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EFFECTS OF FAT SUPPLEMENTATION ON REPRODUCTION IN BEEF CATTLE

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Introduction

Adequate nutrition is critical for successful reproductive function. Inadequate dietary energy intake and poor body condition can negatively affect reproductive function. Supplemental lipids have been used to increase the energy density of the diet and avoid negative associative effects often experienced with cereal grains (Coppock and Wilks, 1991; Bowman and Sanson, 1996). Supplemental lipids may also have direct positive effects on reproduction in beef cattle independent of the energy contribution.

Sources

Several different fatty acid sources have been studied as they relate to direct actions on reproductive function. Plant derived oils appear to have the greatest impact on reproductive performance, several of the more common sources include: sunflower, safflower, cottonseed, rice hulls, and soybeans. Animal tallow and calcium salts of predominately saturated fatty acids escape rumen biohydrogenation to a greater extent and are incorporated into adipose tissue and milk. Effects on reproductive function appear to be more variable. Highly polyunsaturated fatty acids such as those found in fishmeal also bypass the rumen unaltered and have fewer effects on rumen fermentation. These have also been documented to affect reproductive processes.

Mechanism of Action

Potential mechanisms by which supplemental fat affects reproductive processes have recently been reviewed (Williams and Stanko, 1999; Mattos et al., 2000). Ruminal microflora hydrolyze triglycerides and phospholipids that contain polyunsaturated fatty acids. Fats of plant or animal origin contain the unsaturated fatty acids palmitoleic, oleic, linoleic, and α-linolenic acids. Linoleic acid predominates in seed and seed products, and α-linolenic predominates in forages.

The fatty acids are mostly metabolized in the rumen. However, some are spared and pass through the rumen unaltered. Fats are hydrolyzed to their polyunsaturated fatty acid constituents and glycerol. A high proportion of the fatty acids are then partially or completely hydrogenated and much of the glycerol is fermented to propionic acid, one of the major volatile fatty acids, that is a precursor for glucose. Feeding of supplemental fat increases propionic acid production and the propionate:acetate ratio. The potential for differences in the efficiency of energy utilization and energy partitioning exist when supplemental fat is provided. The consumption of polyunsaturated plant oils increases basal serum insulin concentrations in both dairy and beef cows. It is possible that increased serum concentrations of insulin may play a role in mediating increased follicular growth either directly or indirectly by modulating granulosa IGF-I (insulin-like growth factor – 1) production. Fat supplementation has also been shown to increase concentration of circulating growth hormone (Williams and Stanko, 1999).

Secretion of luteinizing hormone (LH) from the pituitary and follicular growth in cattle are regulated partially by the energy status of the animal. Energy provided by fat supplementation increases LH secretion in animals deficient in energy. A mechanism independent from energy by which dietary fatty acids affect LH secretion has not been established (Mattos et al., 2000). Feeding supplemental dietary fat also increased serum and follicular fluid cholesterol, serum progesterone, lifespan of induced corpus luteum (CL), the number of medium-sized follicles, and growth of the preovulatory follicle (Williams and Stanko, 1999).

Prostaglandins play an important role in reestablishing estrous cycles both immediately after parturition and thereafter until conception occurs. Prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) is responsible for uterine involution after parturition. The greater the post-partum prostaglandin concentration, the faster the uterus involution. The uterus releases $PGF_{2\alpha}$ during each estrous to regress each new CL if the cow is not pregnant and initiate a new estrous cycle. During the period of CL regression, concentrations of $PGF_{2\alpha}$ and progesterone are inversely related. If the cow does conceive, release of $PGF_{2\alpha}$ from the uterus is prevented in order to preserve the CL and maintain pregnancy.

The fatty acid, linoleic acid is a substrate for the synthesis of $PGF_{2\alpha}$. Linoleic acid can be desaturated and elongated to form arachidonic acid (C20:4), which is a precursor for $PGF_{2\alpha}$. Regulatory enzymes for this conversion include delta six desaturase and cyclooxygenase. Linoleic acid can inhibit prostaglandin synthesis by competitive inhibition with these key enzymes. Arachidonic, and two fatty acids found in fishmeal, eicosapentaenoic (C20:5) and docosahexanoic (C22:6), have been shown to inhibit cyclooxygenase activity as well. It is important to note that linolenic acid (C18:3) was also present in the endometrial prostaglandin synthesis inhibitor isolated by Thatcher et al. (1994), and that linolenic acid has been shown to be a strong inhibitor of prostaglandin synthesis (Pace-Asciak and Wolfe, 1968). The amount and probably type of particular fatty acids reaching the target tissues likely influence whether prostaglandin synthesis is stimulated or inhibited (Thatcher and Staples, 2000).

Production and Reproductive Responses

Research with supplemental fat has been conducted on cows that have had one or more calves, and in replacement heifers. Fats have been fed before and after calving, and during the breeding season. Several response variables have been examined including: body weight and body condition score, age at puberty, postpartum interval, first service conception rates, pregnancy rates, calving interval, mammary gland development, milk yield and composition, calving difficulty, and calf birth and weaning weight. To determine potential mechanisms of action scientists have investigated changes in follicular and uterine development, hormonal profiles and changes, brain function, and embryonic development. Research on feeding supplemental fat has resulted in varied and inconsistent results as it relates to reproductive efficiency including positive, negative, and no apparent effect.

Elucidating mechanisms of action of how supplemental fat can influence reproductive function has been a difficult process. Animal response appears to be dependent on body condition score, age (parity), nutrients available in the basal diet (pasture or range conditions), and type of fat supplement. The complexity of the reproductive system and makeup of fat supplements are often confounded by management conditions and forage quality both in research and in commercial feeding situations. This has contributed to inconsistencies in research findings.

Research Summary

Currently, research is inconclusive on exactly how to supplement fat to improve reproductive performance beyond the energy contribution of fat. Most studies have tried to achieve isocaloric and isonitrogenous diets, however, this can be challenging. Some studies only have sufficient animal numbers to detect very large differences in reproductive parameters such as conception and pregnancy rate. The following is a summary of several research trials investigating the effect of supplemental fat on reproductive performance in beef heifers and cows.

Heifer development

- Heifers fed safflower seeds (4.4% dietary fat) for 162 d had a tendency to have a greater percentage reaching puberty at the beginning of the breeding season than heifers fed no added dietary fat but had no difference in overall pregnancy rate. The diet x sire breed interaction suggested that the response to fat supplementation may be breed dependent. Heifers fed supplemental fat had greater cholesterol and progesterone concentrations than non-fat supplemented heifers. (Lammoglia et al., 2000).
- Supplementing soybean oil at 3% of the diet to a forage-based ration (hay plus oil as a top-dressed supplement) to pre-pubertal heifers for approximately 100 days increased feed efficiency in one experiment, but not in another, compared to heifers receiving a corn-based control supplement. Additionally, in the second experiment, but not the first, heifers tended to conceive earlier in the breeding season. In the above experiments, supplementing at a level of 6% soybean oil decreased feed efficiency compared to 3% added oil and did not change growth or reproductive performance compared to the other diets. No improvement in pregnancy rate was found among groups (Whitney et al., 2000).
- Feeding 2 lb (6-7 % total dietary fat) of whole sunflower seeds for either 30 or 60 d before AI did not improve estrous response, conception, or pregnancy rate in beef heifers (Funston et al., 2001).

Pre-calving

- Feeding 1 lb/day of protected fat (calcium salts of palm oil; 5% fat in diet) to well developed heifers (1,036 lb) from the beginning of the third trimester of pregnancy until the end of the their third estrus after calving increased the time from calving until first estrus. In this study fat had a negative effect on reproduction (Oss et al., 1993).
- Supplementing the diet of late gestation heifers (day 230 until calving) with safflower seeds at 1.5 lb/day (approximately 4.7% fat in the diet) increased subsequent pregnancy rate by 19% compared to control diets with similar energy and protein content (Lammoglia et al., 1997).

- Supplementation with safflower seeds, soybeans, or sunflower seeds (4.7, 3.8 and 5.1% fat in diet, respectively) for the last 65 d before calving increased subsequent pregnancy rates (94%, 90%, and 91%, respectively) of first-calf heifers compared to controls (79%) receiving diets with equivalent energy (2.4% fat). In a second experiment, supplementing diets with sunflower seeds (6.5% fat in diet) the last 68 days before calving did not improve subsequent pregnancy rate compared to control diet (2.2% fat). The major difference between the two studies was forage availability. When adequate nutrients are available, the effects of supplemental fat may be masked (Bellows, et al., 2001).
- First-calf heifers supplemented with 5% fishmeal 25 days before and through a 90 d breeding season tended to have a higher first service conception rate than heifers supplemented with corn gluten meal in a silage based diet (Bonnette et al., 2001).
- Two and three-year old cows were supplemented with fishmeal (1 lb/d) 25 days before and through the end of a 70 d breeding season while grazing on pasture. Synchronized estrous response, first service conception rates, AI pregnancy rates, and overall pregnancy rates did not differ between cows receiving the fat supplement and controls (no supplement). Plasma linolenic (LNA) and eicosapentaenoic acid (EPA) were similar at the start of the study, however, plasma LNA was higher in cows grazing pasture alone on d –7 and 70 of the breeding season, whereas plasma EPA was higher in cows supplemented with fishmeal on d –7, 45, and 70 of the breeding season. Fishmeal supplementation increased plasma EPA in cows grazing pasture but did not affect reproductive performance. It was stated that EPA and LNA have the ability to inhibit uterine prostaglandin synthesis, which may be the reason there were no differences in reproductive measures (Burns et al., 2002).
- Mature crossbred cows were supplemented with safflower seeds (5% vs 2.5% fat for control diet) in two studies from 50-56 days before calving. Cows on high fat diet tended to have higher intake and gain more weight throughout the trial. Body weight and condition of cows were similar. Pregnancy rate, calf birth weight, and weaning weight were not affected by treatment. In both studies cows were in adequate (5-6) body condition and on a positive plane of nutrition throughout the experiment (Encinias et al., 2001).
- Mature crossbred cows received a low fat milo-based supplement (6 lb; 2% fat; 18% CP) or a high fat sunflower-based supplement (3.5 lb; 26% fat; 18% CP) either prepartum (64 d) or postpartum (76 d). Reproductive response was not effected by type of supplement fed prepartum. In contrast, the proportion of cows cycling at the beginning of the breeding season and pregnancy rate to AI was greater for cows receiving the low fat supplement postpartum. Pregnancy rate at the end of the breeding season was not different between treatments (95%; Johnson, et al., 2001).
- Feeding whole soybeans (WSB; 3.5 lb) before calving improved first service pregnancy rates in a 45-d natural service breeding period (WSB fed 45 d) and also in a synchronized AI program (WSB fed 30 d). No advantage was seen when supplementation was initiated at calving or 30d before breeding (Graham et al., 2001).

- Feeding high linoleate safflower seeds (5.3 % total dietary fat) 56 d before calving had no effect on weight gain, BCS, pregnancy rate, or postpartum interval. Calf birth weight, calving difficulty, and weaning weight were not affected by treatment; however, calf vigor was greater in calves born to heifers fed the high fat diet. Heifers were BCS 4.4 at the beginning of treatment and 5.8 at calving (Geary et al., 2002).
- Performance of cows supplemented with safflower seeds (3.5 – 4% estimated total dietary fat) 49 d before calving on native range was influenced by calving season and cow age. Three-year-old cows calving in February and 5-year-old cows calving in April receiving a high fat supplement had greater pregnancy rates than those fed a low fat supplement. The opposite was found for 3-year-olds calving in April. There was no effect of supplement type on cows calving in June (Grings et al., 2001).

Post-calving

- Feeding 0.5 lb/day of protected fat (calcium salts of palm oil; 4.7% fat in diet) to first calf (BCS = 5) heifers for 30 days immediately after calving increased beneficial prostaglandin hormones after calving. However, no improvement in days to first estrus or pregnancy rate was found (Filley et al., 2000).
- Supplementing rice bran (5.2% fat in the diet) from day 1 to 50 after calving tended to improve pregnancy rate in mature cows compared to cows receiving a control diet (3.7% dietary fat; De Fries et al, 1998).
- Feeding 1.8 lb/day of rice bran (5.1% fat in diet) to BCS 6 cows starting one day after calving increased cumulative rate of return to estrus by day 60 after calving compared to cows consuming control diets of similar energy. However, diets containing rice bran plus lasalocid had lower reproductive performance (Webb et al., 2001).
- Supplementation with 3 lbs of whole cottonseed (5.5% fat in diet) 30 days before the breeding season increased the number of cows cycling at the start of the breeding season by 18%. Cow BCS was less than 5 (Wehrman et al., 1991).
- Supplementation with two different fat supplements (21 and 17% fat; 4 lb/d) improved estrous response in 2-year-old cows and first service conception rate in mature cows when fed for 51 and 45 d postpartum, respectively, compared to control supplement (3% fat; Bader et al., 2000).
- First-calf heifers were supplemented with two types (high oleate or linoleate; 5% fat in the diet) of cracked safflower seeds for 90 d postpartum. Type of supplement had no effect on length of postpartum interval, pregnancy rate, cow or calf weight change, calf weaning weight, and total or forage organic matter intake. Overall mean serum IGF-I was greater in heifers fed high linoleate safflower seeds compared to high oleate or control. Treatment did not affect growth hormone, glucose, or NEFA concentrations (Bottger, et al., 2000).
- Cows calving with a BCS less than 4, and fed such that body weight and BCS do not increase, are unlikely to respond to short-term dietary fat supplementation (Ryan et al., 1994).

Feeding Considerations

Dose response studies indicate that the amount of added plant oil necessary to maximize positive ovarian effects is not less than 4% (Stanko, et al., 1997). This appears to be in agreement with most studies when a positive response to fat supplementation was seen, total dietary fat ranges from 4-6%. The duration of supplement feeding needed to elicit a positive response is not known, however, from the research that has been conducted, thirty to sixty days appears to be a reasonable duration of supplementation. The period of supplementation has varied from different times before breeding in heifer development, pre-calving, post-calving, and/or pre-breeding periods. The young, growing cow appears to be the most likely to respond to supplemental fat. An appropriate situation for fat supplementation may be when pasture or range conditions are limiting or are likely to be limiting before and during the breeding season. Feeding supplemental fat to well-developed heifers or cows in adequate body condition on pasture or range resources that are adequate may not provide any benefit beyond energy contribution to the diet.

Fats are highly digestible (approximately 80% digestible). However, high levels of fat in the diet have the potential to negatively impact fiber digestibility, decrease calcium absorption by formation of calcium salts of fatty acids, and increase vitamin E requirements (NRC Beef, 1996). In general, the amount of added fat in predominantly forage-based cattle diets should not exceed 6% of the total ration on a dry matter basis. Provide adequate calcium in the ration, and make sure the vitamin E content meets or exceeds requirements, especially when highly unsaturated oils are used.

Whole safflower seeds need to be processed to improve digestibility. Seeds should be processed (rolled) with enough pressure to crack about 90% of the seed hulls without extracting the oil (Lammoglia et al., 1999). Processed fats can be either liquid or solid at room temperature, therefore, transportation and storage of fats will differ. Some fats need to be melted before mixing with feed, especially in cold environments. It is important to keep moisture in the storage tank at less than 1.5% water so the fat does not become rancid (Zinn, UCD Research Report). Gossypol levels may be a concern when high levels of whole cottonseed are fed.

Implications

Improvements in reproduction reported in some studies may be a result of added energy in the diet or direct effects of specific fatty acids on reproductive processes. As is the case for any technology or management strategy that improves specific aspects of ovarian physiology and cyclic activity, actual improvements in pregnancy rates, weaned calf crop, or total weight of calf produced are dependent on an array of interactive management practices and environmental conditions. Until these interrelationships are better understood, producers are advised to strive for **low cost and balanced rations**. If a source of supplemental fat can be added with little or no change in the ration cost, producers would be advised to do so. Research investigating the role of fat supplementation on reproductive responses has been variable, therefore, adding fat when significantly increasing ration cost would be advised when the risk of low reproduction (young, growing, thin, and limited nutrients in the basal diet) is greatest.

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