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Short-term effects of soybean oil supplementation on performance, digestion, and metabolism in dairy cows fed sugarcane-based diets

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ABSTRACT

We aimed to quantify the productive and metabolic responses, and digestive changes in dairy cows fed various concentrations of soybean oil (SBO) in high-concentrate, sugarcane-based diets. Eight rumen-cannulated multiparous Holstein cows in mid lactation (574 ± 19.1 kg of body weight and 122 ± 6.9 d in milk), averaging 22.5 ± 1.22 kg/d of milk were assigned to replicated 4 × 4 Latin squares. The experimental period lasted 21 d as follows: 14 d for adaptation, followed by a sampling period from d 15 to 21. The diets were formulated with increasing concentrations of SBO [% of dry matter (DM)]: control (0%), low (LSBO; 1.57%), medium (MSBO; 4.43%), and high (HSBO; 7.34%). Dry matter intake decreased quadratically in response to SBO addition. The greatest decrease in DM intake was observed in MSBO and HSBO diets. Both milk and energy-corrected milk yield were quadratically affected by the SBO inclusion, with a slight decrease up to MSBO and substantial decrease in the HSBO diet. The milk fat concentration linearly decreased from 3.78% in the control to 3.50% in the HSBO diet. The potentially digestible neutral detergent fiber digestibility in the rumen decreased from 55.7% in the control to 35.2% in the HSBO diet. The fractional rate of digestion of potentially digestible neutral detergent fiber in the rumen decreased linearly from 3.13 to 1.39%/h from the control to HSBO diet. The fractional rate of indigestible neutral detergent fiber passage in the rumen was quadratically affected, with the lowest value (2.25%/h) for the HSBO diet. Rumen pH increased from 6.42 to 6.67, and ammonia nitrogen decreased from 28.1 to 21.4 mg/dL, in the control and HSBO diets, respectively. Rumen volatile fatty acids decreased quadratically, with the greatest decrease observed in MSBO and HSBO diets. Serum concentrations of glucose, fatty acids, and β-hydroxybutyrate were unaffected by SBO inclusion. However, serum concentrations of total cholesterol and high- and low-density lipoproteins linearly increased with increasing concentrations of SBO in the diet. Inclusion of SBO at concentrations from 4.43 to 7.34% of the diet DM decreased DM intake, energy-corrected milk production, fiber digestibility, and rumen fermentation and was thus not recommended. Soybean oil supplementation at 1.57% of the diet DM proved to be a safe concentration for dairy cows fed high-concentrate diets with sugarcane as the sole forage.

Key words: fat supplementation, microbial protein synthesis, rumen kinetics, omasal flow

INTRODUCTION

Sugarcane is a forage commonly fed to cattle in tropical environments and often used as the main dietary fiber source. It has an excellent feeding potential for dairy cows because of its high productivity and wide harvesting window (Daniel et al., 2014). However, its use for high-yielding dairy cows is usually associated with feeding high amounts of concentrates, leading to a high proportion of NFC in the diet (Oliveira et al., 2011). Furthermore, sugarcane fiber contains a high proportion of indigestible neutral detergent fiber (**iNDF**) and low potentially digestible neutral detergent fiber (**pdNDF**), at about 25 and 27% DM, respectively (Daniel et al., 2014), which is associated with a low DMI. Consequently, more concentrate is needed compared with corn silage-based diets (Oliveira et al., 2011).

Under these feeding situations, fat supplementation could be an alternative to increasing energy intake. However, the optimal inclusion rate of added fat in diets with sugarcane as the sole forage needs to be defined. Previous research has indicated that the forage source can affect the response of fat supplementation on fiber digestion (Ueda et al., 2003). For instance, adding rapeseed oil at 6.6% DM, Ben Salem et al. (1993) observed a lower decrease in grass hay NDF digestibility when compared with corn silage. Incorporating linseed oil at 4% DM, Benchaar et al. (2015) observed a decrease in

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NDF digestibility in corn silage diets but not in red clover silage diets. Bateman and Jenkins (1998) included soybean oil (**SBO**) up to 8% DM in diets with Bermuda grass hay and did not observe any effects on fiber digestibility. Studies evaluating fat supplementation in diets with sugarcane and other tropical forages are scarce. In this way, the diets are usually formulated based on recommendations of maximum supplementary fat concentration of 4 to 5% DM (Lewis et al., 1999) or 6 to 7% ether extract (**EE**) in diet DM (NRC, 2001).

The effects of fat supplementation on rumen metabolism in dairy cows have been widely studied (Lerch et al., 2012; Piantoni et al., 2015). Despite the advances in knowledge of the effects of fat supplementation on rumen digestion, metabolism, and milk quality (Shingfield et al., 2008), little attention has been paid to the effects of fat supplementation in dairy diets based on tropical forages. In addition, vegetable oils are rich in UFA and highly hydrolyzed in the rumen (Jenkins and Harvatine, 2014). A better understanding of production responses in dairy cows to increasing dietary fat concentrations is warranted, particularly when tropical forages such as sugarcane are fed.

We hypothesized that SBO supplementation would increase energy intake and milk production in cows fed high-concentrate diets with sugarcane. Based on this hypothesis, our objective was to quantify the productive, nutritional, and metabolic responses of dairy cows fed different concentrations of SBO in high-concentrate diets with sugarcane as the sole forage.

MATERIALS AND METHODS

The Committee of Production Animal Care and Use of the Federal University of Viçosa approved all animal feeding, management, and procedures involved in this study (Protocol no. 072/2014).

Animals, Experimental Design, and Diets

Eight rumen-cannulated, multiparous Holstein cows in mid lactation (574 ± 19.1 kg of BW and 122 ± 6.9 DIM) were used. Milk production was 22.5 ± 1.22 kg/d at the beginning of the study. The animals were housed in individual stalls (17.5 m^2) with rubber powder beds, water, and feed bunks. Cows were grouped in a replicated 4 × 4 Latin square design balanced for residual effects. The experimental period lasted 21 d, comprising 14 d for adaptation followed by a sampling period from d 15 to 21.

Four diets were formulated with increasing concentrations of SBO (%DM): control (0%), low (**LSBO**; 1.57%), medium (**MSBO**; 4.43%), and high (**HSBO**; 7.34%; Table 1). The SBO concentrations were selected to achieve 4, 7, and 10% EE in total DM in the LSBO, MSBO, and HSBO diets, respectively. The diets were formulated to be isonitrogenous (16% CP) by changing the proportions of corn and soybean meal, and a fixed forage-to-concentrate ratio of 40:60 was used. The sugarcane (variety RB-867515) used was a third-cut crop (Table 2). It was harvested daily in the afternoon and chopped before the morning feeding. The sugarcane stems had an average soluble content of 18.0 ± 1.68° Brix. Oxidation was prevented by preparing a single batch of concentrate at the beginning of each experimental period and adding antioxidant butylated hydroxytoluene. The SBO was mixed with the soybean meal and corn meal first, and then the minerals, using a horizontal concentrate mixer. The cows were milked twice daily at 0550 and 1450 h, and fed diets as a TMR individually after each milking session. Intake was calculated by manually weighing the offered TMR and collected orts. Diets were offered on an ad libitum basis (target = 100 g of refusal/kg fed) and the amount offered was adjusted daily.

Samplings

To estimate diets compositions, each ingredient was sampled at each batch of concentrate. Samples of soybean meal, corn meal, and soybean oil were taken in each batch of concentrate and stored at −20°C until analysis. Samples of sugarcane and orts were taken from d 15 to 19 of each experimental period, stored at −20°C, and pooled fresh based on the period for chemical analysis.

Milk production was measured and samples were collected from d 16 to 18 of each experimental period. A pooled sample was made proportionally to production in each milking session and stored as duplicates at −20°C until analysis. For MUN analysis, 10 mL of milk was deproteinized with 5 mL of trichloroacetic acid (250 g/L), filtered, and stored at −20°C until analysis.

Digestibility and microbial protein synthesis (**MPS**) were estimated by collecting a total of 8 spot fecal and urine samples at 9-h intervals starting at 0900 h on d 16. Fecal samples (300 mL) were collected from the rectum and immediately oven-dried at 55°C for 72 h and stored. Urine samples (200 mL) were collected by stimulating the vulva and 2 aliquots were made: the first 10 mL was acidified with 40 mL of sulfuric acid (H_2SO_4, 1 mL/L) and the second was stored as obtained. Both urine samples were kept frozen at −20°C. Both urine and feces were pooled by cow and period before analysis.

From d 13 to 18 of each period, infusions of 8 g/d of Co-EDTA (766 mg of Co/d) were performed 4 times daily at 0000, 0600, 1200, and 1800 h. The Co-EDTA