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Palmitic acid increased yields of milk and milk fat and nutrient digestibility across production level of lactating cows

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ABSTRACT

The effects of palmitic acid supplementation on feed intake, digestibility, and metabolic and production responses were evaluated in dairy cows with a wide range of milk production (34.5 to 66.2 kg/d) in a crossover design experiment with a covariate period. Thirty-two multiparous Holstein cows (151 ± 66 d in milk) were randomly assigned to treatment sequence within level of milk production. Treatments were diets supplemented (2% of diet DM) with palmitic acid (PA; 99% C16:0) or control (SH; soyhulls). Treatment periods were 21 d, with the final 4 d used for data and sample collection. Immediately before the first treatment period, cows were fed the control diet for 21 d and baseline values were obtained for all variables (covariate period). Milk production measured during the covariate period (preliminary milk yield) was used as covariate. In general, no interactions were detected between treatment and preliminary milk yield for the response variables measured. The PA treatment increased milk fat percentage (3.40 vs. 3.29%) and yields of milk (46.0 vs. 44.9 kg/d), milk fat (1.53 vs. 1.45 kg/d), and 3.5% fat-corrected milk (44.6 vs. 42.9 kg/d), compared with SH. Concentrations and yields of protein and lactose were not affected by treatment. The PA treatment did not affect dry matter (DM) intake or body weight, tended to decrease body condition score (2.93 vs. 2.99), and increased feed efficiency (3.5% fat-corrected milk/DM intake; 1.60 vs. 1.54), compared with SH. The PA treatment increased total-tract digestibility of neutral detergent fiber (39.0 vs. 35.7%) and organic matter (67.9 vs. 66.2%), but decreased fatty acid (FA) digestibility (61.2 vs. 71.3%). As total FA intake increased, total FA digestibility decreased ($R^2 = 0.51$) and total FA absorbed increased (quadratic $R^2 = 0.82$). Fatty acid yield response, calculated as the additional FA yield secreted in milk per unit of additional FA intake, was 13.4% for total FA and 16.6% for C16:0 plus *cis*-9 C16:1 FA. The PA treatment increased plasma concentration of nonesterified FA (101 vs. 90.0 μEq/L) and cholecystokinin (19.7 vs. 17.6 pmol/L), and tended to increase plasma concentration of insulin (10.7 vs. 9.57 μIU/mL). Results show that palmitic acid fed at 2% of diet DM has the potential to increase yields of milk and milk fat, independent of production level without increasing body condition score or body weight. However, a small percentage of the supplemented FA was partitioned to milk.
Key words: palmitic acid, production level, milk fat, fat supplementation

INTRODUCTION

Long-chain saturated fat supplements have been used to increase the energy density of diets (Wang et al., 2010) and milk fat yield (Steele and Moore, 1968; Steele, 1969; Wang et al., 2010) in dairy cows and have been reported to increase feed efficiency (Wang et al., 2010; Lock et al., 2013) and milk yield (Steele, 1969; Enjalbert et al., 2000). Moreover, they are considered to be inert in the rumen (Grummer, 1988; Schauff and Clark, 1989), and have little effect on DMI (Allen, 2000) and nutrient digestibility (Grummer, 1988; Schauff and Clark, 1989; Elliott et al., 1996). However, production responses to highly saturated fats (>85% saturated) have varied greatly. For instance, supplementation of a highly saturated fat fed at 1.5 to 2% of diet DM had various effects on productive performance compared with a control diet with no fat added: increasing milk yield by 3.1 kg/d (Mosley et al., 2007) and 2.2 kg/d (Wang et al., 2010), or not affecting milk yield (Lock et al., 2013); increasing fat yield by 286 g/d (Mosley et al., 2007) and 90 g/d (Lock et al., 2013), or not affecting fat yield (Warntjes et al., 2008); and increasing DMI by 3.1 kg/d (Mosley et al., 2007), not affecting DMI (Wang et al., 2010), or decreasing DMI by 1.4 kg/d (Lock et al., 2013).

Variability across experiments could be due to the level of milk production of the cows used. Harvatine and Allen (2005) showed that milk protein yield was increased to a greater extent for high-producing cows than lower-producing cows for saturated compared with unsaturated FA supplements. Furthermore, early-

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lactation cows with lower milk yield responded more favorably to the dietary inclusion of a highly saturated fat supplement than cows with higher milk production in a field study (Warntjes et al., 2008). Variability across experiments could also be related to the use of different types of fat supplements and rates of feeding. Fat supplements vary in FA chain lengths and degree of esterification and in their feeding rates, which vary widely from less than 2% (Wang et al., 2010) to greater than 5% of diet DM (Mosley et al., 2007) across experiments. In addition, the substitution method might also affect production responses if the supplement is added in place of a source of glucose precursors such as corn (Wang et al., 2010), a fermentable fiber source such as soyhulls (Lock et al., 2013), or the base diet (Mosley et al., 2007). Because of inconsistent responses to feeding saturated fats, it is currently not clear when these supplements should be fed and whether their use can increase production and feed efficiency of cows and profitability of dairy farms.

To identify the effects of specific FA on dairy cow performance, studies involving the use of pure FA are required. Palmitic acid is an SFA that is commonly found in many different saturated fat supplements and dairy cow feedstuffs. Although several studies have been reported with fat sources containing approximately 85% palmitic acid, the remaining FA might have influenced responses to treatment, so studies with pure FA are required. Steele and Moore (1968) evaluated a pure (96%) palmitic acid supplement on production responses for cows in mid lactation but the milk yield of the cows was low (~12 kg/d) and responses measured were limited. To our knowledge, no studies exist that have evaluated the effects of supplementation of a pure palmitic acid supplement on digestion and metabolic and production responses in lactating dairy cows or how responses vary with level of milk production. The objectives of this experiment were to evaluate the effects of palmitic acid supplementation and its interaction with level of milk production on digestion, metabolism, and production of lactating dairy cows. We hypothesized that a palmitic acid-enriched supplement compared with soyhulls would increase milk yield, milk fat yield, and feed efficiency of dairy cows and that responses would differ across production levels.

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). All cows were housed in the same tie-stall throughout the entire experiment. Cows were fed once daily (0800 h) at 110% of expected intake and milked twice daily (0400 and 1500 h). The amounts of feed offered and orts were weighed for each cow daily.

Design and Treatment Diets

Thirty-two multiparous Holstein cows (151 ± 66 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 (34.5 to 66.2 kg/d). Cows were randomly assigned to treatment sequence within levels of milk production varying by approximately 5 kg/d. The experiment was 63 d in duration and consisted of a 21-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 were fed the control diet (**SH**) with no supplemental fat added, whereas the remaining cows were fed the palmitic acid-supplemented diet (**PA**; prilled FFA supplement: 99% C16:0; Emery Oleochemicals, Selangor, Malaysia). The palmitic 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 NRC (2001).

Data and Sample Collection

Samples and data were collected during the last 4 d of the second week 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 preservative at 4°C for component analysis (Universal Lab Services, East Lansing, MI). 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 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