The Role of Specific Fatty Acids on Dairy Cattle Performance and Fertility

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Introduction

Cattle are fed moderate amounts of fatty acids (**FA**) with the objective to enhance growth, lactation, health and reproduction. Most lipids fed to cattle are in the form of triacylglycerols in plant and animal products or as free FA or FA saponified to Ca in processed fat supplements. One of the premises of feeding fat to cattle is the inherited more dense caloric content than other dietary ingredients, which typically increases the caloric content of the diet in an attempt to meet increased energy needs of more productive animals. However, feeding fat can influence appetite and, when depressed, it can offset any benefit to caloric intake.

Some groups of FA are considered essential to mammals because mammalian cells are unable to synthesize them. The essentiality of FA was first described by Burr and Burr in a series of manuscripts published in the late 1920's to the early 1930's (Burr et al., 1932). The authors identified linoleic acid (C18:2 n6) and alpha linolenic acid (C18:3 n3) as two essential fatty acids for growth, skin structural health, and reproduction in guinea pigs and rats. Since then, researchers have demonstrated the importance of polyunsaturated FA as precursors of lipid mediator molecules, such as prostaglandins, prostacyclins, thromboxanes, leukotrienes, lipossines, resolvines, among others, that influence cellular function. Polyunsaturated FA are incorporated into phospholipids of cell membranes, which influence structural and functional properties of cells.

In cattle, a major impediment for delivery of polyunsaturated FA for absorption is ruminal biohydrogenation. In fact, ruminal biohydrogenation of n-3 and n-6 FA was extensive; greater than 80% of PUFA from the diet were modified by the ruminal microflora and, therefore, not available for absorption in the small intestine (Doreau and Ferlay, 1994). Despite extensive biohydrogenation of u[1]nsaturated FA, feeding increasing amounts of n-6 and n-3 FA alters tissue composition and influences cellular function and animal performance (Silvestre et al., 2011a; 2011b).Therefore, it is clear that despite limitations in delivery of specific amounts of polyunsaturated FA for absorption, altering the FA composition of the diet is capable of influencing animal performance.

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The polyunsaturated FA of the n-6 and n-3 families seem to have the most remarkable effects on animal performance; however, it is not completely clear whether these effects are mediated only by these specific FA or other potential intermediates produced during rumen biohydrogenation.

Recent Studies at the University of Florida

Several experiments have been conducted at the University of Florida in the last 6 years evaluating the role of specific fatty acids on pre-weaning calf performance and lactating cow performance. Multiple parameters were evaluated in those studies, and emphases were given to tissue composition, growth, lactation, immune responses, and gene expression.

Calf Performance

Two experiments were conducted to evaluate the impact of pre- and/or post-natal manipulation of the FA profile of diets fed to dams and/or calves on colostrum composition, transfer of passive immunity, calf growth, and performance.

Altering the FA profile of diets of prepartum cows and passive transfer

The hypothesis of this study was that supplementing dam diets with linoleic acid modifies the FA profile of colostrum and influences the efficiency of immunoglobulin (**Ig**) G absorption in calves. Pregnant nulliparous (n = 28) and previously parous (n = 50) Holstein cows were assigned to receive prepartum diets containing low amounts of long chain FA (< 1.8%) and dietary treatments were no fat supplementation (control), 1.7% of dietary dry matter (**DM**) of mostly free saturated FA (**SFA**, “Energy Booster 100”, Milk Specialties, Dundee, IL), and 2.0% of dietary DM as Ca salts of FA containing the essential fatty acids linoleic acid and alpha-linolenic acid (**EFA**, “Megalac R”, Church and Dwight, Princeton, NJ). Diets had similar nutrient content, except for those supplemented with FA that had greater caloric density and altered FA profiles.

The FA profile of colostrum of cattle fed EFA reflected the concentration of linoleic acid in the fat supplement and its metabolism in the rumen of the pregnant cattle. Feeding EFA to prepartum cows increased proportions of linoleic acid and n-6 derivatives indicating that elongase and desaturase activities in the mammary gland. Also, feeding EFA increased the concentrations of total and individual conjugated linoleic acids (**CLA**) as well as total C18:1 *trans* FA in colostrum clearly demonstrating that unsaturated FA in Ca salts were susceptible to microbial biohydrogenation in the rumen.

Table 1 depicts the main results of the experiment. Intake of IgG did not differ due to dietary treatments but serum concentrations of total IgG and anti-ovalbumin IgG after colostrum feeding were greater in calves born from cows supplemented with SFA compared with EFA. These data suggest that feeding calves colostrum from cows fed diets supplemented with SFA improved transfer of passive immunity. Feeding fat to

prepartum cows improved apparent efficiency of IgG absorption from 23.3 to 27.9% regardless of type of fat supplemented. Therefore, it is possible to influence passive immunity of newborn calves by supplementing dams with fat.

Increasing linoleic acid content of milk replacer

Calves originated from cows fed control, SFA and EFA were blocked by gender and dam diet and randomly assigned to receive a milk replacer containing low (**LLA**, 19.4% fat and 0.56% linoleic acid on a dry matter basis) or high concentrations of LA (**HLA**, 19.8% fat and 1.78% linoleic acid) from birth to day 60 of age. Calves were fed only milk replacer for the first 30 d of age, after which they were also offered a starter grain with a low FA and linoleic acid contents. The milk replacer was fed daily at a constant rate of 0.149 g of LA/kg of $BW^{0.75}$ for the LLA treatment group and 0.487 g of LA/kg of $BW^{0.75}$ for the HLA treatment, respectively. Milk replacer was fed to provide 6.72 g of fat/kg of $BW^{0.75}$.

Prepartum dam diet had minor effects on calf performance during the pre-weaning period, either in the first 30 d of life when only fed milk replacer or between 31 and 60 d of life (Table 2). Nevertheless, calves born from dams fed SFA had improved total DM intake, which resulted in better average daily gain than calves born from dams fed EFA (2.6 kg more BW by 60 d of age). Increased intake of LA from approximately 6.2 to 13.2 g/d on average over the 60-d period by feeding the HLA milk replacer increased BW gain by 3 kg over a 60-d period. Because feed intake was not changed, conversion of feed to gain was improved by 8%. This enhanced performance was accompanied by increased plasma concentrations of glucose and IGF-I. Feeding more LA in the milk replacer influenced immune cell function by increasing the proportion of phagocytosis by blood neutrophils and greater synthesis of cytokines by blood mononuclear cells.

One of the most interesting effects of altering the FA intake of calves was the long-term impacts on first lactation performance (Table 3). Heifers from dams fed fat prepartum produced 1,400 kg more 305-d mature equivalent milk yield in the first lactation than those fed diets with no supplemental fat. Furthermore, although calves born from dams fed SFA gained more BW than those born from dams fed EFA, heifers born from EFA dams had numerically greater (517 kg) 305-d mature equivalent milk production than heifers born from SFA dams. Although no interaction was observed between dam diet and newborn milk replacer, heifers born from dams fed a prepartum diet with no supplemental fat produced 1,000 kg more 305-d mature equivalent milk when fed milk replacer containing a high linoleic acid content than those fed a milk replacer containing a low linoleic acid content. These data suggest that feeding fat prepartum and the FA profile of the supplemental fat can influence growth of newborn calves and have long-lasting effects on future performance. Furthermore, milk replacer of new born calves should contain a minimum concentration of linoleic acid.

Cow Performance

Three experiments were conducted to evaluate the impact of pre- and/or postpartum manipulation of dietary FA on postpartum performance of dairy cows.

Altering the FA profile of diets of late gestation and early lactation dairy cows

The objectives of this study were the evaluate the impacts of supplementing diets containing low amounts of long chain FA (< 1.8%) with either mostly saturated free FA (SFA) or with Ca salts enriched with polyunsaturated FA during the last 50 d of gestation and first 90 d of lactation. Pregnant Holstein cows (n = 76) were assigned to receive prepartum and postpartum diets containing low amounts of dietary FA (< 1.8%; control) or the same diets, but supplemented with 1.7% of DM as mostly free saturated FA (**SFA**, "Energy Booster 100", Milk Specialties, Dundee, IL), or 2.0% as Ca salts of FA containing the essential fatty acids linoleic and alpha-linolenic acids (**EFA**, "Megalac R", Church and Dwight, Princeton, NJ). Diets had similar nutrient content, except for those supplemented with FA that had greater caloric density and altered FA profiles.

Prepartum DM intake was less for cows fed EFA (control = 11.3 vs. SFA = 11.4 vs. EFA = 10.2 kg/d), but other measures of prepartum performance were not altered by dietary fat or source of FA. Feeding EFA reduced postpartum DMI in multiparous but not in primiparous cows (Table 4). Despite the lower DM intake, cows feeding EFA improved milk yield compared with cows fed SFA, particularly in primiparous cows. Milk protein yield was greater for primiparous cows fed EFA, however, fat yield did not differ. Postpartum BW, BW change, and BCS were not different among treatments. Because of the greater milk yield with and slight reduction in DM intake, cows fed EFA had greater efficiency of converting feed into milk.

Altering the amount of supplemental fat and the FA profile of diets of cows in early lactation

Thirty Holstein cows at 15 d postpartum were randomly assigned to receive diets containing low amounts (2.1%) of long chain FA and not supplemented with fat (control), or supplemented with 1.5% FA from mostly saturated free FA (**SFA**) or from Ca salts of FA containing essential fatty acids (**EFA**, "Megalac R", Church and Dwight, Princeton, NJ). The study lasted from 15 to 106 d postpartum.

Feeding fat starting at 15 d postpartum tended (P = 0.09) to increase DM intake approximately 1.2 kg/d, but source of FA did not alter intake (Table 5). Cows fed fat produced 4.4 kg/d more milk, and response to fat feeding was greater when cows were fed EFA. Similar to milk yield, 3.5% FCM also increased with fat feeding and with feeding EFA. Concentrations of milk fat, true protein and lactose were not altered by dietary treatments, but cows fed fat, particularly those fed EFA had greater yields of milk components. The BW of cows was not altered in the first 106 d postpartum by feeding FA.

Feeding early lactation cows diets differing in ratios of n-6 to n-3 fatty acids

Forty-five multiparous Holstein cows at 15 d postpartum were randomly assigned to receive diets containing the same concentration of FA, but differing in profile such that the ratios of n-6 to n-3 FA consumed would be 4 to 1, 5 to 1, and 6 to 1. Treatments lasted 90 d and supplemental fat sources were fed as Ca salts of fatty acids.

- **R4** = a ratio of 4 parts of n-6 to 1 part of n-3 in the diet. This was expected to result in a ratio of 2 to 1 of n6 to n3 in the duodenal content based on estimates of duodenal flow of fatty acids (CPM-Dairy ver. 3.0.8);
- **R5** = a ratio of 5 parts of n-6 to 1 part of n-3 in the diet. This was expected to result in a ratio of 4 to 1 of n6 to n3 in the duodenal content; and
- **R6** = a ratio of 6 parts of n-6 to 1 part of n-3 in the diet. This was expected to result in a ratio of 8 to 1 of n6 to n3 in the duodenal content.

The FA composition of diets was manipulated by altering the mixture of Ca salts that contained either palm oil FA (EnerGII; Virtus Nutrition, Corcoran, CA), safflower oil FA (Prequel; Virtus Nutrition), and fish oil FA (StrataG, Virtus Nutrition). These Ca salts were blended such that the amount incorporated into the diets (1.43% of the diet DM) would result in different ratios of n-6 to n-3 fatty acids, but similar amounts of total polyunsaturated fatty acids.

Intake of DM increased linearly ($P = 0.05$) with reducing the ratio of n-6 to n-3 FA in the diet and cows fed the R4 diet had the greatest DM intake (Table 6). Because of the differences in DM intake and diet composition, a linear effect ($P < 0.001$) was detected for intakes of n-6 and n-3 fatty acids. As the ratio of n-6 to n-3 increased, intakes of linoleic and total n-6 FA increased. Conversely as the ratio n-6 to n-3 decreased the intake of eicosapentaenoic and docosahexanoic and total n-3 FA increased. Body weight was similar ($P = 0.40$) across treatments and the dynamics of BW changes during the study did not differ with source of FA. Cows fed R5 tented ($P = 0.06$) to have greater BCS than the other two treatments. A tendency for linear ($P = 0.07$) response in feed efficiency was observed with decreasing the n-6 to n-3 ratio in the diet. Cows fed R4 and R5 were more efficient in converting dietary DM into 3.5% FCM. Because of the differences in feed efficiency and same dietary caloric density, the energy balance of cows increased ($P = 0.03$) with increasing the ratio of n-6 to n-3 FA in the diet. Yields of milk and 3.5% FCM were greater for cows receiving the R4 diet followed by cows receiving R5 diet, which was greater than those of cows receiving the R6 diet ($P < 0.01$). Concentrations of milk fat, true protein and lactose were not affected by treatments (Table 6); however, because of the increased milk yield, yields of milk components increased linearly ($P < 0.01$) as the ratio of dietary n-6 to n-3 FA decreased.

Feeding transition dairy cows diets differing in FA profile and effects on fertility

Feeding fat to dairy cows usually result in modest to moderate improvements in fertility (Santos et al., 2004). When fat feeding exacerbated BW loss, primiparous cows

fed fat had reduced pregnancy at first AI (Sklan et al., 1994). Ferguson et al. (1990) observed a 2.2-fold increased odds of becoming pregnant at first and all AI in lactating cows fed 0.5 kg/d of fat. Similarly, grazing cows supplemented with 0.35 kg of FA had greater pregnancy after the first postpartum AI than unsupplmeneted controls (McNamara et al., 2003). Feeding Ca salts of palm oil FA improved pregnancy of dairy cows (Schneider et al., 1988).

Because the benefits of feeding fat may originate from specific FA (Staples et al., 1998), recent attention has been given to manipulating the FA profile of supplemental fat sources to improve fertility. Fatty acids of the n-3 family are thought to attenuate measure of inflammatory response, and these effects have been observed in lactating dairy cows (Silvestre et al., 2011b). It has been proposed that reducing attenuating the uterine prostaglandin secretion might be a potential mechanism by which some FA improve fertility in dairy cattle (Mattos et al., 2000; Mattos et al., 2004).

In a recent study at the University of Florida (Silvestre et al., 2011a), 1,380 Holstein cows were assigned randomly to be fed a combination of supplemental FA during the transition and the breeding periods. Prepartum diets were supplemented with Ca salts containing palm oil FA, which is mostly saturated and monunsatured (**Sat**), or with Ca salts of safflower oil fatty acids (**n6)** from 30 d before to 30 d postpartum. At 30 d postpartum, half of the cows in each transition treatment was assigned to receive a breeding diet supplemented with Ca salts containing either palm oil FA or fish oil fatty acids (**n3**) until 160 d postpartum. Therefore, the dietary treatment sequences were Sat-n6, Sat-n3, n6-Sat, and n6-n3. The Ca salts were added at 1.5% of the diet DM pre- and postpartum. At 43 d postpartum, cows were assigned to a synchronized ovulation protocol for first AI and nonpregnant cows to first AI had their ovulation synchronized for a second time.

Transition and breeding diets did not affect pregnancy per AI at 32 and 60 days after first insemination. However, pregnancy loss from day 32 to day 60 after the first postpartum insemination was less ($P < 0.05$) in cows fed breeding diets containing n3 FA compared with cows supplemented with Sat FA (Figure 1). For second service, breeding diet altered ($P < 0.05$) affected pregnancy per AI on day 32 after insemination, and an interaction between transition and breeding diet was observed. The increase in day 32 pregnancy per AI caused by n3 FA was greater in cows fed transition diets supplemented with n6 FA. The reduced pregnancy loss and increased second insemination pregnancy per AI resulted in a greater cumulative proportion of pregnant cows after the first two postpartum inseminations for cows fed breeding diets supplement with n3 FA, particularly when combined with a transition diet supplemented with n6 FA.

Conclusion

Recent studies at the University of Florida have demonstrated that responses to dietary fats depend on the composition of FA in the supplement. Feeding fat to prepartum cows seem to influence passive transfer and pre-weaning growth of calves.

Interestingly, the response to exposure to FA during the pre-natal period and from colostrum on the day of birth seems to extend beyond the pre-weaning period. Heifers born from cows fed diets supplemented with essential FA were more productive in the first lactation. Such findings warrant further studies. Calves require a minimum amount of linoleic acid in milk replacer for proper pre-wean growth. Fat feeding to during late gestation and early lactation had differential effects on primiparous and multiparous cows. For multiparous, feeding fat during the transition period resulted in numerical increase in milk production, but no difference with fat source was observed. On the other hand, primiparous cows were more productive when fed a supplemental fat source containing essential FA. When fed fat only during the postpartum period, cows responded to better when the supplemental source of FA containing essential FA. Finally, manipulating the n6 and n3 FA in the diet influence lactation performance and fertility. Replacing n6 FA with the n3 FA eicosapentaenoic and docosahexaenoic from fish oil resulted in greater yields of milk and milk components and improved pregnancy per AI. The benefits to fertility were observed primarily because of reduced pregnancy loss in the first 60 d of gestation.

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Table 1. Measures of passive immunity of Holstein calves born from dams fed diets supplemented with no fat (control), saturated fatty acids (SFA), or essential fatty acids (EFA) during late gestation[1]

	Control		SFA		EFA			P value[2]				
Item	Null	Parous	Null	Parous	Null	Parous	SEM	Fat	FA	Parity	Fat x Parity	FA x Parity
Calves	8	17	11	16	9	17						
Birth												
BW, kg	37.2	39.8	37.8	43.7	35.5	43.8	1.32	0.13	0.40	<0.01	0.06	0.38
STP[3], g/dL	4.83	4.82	4.78	4.62	4.79	4.80	0.11	0.44	0.39	0.57	0.75	0.42
IgG intake, g	410	383	344	487	336	431	37.0	0.94	0.42	0.04	0.04	0.54
ST IgG[4], g/dL	0.02	0.02	0.03	0.02	0.01	0.02	0.01	0.77	0.34	0.95	0.66	0.44
24 h after birth												
STP, g/dL	6.35	6.16	6.21	6.58	6.33	6.23	0.21	0.67	0.59	0.90	0.39	0.25
ST IgG, g/dL	2.40	2.21	2.69	2.97	2.51	2.36	0.22	0.09	0.07	0.90	0.52	0.32
ST IgG, % of STP	37.5	35.2	42.3	44.6	39.1	37.3	2.57	0.05	0.05	0.79	0.59	0.42
Anti-OVA IgG[5], OD	1.03	1.04	1.16	1.10	0.91	0.89	0.08	0.80	0.01	0.76	0.71	0.85
AEA[6], %	23.7	23.0	30.5	28.6	27.3	25.1	2.27	0.03	0.14	0.41	0.73	0.95

[1] Control = no fat supplemented; SFA = Energy Booster 100 (Milk Specialties, Dundee, IL); EFA = Megalac-R (Church & Dwight, Princeton, NJ). Null = nulliparous.
[2] *P*-values for orthogonal contrasts and interactions. Fat = SFA + EFA vs. Control; FA = EFA vs. SFA.
[3] Serum total protein.
[4] Serum total IgG.
[5] Optical density for serum anti-ovalbumin antibodies (IgG) of calves of colostral origin.
[6] Apparent efficiency of IgG absorption, % = [IgG concentration in serum at 24 h of life × (0.099 x BW at birth)] ÷ IgG intake] x100.

Table 2. Performance of calves born from dams fed prepartum diets containing no supplemental fat (control), saturated fatty acids (SFA) and Ca salts containing essential fatty acids (EFA), and fed milk replacer with low (LLA) or high (HLA) concentrations of linoleic acid[1]

	Control		SFA		EFA			P value[2]				
Item	LLA	HLA	LLA	HLA	LLA	HLA	SEM	Fat	FA	MR	Fat x MR	FA x MR
Birth to 30 d												
Birth weight, kg	38.7	41.6	40.6	42.4	41.7	40.3	1.31	0.32	0.71	0.30	0.23	0.23
MR intake, kg of DM	14.7	15.6	15.3	16.0	15.3	15.2	0.42	0.43	0.35	0.15	0.41	0.35
MR intake, % of BW	1.15	1.12	1.14	1.13	1.11	1.14	0.02	0.75	0.70	0.73	0.22	0.20
BW gain, kg	7.59	9.42	8.16	10.2	8.07	8.39	0.72	0.75	0.19	0.02	0.61	0.24
ADG, Kg/d	0.25	0.31	0.27	0.34	0.27	0.28	0.02	0.76	0.19	0.02	0.60	0.23
FE, (kg BW gain/kg MR intake)	0.51	0.60	0.53	0.63	0.52	0.56	0.05	0.99	0.34	0.05	0.87	0.54
31 d to weaning												
MR intake, Kg of DM	18.8	20.1	19.5	20.6	19.4	19.6	0.47	0.50	0.28	0.03	0.42	0.30
Grain mix intake, Kg of DM	10.4	11.9	13.8	12.5	11.3	10.6	1.14	0.36	0.06	0.81	0.22	0.79
Total DMI, kg of DM	29.3	32.0	33.3	33.1	30.7	30.2	1.38	0.32	0.05	0.58	0.19	0.90
Total DMI, % of BW	1.75	1.74	1.87	1.75	1.75	1.70	0.05	0.61	0.10	0.19	0.37	0.50
BW gain, Kg	19.0	20.3	20.2	21.4	17.8	20.5	1.07	0.71	0.13	0.05	0.76	0.50
ADG, Kg/d	0.63	0.68	0.68	0.71	0.59	0.68	0.03	0.69	0.11	0.05	0.81	0.44
FE, (kg BW gain/kg total DM intake)	0.65	0.64	0.62	0.64	0.58	0.68	0.03	0.66	0.93	0.09	0.13	0.19
Birth to weaning												
Final BW, Kg	65.3	71.7	69.0	74.1	67.6	69.3	1.97	0.36	0.12	0.01	0.40	0.39
Total DMI, Kg	44.0	47.7	48.6	49.0	46.0	45.3	1.66	0.32	0.07	0.39	0.18	0.73
Total DMI, % of BW	1.41	1.40	1.47	1.41	1.40	1.38	0.02	0.63	0.04	0.16	0.38	0.43
BW gain, Kg	26.6	29.6	28.4	31.6	25.9	28.9	1.27	0.55	0.04	<0.01	0.95	0.92
ADG, Kg/d	0.44	0.49	0.47	0.53	0.43	0.48	0.02	0.49	0.04	<0.01	0.94	0.92
FE, (kg BW gain/kg total DMI)	0.60	0.62	0.59	0.64	0.57	0.64	0.03	0.93	0.63	0.01	0.23	0.61

[1] Control = no fat supplement; SFA = Energy Booster 100 (Milk Specialties, Dundee, IL); EFA = Megalac-R (Church & Dwight, Princeton, NJ). LLA = 0.175 g of LA/$BW^{0.75}$, HLA = 0.562 g of LA/$BW^{0.75}$. Milk replacer (~ 20% fat) was exclusively fed the first 30 d of life to provide 6.72 g of fat/kg of $BW^{0.75}$.

[2] *P*- values for orthogonal contrasts. Fat = SFA + EFA vs. control prepartum, FA = EFA vs. SFA prepartum, MR = milk replacer.

Table 3. Performance of Holstein heifers born from dams fed prepartum diets containing no supplemental fat (control), saturated fatty acids (SFA) and Ca salts containing essential fatty acids (EFA), and fed milk replacer with low (LLA) or high (HLA) concentrations of linoleic acid[1]

	Control		SFA		EFA			P value[2]				
Item	LLA	HLA	LLA	HLA	LLA	HLA	SEM	Fat	FA	MR	Fat x MR	FA x MR
Age at 1st AI, mo	13.2	13.1	13.2	12.8	13.2	13.1	0.2	0.69	0.35	0.20	0.66	0.35
AI number	1.6	1.9	2.4	2.3	2.8	2.8	0.5	0.04	0.39	0.92	0.66	0.99
Age 1st calving, years	1.9	1.9	2.1	2.0	2.0	2.0	0.1	0.02	0.76	0.44	0.43	0.45
BW after calving, kg	515	508	545	545	565	538	19.5	0.04	0.75	0.49	0.85	0.51
BCS at calving	3.1	3.0	3.3	3.3	3.4	3.2	0.1	0.04	0.89	0.64	0.86	0.35
BW at dry off, kg	606	635	637	645	715	650	32.4	0.14	0.23	0.72	0.29	0.29
BCS at drying	3.4	3.5	3.4	3.4	3.8	3.5	0.1	0.08	0.02	0.55	0.03	0.07
Lactation, days	301	302	302	301	276	304	12.4	0.56	0.38	0.37	0.54	0.25
DIM at peak, d	107.4	85.3	76.4	89.5	78.0	78.0	10.2	0.08	0.64	0.72	0.11	0.54
305-d ME milk, kg	10,107	11,103	11,542	11,948	12,136	12,389	694	0.02	0.48	0.34	0.57	0.92
Fat, %	3.65	3.64	3.67	3.63	3.63	3.53	0.10	0.71	0.53	0.56	0.75	0.80
Protein, %	3.09	3.05	3.08	3.07	3.05	3.03	0.04	0.69	0.31	0.48	0.68	0.93
Lactose, %	4.78	4.78	4.77	4.85	4.80	4.83	0.02	0.08	0.71	0.07	0.16	0.30

[1] Control = no fat supplement; SFA = Energy Booster 100 (Milk Specialties, Dundee, IL); EFA = Megalac-R (Church & Dwight, Princeton, NJ). LLA = 0.175 g of LA/$BW^{0.75}$, HLA = 0.562 g of LA/$BW^{0.75}$. Milk replacer (~20% fat) was exclusively fed the first 30d of life to provide 6.72 g fat/kg $BW^{0.75}$.

[2] *P*- values for orthogonal contrasts. Fat = SFA + EFA vs. control prepartum, FA = EFA vs. SFA prepartum, MR = milk replacer.

Table 4. Performance of Holstein cows fed pre- and postpartum diets containing no supplemental fat (control), saturated fatty acids (SFA) and Ca salts containing essential fatty acids (EFA)

	Treatment[1]								
	Control		SFA		EFA		P value[2]		
Item	Primip	Multip	Primip	Multip	Primip	Multip	TRT x Parity	Fat	FA
DM intake, kg/d	15.1	21.0	16.5	22.1	17.5	18.6	0.01	0.42	0.12
BW, kg	495	641	502	671	515	629	0.37	0.55	0.45
Milk, kg/d	28.1	35.3	25.8	37.8	30.7	37.5	0.07	0.27	0.06
Milk fat, kg/d	1.0	1.3	0.8	1.3	1.0	1.3	0.17	0.10	0.24
Milk protein, kg/d	0.8	1.0	0.7	1.0	0.9	1.0	0.08	0.40	0.05
Milk/DMI, kg/kg	1.9	1.7	1.6	1.8	1.8	2.1	0.03	0.94	0.01
BHBA, mg/dL	6.4	8.4	5.6	7.6	5.8	12.3	0.01	0.45	0.01
NEFA, mM	432	468	317	464	341	522	0.04	0.13	0.11

[1] Control = no fat supplement; SFA = Energy Booster 100 (Milk Specialties, Dundee, IL); EFA = Megalac-R (Church & Dwight, Princeton, NJ) fed from 50 d before to 90 d after calving. Primip = primiparous; Multip = multiparous.

[2] *P*- values for the interaction between treatment and parity, and orthogonal contrasts. Fat = SFA + EFA vs. control; FA = EFA vs. SFA.

Table 5. Performance of Holstein cows fed postpartum diets containing no supplemental fat (control), saturated fatty acids (SFA) and Ca salts containing essential fatty acids (EFA)

	Treatment[1]			P value[2]		
	Control	SFA	EFA	TRT x P	Fat	FA
DM intake, kg/d	20.2	21.4	21.4	0.42	0.09	0.93
Milk, kg/d	37.6	40.3	43.6	0.56	< 0.001	<0.01
3.5% FCM, kg/d	38.9	41.4	45.4	0.89	< 0.001	< 0.01
Milk fat, %	3.52	3.54	3.70	0.36	0.30	0.14
Milk protein, %	2.88	2.93	2.92	0.55	0.34	0.87
Milk lactose, %	4.89	4.92	4.90	0.70	0.32	0.41
BW, kg	558.0	566.3	598.4	0.22	0.20	0.14

[1] Control = no fat supplement; SFA = Energy Booster 100 (Milk Specialties, Dundee, IL); EFA = Megalac-R (Church & Dwight, Princeton, NJ) fed from 15 to 106 d after calving.

[2] *P*- values for the interaction between treatment and parity (TRT x P) and orthogonal contrasts. Fat = SFA + EFA vs. control; FA = EFA vs. SFA.

Table 6. Effect of altering the ratio of n-6 to n-3 fatty acids of supplemental fat on lactation performance

	Treatment[1]				*P*[2]		
	R4	R5	R6	SEM	TRT	Linear	Quad
DM intake, kg/d	26.1	24.6	24.7	0.5	0.07	0.05	0.17
Fatty acid intake,[3] g/d							
Linoleic	298.1	329.5	369.4	8.6	<0.001	<0.001	0.69
EPA + DHA	20.3	14.9	10.0	0.3	<0.001	<0.001	0.65
Total n-6	300.6	332.0	371.9	8.6	<0.001	<0.001	0.69
Total n-3	76.3	67.3	62.8	1.7	<0.001	<0.001	0.27
Ratio of n-6 to n-3	3.9	4.9	5.9				
Milk, kg/d	46.8	44.8	43.2	0.7	< 0.01	< 0.01	0.77
3.5% FCM, kg/d	48.0	45.4	43.4	0.8	< 0.01	< 0.01	0.73
3.5% FCM/DMI	1.86	1.87	1.78	0.03	0.08	0.07	0.21
Milk fat							
%	3.64	3.58	3.54	0.05	0.42	0.19	0.81
Kg/d	1.71	1.60	1.53	0.03	< 0.01	< 0.01	0.73
Milk true protein							
%	2.82	2.86	2.86	0.02	0.23	0.13	0.40
Kg/d	1.32	1.28	1.24	0.02	0.03	0.01	0.94
Milk lactose							
%	4.90	4.88	4.88	0.01	0.37	0.23	0.44
Kg/d	2.29	2.19	2.12	0.04	0.01	< 0.01	0.77
Net energy							
Mcal/kg of milk	0.69	0.69	0.68	0.01	0.68	0.38	0.95
Mcal/d	32.3	30.8	29.5	0.6	< 0.01	< 0.01	0.82
Energy balance, Mca/d	-1.22	-0.79	1.03	0.69	0.06	0.03	0.41
BW, kg	558.0	566.3	598.4	14.9	0.22	0.20	0.14

[1] R4 = ratio of 4 to 1 of n6 to n3 fatty acids; R5 = ratio of 5 to 1 of n6 to n3 fatty acids; R6 = ratio of 6 to 1 of n6 to n3 fatty acids.

[2] TRT = effect of treatment; Linear = linear effect of altering the ratio of n-6 to n-3 fatty acids; Quad = quadratic effect of altering the ratio of n-6 to n-3 fatty acids.

[3] EPA = eicosapentaenoic fatty acid; DHA = docosahexaenoic fatty acid; total n-6 = C18:2 + C18:3γ + C20:2 + C20:3 + C20:4 + C22:2 + C22:4; total n3 = C18:3α + C20:3 + C20:5 (EPA) + C22:5 (DPA) + C22:6 (DHA).

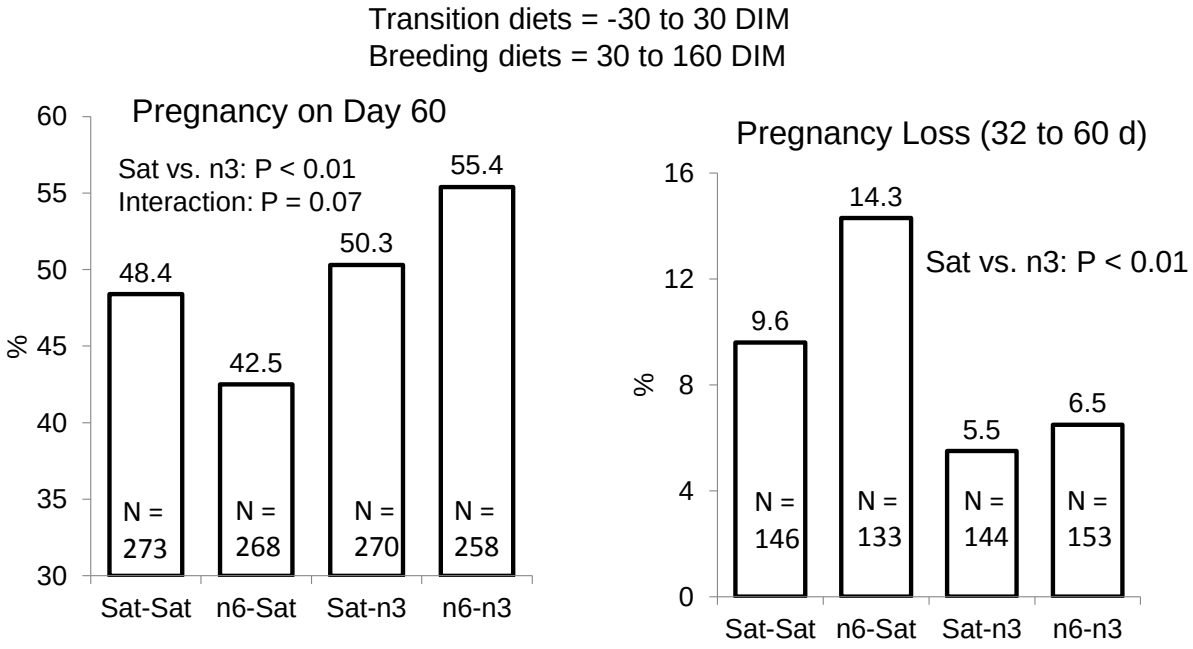

Figure 1. Cumulative pregnancy on day 60 after the first two postpartum inseminations and pregnancy loss between 32 and 60 d of gestation in cows fed transition (-30 to 30 d relative to calving) diets supplemented with Ca salts of palm oil (Sat) or safflower oil fatty acids (n6) and then feeding breeding diets supplemented with Ca salts of palm oil (Sat) or fish oil fatty acids (n3). Data from Silvestre et al. (2011a).

SESSION NOTES