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Effect of high-oleic-acid soybeans on production performance, milk fatty acid composition, and enteric methane emission in dairy cows

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ABSTRACT

The objective of this study was to investigate the effect of 3 soybean sources differing in fatty acid profile and processing method on productivity, milk composition, digestibility, rumen fermentation, and enteric methane emission in lactating dairy cows. The soybean sources were conventional, high-linoleic-acid variety extruded soybean meal (ESBM; 8.7% ether extract with 15% oleic and 54% linoleic acids); extruded Plenish (DuPont Pioneer, Johnston, IA), high-oleic-acid variety soybean meal (EPSBM; 8.4% ether extract with 73% oleic and 8% linoleic acids); and whole, heated Plenish soybeans (WPSB; 20.2% ether extract). The study involved 15 Holstein cows in a replicated 3 × 3 Latin square design experiment with three 28-d periods. The inclusion rate of the soybean sources in the diet was (dry matter basis) 17.1, 17.1, and 7.4% for ESBM, EPSBM, and WPSB, respectively, which resulted in ether extract concentration of the diets of 3.99, 3.94, and 4.18%, respectively. Compared with ESBM, the Plenish diets tended to increase dry matter intake and decreased feed efficiency (but had no effect on energy-corrected milk feed efficiency). The Plenish diets increased milk fat concentration on average by 5.6% and tended to increase milk fat yield, compared with ESBM. The WPSB diet tended to increased milk true protein compared with the extruded soybean meal diets. Treatments had no effect on rumen fermentation and enteric methane or carbon dioxide emissions, except pH was higher for WPSB versus EPSBM. The Plenish diets decreased the prevalence of *Ruminococcus* and increased that of *Eubacterium* and *Treponema* in whole ruminal contents. Total-tract apparent digestibility of organic matter and crude protein were decreased by WPSB compared with ESBM and EPSBM. Compared with the other treatments, urinary N excretion was increased by EPSBM and fecal N excretion was greater for WPSB. Treatments had marked effects on milk fatty acid profile. Generally, the Plenish diets increased mono-unsaturated (mostly *cis*-9 18:1) and decreased polyunsaturated, total *trans*-, and conjugated linoleic fatty acids concentrations in milk fat. In this study, compared with conventional, high-linoleic-acid variety extruded soybean meal, the Plenish soybean diets increased milk fat concentration and tended to increase fat yield, decreased feed efficiency, and modified milk fatty acid profile in a manner expected from the greater concentration of oleic acid in Plenish soybean oil.
Key words: high-oleic-acid soybean, milk fat, dairy cow

INTRODUCTION

The production benefits of inclusion of extruded oilseed meals in the diet of lactating dairy cows may come from (1) increased energy intake (due to higher oil content of extruded vs. solvent-extracted meals), (2) increased RUP (the extrusion process generates heat that increases the RUP content of the meal), and (3) increased DMI due to increased palatability or increased digestible AA intake. The production responses to extruded oilseed meals, however, have been variable (Socha, 1991; Santos et al., 1998). In a study related to the current experiment, we observed a 1.25-kg/d increase in DMI and a corresponding 3.25-kg/d increase in milk yield in dairy cows fed soybean meal (**SBM**) extruded at 2 temperatures versus the control, solvent-extracted SBM (Giallongo et al., 2015). It is worth noting that the extruded SBM increased plasma concentration of His, an AA that has been positively related to DMI in dairy cows (Lee et al., 2012; Giallongo et al., 2016). In the experiment of Giallongo et al. (2015), the extruded meals were included at 13% of dietary DM and had no statistical effect on milk fat concentration, although there was a numerical decrease of about 0.2 percentage units at both extrusion temperatures compared with the control.

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The oil of conventional soybean varieties contains a high concentration of 18:2 (and 18:3), the biohydrogenation of which is responsible for formation of CLA isomers known to cause milk fat depression (Baumgard et al., 2000; Moate et al., 2008). The modeling exercise of Moate et al. (2008) found that *trans*-10,*cis*-12 CLA concentration in milk fat was related to intestinal absorption of 18:2 (presumably mostly as *cis*-9,*cis*-12 18:2), whereas milk production of *cis*-9 18:1 or total *trans*-18:1 was related to 18:1 absorption. The role of 18:1 isomers in milk fat depression is debatable. Several studies have reported an association between *trans*-18:1, particularly *trans*-10 18:1, concentrations in milk fat and lowered milk fat synthesis (see Griinari et al., 1998; Bauman and Griinari, 2003). A study with abomasal infusion of *trans*-10 18:1, however, clearly demonstrated this isomer had no effect on milk fat concentration in dairy cows (Lock et al., 2007). A study by Hinrichsen et al. (2006) showed milk fat depression by high-linoleic-acid safflower oil, but no effect on milk fat by high-oleic-acid sunflower oil. Further, a meta-analysis by Glasser et al. (2008) suggested a greater negative effect on milk fat concentration by soybean oil (higher in 18:2) versus canola oil (higher in 18:1). Therefore, it is plausible that substitution of 18:2 with 18:1 in the diet may alleviate potential milk fat depression caused by high inclusion rates of extruded oilseed meals or even enhance milk fat synthesis in dairy cows. Additionally, increased intake of 18:1 results in increased MUFA concentration in milk fat (DePeters et al., 2001; Kliem et al., 2011; Hristov et al., 2011a), which may be beneficial for milk quality in terms of consumer perception (Jenkins and McGuire, 2006).

The current experiment was conducted to investigate the effect of 3 soybean sources differing in their fatty acid profile and processing method on productivity, milk composition, digestibility, rumen fermentation, and enteric methane emission in lactating dairy cows. Our main hypothesis was that substitution of conventional extruded SBM (predominantly 18:2) with extruded SBM high in 18:1 will increase milk fat synthesis and MUFA concentration in milk fat.

MATERIALS AND METHODS

All procedures carried out in the experiment were approved by the Animal Care and Use Committee at The Pennsylvania State University.

Animals and Experimental Design

The experiment was a replicated 3 × 3 Latin square design balanced for residual effects and was conducted in the tiestall barn of The Pennsylvania State University's Dairy Teaching and Research Center. Fifteen multiparous lactating Holstein cows, averaging 2.6 ± 0.22 lactations, 53 ± 7.7 DIM, and 641 ± 12.5 kg of BW at the beginning of the study, were grouped into 5 squares based on DIM, milk yield, and parity. Six cows (2 squares) were fitted with 10-cm (internal diameter) soft plastic ruminal cannulas (Bar Diamond Inc., Parma, ID). Each experimental period lasted 28 d, with 21 d of adaptation to the diets followed by 7 d of data and sample collection. Cows within square were randomly assigned to 1 of 3 treatment diets containing conventional variety, high-linoleic-acid extruded SBM (**ESBM**), extruded Plenish (DuPont Pioneer, Johnston, IA), high-oleic-acid variety SBM (**EPSBM**), or whole, heated Plenish soybeans (**WPSB**). Chemical composition of the soybeans is shown in Table 1. Diets (Table 2) were formulated to meet or exceed the NRC (2001) nutrient requirements for lactating Holstein cows yielding 42 kg of milk/d with 3.70% milk fat and 3.05% true protein at 27 kg/d of DMI and 660 kg of BW. At the inclusion rate of the 3 soybean sources, the diets contained 1.5, 1.4, and 1.9% soybean oil for ESBM, EPSBM, and WPSB, respectively. The lower inclusion rate for WPSB was intended to maintain similar CP and ether extract concentrations among the 3 diets (see notes in Results and Discussion). The extruded SBM (ESBM and EPSBM) were produced by Fabin Bros. Farms (Indiana, PA) from conventional and Plenish varieties of whole soybeans, respectively. Extrusion temperature was set at 160°C (320°F). The whole Plenish soybeans were roasted (WPSB) by Groff's Grain Roasting, Inc. (Lewisburg, PA). Temperature of the beans leaving the roaster was measured and averaged 158°C (317 ± 0.94°F). Beans were not steeped after roasting. The WPSB were stored whole and rolled using a Roskamp electric roller mill (California Pellet Mill Co., Waterloo, Iowa) before inclusion in the TMR. Diets were mixed using a Kuhn Knight model 3142 Reel Auggie Mixer Wagon (Kuhn Knight Inc., Brodhead, WI) and were fed once daily (0630 h) as TMR to achieve about 10% refusals. Cows in this experiment did not receive rbST.

Sampling and Measurements

Individual feed intake (on an as-fed basis) and milk yield of the cows were recorded daily throughout the experiment. Cow BW was also recorded daily for the entire experiment using AfiFarm 3.04E scale system (S.A.E. Afikim, Rehovot, Israel) while cows exited the milking parlor. Total mixed ration and refusals from each diet were sampled twice weekly and samples were composited (on an equal weight basis) by week and diet. Samples of individual forages and concentrate