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Stearic, palmitic acids in dairy cow nutrition

Research has shown that long-chain fatty acids are not just a source of energy but are bioactive compounds and have metabolically different functions in the cow.

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INCLUSION of fat in lactating dairy cow diets is a common practice today to meet energy requirements for milk production, reproduction and body condition restoration.

Dry rumen inert fat supplements have increased in usage because of their versatility on farms in that they can be added to grain/mineral mixes, added directly to total mixed rations or top-dressed.

The fatty acid composition of rumen inert fats will vary, but the long-chain fatty acids (LCFAs) — palmitic (C16:0), stearic (C18:0), oleic (C18:1) and linoleic (C18:2) acids — are the most common.

Research over the last severals years has shown that these LCFAs are not just a source of energy but are bioactive compounds and have metabolically different functions in the cow.

The two saturated fatty acids C16:0 and C18:0 differ greatly in metabolic function and in how they support milk production. Until recently, there was limited information to differentiate the role of these two fatty acids in dairy cow nutrition (Loften et al., 2014).

Digestion, absorption

While C16:0 and C18:0 are similar in chemical formula — only differing by two carbon atoms — their presence and role in dairy cow metabolism are quite different.

Palmitic acid is the most common saturated fatty acid found in plants, animals and microorganisms. Common sources of C16:0 include palm oil, palm kernel oil, coconut oil and milk fat.

Stearic acid is prevalent in nature, found in animal and vegetable fats, but generally is higher in animal than in vegetable fats. Melting points (145°F for C16:0 and 157°F for C18:0) and pK_a (4.78 for C16:0 and 4.5 for C18:0) of the two fatty acids are similar.

The composition of dietary fatty acids and those fatty acids entering the small intestine are quite different. Wu et al. (1991) was one of the first to show that C18:0 was the only fatty acid to increase in the amount flowing from the rumen above the amount fed with or without fat supplemented in the diet (Table 1).

Later studies have shown that the amount of C18:0 leaving the rumen can be as much as 25 times greater than intake amounts and accounts for 40-70% of total fatty acid flow into the duodenum. The amount of C16:0 flowing into the duodenum from the rumen is generally similar to the dietary intake and represents 10-20% of the total fatty acid flow.

Early digestibility studies underestimated the digestibility of C18:0 because these studies were based on whole-tract disappearance and did not account for increased C18:0 leaving the rumen as a result of the rumen biohydrogenation of oleic, linoleic and linolenic fatty acids.

More recent studies (Doreau and Ferlay, 1994; Doreau and Chilliard, 1997; Enjalbert et al., 1997; Lock et al., 2006) compared digestibility between the duodenum and ileum or the duodenum and feces and concluded that digestibility of C16:0 and C18:0 is essentially the same (Table 2). Thus, digestibility of C16:0 and C18:0 as free fatty acids is essentially equal, as shown.

1. Fatty acid intake and rumen outflow in cows fed a 40% concentrate diet without fat (control) or with rumen inert fat or animal/vegetable (AV) blend[1]

	Fat supplementation		
Fatty acid, g/day[2]	Control	Rumen inert[3]	AV blend[4]
C16:0			
Intake	71	400	165
Outflow	83	313	152
C18:0			
Intake	12	39	104
Outflow	186	254	410
C18:1 — total			
Intake	79	308	297
Outflow	60	158	126
Total fatty acids			
Intake	431	1,052	934
Outflow	402	837	810

[1]Adapted from Wu et al. (1991).
[2]Rumen inert and AV blend intake and outflow values are means of feeding supplements at 3% and 6% of diet dry matter.
[3]Fatty acid composition of rumen inert fat was 50.8% C16:0, 4.2% C18:0 and 35.5% *cis* C18:1.
[4]Fatty acid composition of the AV blend was 17.0% C16:0, 17.2% C18:0 and 34.5% *cis* C18:1.

2. Average digestibility values of LCFAs in dairy cows

Fatty acid	Ferlay and Doreau, 1994	Lock et al., 2006	Doreau and Chilliard, 1997	Enjalbert et al., 1997
C16:0	77	75	79	76
C18:0	76	72	77	79
C18:1	—	80	85	78

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Metabolism

Stearic acid is the predominate fatty acid flowing out of the rumen and absorbed by the dairy cow, yet C18:0 is not the predominate fatty acid found in tissues of the cow. Adipose tissue contains 27% C16:0, 11% C18:0 and 48% C18:1. Nearly all of the C18:0 and C18:1 in adipose tissue is from the elongation of C16:0 to C18:0 and the subsequent desaturation of C18:0 to form C18:1 (Smith et al., 2006).

C18:0 is a poor source for lipogenesis in adipose tissue, while C16:0 is an excellent source. The presence of the delta-9-desaturase enzyme in adipose tissue is likely an adaptive mechanism that allows ruminants to utilize the abundance of saturated fatty acids flowing out of the rumen.

Key differences in C16:0 and C18:0 utilization by the cow can be found during the transition period. Douglas et al. (2007) found that weight percentages of C16:0, C18:0 and C18:1 in plasma were similar during the dry period, but following parturition and during negative energy balance, C16:0 and C18:1 increased, whereas C18:0 decreased (Table 3).

Increases in plasma non-esterified fatty acids during the transition period lead to increased liver uptake of fatty acids, their esterification and the accumulation of triacylglycerol (TAG) in the liver (Drackley, 1999; Grummer, 1993).

Research by Contreras and Sordillo (2011) suggested that excessive accumulation of lipid components in transition cow liver tissue and other cells could cause physical damage, including compression and reduction in the size and number of organelles. They also concluded that this compression could result in cell death.

Several research trials have shown that after parturition, C16:0 increases in liver tissue, while C18:0 does not (Rukkwamsuk et al., 2000; Mashek and Grummer, 2003; Sato and Inoue, 2006; Douglas et al., 2007). This indicates that cows metabolize C18:0 for energy — e.g., beta oxidation — in the liver and muscle and/or secrete large proportions of C18:0 through milk as both C18:0 and desaturation to C18:1.

3. Fatty acid composition of tissues in prepartum and postpartum dairy cows*

	Day relative to parturition			
Tissue, g/100 g fatty acid	-45	1	21	65
Adipose				
C16:0	27.0	27.5	—	—
C18:0	10.7	10.8	—	—
C18:1 *cis* 9	49.4	48.1	—	—
Liver triacylglycerol				
C16:0	26.8	42.3[a]	39.0[a]	26.0[b]
C18:0	25.5	10.6[b]	12.2[b]	24.7[a]
C18:1 *cis* 9	23.9	26.6[a]	26.6[a]	17.2[b]
Plasma				
C16:0	16.7	18.2[a]	14.5[b]	12.2[c]
C18:0	16.5	15.6[a]	13.9[b]	13.7[b]
C18:1 *cis* 9	18.0	19.6[a]	20.1[a]	14.5[b]

*Adapted from Douglas et al., 2007.
[a,b]Means within row with different superscripts differ.

White et al. (2011) suggested that circulating fatty acids that are characteristically increased in transition cows may stimulate gluconeogenesis. Stearic acid was shown to regulate specific enzyme systems by regulating promoters of these enzymes. These data suggest that C18:0 contributes to partitioning of energy during periods of upregulated gluconeogenesis, increased liver fatty acid supply or both.

More research on stearic acid and its effect on nutrient partitioning in early lactation is needed to further understand its role.

Karcagi et al. (2010) fed prepartum diets containing no fat (control), hydrogenated palm oil TAG with 69% C18:0 and 23% C16:0 (HTG) or calcium salts of palm oil fatty acids with 33% C16:0 and 4% C18:0 (CaS).

The diet containing the most C18:0 (HTG) was found to provide a better energy supply for high-yielding dairy cows in negative energy balance than the control or CaS diets. There was less TAG accumulated in the liver at five days postpartum of HTG-fed cows, and these cows ate more dry matter and produced more milk during the first 100 days of lactation than cows fed the other two diets.

This and other research (Litherland et al., 2011; Mashek and Grummer, 2003; Rukkwamsuk et al., 2000) suggests that C16:0 appears to have a greater probability of increasing in liver tissue postpartum than C18:0. Thus, feeding a high-C18:0/low-C16:0 fatty acid supplement in the close-up period and in early lactation may be the most energetically advantageous to the dairy cow than other combinations of fatty acids, although more research is required to confirm this idea.

A major difference between C16:0 and C18:0 is TAG accumulation in the liver during the transition period and during negative energy balance. Stearic acid does not accumulate in the liver, and it appears to be primarily utilized as an energy source in the early-lactation cow. In contrast, C16:0 can accumulate in liver cells during negative energy balance and can potentially cause damage to liver cells as fatty liver syndrome develops.

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). ■