowsi University of Mashhad (Iran) according to the guidelines of the Iranian Council of Animal Care (1995). Eight multiparous Holstein dairy cows (BW = 620 ± 15 kg, 60 ± 10 DIM, mean ± SD) were randomly assigned to treatments in a replicated 4 × 4 Latin square design with a 2 × 2 factorial arrangement. Cows were fed TMR for ad libitum intake. Each 21-d period consisted of a 14-d diet adaptation period and 7-d collection period. Dairy cows were fed 1 of the following 4 diets: (1) no additional SC without SF supplementation (**NSC-SF**), (2) no additional SC with SF supplementation (**NSC+SF**), (3) SC without SF supplementation (**SC-SF**), and (4) SC with SF supplementation (**SC+SF**). Sucrose at 4% and ground SF at 8% of diet DM were included by replacing corn grain to create dietary treatments (Table 1). All diets were formulated to be isoenergetic and isonitrogenous; therefore, diets with SF supplementation contained less canola meal and more sugar beet pulp level compared with unsupplemented diets, because sugar beet pulp is relatively low in energy and protein contents. Sunflower seed was chosen because of its richness in *cis*-9,*cis*-12 18:2 as a main substrate for BH. Diets were formulated using the Cornell-Penn-Miner System (CPM Dairy, version 3.0.8; Cornell University, Ithaca, NY; University of Pennsylvania, Kennett Square, PA; and William H. Miner Agricultural Research Institute, Chazy, NY) to supply adequate NE_L for a 600-kg cow producing 40 kg of milk with a fat concentration of 3.5%. Cows were housed in tie stalls and allowed to exercise for 1 h every afternoon. Cows were fed individually at 0800, 1600, and 2400 h for 5 to 10% refusals, and DMI was recorded daily. They were milked 3 times per day at 0700, 1500, and 2300 h, and milk production was recorded at each milking.

Sampling Procedures

Feed intake and milk yield were measured daily in the last 7 d of the experiment. Samples of the diets were taken weekly, frozen, and pooled on a 3-wk basis. Composited samples were mixed thoroughly and subsampled for chemical analyses. Milk samples were obtained from the last 7 d of each period. One sample was stored at 4°C with a preservative (potassium bichromate) for milk component analysis. Another sample without preservative was stored at −20°C for analysis of milk fatty acid profile by gas chromatography. Energy-corrected milk