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Stearic, palmitic acids affect milk composition

The composition of dietary fat supplements appears to be important for milk fat production in the lactating dairy cow's mammary gland.

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IN our first article (*Feedstuffs*, July 21), we reviewed the digestibility, absorption, utilization and metabolism of palmitic (C16:0) and stearic acid (C18:0) in lactating cows. This article will focus on how C16:0 and C18:0 affect milk yield, milk fat production and milk fatty acid composition.

In a survey of retail milk in the U.S. by O'Donnell-Megaro et al. (2011) and a summary by Moate et al. (2007) of research studies reporting milk fatty acid, C16:0 was found to be highest in milk fat at about 28 g/100 g, followed by oleic acid (C18:1) at 20-24 g/100 g, with C18:0 comprising about half of C18:1 at 11 g per 100 g. Both studies showed that C16:0 was about 80% of C18:0 plus C18:1.

While milk fatty acid concentrations are rather consistent when averaged across a large number of milk samples, individual studies, especially short-duration studies, have shown that both milk fat yield and milk fatty acid concentrations can be altered by diet and types of fatty acids supplemented in the diet.

Milk production studies

Table 1 summarizes six published studies that have fed C16:0 to lactating dairy cows. Supplementation of C16:0 at between 361 g and 545 g per cow per day either did not change or decreased dry matter intake (DMI) of lactating cows in five of the six studies, and only one study reported an increase in DMI.

Two of the six studies reported a significant increase in milk yield — 1.1-3.1 kg per cow per day — and three of the six studies reported an increase in milk fat percentage of 0.11-0.49%. The longest-duration feeding study (Warntjes et al., 2008) reported a decrease in milk fat percentage when C16:0 was fed.

In all three studies in which the milk fat percentage increased (Mosley et al., 2007; Lock et al., 2013; Piantoni et al., 2013) and in Warntjes et al. (2008) where the milk fat percentage decreased, the concentration of C16:0 in the milk fat increased while concentrations of C18:0 and C18:1 decreased. The ratio of C16:0 to C18:0 plus C18:1 in the milk fat of cows supplemented with C16:0 increased to 1:1 compared to the 0.8:1 ratio found in retail milk.

Very little research has studied feeding a pure (greater than 85%) C18:0 fat supplement to dairy cattle. The classic study of Steele and Moore (1968a) fed 0.56 kg of C18:0 per day to mid-lactation dairy cows and found no change in DMI or milk yield, but milk fat increased 9% compared to the no-fat control (3.61% versus 3.31%). Milk fat composition changes included a 200% increase in C18:0, a 150% increase in C18:1 and about a 20% decrease in C16:0.

In later studies (Steele, 1969; Nobel et al., 1969), inclusion of 5% and 10% C18:0 in lactation diets increased milk

1. Effect of feeding highly purified palmitic acid to lactating cows on milk production and milk composition

Study	DMI, kg/day	Suppl. C16:0,* g/day	Milk, kg/day	Milk fat, %	Milk protein, %	Cows/treatment	Study length, days
Mosley et al. (2007)							
Control	23.3[a]	0	30.9[a]	3.44[a]	2.98	18	16
Treatment	26.4[b]	412	34.0[b]	3.93[b]	2.97	18	16
Warntjes et al. (2008)							
Control	26.2	0	36.7	3.75[a]	2.96	214	35
Treatment	26.4	384	38.0	3.60[b]	2.99	214	35
Rico and Harvatine (2011)** — Low cows							
Control	25.3[a]	0	28.8	3.86	3.19	24	14
Treatment	23.0[b]	394	29.0	3.92	3.14	24	14
Rico and Harvatine (2011)** — High cows							
Control	28.3[a]	0	41.5	3.14	3.14	24	14
Treatment	26.4[b]	449	42.0	3.22	3.17	24	14
Lock et al. (2013) — Dry corn treatment							
Control	24.7[a]	0	32.0	3.88[a]	3.33[a]	16	25
Treatment	23.3[b]	361	32.0	4.16[b]	3.28[b]	16	25
Piantoni et al. (2013)							
Control	27.8	0	44.9[a]	3.29[a]	3.11	32	21
Treatment	27.8	545	46.0[b]	3.40[b]	3.09	32	21

*Actual intake of supplemented C16:0. All supplemented sources of C16:0 were greater than 85% C16:0.

**Data from reference and personal communication from authors.

[a,b]Means within a study and within a response category with different superscripts are different ($P < 0.05$).

2. Fatty acids at three different positions (*sn*) on the milk fat triglyceride and their corresponding melting points

Fatty acid	----------% of fatty acid in *sn* position---------- *sn*-1	*sn*-2	*sn*-3	Melting point, °F
C4:0	1.6	0.3	48.1	17.8
C6:0	3.1	3.9	93.0	25.9
C8:0	10.3	55.2	34.5	62.1
C10:0	15.2	56.6	28.2	88.9
C12:0	23.7	62.9	13.4	109.8
C14:0	27.3	65.6	7.1	129.9
C16:0	44.1	45.4	10.5	145.0
C18:0	54.0	16.2	29.8	157.3
C18:1	37.3	21.2	41.5	56.1

Adapted from Jenson, 2002.

production 9% and 4%, respectively, but milk fat percentage was unchanged compared to feeding no fat.

A recent study (Boerman and Lock, 2014) found that DMI increased with increasing C18:0 supplementation (0%, 0.8%, 1.6% and 2.4% of diet dry matter) in the diet of mid-lactation cows, but milk yield and milk fat yield were unchanged.

Milk fatty acid antagonism

The early studies of Steele and Moore (1968a) and Noble et al. (1969) were the first to look at the effects of feeding C16:0 and C18:0 on milk fat yield and milk fatty acid composition.

Steele and Moore (1968a) showed that feeding 578 g of C16:0 per day or 564 g of C18:0 per day to mid-lactation cows increased milk fat percentage by 0.86% and 0.30% units, respectively. Feeding C16:0 increased the concentration and yield of C16:0 in milk fat but decreased the concentration and yield of short-chain, *de novo* synthesized milk fatty acids (C4 to C14) as well as C18:0 and C18:1 in milk fat. Feeding C18:0 had little effect on short-chain milk fatty acids but decreased C16:0 and increased the C18:0 and C18:1 concentrations in milk fat.

Subsequent research by Noble et al. (1969) observed similar shifts in milk fatty acid proportions when 448 g of C16:0 or C18:0 per day were fed to early-lactation Ayrshire cows.

Enjalbert et al. (2000) abomasally infused lactating dairy cows with 490 g of C16:0 per day or 460 g of C18:0 per day and observed elevated milk fat percentage and similar shifts in milk fatty acid proportions.

It can be concluded from these studies that a high intake of C16:0 increases the C16:0 proportion and yield in milk, interferes with *de novo* synthesis of short- and mid-chain milk fatty acids and decreases proportions and yields of C18:0 and C18:1 acids in milk fat. Conversely, a high intake of C18:0 increases the proportions and yields of C18:0 and C18:1 in milk fat, interferes with *de novo* synthesis and reduces the yield and proportion of C16:0 in milk fat.

Studies in which mixtures of C16:0 and C18:0 were fed or infused showed reductions in *de novo* synthesis of short- and mid-chain milk fatty acids but resulted in increases in milk yield, milk fat percentage and milk fat yield, with no significant changes in C16:0, C18:0 or C18:1 in milk (Steele and Moore, 1968; Drackley et al., 1992; Relling and Reynolds, 2007).

Kadegowda et al. (2008) abomasally infused lactating cows with milk fat at 400 g per day and observed a 21% increase in milk fat yield, a 14% increase in milk fat percentage (4.26% versus 3.74%) and a 7% increase in milk yield (33.7 kg versus 31.8 kg per day) but no changes in milk fatty acid composition compared to non-infused control cows.

Milk fluidity

Milk fat must remain fluid to leave the mammary gland, and the mammary gland is constantly combining fatty acids of different melting points to maintain fluidity. The melting points of C16:0, C18:0 and C18:1 are 145°F, 157°F and 56°F, respectively.

The cow's normal body temperature of 101.5°F is well below the melting point of saturated fatty acids, and therefore, unsaturated fatty acids must be incorporated into milk fat triglycerides to maintain milk fat fluidity. It does this by blending fatty acids with a lower melting point onto the third position (*sn*-3) of the milk fat triglyceride molecule, which is preferentially reserved for milk fat fluidity-regulating fatty acids (Table 2).

In forming milk fat triglycerides that are to be secreted by the mammary cell, the first two positions (*sn*-1 and *sn*-2) on the triglyceride are heavily populated with high-melting point fatty acids like palmitic and stearic acids. The last position of the triglyceride is reserved for lower-melting point fatty acids such as C4:0, C6:0 and C18:1 (Jensen, 2000).

Essentially, C16:0 is a terminal fatty acid in milk fat due to its high melting point and limited conversion to another fatty acid, whereas the desaturation of C18:0 to C18:1 in the mammary gland provides for triglyceride fluidity and reduces the amount of C18:0 for accumulation on the *sn*-1 or *sn*-2 position.

The intake of high amounts of C16:0 poses a problem for the lactating dairy cow with respect to milk fatty acid content. As observed in the six recent production studies listed in Table 1, only 15-20% of the added dietary C16:0 intake is incorporated into milk fat. The principal means of assuring milk fat fluidity is incorporation of C18:1 and short-chain fatty acids (C4:0 to C10:0) into triglyceride destined for milk fat globules (Timmen and Patton, 1988).

Because rumen biohydrogenation reduces unprotected C18:1 to C18:0, the major source of C18:1 going into milk fat is desaturation of C18:0 in the mammary gland. Therefore, the composition of the dietary fat supplement appears to be very important for milk fat production and milk fatty acid composition. Fatty acid supplements high in C16:0 will require either adequate short- and medium-chain fatty acids from *de novo* synthesis or adequate C18:0 for desaturation to C18:1 in the mammary gland to balance fluidity.

Available data indicate that a balance of C16:0 and C18:0+C18:1 at or near a 1:1 ratio, similar to a normal milk fatty acid content, may be preferred in maximizing milk fat production. More long-term research in early and mid-lactation is needed to determine the proper ratio of palmitic and stearic acids in fatty acid supplements.

References

References available in: J.R. Loften, J.G. Linn, J.D. Drackley, T.C. Jenkins, C.G. Soderholm and A.F. Kertz. 2014. Invited review: Palmitic and stearic acid metabolism in lactating dairy cows. J. Dairy Sci. (In press). ■