J. Dairy Sci. 98:431–442
http://dx.doi.org/10.3168/jds.2014-8328

Effect of dietary fatty acid supplements, varying in fatty acid composition, on milk fat secretion in dairy cattle fed diets supplemented to less than 3% total fatty acids

C. M. Stoffel, P. M. Crump, and L. E. Armentano[1]
Department of Dairy Science, University of Wisconsin, Madison 53706

ABSTRACT

Dietary fatty acids can affect both milk fat yield and fatty acid (FA) composition. This relationship is well established when the dietary level of FA exceeds 3% of diet dry matter (DM). We could find no reports directly examining the effects of dietary FA profile on milk fat at levels below 3%. Twenty-four primiparous and 36 multiparous lactating cows were paired by production (1 high with 1 low, within parity) to form 30 experimental units. Pairs were fed 6 diets in five 6 × 6 balanced Latin squares with 21-d periods, and data were collected during the last 5 d of each period. Two control diets were fed: a corn control diet (CC; 29% corn silage, 16% alfalfa silage, 19% corn grain, and 8% distillers grain on a DM basis) containing 1.8% FA; and a low-oil control diet (LOC; 9% corn silage, 35% alfalfa silage, 20% food-grade corn starch, and 8% corn gluten feed on a DM basis) containing 1.2% FA. A portion of the food-grade corn starch in LOC was replaced with 4 different FA supplements to create the 4 treatment diets. Treatments were 1.7% (DM basis) of a 50:50 blend of corn oil and high-linoleic safflower oil (LO), 1.7% high-oleic sunflower oil (OO), 1.7% palm oil (PO), or 1.8% calcium salts of palm fatty acids (PFA). The resultant diets were thus enriched in linoleic (LO), oleic (OO), or palmitic acid (PO and PFA). Dietary treatments did not affect dry matter intake. Addition of any of the fat sources to LOC resulted in increased milk yield, but milk fat yields and milk FA composition were variable for the different treatments. The LO treatment resulted in lower milk fat yield, fat concentration, and C16:0 yield but increased both *trans*-10 C18:1 and *trans*-10,*cis*-12 C18:2 yields compared with the other added FA treatments. Diets PO and PFA resulted in increased milk C16:0 yield and decreased total milk C18 yield compared with OO. Regression analysis revealed a negative coefficient for dietary linoleic acid content over basal (LOC) for both milk short-chain FA yield and C16:0 yield. Dietary linoleic acid content also had a positive coefficient for milk *trans*-10 C18:1 and *trans*-10,*cis*-12 conjugated linoleic acid yield. These results demonstrate that even when total dietary FA are below 3%, free oils rich in linoleic acid can reduce milk fat yield by reducing secretion of milk FA with fewer than 18 carbons. Fatty acid composition of fat supplements is important even at this low level of total dietary fat.
Key words: linoleic, oleic, palmitic, milk fat depression

INTRODUCTION

Fat fed to dairy cows can come from fat endogenously present in the feed ingredients or added in supplements. Previous experiments in which free vegetable oils were added as supplements found that the variation in the FA composition of added oils can affect milk fat yield (Grummer, 1991). Vegetable oils, such as those found in common feeds and some fat supplements, vary in contents of oleic, linoleic, and palmitic acids. The unsaturated FA found in these vegetable oils are not inert in the rumen, but rather are subject to biohydrogenation. Complete biohydrogenation converts all ingested unsaturated FA into saturated FA (Harfoot and Hazlewood, 1997). Accumulation of bioactive intermediates from incomplete biohydrogenation contributes to reduced milk fat secretion, a condition known as milk fat depression (**MFD**; Chouinard et al., 1999b; Perfield et al., 2007; Shingfield et al., 2009). One bioactive FA that has been identified as a significant cause of dietary induced MFD is *trans*-10,*cis*-12 CLA, a biohydrogenation product of linoleic acid (*cis*-9,*cis*-12 C18:2; Baumgard et al., 2000). As dietary starch is increased at the expense of fiber, rumen bacterial biohydrogenation of unsaturated FA can shift toward the formation of this and other bioactive FA (Griinari et al., 1998; Loor et al., 2004). In these diets, or when pure milk fat depressing FA are infused (Baumgard et al., 2000, 2001), MFD is a result of increased bioactive FA with a constant supply of dietary FA. Almost all milk short-chain (<C16) FA are synthesized by the mammary gland along with roughly half of the palmitic acid (C16:0). The other half of the

Received May 5, 2014.
Accepted July 16, 2014.
[1]Corresponding author: learment@wisc.edu

C16:0 and the majority of the 18-carbon (C18) and longer FA are of dietary origin (Bauman and Davis, 1974). For the purpose of this paper, the abbreviation <C16 will include all milk FA shorter than 16 carbons, C16:0 will denote milk C16:0, and C18 will denote all 18-carbon FA, regardless of saturation. The exact proportion of C16:0 from diet or mammary synthesis can vary and is partly dependent on the palmitic acid content of the diet (Palmquist, 2006). *Trans*-10 C18:1, a biohydrogenation product of both linoleic and oleic acid, has also been linked to MFD (Shingfield et al., 2009). Bioactive FA decrease mammary gland FA synthesis, which reduces milk <C16 and C16:0 FA yields; however, bioactive FA can also inhibit incorporation of blood C16:0 and C18 FA into milk fat (Baumgard et al., 2001). Supplemental unsaturated FA, therefore, can affect milk fat yield in 2 opposing ways: they supply additional substrate for bioactive FA formation and they supply more preformed FA for direct incorporation into milk fat. Whether a cow exhibits MFD in response to added dietary fat depends on the balance between depression of milk fat yield by bioactive FA and increased milk C16:0 and C18 FA by provision of dietary FA.

Figure 1 reports yield of milk <C16 and C18 FA for cows fed a fat supplement minus the milk <C16 and C18 FA yield achieved with a low-fat control diet from previous studies (open symbols). All diets in which the main supplementary FA was either C18:1 or C18:2 resulted in decreased milk <C16 FA yield, with the most severe decreases in <C16 FA being associated with supplemented C18:2. These diets also increased milk C18 yield. In contrast, for supplements in which the primary FA were a mixture of C16:0 and C18:1, the magnitude of decreased milk <C16 and increased C18 FA yields were both 80 g/d or less. For supplements that contained almost completely C16:0, the average milk FA yield response was negligible for both <C16 and C18 FA. Although not shown in Figure 1, the response for milk C16:0 relative to the control averaged −92.2, −72.0, 32.4, and 182.9 g/d for primarily C18:2, C18:1, mixed C16:0 plus C18:1, or pure C16:0 diets, respectively. Although the studies in Figure 1 differed in their primary FA, other FA also varied among supplements.

It is well documented that diets supplemented with vegetable oils can cause MFD when fat content of the supplemented diets ranged from 3.6% (DePeters et al., 2001) to 8.0% (Chilliard et al., 2009) of diet DM. However, we could find no research exploring the effects of feeding different dietary FA when the final dietary FA concentration remains below 3%. Endogenous feed FA can contribute up to 3% of diet DM and might contribute to MFD. Additionally, the effects of *trans*-10,*cis*-12 CLA on milk fat yield and concentration appear to be curvilinear, with greater MFD per unit of increased *trans*-10,*cis*-12 CLA at lower infusion doses than at higher doses (Peterson et al., 2002).

The objective of this study was to examine the effect of oils rich in linoleic, oleic, or palmitic acid on milk fat secretion when supplemented at levels to achieve total dietary FA levels below 3% of DM. We hypothesized that (1) dietary linoleic acid would reduce the secretion of milk C16:0 and <C16 FA, which would offset any positive effects of increased dietary C18 on milk C18 yield; (2) dietary oleic acid would result in less depression of C16:0 and <C16 FA yields compared with linoleic acid, while still providing preformed C18 to be incorporated into milk fat; and (3) dietary palmitic acid would not depress milk C16:0 or <C16 yield and would provide a source of preformed C16:0 for inclusion into milk. Therefore, we predicted the lowest fat yield with the linoleic-rich fat supplement and the greatest fat yield with fat supplements consisting of palmitic plus oleic, with an intermediate milk fat yield for the oleic-rich oil supplement. Our study did not address the effect of endogenous feed FA, which, by way of being

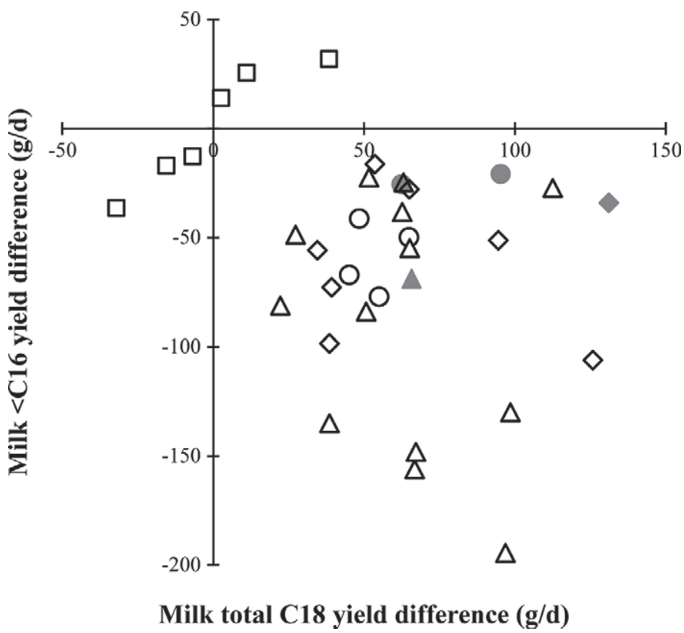

Figure 1. Change in milk yield of C18 versus change in milk <C16:0 yield in response to adding oils consisting primarily of C16:0 (squares), C16:0 + C18:1 (circles), C18:1 (diamonds), and C18:2 (triangles). Observations are yield of the indicated FA in milk for the oil supplemented minus the yield for a low-fat control diet. Data from the present study are presented in solid gray points. Data sources: Elliott et al. (1996); Kalscheur et al. (1997); Jenkins (1998); Fearon et al. (2004); Leonardi et al. (2005, 2012); Bell et al. (2006); Mosley et al. (2007); Bu et al. (2007); AlZahal et al. (2008); Warntjes et al. (2008); Huang et al. (2008); Abdelqader et al. (2009); Rego et al. (2009); Ye et al. (2009); He and Armentano (2011); Lock et al. (2013); Piantoni et al. (2013).