Effects of Supplemental Fat on Reproductive Performance in Beef and Dairy Cattle

Les H. Anderson and Eric S. Vanzant

Introduction

The most limiting factor for reproductive success is nutrition. In cattle, the most studied aspects of the nutrition-reproduction interaction have been the effects of dietary energy and body energy reserves on postpartum rebreeding performance. An important goal in beef and dairy production systems has been to develop novel supplementation strategies for enhancing reproductive efficiency in cattle maintained in less than optimal environments. Since energy is often the factor most limiting in diets, researchers have investigated the effects of supplementation of fat, the most concentrated source of energy available, on production and reproductive efficiency. As might be expected, fat supplementation alters the energy balance and increases body condition score in cows. However, fat supplementation alters reproductive function independent of its effects on body energy reserves.

Biochemistry of Fat

Fat in diets is most commonly in the form of triglycerides, a conglomeration of three fatty acid molecules attached to glycerol. Shortly after ingestion, microbial lipases break down these triglycerides to free fatty acids and glycerol. The glycerol is immediately fermented to proprionic acid. Fatty acids are classified as either saturated, monounsaturated, or polyunsaturated. Saturated fatty acids contain more molecules of hydrogen and no double bonds and therefore, degree of hydrogenation is indicated in the nomenclature. Unsaturated fatty acids do not survive long in the rumen because they are quickly hydrogenated to more saturated end products. Fats of plant or animal origin containing palmitoleic, oleic, linoleic, and linolenic acids are hydrogenated extensively, with linoleic being the most abundant in plants and plant products. Estimates of hydrogenation efficiency of linoleic acid ranges from 70-90%.

Cholesterol and steroids are other forms of fat. Cholesterol is the major sterol in animal tissues. Cholesterol and its esters with long-chain fatty acids are important components of plasma lipoproteins and of the outer cell membrane. Lipoproteins are proteins that can associate with lipids and are used to transport cholesterol, steroids, and triglycerides in the blood stream. There are three major lipoproteins in plasma, very-low-density lipoproteins (VLDL), low-density (LDL), and high-density lipoprotein (HDL). The predominant lipoprotein in blood of ruminants is HDL. Supplementation of fat stimulates the synthesis and accumulation of lipoprotein-cholesterol and cholesterol esters in tissues and body fluids, including the ovary.

Sources of Fat

Many different types of fat have been fed to lactating beef and dairy cows. Some of these include blends of animal and vegetable fat, tallow, yellow grease, oil in fish meal, whole oilseeds (cottonseed, soybeans, rapeseeds, canola seeds, peanut hearts, safflower seeds, sunflower seeds), flaked fat, prilled fat, hydrogenated fat, calcium soaps of long chain fatty acids, medium-chain triglycerides, and fee fatty acids. The fatty acid makeup of these fat sources varies widely (Table 1).

Table 1. Fatty acid composition of some common feedstuffs[a].

Fatty acid	Alfalfa hay	Grass pasture	Soybean seeds	Corn seeds	Tallow
Total fat (ether extract) (% of DM)	2.4 to 3.4	3.5 to 5.5	18.2	4.1	99.0
	weight % of total fatty acids				
Myristic (14:0)	.9	1.1	---	---	---
Palmitic (16:0)	33.9	15.9	12.4	14.3	26.0
Palmitoleic (16:1)	1.2	2.5	---	.1	.
Stearic (18:0)	3.8	2.0	3.7	1.9	19.0
Oleic (18:1)	3.0	3.4	25.4	39.0	40.0
Linoleic (18:2)	24.0	13.2	50.6	43.5	5.0
Linolenic (18:3)	31.0	61.3	7.9	1.1	1.0

[a]Adapted from Palmquist and Jenkins, 1980, J. Dairy Sci. 63:1; Kennelly, 1996, Anim. Feed Sci. Technol. 60:137; and NRC, 1996, Nutrient Requirements of Beef Cattle.

Many of the naturally occurring, unprocessed plant oils contain a large proportion of long-chain, polyunsaturated fatty acids, such as linoleic acid. The rendered fats such as tallow and yellow grease contain a large proportion of the monounsaturated fatty acid oleic acid. Granular fats such as calcium soaps of long-chain fatty acids contain mainly the saturated fatty acids palmitic and stearic acids.

Supplemental Fat Influences Reproductive Performance

It is difficult to determine the effect of fats on reproductive efficiency. The results in both beef and dairy cows have been mixed. In lactating dairy cows, 11 studies indicated an improvement in either first service conception rate or in overall pregnancy rate. In these studies, pregnancy rate/conception rate was improved an average of 17 percentage points. The fat sources that were used were calcium soaps of long-chain fatty acids (Ca-LCFA), fish meal, tallow and prilled fat. Fat supplementation was shown in one large study to have multiple effects on reproductive response. In addition to improved conception rate, this large study (n = 443) from five herds in Wisconsin indicated that cows fed Ca-LCFA exhibited stronger signs of estrus, had more active ovaries (as determined by rectal palpation every 2-4 weeks), and required less exogenous prostaglandin to induce estrus. Three studies have reported a strong negative impact of fat supplementation on conception rate to AI. In each case, the lower conception rate was associated with a large increase in milk production. In one study primiparous cows fed Ca-LCFA produced 4.5 kg/d more 3.5% fat-corrected milk, took longer to regain lost body weight, and had lower conception rates to AI (73 vs 33%) than did control cows. The other two studies that reported negative reproductive responses also observed increases in milk production.

Limited data is available examining the effects of fat supplementation, independent of energy effects, on reproductive efficiency in beef cows. In the initial report, extremely thin (BCS = 2.3-4.1) cows supplemented with Ca-LCFA for 150 days beginning 60 days prepartum gained more weight and were in better condition than cows not supplemented with the fat source. Fat supplementation increased serum lipids (cholesterol, HDL, LDL, VLDL, and triglycerides) and reduced the postpartum interval. Reduction in the postpartum interval led to more cows conceiving early in the breeding season. No difference in total pregnancy rate was observed in this study. Another report determined the effects of 3 types of fat supplements (soybeans, safflower seeds, and sunflower seeds) on pregnancy rate in primiparous beef cows. Cows were supplemented for approximately 65 days precalving. Fat supplementation had no effect on body condition score, dam weight, calving ease, birth weight or estrous cyclicity prior to the breeding season. Heifers from fat supplemented groups had greater pregnancy rates and calf weaning weights (Table 2). Another report indicated that feeding Ca-LCFA for the first 30 days postpartum in primiparous cows did not affect days to first estrus, pregnancy rate, or calving interval. However, body condition score decreased in these cows from 5.1 at parturition to 4.1 after 30 days and to 3.5 after 150 days. This massive decrease in body condition resulted in a mean days to first estrus of approximately 112 days in all cows regardless of treatment. Therefore any beneficial effects of 30 days of fat supplementation were probably masked by the severe metabolic crisis exhibited by these females.

Table 2. Reproductive response of primiparous beef cows to fat supplementation.

Dietary Fat Source	Pregnancy rate (%)	Calf weights (kg)
Control	79	182.4
Safflower	94	193.6
Soybeans	90	197.7
Sunflower	91	196.8

Bellows et al. 1999. J. Anim. Sci. 77(Suppl. 1):236

Recently, researchers at the University of Kentucky began to examine the effects of type of supplement on reproductive response in beef females. Our model was the yearling beef heifer. The objective of the experiment was to determine if type of nutrient supplement (i.e. fat, fiber, or starch) would alter conception rate to AI of beef heifers. Ninety-six crossbred virgin heifers (BW = 249 kg) were used to determine the effects of source of supplemental nutrients on average daily gain (ADG) and reproductive performance. All diets were fed to achieve target weights equal to 65% of expected mature weight at the time of AI. This was equivalent to 2.2 x maintenance requirements. Corn silage served as the basal constituent at 42% of the diet dry matter (DM) with the following treatments providing the bulk of the remaining diet: 1) corn and soybean meal (CSBM); 2) whole, linted cottonseed at 15% of the DM (COT); 3) whole, raw soybeans at 15% of the DM (SB); 4) pelleted soyhulls at 30% of the DM (SH). In diets 2 through 4, COT, SB, and SH replaced a portion of the corn and soybean meal. Diets were formulated to be isonitrogenous (13.7% CP) and were fed to supply equal amounts of energy.

Heifers were weighed every 28 days for 112 days with weights obtained on consecutive days at the beginning and end of the feeding period. At the end of each 28-day period, feeding levels were adjusted to maintain projected weight gains.

At the conclusion of the feeding period, all heifers were fed melengestrol acetate (MGA; .5 mg/hd/day) for 14 days to synchronize estrus. Heifers were administered prostaglandin F2 (Lutalyse, Pharmacia & UpJohn, Kalamazoo, MI) on day 33 and were observed for estrus behavior twice daily for 5 days beginning on day 34 (Day 0 = first day of MGA feeding). Heifers were inseminated 12 hours after first observed estrus. Pregnancy rate was determined using transrectal ultrasonography 90 days after insemination.

Blood samples were obtained on day -6 and day 0. These samples were used to determine the physiological status (anestrus versus cyclic) of the heifers. If plasma progesterone concentrations exceeded .5 ng/ml in either of the samples the heifers were considered to have initiated estrous cycles.

As a consequence of diet formulation, heifers in the SH treatment gained more weight during the development period than heifers in the other three groups (Table 3), yet conception rate to the AI was similar among heifers in the CSBM (37%), COT (38%), SB (55%), and SH (42%) groups. Conception rate to the AI was numerically but not significantly higher in the SB group than the SH, CSBM, and CS groups. The lack of significance was likely due to the low number of animals in the treatment. This numerical trend suggests that supplementation of heifers with whole soybeans may be a viable option to improve reproductive performance.

Table 3. Average daily gains for heifers.

	Corn/SBM	Cottonseed	Soybean	Soyhull	SE
Initial Weight	549	547	547	550	1.84
ADG d 1-28	1.5[ab]	1.44[a]	1.28[a]	1.73[b]	0.102
ADG d 29-56	2.28	2.41	2.62	2.81	0.193
ADG d 57-84	2.06	1.70	1.54	2.17	0.235
ADG d 85-112	2.07	2.17	2.24	2.43	0.146
Total ADG	1.95[a]	1.91[a]	1.90[a]	2.26[b]	0.159

[a,b]means with different superscripts differ ($P < .10$).

To further determine the specific dietary constituents associated with these changes, we are feeding these same diets to steers with cannulas in their rumens and duodenums. We plan to examine the profile of fatty acids that escape the rumen as well as ruminal fermentation profiles and microbial production, rumen degradation and total tract digestibility of the diets. Clearly, much work needs to be accomplished to delineate the effects of fat on reproductive function.

Mechanisms of Action of Fats

Fat supplementation has been shown to affect a variety of reproductive functions in both dairy and beef females. Alterations in any or all of these variables may account for the potential increase in reproductive efficiency. Supplementation of fat results in the following:

- increases the production of propionic acid from the rumen microbes (polyunsaturated fatty acids only),
- increases basal serum insulin concentrations,
- increases serum concentrations of growth hormone,
- increases availability of lipoproteins and cholesterol which increases steroidogenesis of corpora lutea,
- increases follicle growth,
- reduces the occurrence of short luteal cycles in cows transitioning from anestrus to cyclicity.

Conclusions

Supplementation of fats has the potential to positively alter reproductive performance in both beef and dairy cows. Development of supplementation strategies that include fat could enable producers to overcome reproductive problems associated with young and energy-challenged females. The mechanisms through which fat alters reproductive efficiency remain to be determined.