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Milk production and nutrient digestibility responses to increasing levels of stearic acid supplementation of dairy cows

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ABSTRACT

The objective of our study was to evaluate the dose-response effects of a stearic acid (C18:0)-enriched supplement on nutrient digestibility, production responses, and the maximum amount of C18:0 that can be incorporated into the milk fat of dairy cows. Multiparous Holstein cows (n = 32; 145 ± 66 d in milk) with a wide range in milk yield (30 to 70 kg/d) were blocked by milk yield and assigned to replicated 4 × 4 Latin squares. Treatments were diets supplemented with a C18:0-enriched supplement (SA; 93% C18:0) at 0, 0.80, 1.50, or 2.30% of diet dry matter (DM). Periods were 21 d with the final 5 d used for data and sample collection. Dry matter intake increased linearly as SA supplementation increased. Supplementation of SA had no effect on the yield of milk or milk components. Due to the increase in DM intake, SA linearly reduced the ratio of energy-corrected milk to DM intake. Supplementation of SA did not affect body weight. Increasing SA reduced digestibility of 16-carbon, 18-carbon, and total fatty acids (FA), with the reduction in digestibility of 18-carbon FA being approximately 30 percentage units from the 0.0 to 2.30% SA supplemented diets. Supplementation of SA linearly increased concentrations of preformed milk fatty acids (FA) but did not affect the yield of preformed milk FA. Yields of C18:0 plus *cis*-9 C18:1 were increased by SA supplementation; however, the increase from 0 to 2.3% SA was only 16 g/d. The concentration and yield of de novo and 16-carbon milk FA were unaffected by SA supplementation. In conclusion, increasing doses of SA decreased FA digestibility and had little effect on production parameters. Although SA increased the yield of C18:0 and *cis*-9 C18:1 in milk fat, it had no overall effect on milk fat yield. The lack of production responses to a C18:0-enriched fat supplement was most likely associated with the marked decrease in FA digestibility.

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

INTRODUCTION

Fat supplements are commonly added to dairy cow diets to increase dietary energy density and yields of milk and milk fat and to improve energy balance (Rabiee et al., 2012). Although most commercially available fat supplements have typically contained mixtures of different fatty acids (**FA**), supplements enriched with individual FA are becoming increasingly available. Determining the effects of individual FA on nutrient digestibility, production responses, and metabolism of lactating dairy cows is therefore important. Much of the focus has been on individual SFA, particularly palmitic acid (C16:0; e.g., Piantoni et al., 2013; de Souza et al., 2016; Rico et al., 2017). There has been less focus on nutrient digestibility (Piantoni et al., 2015) and production (Steele and Moore, 1968; Steele, 1969; Piantoni et al., 2015) responses to stearic acid (C18:0), with all studies feeding only single or very high levels of C18:0. Because C18:0 is the main end product of biohydrogenation and the major FA available for absorption in the small intestine (Palmquist et al., 2005), it is often considered rumen inert and potentially an ideal FA to feed in a FA supplement for lactating dairy cattle. However, in our recent meta-analysis examining individual FA digestibility, we observed that increasing C18:0 flow through the duodenum had a strong negative effect on digestibilities of C18:0 and total FA (Boerman et al., 2015). This raises a question regarding the effect of C18:0-enriched supplements on total FA digestibility and performance of dairy cows. Hence, determining the dose-response effects of a C18:0-enriched supplement on nutrient digestibility and production responses of dairy cows is of particular interest.

Both C18:0 and *cis*-9 C18:1 are major FA in milk fat, with concentrations potentially limited by the requirement of the mammary gland to produce milk fat that is fluid at body temperature. The relatively high melting point of C18:0 requires the production of de novo synthesized FA and the conversion of C18:0 to *cis*-9 C18:1

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in the mammary gland to maintain fluidity (Palmquist, 2006). In a meta-analysis, Glasser et al. (2008) reported that desaturation of C18:0 in the mammary gland is positively and linearly related to mammary uptake of C18:0. Because there is an interdependence between de novo and 18-carbon milk FA for milk fat synthesis (Glasser et al., 2008), we are uncertain if C18:0 itself will affect the synthesis of de novo FA in the mammary gland. Therefore, it would be interesting to determine whether there is a maximum amount of C18:0 that can be incorporated into milk fat while not reducing de novo synthesis, thus maximizing milk fat yield.

Few studies have evaluated production responses to purified sources of C18:0 in dairy cows, and inconsistent results have been observed (Steele and Moore, 1968; Steele, 1969; Piantoni et al., 2015). Variability across experiments could be due to the use and feeding rate of different types of fat supplements, interaction with other dietary components, or the physiological status of cows. Feeding a relatively pure source of C18:0 at approximately 4% of diet DM resulted in an increase in milk fat yield with no effect on milk yield (Steele and Moore, 1968). However, in a subsequent study with a similar C18:0 inclusion level, an increase in milk yield was observed with no effect on milk fat concentration or yield (Steele, 1969). More recently, Piantoni et al. (2015) fed a C18:0-enriched supplement at 2% of diet DM and reported increased DMI, milk yield, and milk fat yield, with increases more evident in cows with higher milk yields, indicating that there was significant variation in response. Considering that most dairy farms that use supplemental fat would include it in diets within the range of 0.5 to 2.5% of ration DM, determining an optimal dose within this range has important applications. Therefore, the objective of our study was to evaluate the dose-response effects of a C18:0-enriched supplement on nutrient digestibility, production responses, and the maximum amount of C18:0 that can be incorporated into milk fat of dairy cows with a wide range of milk production levels.

MATERIALS AND METHODS

Design and Treatments

Experimental procedures were approved by the Institutional Animal Care and Use Committee at Michigan State University, East Lansing. Thirty-two mid-lactation (147 ± 66 DIM; mean ± SD) multiparous Holstein cows from the Michigan State University Dairy Field Laboratory were blocked by milk yield [46.6 ± 9.6 kg/d (mean ± SD), range 29.6 to 70.4 kg/d] and then randomly assigned to treatment sequence in a replicated 4 × 4 Latin square design balanced for carryover effects with 21-d periods. All animals received a common diet with no fat supplementation during a 14-d preliminary period to obtain baseline values.

Treatments consisted of a control diet (**CON**) and 3 treatments supplemented with increasing doses of a stearic acid (C18:0)-enriched supplement (**SA**) at 0.80% (**L-SA**), 1.50% (**M-SA**), and 2.30% SA (**H-SA**). The SA supplement was a free FA product of high purity and contained approximately 6.60% C16:0, 93.0% C18:0, and 0.60% C22:0 (Wawasan Agrolipids Johor, Malaysia). Chemical composition and characteristics of the SA supplement are presented in Table 1. The ingredient and nutrient composition of the diets fed as TMR are described in Table 2. Minerals and vitamins were formulated to meet NRC (2001) recommendations. The SA supplement replaced soyhulls in the diet; replacing soyhulls would have less of an effect on production and metabolic responses, as well as on rumen function, compared with other feed ingredients. For example, we recently observed that the production response to a C16:0-enriched supplement was greater when it replaced soyhulls compared with when it replaced dry ground corn in the diet (de Souza et al., 2016). The DM concentration was determined twice weekly for forages, and diets were adjusted when necessary. All cows were housed in a tiestall barn throughout the experiment and milked twice daily (0430 and 1530 h). Access to feed was blocked from 1000 to 1200 h to allow for collecting orts and offering feed. Cows were fed 115% of expected intake at 1200 h daily. Water was available ad libitum in each stall and stalls were bedded with sawdust and cleaned twice daily.

Data and Sample Collection

Samples and data for production results were collected during the last 5 d of each treatment period (d 17

Table 1. Characterization of the C18:0-enriched supplement fed during treatment periods

Item	Mean ± SD[1]
Particle size, μm	659 ± 16.5
Melting point, °C	67.7
Iodine value	11.3
Free fatty acids (FA), %	98.0
Gross energy, Mcal/kg	9.41
FA profile, g/100 g of FA	
16:0	6.59 ± 0.01
17:0	0.14 ± 0.001
18:0	92.6 ± 0.02
cis-9 18:1	0.08 ± 0.001
22:0	0.59 ± 0.01

[1]Mean ± SD from composited samples taken during each period (n = 4).