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Effect of a high-palmitic acid fat supplement on milk production and apparent total-tract digestibility in high- and low-milk yield dairy cows

D. E. Rico, Y. Ying, and K. J. Harvatine[1]
Department of Animal Science, Penn State University, University Park 16802

ABSTRACT

The effect of a high-palmitic acid fat supplement was tested in 12 high-producing (mean = 42.1 kg/d) and 12 low-producing (mean = 28.9 kg/d) cows arranged in a replicated 3 × 3 Latin square design. Experimental periods were 21 d, with 18 d of diet adaptation and 3 d of sample collection. Treatments were (1) control (no supplemental fat), (2) high-palmitic acid (PA) supplement (84% C16:0), and (3) Ca salts of palm fatty acid (FA) supplement (Ca-FA). The PA supplement had no effect on milk production, but decreased dry matter intake by 7 and 9% relative to the control in high- and low-producing cows, respectively, and increased feed efficiency by 8.5% in high-producing cows compared with the control. Milk fat concentration and yield were not affected by PA relative to the control in high- or low-producing cows, although PA increased the yield of milk 16-C FA by more than 85 g/d relative to the control. The Ca-FA decreased milk fat concentration compared with PA in high-, but not in low-producing cows. In agreement, Ca-FA dramatically increased milk fat concentration of *trans*-10 C18:1 and *trans*-10,*cis*-12 conjugated linoleic acid (>300%) compared with PA in high-producing cows, but not in low-producing cows. No effect of treatment on milk protein concentration or yield was detected. The PA supplement also increased 16-C FA apparent digestibility by over 10% and increased total FA digestibility compared with the control in high- and low-producing cows. During short-term feeding, palmitic acid supplementation did not increase milk or milk fat yield; however, it was efficiently absorbed, increased feed efficiency, and increased milk 16-C FA yield, while minimizing alterations in ruminal biohydrogenation commonly observed for other unsaturated fat supplements. Longer-term experiments will be necessary to determine the effects on energy balance and changes in body reserves.

Key words: palmitic acid, nutrient digestibility, milk fat, dairy cow

INTRODUCTION

Fat supplements are commonly fed to dairy cows to increase dietary energy density, increase energy intake, and maximize milk yield without the risks associated with feeding excessive fermentable carbohydrates (Jenkins and McGuire, 2006). The ideal fat supplement has no effect on ruminal fermentation or DMI, is highly digestible in the intestine, and increases milk and milk component yields. However, some fat supplements decrease fiber digestibility (Jenkins and Palmquist, 1984), decrease DMI (Allen, 2000), or alter ruminal FA biohydrogenation (**BH**; Beam et al., 2000). Specifically, unsaturated FA often result in a greater decrease in DMI compared with saturated fat sources (e.g., Relling and Reynolds, 2007) and are associated with ruminal production of BH intermediates that induce milk fat depression (**MFD**; Harvatine et al., 2009).

Formation of calcium salts of unsaturated FA was devised over 30 yr ago to minimize the negative effects of PUFA on ruminal digestion of fiber (Jenkins and Palmquist, 1984; Palmquist, 1991). Most Ca-salt FA supplements available in the United States are derived from palm FA distillate, a by-product of palm oil processing, and contain a balance of saturated and unsaturated FA (approximately 50% C16:0 and 42% unsaturated FA). Importantly, Ca salt protection of PUFA from BH is incomplete (Wu et al., 1991), and the increased formation of BH intermediates such as *trans*-10 C18:1 indicates that PUFA negatively affect ruminal bacterial populations and BH pathways (Maia et al., 2007).

The FA profile of dietary fat has an effect on milk fat concentration and yield. Kadegowda et al. (2008) observed that abomasal infusion of a mix of short- and medium-chain SFA increased milk fat concentration and yield, whereas long-chain FA supplements had no effect compared with no fat infusion. Similarly, high-palmitic acid (**PA**) supplements were reported to increase milk fat yield (Steele and Moore, 1968; Enjalbert et al., 2000; Mosley et al., 2007). Specifically, Mosley et al. (2007) reported a linear increase in milk fat yield and C16:0 incorporation into milk fat when diet C16:0 concentration was increased from 1.8 to 5.2% of DM.

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[1]Corresponding author: kjh182@psu.edu

Furthermore, higher mammary extraction efficiency of C16:0 compared with C18:0 was observed during duodenal infusions of C16:0 and C18:0 FA (Enjalbert et al., 1998, 2000). Lastly, C18:0 supplements have also been observed to increase milk fat yield in some instances, although the response is smaller compared with C16:0 supplementation (Steele and Moore, 1968; Enjalbert et al., 2000; Rico et al., 2014).

Within a herd, the physiology and metabolism of individual cows is very diverse and may interact with some dietary treatments. For example, cows with higher milk yields have greater energy demands, resulting in changes in DMI, ruminal pool size, ruminal passage rates, and microbial fermentation (e.g., Kammes et al. 2012). Harvatine and Allen (2006b) reported a reduction in milk fat in high- but not in low-producing cows when increasing diet unsaturated FA, presumably due to an interaction of the rumen environment of higher-production cows and unsaturated FA. Although not well explored, other differences in partitioning of absorbed fat between milk and body reserves are also possible.

The objective of the current experiment was to characterize the effect of a high-PA supplement on intake, milk and milk component yields, and total-tract digestibility in high- and low-producing dairy cows. The PA supplement was compared with a no-fat control and the well-investigated Ca salt of palm FA. The hypothesis was that a high-PA supplement would be ruminally inert and highly digestible, similar to previous reports of other saturated FFA supplements (Harvatine and Allen, 2006b,c). Additionally, high-producing cows were expected to increase milk yield, whereas low-producing cows were expected to increase milk fat yield when fed the high-PA supplement.

MATERIALS AND METHODS

Experimental Design and Treatments

The experiment was conducted from May to July 2010 in a tie-stall barn located at the Pennsylvania State University Dairy Research and Teaching Center (University Park). All experimental procedures were approved by the Pennsylvania State University Institutional Animal Care and Use Committee. Twelve high-milk yield cows (pretrial milk yield = 48.3 ± 7.2 kg/d; mean ± SD) and 12 low-milk yield cows (pretrial milk yield = 33.8 ± 3.7 kg milk/d; mean ± SD) were blocked by production level at the beginning of the study in a replicated 3 × 3 Latin square design with 21-d periods. All cows were multiparous Holsteins (688 ± 76 kg of BW) and DIM was similar between production blocks [211 ± 68 and 196 ± 43 DIM (mean ± SD) for high- and low-production cows, respectively]. Milk fat concentration differed between the production blocks when fed the control diet (3.14 and 3.86% milk fat in high- and low-production cows, respectively), but this was not a selection criterion. Three of the cows in the low- and 3 in the high-production block were ruminally cannulated. Treatments were (1) control (no supplemental fat), (2) high-palmitic FFA (PA) supplement (BergaFat F-100; Berg + Schmidt GmbH & Co., Hamburg, Germany), and (3) Ca salts of palm FA (**Ca-FA**) supplement (Megalac; Church & Dwight Co. Inc., Princeton, NJ). The PA supplement contained 84.8% C16:0 and 8.3% C18:1 and the Ca-FA supplement contained 47.4% C16:0, 35.9% C18:1, and 8.4% C18:2 (% of total FA; Supplemental Table S1; http://dx.doi.org/10.3168/jds.2013-7341). Both fat supplements were fed to provide approximately 2% FA in the diet on a DM basis. All cows received bST (Posilac; Elanco Animal Health, Greenfield, IN) every 14 d. Milk yield and DMI are known to slightly increase and then decrease during the bST cycle. The 14-d cycle and 21-d periods resulted in supplementation occurring on different days in each period. Little reason exists to expect an interaction between the small changes during the bST cycle and the treatments and changes during the cycle were accounted for by the period effect in the model.

Milk Sampling and Analysis

Cows were milked twice daily at 0500 and 1700 h and milk yield determined by an integrated milk meter (Afimilk; SAE Afikim, Kibbutz Afikim, Israel). Milk samples were taken at 6 consecutive milkings on d 19 to 21 of each period. A subsample from each milking was stored at 4°C with liquid preservative (Bronolab-WII; Dairy One Lab, State College, PA) until analyzed for fat (Filter B), protein, and lactose by infrared spectroscopy [Fossomatic 4000, MilkoScan, and Fossomatic 400 (Foss Electric A/S, Hillerød, Denmark); AOAC International (2000) method 972.160 (Dairy One laboratory, State College, PA)]. A second subsample of each milking on d 21 was stored at −20°C without preservative until analyzed for FA profile as described by Rico and Harvatine (2013). Briefly, lipids were extracted with hexane:isopropanol, base transmethylated with sodium methoxide, and quantified by gas chromatography with a flame ionization detector (**GC-FID**; Agilent 6890A; Agilent Technologies Inc., Santa Clara, CA) and a capillary column [SP-2560; 100 m × 0.25 mm (i.d.) with 0.2-μm film thickness; Supelco Inc., Bellefonte, PA]. Milk FA are reported as nonesterified FA calculated as described by Rico and Harvatine (2013).

Energy-corrected milk (kg/d) was calculated as (0.327 × milk kg/d) + (12.95 × fat kg/d) + (7.65 ×