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Milk production responses to dietary stearic acid vary by production level in dairy cattle

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ABSTRACT

Effects of stearic acid supplementation on feed intake and metabolic and production responses of dairy cows with a wide range of milk production (32.2 to 64.4 kg/d) were evaluated in a crossover design experiment with a covariate period. Thirty-two multiparous Holstein cows (142 ± 55 d in milk) were assigned randomly within level of milk yield to treatment sequence. Treatments were diets supplemented (2% of diet dry matter) with stearic acid (SA; 98% C18:0) or control (soyhulls). The diets were based on corn silage and alfalfa and contained 24.5% forage neutral detergent fiber, 25.1% starch, and 17.3% crude protein. Treatment periods were 21 d with the final 4 d used for data and sample collection. Compared with the control, SA increased dry matter intake (DMI; 26.1 vs. 25.2 kg/d) and milk yield (40.2 vs. 38.5 kg/d). Stearic acid had no effect on the concentration of milk components but increased yields of fat (1.42 vs. 1.35 kg/d), protein (1.19 vs. 1.14 kg/d), and lactose (1.96 vs. 1.87 kg/d). The SA treatment increased 3.5% fat-corrected milk (3.5% FCM; 40.5 vs. 38.6 kg/d) but did not affect feed efficiency (3.5% FCM/DMI, 1.55 vs. 1.53), body weight, or body condition score compared with the control. Linear interactions between treatment and level of milk yield during the covariate period were detected for DMI and yields of milk, fat, protein, lactose, and 3.5% FCM; responses to SA were positively related to milk yield of cows. The SA treatment increased crude protein digestibility (67.4 vs. 65.5%), tended to increase neutral detergent fiber digestibility (43.6 vs. 42.3%), decreased fatty acid (FA) digestibility (56.6 vs. 76.1%), and did not affect organic matter digestibility. Fatty acid yield response, calculated as the additional FA yield secreted in milk per unit of additional FA intake, was only 13.3% for total FA and 8.2% for C18:0 plus *cis*-9 C18:1. Low estimated digestibility of the SA supplement was at least partly responsible for the low FA yield response. Treatment did not affect plasma insulin, glucagon, glucose, and nonesterified FA concentrations. Results show that stearic acid has the potential to increase DMI and yields of milk and milk components, without affecting conversion of feed to milk, body condition score, or body weight. Moreover, effects on DMI and yields of milk and milk components were more pronounced for higher-yielding cows than for lower-yielding cows.

Key words: fat supplementation, milk fat, production level, stearic acid

INTRODUCTION

Production responses to highly saturated fats (≥85% saturated) have varied greatly in past experiments. Reasons for variability across experiments could be from use of different types of fat supplements, diets, and physiological states of cows. Variation in response among cows was demonstrated by Harvatine and Allen (2005) by comparing saturated and unsaturated FA supplements fed to mid-lactation cows with a wide range of milk production. In that experiment, response to treatment for yield of milk protein varied across milk yield of cows; high-producing cows responded better to the saturated FA supplement, whereas low-producing cows responded better to the unsaturated FA supplement. Moreover, Palmquist and Jenkins (1980) reported that cows with low production potential did not respond to fat supplementation compared with cows with high production potential in their feeding trials. Saturated long-chain FA often increase milk fat yield in dairy cows (Steele and Moore, 1968; Steele, 1969; Wang et al., 2010). In addition, saturated long-chain FA supplements have been shown to increase milk yield (Steele, 1969; Piantoni et al., 2013) and feed efficiency (**FE**; Wang et al., 2010; Lock et al., 2013; Piantoni et al., 2013) in some experiments. Interestingly, Piantoni et al. (2013) showed that a palmitic acid supplement increased milk yield, milk fat yield, and feed efficiency regardless of level of milk production.

Several studies evaluated the use of palmitic acid supplements (Mosley et al. 2007; Lock et al., 2013; Piantoni et al., 2013), but few reported the use of highly enriched stearic acid supplements. Steele and Moore (1968) evaluated a stearic acid supplement (94% pure), fed at ∼4% of diet DM, on production responses for

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cows in mid-lactation; the supplement increased milk fat yield but did not affect milk fat concentration or milk yield compared with a control with no supplemental fat added. In a later study, stearic acid (85% pure; fed at ~4.25% of diet DM) increased milk yield but did not affect milk fat concentration or yield compared with a control diet with no supplemental fat added (Steele, 1969). Interestingly, and in the same experiment, the same stearic acid supplement fed at half that inclusion rate (~2.1% of diet DM) increased not only milk yield but also milk fat yield compared with the control (Steele, 1969). Even though Steele and colleagues evaluated effects of highly enriched stearic acid supplements on production of lactating cows (Steele and Moore, 1968; Steele, 1969), the cows used had low milk yield (~12 kg/d) and responses measured were related to milk yield, composition, and FA analysis only and not to DMI, digestibility, metabolic responses, or FE.

Inconsistent responses to feeding saturated fats call for additional research with pure FA sources to identify the effects of specific FA on production response of cows varying in milk yield to clarify when these supplements should be fed and their potential for increasing profitability of dairy farms. To our knowledge, no studies have evaluated the effects of a pure stearic acid supplement on digestion and metabolic and production responses in lactating dairy cows with a wide range of milk production. The objectives of this experiment were to evaluate the effects of stearic acid supplementation on digestion, metabolism, and production of lactating dairy cows and its interaction with level of milk production. Our hypothesis was that a highly pure (98%) stearic acid supplement would increase milk yield, milk fat yield, and feed efficiency of dairy cows and that responses to treatment would differ across levels of milk production.

MATERIALS AND METHODS

Animal Housing and Care

All experimental procedures were approved by the Institutional Animal Care and Use Committee at Michigan State University (East Lansing). Each cow was housed in the same tie-stall throughout the entire experiment. Cows were fed once daily (1000 h) at 110% of expected intake and milked twice daily (0500 and 1600 h). The amounts of feed offered and orts were weighed for each cow daily.

Design and Treatment Diets

Thirty-two multiparous Holstein cows (142 ± 55 DIM; mean ± SD) at the Michigan State University Dairy Field Laboratory were used in a crossover design experiment with a covariate period. Cows were selected from the herd to provide a uniform distribution and a wide range of milk yield (32.2 to 64.4 kg/d). Cows were randomly assigned to treatment sequence within levels of milk production that varied by approximately 5 kg/d. The experiment was 56 d in duration and consisted of a 14-d preliminary (covariate) period and two 21-d treatment periods. During the preliminary period, cows were fed the control diet, and baseline values were obtained for all variables (Table 1). During the first treatment period, half of the cows (n = 16) were fed the control diet (**CONT**) with no supplemental fat added, whereas the other half (n = 16) was fed the stearic acid–supplemented diet (**SA**; prilled free FA supplement: 98% C18:0; Emery Oleochemicals, Selangor, Malaysia). The stearic acid supplement was added at 2% of diet DM, replacing 2% of soyhulls in the control diet. Diets were switched for the second treatment period. The ingredient and nutrient composition of the diets fed as TMR are described in Table 2. Diets were formulated to meet requirements of the average cow in the group according to the NRC (2001).

Data and Sample Collection

Samples and data were collected during the last 4 d of the covariate period (d 11 to 15) and during the last 4 d of each treatment period (d 18 to 21). Samples of all diet ingredients (0.5 kg) and orts from each cow (12.5%) were collected daily and composited by period. Milk yield was recorded, and 2 milk samples were collected at each milking. One milk sample was stored without preservative at −20°C for determination of FA profile, and the other was stored with a preservative (Bronopol tablet; D&F Control Systems, San Ramon, CA) added as preservative at 4°C for component analysis. Fecal (500 g) and blood samples (~15 mL) were collected every 15 h, resulting in 8 samples per cow per period, representing every 3 h of a 24-h period to account for diurnal variation. Feces were stored in a sealed plastic cup at −20°C until they were dried. Blood was collected by coccygeal venipuncture into 3 evacuated tubes; 2 contained potassium EDTA as an anticoagulant and the other contained potassium oxalate as an anticoagulant and sodium fluoride as a glycolytic inhibitor. Blood was stored on ice until centrifugation at 2,000 × *g* for 15 min at 4°C (within 30 min of sample collection). Two aliquots (1 mL) of plasma from the potassium EDTA tube were stored in 0.05 *M* benzamidine (final concentration) to prevent enzymatic degradation of glucagon. The remaining plasma was transferred into microcentrifuge tubes and stored at −20°C until it was composited by cow by period. Body weight and BCS