Using Dietary Fats to Improve Reproductive Performance in Lactating Dairy Cows

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Take Home Messages

- Dietary fat effects are not simply due to energy, but specific fatty acids interact as substrates for specific enzymes and also interact with specific receptors to regulate gene expression in tissues of cows.
- Certain fatty acids such as EPA and DHA in Ca Salts of FO are being absorbed from the gastrointestinal tract and being preferentially taken up in the uterine tissue; such fatty acids alter expression of a complement of genes in the uterus to support development of the conceptus and maintenance of pregnancy.
- Fat supplements fed at a rate of at least 1.5% of the diet dry matter do appear to benefit reproduction. However, reproduction responses are quite variable.
- Feeding flaxseed may not improve initial pregnancy rates but appears to reduce embryonic loss.
- Feeding Ca Salts of Fish Oil reduced pregnancy losses at first service and increased pregnancy rates at 30 and 60 days to second service. Overall pregnancy losses were reduced by 6%.
- Polyunsaturated fats were most effective in increasing ovarian follicle size which contributes to earlier ovarian activity postpartum.

Fats Defined

A nutraceutical is defined as a product isolated or purified from feeds that is demonstrated to have a physiological benefit or provide protection against chronic disease. Specific classes of fatty acids exert direct regulatory effects on tissue function that impact milk production, immune status, and reproduction processes. The challenge is to understand these basic processes and to evaluate whether they have any benefit on reproductive efficiency. Many different types of supplemental fat have been fed to lactating cows. Each fat source is composed of a different mix of individual fatty acids. The short-hand notation for identifying fatty acids is to give the number of carbons and double bonds in the molecule. Fats that have double bonds are classified as unsaturated fats. For example, a designation of 18:2 indicates a fatty acid of 18 carbons long having 2 double bonds. The term "omega" refers to the location of the double bond in the carbon chain. An omega-6 fatty acid has its first double bond located between the 6^{th} and 7^{th} carbon counting from the methyl end of the chain. Likewise an omega-3 fatty acid has its first double bond located between the 3^{rd} and 4^{th} carbon counting from the methyl end of the carbon chain. Linoleic acid, abbreviated C18:2, is an omega-6 fatty acid. Linolenic acid, abbreviated C18:3, is an omega-3 fatty acid. Two additional omega-3 fatty acids are EPA (C20:5) and DHA (C22:6); but these are not considered essential for the cow because they can be synthesized from the omega-3 fatty acid, linolenic acid.

▪ Dietary Fats Are Modified in the Rumen by Bacteria

The ruminal microbes will convert unsaturated fats to saturated fats by replacing the double bonds with single bonds between the carbons (called biohydrogenation). The majority of the consumed unsaturated essential fatty acids, linoleic (C18:2) and linolenic (C18:3) acids, are converted by the bacteria to stearic acid (C18:0). During the process of biohydrogenation of unsaturated fats in the rumen, several intermediate forms of fatty acids, called trans fatty acids, also are formed. Some of the trans fatty acids, such as the trans-10, cis-12 conjugated linoleic acid (CLA) and the trans-10 C18:1, can influence the cow's metabolism, including depressing milk fat synthesis. This intervention by ruminal bacteria to change essential fatty acids in the diet to other fatty acids has made the study of dietary fat effects on reproduction quite challenging.

▪ Evidence that Fatty Acids have Potential Intracellular Effects as Nutraceutical Effectors

Dietary fat effects are not simply due to energy, but that specific nutraceutical effects likely are being manifested whereby certain fatty acids interact as substrates for specific enzymes (e.g., PGHS-2) and also interact with peroxisome proliferator-activated receptors (PPARs) to regulate gene expression. The essential polyunsaturated fatty acids, linoleic (18:2n-6) and α-linolenic (18:3n-3), undergo steps of chain elongation and desaturation forming differential n-6 products, such as dihomo-gamma linolenic (20:3n-6) and arachidonic (20:4n-6) acids, and n-3 products such as eicosapentaenoic acid (EPA; 20:5n-3). These specific long chain polyunsaturated fatty acids produce eicosanoid products of the prostaglandin series PGF1, PGF2 and PGF3, respectively as well as various thromboxanes, leukotrienes, lipoxins, hydroperoxy-eicosatetraenoic acids and hydroxyeicosatetraenoic acids (HETE) that regulate inflammation and immunity (Mattos et al., 1999). The peroxisome proliferator-activated receptors (PPARs) are a family of nuclear receptors activated by specific fatty acids, eicosanoids and peroxisome proliferators. Previous studies have shown that they are involved in the regulation of genes affecting steroid and prostaglandin synthesis (MacLaren et al., 2006).

We examined the effects of feeding Ca salts of fatty acids enriched with fish oil on endocrine responses, ovarian-uterine function, and expression of various genes in the uterus (Bilby etal., 2006a; Bilby etal., 2006b). Two diets were fed in which the oil of whole cottonseed (15% of dietary DM; control diet) was compared to oil prepared as a Ca salt containing fish oil (CaSFO) as one of the primary oils (1.9% of dietary DM; Virtus Nutrition). Formulated concentrations of ether extract (5.7%), nonstructural carbohydrate (36%), crude protein (18%), and net energy of lactation (1.7 Mcal/kg) were similar between diets (100% DM basis). Cows were fed the control diet for the first 10 days postpartum. Starting on day 11 of lactation, 8 of these cows were temporarily assigned to a transition diet containing 0.95% CaSFO to initially adjust cows to eating CaSFO. On day 18 postpartum, the CaSFO was increased to 1.9% of dietary DM which is the diet the cows remained on for the duration of the experiment. Ad libitum feed intakes were measured daily on a group basis. Daily feed intake by the cows fed CaSFO averaged 20.9 kg of DM/cow over the entire period of feeding. The calculated intake of EPA and DHA was 7.4 g/d for each fatty acid (i.e., 14.8 g/d total). All cows were presynchronized and started an Ovsynch protocol at approximately 7 days after a detected estrus. All cows that were designated for slaughter at day 17 after the second GnRH injecton of the Ovsynch protocol had to have ovulated and formed a CL when evaluated at day 7.

An important point is whether feeding a by-pass fat enriched in fish oil results in absorption of EPA and DHA that alters fatty acid concentrations among various tissues (Figure 1). The endometrium and liver had highest concentrations of C18:2n-6, C20:4n-6, C18:3n-3, EPA, and DHA compared to milk fat, mammary tissue, muscle, and both subcutaneous and internal fat tissues (Bilby et al., 2006c). An important observation was that the CaSFO diet reduced the concentrations of arachidonic acid (C20:4n-6) and preferentially increased the concentrations of EPA and DHA in the endometrium. Thus it is clear that EPA and DHA fatty acids of the CaSFO diet are being absorbed from the gastrointestinal tract and being preferentially taken up in the endometrial tissue which is also in agreement with Moussavi et al. (2007).

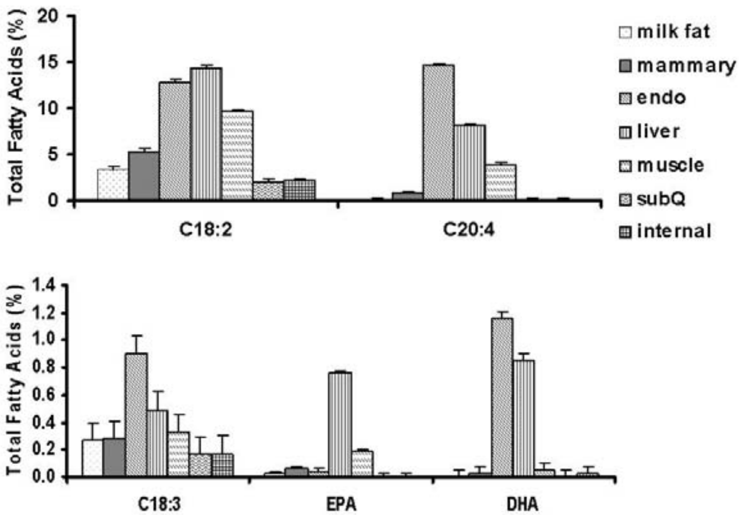

Figure 1. Percent C18:2n-6, C20:4n-6, C18:3n-3, EPA and DHA of total fatty acids in milk fat, mammary, endometrium (endo), liver, muscle, subcutaneous (subQ) and internal fat tissues collected at day 17 of a synchronized estrous cycle.

In the present study, feeding CaSFO appeared to induce subtle antiluteolytic effects when examining immunohistochemistry spatial responses for the progesterone and estradiol-α receptors and PGHS-2 proteins (Bilby et al., 2006b). Staining for progesterone receptors was evident in the superficial glandular epithelial cells of the cyclic cows at day 17 whereby CaSFO increased the moderate and heavy staining. Conversely, moderate to heavy staining intensity for the ER-α receptor was reduced in the luminal epithelial cells of CaSFO-fed cows (Bilby et al., 2006b). This antiluteolytic pattern was associated with an attenuated effector response reflected by a decrease in heavy staining for PGHS-2 protein in the luminal epithelium of cyclic cows (Bilby et al., 2006b).

It is clear that EPA and DHA antagonize the stimulatory effects of arachidonic acid on $PGF_{2\alpha}$ secretion (Mattos et al., 2003). As a consequence, a dietary manipulation of a nutraceutical has possibly altered the cellular and intracellular processes to sustain embryo development or pregnancy. The take home message is that feeding a by-pass fat enriched with fish oil appears to mediate specific effects in the uterus of cyclic cows that may alter expression of a complement of genes in the uterus that impinge on uterine responses to support development of the conceptus and maintenance of pregnancy.

▪ Fat Feeding on Conception Rates

A variety of fat supplements have benefited conception rates of lactating dairy cows (Table 1). The conception rates are sometimes reported for first insemination or for accumulated inseminations. Feedstuffs stimulatory to conception included calcium salts of palm oil distillate, tallow, Energy Booster (prilled tallow), flaxseed (formaldehyde-treated or rolled), MegaPro Gold (which is a calcium salt of palm oil plus rapeseed meal and whey permeate) fed to grazing cows, calcium salt of a mixture of soy oil and monounsaturated trans fatty acids, Megalac-R, CLA, and fish meal. The average improvement in conception rate was 21 percentage units. Any benefit experienced on a commercial dairy farm will likely be less than 10 percentage units because management is usually not as tight as that exercised on an experiment at a research station. In contrast, some of the research station experiments are comprised of a small number of cows or experimental units. Other studies have reported no positive pregnancy benefit to fat-supplementation (Table 2).

From the studies listed in Table 1, it is very difficult to determine which fat supplements or which fatty acid(s) may be most efficacious. When cows fed fats containing mainly palmitic and oleic acids (tallow, Energy Booster, and Ca salts of palm oil distillate) were compared to those fed a no supplemental fat control, the fat-supplemented cows had better conception rates. In four head-to-head comparisons of fat supplements, cows fed calcium salts of palm oil distillate did not conceive as well as those fed formaldehyde-treated flaxseed (Petit et al., 2001), unprocessed whole flaxseed (Petit et al., 2004a), a calcium salt mixture of soybean oil and monounsaturated trans fatty acids (Juchem et al., 2004), or CLA (Castaneda-Gutierrez et al., 2005; Table 1). Therefore fats containing mainly palmitic and oleic acids may not be as effective.

Flaxseeds are a source of α-linolenic acid (C18:3) and have been evaluated as a stimulator of reproductive performance of lactating dairy cows with mixed results. Flaxseeds are the only concentrated source of linolenic acid (~20% of DM) available. First service conception rate was increased from 50 to 87% when lactating cows in the United Kingdom were fed formaldehyde-treated flaxseed at 17% of a ryegrass silage-based diet between 9 and 19 weeks postpartum (Petit et al., 2001). Control cows were fed a calcium salt of palm oil (5.6% of diet) and flaxseed meal. Cows had been on their diets for 6 weeks prior to insemination. In a Canadian study involving 121 Holstein cows (Ambrose et al., 2006b), cows fed coarsely rolled flaxseed at 9% of the diet had a better first service conception rate ($P < 0.07$) compared to the control cows fed rolled sunflower seeds at 8.7% of dietary DM (48.4 vs. 32.2%). Although the overall pregnancy rates (i.e., cumulative pregnancy rate to 1st and 2nd TAI) were not different between the two groups (67.7 vs. 59.3%), the overall pregnancy loss from day 32 of pregnancy to calving was less for cows fed flaxseed (9.8 % <vs.27.3 %; $P < 0.05$). Diets were fed for 28 days prior to insemination using a timed AI protocol and continued for 32 days after AI. In a second Canadian study conducted on two commercial dairy farms, conception rate was not different between cows fed whole flaxseed at 10.6% of the diet and those fed micronized soybeans starting at calving (Petit and Twagiramungu, 2006). However those fed flaxseed had less ($P < 0.07$) embryonic loss. From the same lab, embryos collected from cows fed whole unprocessed flaxseed had a better gestation rate when transferred to heifers than embryos from cows fed Ca salt of palm oil distillate (58.8 vs. 29.3%; Petit et al., 2004a).

Table 1. Studies Reporting Improved Conception Rates (first service or cumulative services) of Lactating Dairy Cows Fed Supplemental Fatty Acids (P < 0.10). Unless otherwise indicated with a footnote, the control diet did not contain a fat supplement.

Reference[5]	Fat source and concentration or amount in diet	Number of cows in trial	Control treatment	Fat treatment
			- - - - - - - - % - - - - - - -	
Ferguson et al., 1990	2% Ca-palm oil	253	43	59[1]
Sklan et al., 1991	2.6% Ca-palm Oil	99	62	82
Scott et al., 1995	1 lb/d Ca-palm oil	443	93	98
Garcia-Bojalil et al., 1998	2.2% Ca-palm oil	43	52	86
Son et al., 1996	3% tallow	68	44	62
Frajblat and Butler, 2003	1.7% Energy Booster	81	58[2]	86
Petit et al., 2001	17% formaldehyde-treated flaxseed	30	50[3]	87[1]
Petit et al., 2004a	Whole unprocessed flaxseed	30	29	59[3]
Ambrose et al., 2006b	9% rolled flaxseed	121	32[4]	48[1]
McNamara et al., 2003	3.3 lb/d MegaPro Gold	129	35	54
Juchem et al., 2004	1.5% (Soy + Trans C18:1)	397	26[3]	34[1]
Cullens, 2004	2% Megalac-R	42	27	58[1]
Castaneda-Gutierrez et al., 2005	0.3 lb/d Ca-CLA	32	44[3]	81
Bruckental et al., 1989	7.3% fish meal	132	52	72
Armstrong et al., 1990	1.8 lb/d fish meal	80	44	64
Carrol et al., 1994	3.5% fish meal	44	68	89[1]
Burke et al., 1997	2.8% fish meal	300	32	41
Average			49.0	70.6

[1] First insemination.
[2] Control diet contained equal energy to fat-supplemented diet. Fat was fed prepartum only.
[3] Control diet contained Ca salt of palm oil distillate.
[4] Control diet contained rolled sunflower seeds.
[5] References are listed in Staples et al. (2007)

Table 2. Studies Reporting a Negative Effect or No Improvement in Conception Rates (first service or cumulative services) of Lactating Dairy Cows Fed Supplemental Fatty Acids. Unless otherwise indicated with a footnote, the control diet did not contain a fat supplement.

Reference[6]	Fat source and concentration or amount in diet	Number of cows in trial	Control treatment	Fat treatment
			- - - - - - - - %	- - - - - -
Schneider et al., 1988	1.1 lb/d Ca-palm oil	108	43	60[1]
Sklan et al., 1989	1.1 lb/d Ca-palm oil	108	28	44[1]
Carroll et al., 1990	5% prilled fat	46	33	75[1]
Holter et al., 1992	1.2 lb/d Ca-palm oil	38	50[2]	44[1]
Lucy et al., 1992	3% Ca-palm oil	40	44	12[a]
Sklan et al., 1994	2.5% Ca-palm oil primiparous cows	40	74	33[1,a]
Sklan et al., 1994	2.5% Ca-palm oil multiparous cows	62	42	33[1]
Salfer et al., 1995	2% partially hydrogenated tallow	32	32	33[1]
Bernal-Santos etal., 2003	0.3 lb/d Ca-CLA	30	27[4]	42
Bruno et al., 2004	1.5% (Ca-palm + fish oils)	331	26[3]	27[1]
Petit and Twagiramungu, 2006	10.6% whole flaxseed	70	58[5]	64
Ambrose et al., 2006a	9% rolled flaxseed	309	37[6]	26[1]
Ambrose et al., 2006 personal comm..	8% rolled flaxseed	266	42[7]	43
Fuentes et al., 2007	5.5% extruded flaxseed	356	39[8]	39[1]
Carroll et al., 1994	3.5% fish meal	18	67	33[1,a]
Burke et al., 1997	2.7% fish meal	341	65	60
Average			44.2	41.8

[1] First insemination. [2] Control diet contained whole cottonseed at 15% of dietary dry matter.
[3] Control diet contained tallow. [4] Control diet contained Ca salt of palm oil distillate.
[5] Control diet contained micronized soybeans. [6] Control diet contained Ca salt of palm oil distillate and High Fat Product from ADM. [7] Control diet contained Ca salt of palm oil distillate and tallow. [8] Control diet contained extruded soybeans and Ca salt of palm oil distillate.
[a] Significant dietary effect, $P < 0.05$.
[6]References are listed in Staples et al. (2007)

Three recent studies involving a greater number of dairy cows did not report any pregnancy advantage to cows fed flaxseed. Holstein cows (n = 356) on a commercial dairy in Spain were fed diets of either 5.5% extruded whole flaxseed or 4.9% extruded soybeans plus 1% calcium salts of palm oil between 4 to 20 weeks postpartum (Fuentes et al., 2007). Cows were detected in estrus using visual observation and the Afimilk system. First service (39 vs. 39%) and overall conception rates (40 vs. 34%) did not differ between soybean and flaxseed groups, respectively. A commercial dairy in Oregon (n = 309 cows) was used to evaluate rolled flaxseed, fed from about 32 days postpartum through 31 days after timed AI (Ambrose et al., 2006a). Cows were on diets at least 28 days prior to AI. Conception rates at 94 days after AI were not different, being 36.7% for controls and 25.6% for cows fed flaxseeds when all cows were considered. When only cows that responded to synchronization were included in the data set (n = 169), conception rate was lower for cows fed flaxseed at 31 days post AI (51.2 vs. 35.3%). Loss of embryos between 31 and 94 days post AI was not affected by diet but 9 control cows lost their embryos whereas 4 flaxseed-fed cows lost their embryos. Lastly, lactating dairy cows fed rolled flaxseed (8% of diet DM) had a similar conception rate (43.3%; n=141) to those fed a mixture of tallow and Ca salt of palm oil distillate (41.6%; n=125) at 35 days post AI (Ambrose et al., 2006, personal communication). Although not different, embryo loss was 8% vs. 16% for cows fed flaxseed vs. control fat. Although the evidence is not strong, it appears that feeding flaxseed may not improve initial pregnancy rates but may reduce embryonic loss.

Although the main nutrient in fish meal is protein and not fat, it is included here because the oils unique to fish may play a role in establishing pregnancy. The inclusion of fish meal in the diet (2.7 to 7.3% of dietary DM) has improved either first service or overall pregnancy rate in four studies. In some of these studies, fish meal partially replaced soybean meal resulting in a reduction of an excessive intake of ruminally degradable protein. Therefore, the improved conception rates may have been due to the elimination of the negative effect of excessive intake of ruminally degradable protein on conception. However, in a field study in which the concentration of ruminally undegradable protein was kept constant between dietary treatments, cows fed fish meal had a better conception rate (Burke et al., 1997) suggesting that the positive response was due to something other than a reduction in intake of ruminally degradable protein.

Recently, Silvestre and Thatcher (unpublished observations) fed cows either Ca-LCFA (Virtus Nutrition) of palm oil or safflower oil (enriched in linoleic acid) from 2 weeks prepartum to 4 weeks postpartum, and then half of the cows in each transition treatment were switched to either Ca-LCFA of palm oil or fish oil (enriched in omega 3 fatty acids EPA and DHA) out to 160 days postpartum. The cows were fed calcium salts of fish oil (CaSFO) at 1.5% of the dietary dry matter were receiving 19 grams per day of the Omega 3 fatty acids EPA and DHA. The study involved 1055 cows with pregnancy rates evaluated at first and second timed inseminations. Among the 4 treatment groups an overall effect of the calcium salts of fish oil was detected on pregnancy rates and embryo survival (Table 3). Feeding CaSFO reduced pregnancy losses at first service and increased pregnancy rates at 30 and 60 days to second service. First two services were programmed to occur within a 35 day period. During this period 52.8% of the CaSFO treated cows conceived when evaluated at 60 days after insemination, which was 7.4% greater than CaSPalmOil. Furthermore pregnancy losses were reduced by 6%.

Table 3. Effects of Calcium Salts of Fish Oil (CaSFO) on Pregnancy Rate to First and Second Services in Lactating Dairy Cows.

	CS-Palm Oil (n=)	CaSFO (n=)	P-value
First Service			
d32	37.3% (203/544)	37.6% (192/511)	N.S.
d60	31.7% (171/539)	34% (178/509)	N.S.
Loss	13.6% (27/198)	6.3% (12/190)	<0.05
Second Service			
d32	27% (84/309)	36.9% (109/295)	<0.05
d60	23.7% (72/303)	34.4% (101/293)	<0.05
Loss	7.7% (6/78)	5.6% (6/107)	N.S.
Total Services			
d32	52.5% (290/552)	56.57% (301/532)	N.S.
d60	45.4% (246/541)	52.8% (279/528)	<0.05
Loss	12% (33/279)	6% (18/297)	<0.05

▪ Amount of Fat to Feed and When

A frequent asked question is "How much fat or a specific fatty acid should be fed in order to improve reproduction?" In the studies listed in Table 1, the fat sources were fed at a minimum of 1.5% of dietary dry matter. We know that feeding these amounts were effective. We do not know if feeding a smaller amount of fat would be effective as well. People are interested in feeding a smaller amount of fat to keep feed costs down and minimize the potential negative effects of supplemental fats on ruminal bacteria. Negative effects can include reduced fiber digestion and reduced fat and protein concentrations in the milk. Generally speaking, fat supplementation at 1.5% of the diet is usually safe in terms of cow performance with the exception of fish oil. Feeding fish oil at more than 1% of dietary dry matter will usually reduce feed intake and/or milk fat and protein concentration. If the fat concentration of the base diet without a fat supplement is 3 to 4%, then increasing it to 4.5 to 5.5% by fat supplementation should not be a problem if the dietary fiber is sufficient and effective. Certainly diets containing higher fat ingredients need to be watched closely so that the total fat content stays below 6%.

It is certainly possible that feeding supplemental fat at a lower rate such as 0.25 or 0.5 pounds per day could be effective. The key fatty acids reaching the small intestine of the cow are absorbed and can accumulate in tissues over time. In a Florida study, the concentration of EPA increased in the liver fat from approximately 0.05 to 0.5 to 0.9% in liver samples collected at 2, 14, and 28 days in milk from cows fed linseed oil starting 5 weeks prepartum. A small but steady supply of these key fatty acids will allow the tissues to accumulate the fatty acids and have them ready at the proper time for reproductive purposes. Therefore, even a smaller fat feeding rate than the 1.5% for some experiments in Table 1 may be beneficial.

Fat feeding must be initiated long enough before the fats are needed for restoring the reproductive tissues to a new fertile state. Cows fed selected fat sources have responded with larger ovarian follicles. Since ovarian activity usually returns within the first 4 weeks of calving, initiating fat feeding prepartum would allow the absorbed fatty acids to influence early ovarian activity. Feeding supplemental fat for at least 21 days, preferably for 40 days, prior to the desired physiological response is our recommendation. We have begun supplementing cows in the close-up dry period (3 to 5 weeks before the calculated due date). This allows the tissues to begin storing the key fatty acids prior to when they will be most needed. In summary, research studies that have documented the benefits of fat supplements for reproduction fed the fats at a rate of at least 1.5% of the diet dry matter. However, the reproduction responses are quite variable with some reports showing no significant benefit.

▪ How Might Fat Supplementation Help Improve Conception Rates?

Improving Energy Status?

Those lactating dairy cows which experience a prolonged and intense negative energy state have a delayed resumption of estrous cycles after parturition that can increase the number of days open. If fat supplementation can help increase energy intake, then possibly the negative energy state can be lessened and estrous cycles start sooner and conception occur sooner. Adding a very energy dense nutrient such as fat to the diet will usually increase the cow's energy intake. However the energy status of the cow is usually not improved because of a slight to moderate depression in feed intake and/or an increase in milk production. Dairy cows fed tallow at 3% of dietary DM tended to have a greater pregnancy rate (62 vs. 44%; Table 1) despite having a more negative calculated mean net energy status from weeks 2 to 12 postpartum compared to cows not fed tallow. Likewise cows fed calcium salts of CLA (Castaneda-Gutierrez, 2005) or palm oil distillate (Garcia-Bojalil et al., 1998; Sklan et al., 1991) had better conception rates without an improvement in energy balance. Although there is evidence that the feeding of fat can improve the energy status of lactating dairy cows, an improvement in reproductive performance occurred in several instances apart from an improving energy status of the experimental animals.

Healthier Ovarian Follicles?

The size of the dominant follicle is often larger in lactating dairy cows receiving supplemental fat. On average, the size of the dominant follicle was 3.2 mm larger (a 23% increase) in fat-supplemented cows compared to control cows (Staples et al., 2007). Yet are certain fats more effective? Some studies did compare fat sources head-to-head. In two studies, it was the feeding of fats enriched in omega-6 (linoleic acid) or omega-3 fatty acids (linolenic or EPA and DHA) (Staples et al., 2000; Bilby et al., 2006d) that stimulated larger dominant follicles compared to fats enriched in oleic acid. Thus the polyunsaturated fats were most effective in increasing follicle size. Thus, cows fed fats enriched with the essential fatty acids are likely to have more progesterone being synthesized due to a formation of a larger ovarian corpus luteum that is derived from a larger ovulatory follicle. Potential increases in progesterone secretion and plasma concentrations need to be considered with regard to the higher rate of metabolism and clearance of progesterone in lactating dairy cows. Our recent study of feeding calcium salts of fish oil, beginning early postpartum, had no positive or negative effect on progesterone concentrations during a programmed estrous cycle (Bilby et al., 2000a). Furthermore, Moussavi et al. (2007) failed to detect any affect of feeding either fishmeal or calcium salts of fish oil on plasma progesterone concentrations during a programmed estrous cycle until day 15.

Antiluteolytic Effect of Reducing Prostaglandin Secretion?

If $PGF_{2\alpha}$ is released by the uterus, the corpus luteum will regress, progesterone synthesis will decline, the embryo will die for lack of support, and the cow will start a new estrous cycle. About 50% of embryos die (~40% during the first 28 days after AI and ~14% between 28 and 45 days after AI). Embryonic loss is a significant problem in the dairy industry. Omega-3 fatty acids stored in the uterus from the diet may aid the process of embryo development and survival by helping to reduce the synthesis of prostaglandin $F_{2\alpha}$. Quite clearly EPA, DHA, α-linolenic fatty acids can inhibit $PGF_{2\alpha}$ release by bovine endometrial cells *in vitro.* Can omega-6 fatty acids have a similar beneficial effect? Not likely, because omega-6 fatty acids are used to synthesize prostaglandin $F_{2\alpha}$; although CLA can suppress $PGF_{2\alpha}$ release *in vitro.* Cows that are fed omega-3 fatty acids partially replace the omega-6 fatty acids stored in the uterus so that there is less omega-6 inventory for the cow to draw from for synthesis of prostaglandin $F_{2\alpha}$. In demonstration of this effect, a series of studies demonstrated: feeding fish meal reduced the PGFM response to an estradiol-oxytocin challenge (Mattos et al., 2002); cows fed sunflower seeds (enriched in linoleic acid) had higher PGFM response compared to cows fed linseed, Megalac or no fat supplement (Petit et al., 2004b); cows fed linoleic or α-linolenic fatty acids did not differ in their PGFM response to oxytocin on days 15 and 16, but response to linoleic was greater on day 17 (Robinson et al., 2002). Moussavi et al., (2007) failed to detect a difference in PGFM response to oxytocin at day 15 of a programmed estrous cycle in the early postpartum period (i.e., d 49 DIM) when either fish meal or calcium salts of fish oil were fed previously. Variability in these results may be associated with timing of the induction response relative to normal time of luteolysis. Alternative models need to be examined to conclusively demonstrate the antiluteolytic effect of omega-3 fatty acids on prostaglandin secretion.

■ Conclusion:

Feeding dietary fats provides nutritional value besides just increasing energy availability because of the array of potential fatty acids, such as polyunsaturated fatty acids, that interact as substrates for specific enzymes and interact with specific receptors to regulate gene expression. Feeding fat supplements enriched in polyunsaturated fatty acids such as EPA and DHA in Ca Salts of fish oil are being absorbed from the gastrointestinal track and taken up preferentially in certain tissues such as the endometrium of the uterus. A complement of genes in the uterus is regulated in a manner that appears to support development of the conceptus and maintenance of pregnancy. Fat supplements fed at a rate of at least 1.5% of the diet dry matter do appear to benefit reproduction although reproduction responses are quite variable. Feeding fats enriched in omega 3 fatty acids appear to increase pregnancy rates (i.e., Ca Salts of fish oil) and reduce embryonic losses (i.e., flaxseed and Ca Salts of fish oil). Feeding fats, in particular those enriched in polyunsaturated fats, stimulates postpartum ovarian activity that results in larger ovarian follicles. The potential benefits of feeding omega 6 and 3 polyunsaturated fatty acids at variable times (transitional pre—postpartum diets and diets during the breeding period) introduces the potential benefits of pro-inflammatory and anti-inflammatory diets that may benefit health, production and reproductive responses of the lactating dairy cow.

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