FEEDING FATTY ACIDS TO DAIRY COWS FOR FERTILITY

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INTRODUCTION

Just as amino acids are the individual units making up the class of nutrients called proteins, so are fatty acids the major individual units of measure of what are broadly called lipids. Just as each amino acid has a distinct structure and function in protein building, so each fatty acid has a distinct structure and possibly function in metabolism.

The essentiality of certain amino acids and certain fatty acids was established for growing rats at about the same time. W.C. Rose at the University of Illinois in the early 1930's identified 10 essential dietary amino acids for rats. Soon thereafter, these same essential dietary amino acids were confirmed experimentally in growing nonruminant livestock. The fatty acids, linoleic acid (**C18:2**) and linolenic acid (**C18:3**), were identified in 1929 and 1930 as essential fatty acids (**EFA**) for growing rats fed nearly fat-free diets (Burr and Burr 1929; 1930). Their work documented that the cessation of growth and scaly skin condition caused by feeding the fat-free diet was reversed dramatically by supplementing with linoleic acid. Stearic (**C18:0**) and oleic acids (**C18:1**) were considered ineffective. Prolonged feeding of the fat-free diets resulted in death of the rats.

As with other essential nutrients, C18:2 and C18:3 cannot be synthesized in sufficient quantity to supply the animal's requirement. The enzymes necessary to synthesize the EFA from nonessential fatty acids are present only in plants (Groff et al., 1995). Because Δ12 and Δ15 desaturase enzymes are absent in cows and apparently in ruminal microorganisms, the C18:1 that is found in many feedstuffs cannot be desaturated to C18:2 or C18:3 within the animal. Therefore, these two polyunsaturated fatty acids must be supplied in the diet.

EFA REQUIREMENT FOR THE BOVINE UNDEFINED

However the identification of C18:2 and C18:3 as EFA did not change the way livestock were fed. In 1936, Morrison stated "Whether or not farm animals need these fatty acids is still an open question. In any event, the usual rations fed stock in all probability provide sufficient amounts of any such essential nutrient substances." In 1954, Lambert et al. reported that the preweaned baby calf required the same two essential fatty acids in their diet. Calves fed a fat-free diet developed deficiency symptoms that included retarded growth, scaly dandruff, long dry hair, excessive loss of hair, and diarrhea.

Although the need for these specific fatty acids by livestock continues to be supported by modern nutritionists, the quantity of each fatty acid required has not been defined and appears to be of little concern. "If farm animals actually have a dietary need for EFA, it seems probable that they are adequately supplied by the commonly fed rations…" (Maynard and Loosli, 1969).

Although current wisdom in the dairy industry is that the dietary intakes of the EFA are sufficient for meeting the lactating cow's requirements, Sanchez and Block (2002), citing simulations, have suggested that the daily amount of C18:2 excreted in 100 lb of milk per day exceeds the post ruminal uptake of those EFA in typical diets. According to the scientific literature dealing with human and lab animal nutrition, a ratio of C20:3 to C20:4 in tissues/serum that exceeds 0.4 is indicative of a C18:2 deficiency or an imbalance of C18:2 to C18:3 (Holman, 1960). If the ratio of C20:3 to C20:5 exceeds 0.4, a deficiency of C18:3 is suspected. The rational behind this ratio is that the synthesis of C20:3 n-9 from oleic acid increases when EFA are deficient. It might be productive if these same ratios could be used to identify situations, if any, in which supplemental EFA would benefit the bovine.

EFFECTS OF LINOLEIC ACID ON REPRODUCTIVE TISSUES AND PERFORMANCE

Although the role of the EFA has been documented as a key nutrient in maintaining healthy skin and hair and good growth rates, reproductive performance has also been affected when EFA were deficient, apparently apart from the general poor health of the animal. In the early work of Burr and Burr (1930), rats were fed a fat-free diet resulting in cessation of growth and, in a majority of rats, cessation of or irregular ovulation. Rats were then supplemented with either corn oil, olive oil, linseed oil, or coconut oil at approximately 1% of dietary DM. With the exception of coconut oil, consumption of the other oils resulted in a quick expression of heat (within 6 to 9 d of diet change). Coconut oil contained no C18:2. The other oils contain between 41% (corn oil) and 7% (olive oil) C18:2. Authors attributed this effect to "ovarian hormone" rather than to simply an improvement in overall animal being because "...the resumption of ovulation is so rapid that growth has hardly begun. Synthesis of ovarian hormone ceases when fatty acids are eliminated from the diet.." In a later study, EFA-deficient female rats could conceive but aborted before gestation was complete (Deuel et al., 1954). Other species such as the chicken also have shown improvements in reproduction when given C18:2. Embryonic mortality was nearly total when pullets were fed an EFA deficient diet, and fertility and hatchability were improved when 1 gram of C18:2 was supplied daily (Menge et al., 1963).

The supplementing with some sources of fat to lactating dairy cows has improved reproductive performance. In several studies, lactating cows fed a basal diet containing whole cottonseed (~9% C18:2) and further supplemented with Ca salts of long chain fatty acids (CaLCFA; Arm and Hammer Nutrition, Princeton, NJ) (~8% C18:2) experienced a better rate of conception or pregnancy than cows fed the diet containing only whole cottonseeds (Staples et al., 1998). Lactating cows fed tallow (4.3% C18:2) at 3% of dietary DM tended to have a better conception rate by 98 days in milk than

cows not fed tallow (Son et al., 1996). Grazing dairy cows supplemented with soybean oil soapstock (53% C18:2) at ~2% of dietary DM experienced a greater pregnancy rate than controls (62.5 vs. 22.2%) whereas those fed fat and housed in a freestall barn had lower pregnancy rates than controls (0 vs. 22.2%) (Boken, 2001). Primiparous beef heifers also have experienced greater pregnancy rates (94, 90, 91, and 79%) from being fed rolled and cracked safflower seeds, soybeans, or sunflower seeds, all high in C18:2 concentration (Bellows et al., 1999). Protection of dehulled cottonseeds (~9% linoleic acid) with protein-aldehyde complexes (Protected Lipid, Rumentek Industries, Australia) delivered approximately 175 g/d of linoleic acid to the lower gut of lactating Hereford cows. Overall pregnancy rates were improved from 63 to 79% (Wilkins et al., 1996).

The physiological basis by which linoleic acid may improve reproductive performance may lie with its influence on the metabolism of progesterone (P4). Progesterone, synthesized and secreted by the corpus luteum (CL) on the ovary, is called the hormone of pregnancy. Progesterone not only prepares the uterus for implantation of the embryo but also helps maintain pregnancy by providing nourishment to the conceptus. Increased concentrations of plasma P4 have been associated with improved conception rates of lactating dairy cows (Butler et al., 1996). A number of studies have reported that dairy cows fed supplemental fat (tallow, CaLCFA, prilled fatty acids, or whole cottonseeds) had elevated concentrations of blood P4 (Table 1). Might fat supplementation improve the synthesis of P4? Cholesterol serves as a precursor for the synthesis of P4. Although the feeding of supplemental fat usually increases blood

Table 1. Concentration of plasma progesterone was increased by feeding supplemental fat to lactating dairy cows.

		Diet		
Reference	Time of measurement	Control	Fat	SEM
		---------- ng/ml ----------		
Lucy et al., 1993	1 - 12 d of estrous cycle	4.2[a]	5.2[b]	0.8
Carroll et al., 1990	9 - 15 d of estrous cycle	6.6[a]	7.7[b]	0.3
Sklan et al., 1991	8 - 20 d of estrous cycle	Greater accumulation[a,b]		
Spicer et al., 1993	5 – 12 wk postpartum	4.5[a]	6.0[b]	0.5
Garcia et al., 1998	1 – 7 wk postpartum	Greater accumulation[a,b]		
Son et al., 1996	2 – 12 wk postpartum	4.2[a]	4.8[b]	0.3
Adams, 1998	2 – 9 wk postpartum	Greater accumulation[a,b]		

[a,b]Means in the same row with different superscripts are different.

cholesterol concentrations (Grummer and Carroll, 1991), Carroll et al. (1992) reported that maximum in vitro synthesis of P4 by bovine luteal cells occurred at much lower concentrations of high density lipoproteins than those found in plasma. If more P4 is not synthesized when fat is fed, then the clearance rate of P4 from the blood may be reduced in cows fed fat. Beef heifers were fed either 0 or 0.57 kg/d of CaLCFA from 100 days prepartum through the third estrous cycle postpartum (Hawkins et al., 1995). Mean concentrations of plasma P4 and cholesterol were elevated in heifers fed fat. On days 12 to 13 of the third cycle, heifers were ovariectomized. Higher concentrations of P4 in repeated blood samples that were taken immediately before and after ovariectomy indicated a greater half-life of P4 and suggested a slower clearance rate from blood of heifers fed CaLCFA. Two recent studies support this influence of fat on progesterone clearance (Sangritavong et al. 2002). Liver slices were incubated with P4, estradiol, and several fatty acids including C18:2. When C18:2 was included in the media, the half-life of P4 (50.7 vs. 31.7 min) and estradiol (37.3 vs. 25.9 min) were increased over that of media containing no fatty acids. This effect of C18:2 was confirmed in vivo using nonlactating Holstein cows. Progesterone and estradiol were infused intravenously with or without a soybean oil emulsion. Cows receiving soybean oil had greater serum concentrations of P4 (3.83 vs. 2.42 ng/ml) and estradiol (379 vs. 287 pg/ml), strongly suggesting that the presence of soybean oil (possibly C18:2) reduced the clearance rate of these steroids.

In addition to an increased concentration of P4 in blood due to fat supplementation, increases in P4 concentration (55.4 vs. 33.0 ng/ml) and total nanograms of P4 (173.9 vs. 68.3 ng) were reported in the fluid of estrogen-active follicles of lactating dairy cows fed CaLCFA from 0 to 150 days postpartum (Moallem et al., 1999). The concentration of P4 in follicular fluid also was greater for beef cows that were fed soybean oil at 5.4% of dietary DM than for control cows (Ryan et al., 1992).

OMEGA-3 FATTY ACIDS

Three other long chain, polyunsaturated fatty acids may have an influence on reproductive performance; namely linolenic acid, eicosapentaenoic acid (**EPA**, **C20:5**) and docosahexaenoic acid (**DHA**, **C22:6**). All three fatty acids have a double bond located between the third and fourth carbon counting from the methyl end of the molecule, and thus are classified as omega-3 fatty acids. These latter two fatty acids are found in marine products such as algae, fish meal, fish oil, and some seafood byproducts. These fatty acids are appearing more often in dairy cow diets due to an increased interest in feeding fish meal as a ruminally undegradable protein source (Kellogg et al., 2001). Linolenic acid is the main fatty acid found in some vegetable oils such as linseed and in pasture forages.

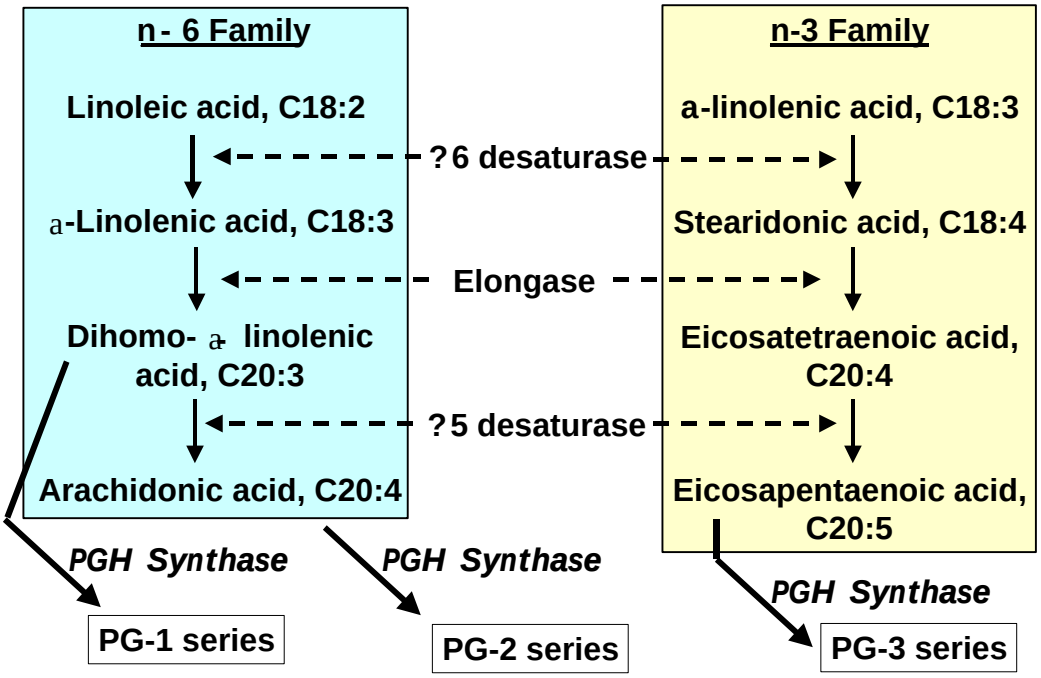
Linolenic acid may have been responsible for the improvement in conception rate (87.5 vs. 50.0%) of lactating dairy cows (n = 35) fed formaldehyde-treated whole flaxseed (17% of dietary DM) compared to those fed CaLCFA (5.6% of dietary DM) from 9 to 19 weeks postpartum (Petit et al., 2001). Supplementing diets of lactating dairy cows with fish meal has improved conception rates (Staples et al., 1998). In some of

these studies (Armstrong et al., 1990; Bruckental et al., 1989; Carroll et al., 1994), 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., 1996) suggesting that the positive response was due to something other than a reduction in intake of ruminally degradable protein. The unique polyunsaturated fatty acids in fish (EPA and DHA) may have been responsible for the improvement in fertility.

These fatty acids may improve overall pregnancy due to their influence on the synthesis of prostaglandin $F_{2\alpha}$ (**PGF_{2a}**). A quick review of the role of PGF_{2a} during the postpartum period of resumption and reoccurrence of estrous cycles is in order here. Within the reproductive tract of cows, uterine tissue is a primary source of the F series prostaglandins (e.g., PGF_{2a}) during the early postpartum period. Concentration of 13, 14-dihydro-15-keto-PGF_{2a} metabolite (**PGFM**) in plasma rose dramatically to a peak of ~2200 pg/ml by 1 day postpartum (Mattos, 2001). This rise is associated with regression of the CL of pregnancy and postpartum regression of the uterus. (The PGFM is produced as the uterus and lung metabolize PGF_{2a}.) Over the next 2 weeks, PGFM gradually returned to baseline concentrations. The uterus then synthesizes and releases PGF_{2a} regularly over the following weeks to regress each newly formed CL in order to initiate a new estrous cycle if the cow is not pregnant. If the cow does conceive, PGF_{2a} release from the uterus is inhibited in order to preserve the CL on the ovary to allow it to synthesize P4 to aid in the implantation and nutrition of the embryo. Because PGF_{2a} has an effect on the regression of the CL, concentrations of plasma P4 are related inversely to PGF_{2a} concentrations during the period of CL regression in late diestrus.

The synthesis of PGF_{2a} is from arachidonic acid (C20:4) and is regulated by the key enzyme, prostaglandin endoperoxide synthase (**PGHS**) (Figure 1). The feeding of C20:5 may aid in the suppression of synthesis of PGF_{2a} by the uterus by competing for PGHS. Dihomo-γ-linolenic acid also can compete for PGHS when it is converted to the series one prostaglandins. Although C22:6 is not a substrate for PGHS, it is a strong inhibitor of PGHS activity. Therefore when intake of C18:3, C20:4, or C22:5 increases, conversion of C20:4 to PGF_{2a} can be reduced, thus potentially increasing the chances of preserving the life of a newly formed embryo. In addition, the increased presence of C20:5 and C22:6 can inhibit the synthesis of C20:4 from C18:2 by inhibiting the desaturation and elongation enzymes required for that conversion (Figure 1; Bezard et al., 1994). Linolenic acid also can compete with C18:2 for the desaturase enzymes so that more C20:5 and less C20:4 are synthesized (Figure 1). In addition, the omega-3 fatty acids can displace C20:4 in the phospholipids of cell membranes thus reducing availability of C20:4 (Howie et al., 1992). Therefore increasing the dietary intake of the omega-3 fatty acids can reduce the production of PGF_{2a}.

Figure 1. Synthesis of the various prostaglandin (PG) series from fatty acid precursors.



If the omega-3 fatty acids are performing as described, embryo survival should be increased. Holstein cows (n = 141) were allotted to one of three dietary treatments initiated at calving (Petit and Twagiramungu, 2002). Diets were isonitrogenous, isoenergetic, and isolipidic. Diets contained either whole flaxseed, CaLCFA, or micronized soybeans. Flaxseeds are ~32% oil, 57% C18:3, 14% C18:2, and 18% C18:1. The diameter of the CL of the cows fed flaxseed was larger than that of cows fed soybeans (19.7 vs.16.9 mm) but not larger than that of cows fed CaLCFA (17.5 mm). Embryo mortality from day 30 to 50 after AI tended to be lower ($P < 0.11$) when cows were fed flaxseed (0%) compared to CalCFA (15.4%) or soybeans (13.6%). In a California field study (Juchem et al., 2002), pregnancy loss from day 28 to 39 tended to be lower (0 vs. 15%; $P < 0.10$) in cows (n = 120) fed a calcium salt of palm and fish oil fatty acids (1.6% of dietary DM) compared to those fed tallow (1.3% of dietary DM).

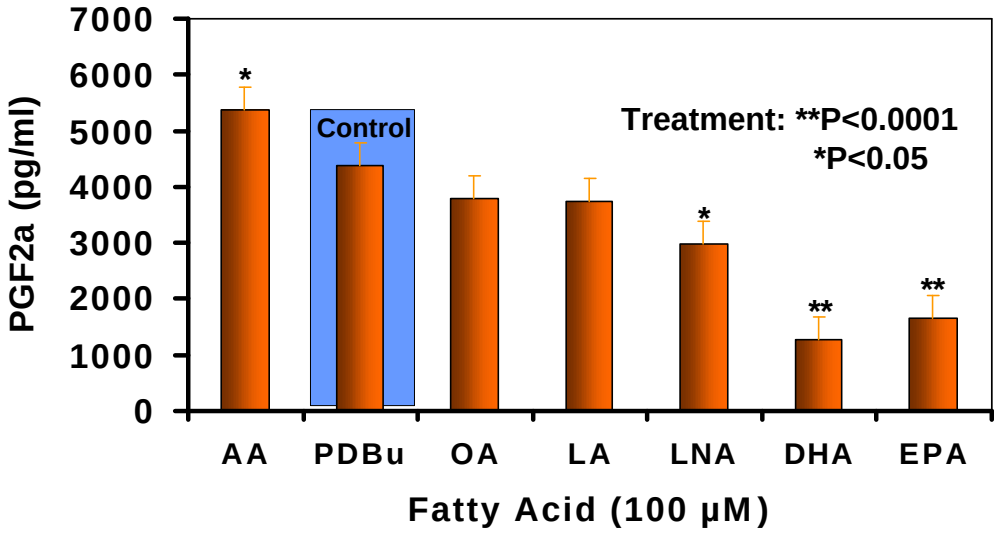
In summary, PGF_{2a} play an important role in reestablishing estrous cycles both immediately after parturition and thereafter until conception occurs. Omega-3 fatty acids may aid in suppressing PGF_{2a} to prevent regression of the CL in order to maintain pregnancy (e.g. prevent early embryonic death).

EVALUATION OF INDIVIDUAL FATTY ACIDS

Which fatty acids are the most potent when it comes to suppression of synthesis of PGF_{2a}? A series of in vitro experiments was performed at the University of Florida (Mattos, 2001) using bovine endometrial (**BEND**) cells from the uterus. The BEND cells were incubated with no fatty acid (control) and a variety of fatty acids that included

C18:1, C18:2, C18:3, C20:4, C20:5, and C22:6 at a concentration of 100 uM (Figure 2). Compared to the control, cells incubated with C20:4 tended to stimulate synthesis of

Figure 2. Synthesis of PGF_{2a} by bovine endometrial cells incubated with a variety of fatty acids. AA = aracidonic acid; OA = oleic acid; LA = linoleic acid; LNA = linolenic acid; DHA = docosahexaenoic acid; EPA = eicosapentaenoic acid. Difference between each fatty acid and control: *P < 0.05; **P < 0.01.

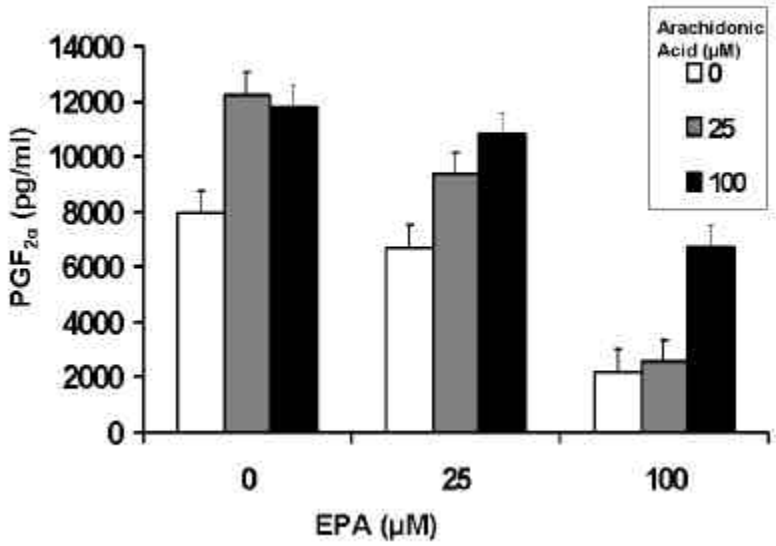


PGF_{2a}. This positive response was expected since C20:4 is the fatty acid precursor of PGF_{2a}. Only the omega three fatty acids (C18:3, C20:5, and C22:6) suppressed synthesis of PGF_{2a} with C20:5 and C22:6 the most repressive. The fact that C18:2 did not affect secretion of $PGF_{2\alpha}$ somewhat contradicts previous reports indicating inhibitory activity of this fatty acid (Elattar and Lin, 1989; Pace-Asciak and Wolfe, 1968). Moreover, C18:2 has been considered a potential mediator of reduced endometrial $PGF_{2\alpha}$ secretion in the pregnant cow (Thatcher et al., 1995). Conversely, because C18:2 is the most abundant precursor for synthesis of C20:4 and $PGF_{2\alpha}$, it could be hypothesized that C18:2 would increase secretion of $PGF_{2\alpha}$ through increased precursor availability. This did not occur in the BEND cell system. One possible reason could involve lack of an efficient system for conversion of C18:2 to C20:4, which involves two steps of desaturation and one step of elongation. It is not clear why C18:3 was less inhibitory than DHA and EPA. Linolenic acid is the precursor for synthesis of DHA and EPA, and can be converted to them in a process that relies on activities of desaturase and elongase enzymes.

In a second study, BEND cells were coincubated with C20:4 and C20:5 for 24 h. Figure 3 illustrates the competing effects of the two fatty acids. Arachidonic acid increased ($P < 0.01$) secretion of PGF_{2a} whereas C20:5 was inhibitory ($P < 0.01$). This illustrates the competition of precursors for processing by the PGHS enzymes involved

in prostanoid synthesis. The reduced secretion of PGF_{2a} observed in cells incubated with C20:5 is likely a result of a shift of the PGHS pathway from synthesis of prostanoids from the 2 series to synthesis of prostanoids of the 3 series. In the presence of C20:5, less of the C20:4 present was converted to $PGF_{2a.}$

Figure 3. Effects of eicosapentaenoic acid (EPA) and arachidonic acid on in vitro synthesis of PGF_{2a} by bovine endometrial cells of the uterus.



Application of these results to the dairy cow was tested. Our hypothesis was that feeding C20:5 and C22:6 through fish oil during the periparturient period would increase the proportion of these fatty acids in uterine tissue and reduce the spontaneous secretion of uterine PGF_{2a} of dairy cows at parturition. Pregnant Holstein cows (n = 17) and heifers (n = 9) were assigned randomly to diets containing fish oil (n = 13) (Arista Industries, Wilton, CT) or olive oil (n = 13) (Classico, Bertolli, Italy). A ration containing either fish oil or olive oil was supplied from 21 days before the expected calving date until parturition, when it was replaced by greater nutrient density rations also containing either fish oil or olive oil that were fed until cows reached 21 days postpartum. Cows (n = 6) and heifers (n = 6) that had moderate to severe dystocia, or that were diagnosed with displaced abomasum, retained fetal membranes, or toxic metritis within 10 days after parturition were removed from the analysis.

Rations were formulated to provide approximately 2% oil prepartum and 1.8% oil postpartum. The fatty acids in olive oil were 61% C18:1, 16% C18:2, and 17% C16:0. The fish oil contained 36% C20:5 and 28% C22:6. The combined intake of C20:5 (68 g/d) and C22:6 (53 g/d) was 121 g/d pre and postpartum. Cows were milked three times daily. Blood was obtained once daily at 1730 h from 14 days prior to calving until parturition and from 14 to 21 d postpartum. Between the day of parturition and day 14 postpartum, blood samples were collected twice daily at 0800 and 1730 h. Blood was analyzed for PGFM, a product of PGF_{2a} metabolism. Caruncles were collected by

manual extraction through the vagina within 12 h of parturition, frozen in liquid nitrogen, freeze-dried, and analyzed for fatty acid composition.

Concentrations of C20:5 and C22:6 in caruncular tissue were increased 5 to 6 fold in cows fed fish oil (Table 2). The combined concentration of caruncular C20:5 and C22:6 were correlated positively with the number of days that cows were supplemented with fish oil (r^2 = 0.64), suggesting that introduction of fish oil before 21 d prepartum could have increased the concentrations of C20:5 and C22:6 in the uterus even further.

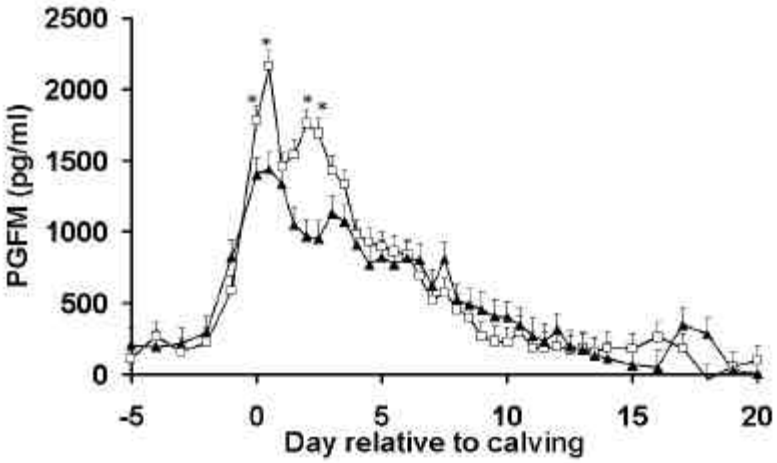
Table 2. Fatty acid profile of caruncles of Holstein cows fed diets containing olive or fish oil (% of total fatty acid in tissue).

	Diet			
Fatty Acid	Olive Oil	Fish Oil	SE	TRT, P=
	----------(g/100 g of fatty acids)----------			
C14	1.30	1.24	0.10	0.69
C14:1	0.27	0.18	0.05	0.25
C15:0	0.41	0.47	0.06	0.50
C16:0	19.84	21.79	0.74	0.09
C16:1	1.11	1.10	0.11	0.91
C18:0	24.97	25.53	0.47	0.04
t-C18:1	1.09	2.44	0.21	<0.01
C18:1 n-9	19.92	20.18	0.77	0.81
C18:2 n-6	12.22	9.30	0.46	<0.01
CLA t-9, t-11	0.35	0.27	0.07	0.40
CLA c-9, t-11	0.36	0.35	0.05	0.88
C18:3 n-3	0.51	0.44	0.08	0.52
C20:0	1.10	0.89	0.05	<0.01
C20:5 n-3	0.23	1.66	0.02	<0.01
C22:0	5.09	4.09	0.20	<0.01
C22:6 n-3	0.59	3.11	0.37	<0.01
C24:0	0.70	0.63	0.08	0.53

Cows fed fish oil had reduced concentrations of plasma PGFM during the period of maximum secretion in the early postpartum period compared to cows fed olive oil. Differences were significant ($P < 0.05$) at 0, 0.5, 2, and 2.5 days postpartum (Figure 4). The pattern of postpartum concentrations of plasma PGFM was similar to what was reported by Mattos et al. (2002). Cows fed fish meal at 0, 2.7, 5.2, and 7.8% of dietary DM attenuated the plasma PGFM response to injections of estradiol-17β and oxytocin given on day 15 of the estrus cycle compared to cows not fed fish meal. The increased concentrations of C20:5 and C22:6 in caruncular tissue of cows fed fish oil suggest that these fatty acids may be the active compounds reducing secretion of PGF_{2a}. However a consistent difference in plasma PGFM concentrations between cows fed olive oil and fish oil was not observed throughout the experimental period. Plasma PGFM concentrations of cows fed olive oil and fish oil converged at about day 5 postpartum and remained similar until the end of the experiment. The reduction in plasma PGFM concentrations could be explained by the detachment and shedding of caruncular tissue

with high PGF_{2a} synthetic activity that normally takes place in the postpartum period. Preferential shedding of caruncular tissue in cows fed olive oil could have reduced the apparent difference between plasma PGFM concentrations of cows fed olive oil and fish oil.

Figure 4. Pre- and postpartum plasma concentrations of prostaglandin F_{2a} metabolite (PGFM) of cows fed fish oil (▲) or olive oil (□) (LSM + SE). The PGFM concentrations were lower in cows fed fish oil at 0, 0.5, 2, and 2.5 days after parturition (*, $P < 0.05$).



Diet did not affect the number of days between the expected due date and actual calving date. It was anticipated that reduced uterine PGF_{2a} secretion could result in delayed parturition. Cows fed olive oil and fish oil calved 3.4 ± 1.8 and 3.3 ± 2.1 days before the due date, respectively.

Pat Burns (Burns et al., 2000) at Colorado State University has demonstrated that nonlactating beef cows will store C20:5 and C22:6 in endometrial tissue when fed fish meal. Mature Angus cows were fed a corn silage-based diet containing either corn gluten meal (n=4) or Menhaden fish meal (n=3) at 8.7 and 5% of dietary DM, respectively. Diets were isonitrogenous and isocaloric. After 25 days of supplementation, estrous cycles of cows were synchronized. Cows were slaughtered at d 18 of the second estrous cycle and uteri were collected, frozen, and analyzed for C18:3, C20:5, and C22:6. The uterus of cows fed fish meal had greater concentrations of C20:5 ($P < 0.01$) and tended to have greater concentrations of C22:6 ($P = 0.12$). Concentrations of C18:3 were similar between the two groups.

In a follow-up study, Bonnette et al. (2001) fed 82 lactating, primiparous beef cows a corn silage-based diet containing either 5% fish meal or 8.7% corn gluten meal (DM basis). Diets were initiated at 25 days prior to the breeding season and continued through the 90-d breeding season. Cows were artificially inseminated and pregnancy

determined at 25-30 days post breeding using ultrasonography. First service conception rate tended to be greater for cows fed fish meal (75.6 vs. 61.5%; P = 0.14). Serum progesterone concentrations after insemination were similar between the two groups.

SUMMARY

Growing evidence indicates that the design and delivery of supplemental unsaturated fatty acids to the lower gut for absorption (specifically linoleic acid, linolenic acid, EPA and DHA) may target reproductive tissues to improve reproductive function and fertility. Improvement in pregnancy may be associated with improved embryo survival due to increased production and/or decreased clearance of progesterone. In addition, the suppression of uterine prostaglandin secretion by omega-3 fatty acids may prevent embryonic mortality. Although not discussed in this paper, changes in follicular dynamics can be affected by fat supplementation and may lead to a more fertile ovulation. This improvement may be due to alterations in metabolic hormones like insulin-like growth factor-I and luteinizing hormone.

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