

## FAT SUPPLEMENTATION ON REPRODUCTION OF BEEF CATTLE

### *SUPLEMENTAÇÃO COM GORDURA NA REPRODUÇÃO DE VACAS DE CORTE*

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#### SUMMARY

Fat supplementation, before and after calving, is a good alternative to increase energy density of the diet. However, feeding supplemental fat has resulted in varied and inconsistent effects on the reproductive function of cattle. Furthermore, understanding how fat supplementation can influence the reproductive function has been a difficult process. Reproductive system and the fat supplementation sources are influenced by management conditions and forage quality.

**KEY-WORDS:** Beef cattle. Reproduction. Nutrition.

#### RESUMO

O uso de suplementação com gordura no pré e pós-parto mostra-se uma alternativa para incrementar a densidade energética da dieta. Entretanto, a suplementação com gordura resulta em efeitos inconsistentes e variados sobre a função reprodutiva. Esclarecer como esta suplementação pode influenciar a reprodução é um processo delicado. A complexidade do sistema reprodutivo assim como das fontes de suplementação com gordura são influenciadas pelas condições de manejo e da qualidade da forrageira.

**PALAVRAS-CHAVE:** Bovinos de corte. Reprodução. Nutrição.

#### INTRODUCTION

Meat production in Brazil has a great potential to be explored yet. Even today, basic deficiencies regarding cattle management still limit larger scale production. Limited dietary energy intake leads to poor body condition, especially in the postpartum period and this is one of the most important factors affecting reproductive performance, thus contributing to a high calving interval. Diet supplementation with vegetable oils from different sources such as cottonseed, soybeans and others, causes metabolic changes that can translate into benefits in the reproductive area.

#### Supplementation with lipids in ruminants

Lipid supplementation may favor ruminant production, being an alternative to raising the energy density without increasing the intake of soluble carbohydrates and lowering intake of fiber (PALMQUIST, 1984). Experimentally, various sources of fat supplementation were used. However, the fatty acid profile of most of these sources is extremely variable (WILLIAMS & STANKO, 1999). The linoleic acid has been described as prevalent in seeds (STAPLES *et al.*, 1998) while the linolenic acid predominates in much of forage plants (BELLOWS *et al.*, 2001). The yellow fat and tallow (lard) contain a large amount of oleic acid; the granular fat found in

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palm oil in the form of calcium soap, and it is also rich in saturated fats, such as stearic acid and palmitic acid (STAPLES *et al.*, 1998). Fishmeal contains high percentage of omega-3 fatty acid, as well as eicosapentaenoic and docosahexanoic acids (MATTOS *et al.*, 2000; BURNS *et al.*, 2002). Oil seeds provide a unique combination of energy, protein, fiber and fat, thus constituting an excellent diet supplementation (WILLIAMS, 2001).

Lipids composition changes qualitatively during microbial digestion in the reticulo-rumen, these changes include: hydrolysis of triglycerides, galactoglycerides and other esterified lipids; hydrogenation of unsaturated fatty acids and microbial biosynthesis of lipids. During biohydrogenation, some of the double bonds of the unsaturated fatty acids are reduced and their orientation is also changed (MATTOS *et al.*, 2000). Much of glycerol is fermented to propionic acid, the precursor of glucose. The supplementary fat increases the proportion of propionic acid, and the propionate: acetate ratio as well (WILLIAMS & STANKO, 1999; HOWLLETT *et al.*, 2003). Normally, the primary objective of supplemental fat is to increase diet energy supply to the animal. The source of fat may influence the productive response through its effects on food intake, ruminal fermentation and nutrients digestion (HESS *et al.*, 2008). Fat can be added up to 3% of the total ration; however, 5% is regarded as beneficial for high production herds (NRC, 2000).

When supplementing the diet with fat, an increase in total energy consumption must be observed, since the decline in dry matter consumption is independent of energy balance in which we find the animal and may be related to the fatty acid composition of the supplement. Changes in ruminal fermentation can reduce diet intake, due to the fact that the polyunsaturated fatty acids decrease fiber digestion. However, despite the fact that supplemental fat decreases organic matter (OM) digestibility when compared to corn-rich diets with similar calorie content, the OM digestibility of animals that were fed fat supplemented diet was higher than those fed only forage (HESS *et al.*, 2008).

The moderate increase in fatty acid intake influences the efficiency of energy use in two ways (BALDWIN *et al.*, 1980). First, the deposition of preformed fatty acids on tissues or products, replaces the metabolic conversion steps of carbohydrates into fatty acids, eliminating the *de novo synthesis* from acetate and reducing the spending with calorie increment associated with this path. However, the efficiency is limited by the amount of fat the animal is able to use in this process. Second, ATP production via oxidation of long-chain fatty acids is around 10% more efficient than the oxidation of acetate. The long-chain fatty acids have greater potential to increase oxidative metabolism efficiency in ruminants (PALMQUIST, 1984).

#### **Supplementation with fat and reproductive function**

Much of the reproductive performance variation is due to differences in energy intake as well as the

body condition of the animal (HESS *et al.*, 2005). Appropriate amounts of nutrients are necessary to improve reproductive performance; however, it is difficult to determine exactly the reproductive nutritional limits. The beneficial effect of lipid supplementation on reproduction, in general, seems to be related to an extra-caloric effect of fat, more specifically of certain fatty acids (GRUMMER, 2004; SANTOS *et al.*, 2008). Several studies report on the effects of supplemental fat on metabolic hormones. The principal metabolites that indicate the variation in lipid metabolism are: total cholesterol, triglycerides, as well as low and high density lipoproteins (MANCIO *et al.* 1999; LUCY, 2003). Supplemental fat supplied to cows stimulates the synthesis and accumulation of cholesterol in body tissues and fluids (NOGUEIRA, 2008; WILLIAMS, 2001) while high density lipoproteins predominate in ruminants (GRUMMER & CARROLL, 1988). Apparently, these lipoproteins have access to the intracellular compartment (WILLIAMS, 2001).

The unavailability of glucose reduces the hypothalamic release of GnRH since this metabolite is necessary for the central nervous system (WETTEMAN *et al.*, 2003). The hypothalamus detects the borderline reduction glucose that hinders the release of GnRH (DHUYVETTER & CATON, 1996). Therefore, increasing the gluconeogenesis of the diet could stimulate the secretion of GnRH (RANDEL, 1990) since the combination of glucose and insulin stimulates the release of hypothalamic GnRH (ARIAS *et al.*, 1992). However, insulin administration by subcutaneous injection in beef cattle as well as by intracerebroventricular infusion in ovariectomized sheep does not change the secretion of LH (DHUYVETTER & CATON, 1996). Wettemann & Bossis (2000) demonstrated that insulin is able to stimulate cell proliferation and ovarian steroidogenesis. The increase of insulin associated with the decrease of GH is an important relationship to assess the nutritional impact on reproduction (HAWKINS *et al.*, 2000).

The somatotrophic pathway also appears to be related in mediating the metabolic status centrally. According to Lucy *et al.* (1999) ovarian follicles do not have receptors for GH although it can act directly on luteal cells. GH interacts with insulin to control hepatic production of IGF-I (MOLENTO *et al.*, 2002) while the functional relationship between insulin and GH appears to have anabolic nature. Postpartum anestrous cows, with energy restriction, did not display increased concentrations of IGF-I unlike animals who had returned to cycle (ROBERTS *et al.*, 1997). HESS *et al.* (2005) concluded that regardless its origin, IGF-I acts positively on the hypothalamic-pituitary-ovarian axis.

Williams & Stanko (1999) demonstrated that the use of polyunsaturated vegetable oil increased the concentration of insulin and GH in serum of beef and dairy cattle. Bottger *et al.* (2002) studied primiparous beef heifers supplemented with oilseed containing high amount of either oleic or linoleic acid, and found no effect on the concentration of glucose, NEFA (Non Esterified Fatty Acids), GH, IGF-I, insulin, and proteins bound to IGF-I. Likewise, Bellows *et al.*

(2001) reported that IGF-I, glucose and NEFA concentrations were similar for animals receiving either no supplementation or primiparous beef cows supplemented with sunflower seeds in pre-natal period. Staples *et al.* (1998) while reviewing several studies about fat supplementation of dairy cows reported low concentration of insulin in animals supplemented with fat. It has been reported that usually NEFA increases in cows supplemented with fat; however, the glucose concentration is rarely influenced by fat supplemented diet. According to Thomas & Williams (1996) the intake of vegetable oils increases the basal concentration of insulin in beef cattle, and this hormone may mediate the effects on follicular dynamics, directly on their own receptors, or indirectly, by modulating IGF-1 in granulosa cells (YOSHIMURA *et al.*, 1994).

It must be considered that peripheral concentrations of metabolic hormones may have low efficiency in demonstrating the metabolic status of the animal, because such concentrations disregard clearance rates, as well as cellular usage, which can occur during fat supplementation.

#### **Cholesterol concentration and its relationship to progesterone synthesis**

In mammals, ovarian luteal cells use cholesterol as precursor for the synthesis of progesterone through a pool of lipoproteins, combined with cholesterol (WILLIAMS & STANKO, 1999). In horses and ruminants, high density lipoproteins (HDL) are the major lipoproteins which carry cholesterol to steroidogenic tissues such as liver, ovary, adrenal gland and testis and to other tissue for membrane synthesis. The use of fat has the advantage of increasing plasma cholesterol concentration, needed for the synthesis of P<sub>4</sub>. The success of maternal recognition in bovine is dependent on a sufficiently elongated embryo able to produce sufficient quantities of IFN-tau, which is dependent on the stimulation by circulating progesterone (BUTLER, 2000; GOFF, 2002; THATCHER *et al.* 2001).

Nutrition can affect the reproduction via ovary. Effects related to the ovaries can be direct: on follicular growth, oocyte maturation and early embryonic development; or related to some specific substrates and nutrients, as well as metabolic hormones, among them, growth hormone, insulin, IGF and leptin (ROBINSON, 1996, WEBB *et al.* 1999; BOLAND *et al.* 2001).

Fat supplemented diet increases the levels of circulating cholesterol (STAPLES *et al.*, 1998), stimulates the programmed growth of preovulatory follicle and increases the amount of hair follicles, as well as the size of the preovulatory follicle (LAMMOGLIA *et al.* 1996; MATTOS *et al.*, 2000). This effect may be partially due to the increase of LH concentration in the plasma, which stimulates the final stage of follicular growth. The ovulation of larger follicles may lead to the formation of larger corpus luteum with increased steroidogenic capacity, thus explaining the increased progesterone production (HAWKINS *et al.*, 1995; KERBLER *et al.*, 1997; MANCIO *et al.*, 1999; LAMMOGLIA *et al.*, 2000).

Some polyunsaturated fatty acids such as linoleic (C18:2), eicosapentaenoic acid (C20:5) and docosahexaenoic acid (C22:6) increased the size of the dominant follicle in dairy cows more effectively (STAPLES *et al.*, 1998).

Lipid metabolism changes when supplemental fat is added to diet above the recommended limit. Plasma cholesterol increases due to the larger amount of precursors to ovarian steroidogenesis since these higher HDL serum concentrations stimulate IGF-1 cells and granulosa lutein, as well as progesterone synthesis, in granulosa and theca cells and androstenedione in theca cells (GRUMMER & CARROL, 1988; WILLIAMS, 1989; STAPLES *et al.*, 1998) or even reduce their blood clearance (HAWKINS *et al.*, 1995; WILLIAMS & STANKO, 2000). Positive correlation between the concentrations of progesterone, HDL and cholesterol has been demonstrated for high fat diets (MANCIO *et al.*, 1999).

Rhodes *et al.* (1996) induced anoestrus in heifers via long food restriction and found no effect on the circulating concentration of FSH, during or after the restriction period, even while providing twice the maintenance requirements for heifers during three weeks (GUTIERREZ *et al.*, 1997). In lactating dairy cows, the return to the normal pattern of FSH secretion, soon after birth, was not considered a limiting factor (BEAM & BUTLER, 1999; GONG *et al.* 2002). Severe and prolonged changes in nutritional status can alter LH pulse in cattle; however, the same was not observed in monogastric (CAMERON, 1996). Nevertheless, short period changes in ruminants do not affect pulsatile secretion of LH (BOLAND *et al.* 2001); the energetic condition of cattle is responsible for secretion of pituitary LH as well as its follicular growth. The energy provided by fat supplementation increases LH secretion in energy-deficient animals. According to Mattos *et al.* (2000), the mechanism by which the energy acts on LH secretion has not yet been established. Some studies have shown that LH release was stimulated by fat supplementation while in others it has not been altered or it has decreased (STAPLES *et al.* 1998). Similarly, fat supplementation may increase the production of glucose by increasing propionate. According to Funston *et al.* (1995), perhaps the increased synthesis of glucose is responsible for the positive effect on the LH release. Modest increases in basal concentrations of LH have been observed in lactating cows by Morgan & Williams (1989), in response to supplementation with polyunsaturated fats.

Some studies demonstrated the ability of insulin to signal nutritional effects on follicular dynamics in cattle (WEBB *et al.*, 2004). Gong (2002) while reviewing the influence of nutrition and metabolic hormones on follicular development in cattle, reported that treatment with rGH (recombinant bovine somatotropin) may enhance the recruitment of small ovarian follicles in cattle. This effect of rGH does not appear to be mediated by changes in gonadotrophin secretion (GONG *et al.* 1997) or the increasing number of binding sites for ovarian gonadotrophin (GONG *et al.*, 1991) suggesting, perhaps, a direct effect of GH, IGF-I and/or insulin on the ovarian

follicles or a synergistic effect thereof with gonadotropins.

### Synthesis of prostaglandin

Unlike many autacoids, prostaglandins are not stored. Thus its presence in the organism depends solely on the synthesis from available fatty acids that, as phospholipid complexes, are part of cell membrane (NELSON & COX, 2000). Originally, the prostaglandins were discovered in seminal plasma and today we know that they are virtually present in all mammalian tissues, acting as local hormones. They are synthesized "in vivo", by cyclization of the center of the carbon chain of 20-carbon polyunsaturated fatty acid of such as arachidonic acid, forming the cyclopentane ring. Variations in substituent groups attached to the rings form different types in each series of prostaglandins and thromboxanes named A, B, etc. (MAYES, 2002).

The role of prostaglandins in the restoration of the estrous cycle immediately after birth and soon after conception is of great importance. The  $\text{PGF}_{2\alpha}$  is responsible for uterine involution postpartum. Thus, higher concentrations of  $\text{PGF}_{2\alpha}$  during postpartum are associated with faster uterine involution. The uterine release of  $\text{PGF}_{2\alpha}$  in each estrous cycle acts on the regression of each new corpus luteum and the starting of a new cycle. Concentrations of  $\text{PGF}_{2\alpha}$  and progesterone are inversely correlated during regression of the corpus luteum (FUNSTON, 2004). When the cow conceives, the release of uterine  $\text{PGF}_{2\alpha}$  is avoided in order to preserve the corpus luteum and maintain the pregnancy since its increased production and release, before conception, can trigger luteolysis and increased embryo mortality (NELSON & COX, 2000).

Linoleic acid is the substrate for the synthesis of  $\text{PGF}_{2\alpha}$  and this acid can be elongated and desaturated to form the arachidonic acid (C20: 4), the precursor of  $\text{PGF}_{2\alpha}$ . The enzymes that regulate this conversion include  $\Delta^6$ -desaturase and cyclooxygenase. According to Staples *et al.* (1998), linoleic acid may inhibit the synthesis of  $\text{PGF}_{2\alpha}$  by competitive inhibition of such regulatory enzymes. Linoleic acid has inhibitory effects on the synthesis of prostaglandins by the uterus, both "in vitro" and "in vivo", by inhibiting the enzyme cyclooxygenase (KADUCE *et al.* 1982; STAPLES *et al.* 1998). This effect could be responsible, at least in part, by increased pregnancy rates and luteal function registered by Staples *et al.* (1998). The arachidonic acid effect, as well as the essential fatty acids, omega 3, found in fish meal, seems to have inhibitory activity on cyclooxygenase (MATTOS *et al.* 2000). Wamsley *et al.* (1996) observed that heifers with a low concentration of progesterone in the luteal phase, supplemented with fish meal, had a lower concentration of the  $\text{PGF}$  metabolite after administration of oxytocin. However, using fishmeal in heifers with high progesterone levels during the luteal phase, showed no similar effect. Linolenic acid was also present in synthesis inhibitor endometrial  $\text{PGF}_{2\alpha}$  (THATCHER *et al.* 1994). Linolenic acid was also present in the inhibitor of the endometrial synthesis of  $\text{PGF}_{2\alpha}$  (PACE-ASCIAK &

WOLF, 1968). Probably, the amount and type of fatty acid that reach certain tissues regulate whether the synthesis of  $\text{PGF}_{2\alpha}$  will be stimulated or inhibited (THATCHER & STAPLES, 2000). It was also suggested that the reduction in serum and intrafollicular levels of estradiol associated with fat supplementation may play an important role in the modulation of the luteal response to prostaglandin.

### Supplementation pre and postpartum

The presence of small ovaries, with no corpus luteum, is a signal that characterizes the postpartum anestrus (WILTBANK *et al.* 2002). In beef cows, the duration of postpartum anestrus is affected by several factors including: nutrition (HESS *et al.* 2005), breastfeeding (WETTEMANN *et al.* 2003), uterine involution, and the number of calvings among others (YAVAS & WALTON, 2000).

The control mechanisms of postpartum anestrus involve a complex relationship between the hypothalamus, pituitary, ovary and uterus (NETT, 1987). The production of large amounts of placental steroids, especially estradiol and  $\text{P}_4$ , during the final stage of gestation, has a strong negative effect on the hypothalamus, resulting in low release of GnRH (SHORT *et al.* 1990). Between 15 and 30 days postpartum,  $\text{E}_2$  receptors in the pituitary are reestablished, thus normalizing hypothalamic responsiveness to  $\text{E}_2$  (NETT *et al.* 1988). Thus in the postpartum, the stored LH and FSH of the anterior pituitary are reduced due to negative  $\text{E}_2$  feedback of the hypothalamus and the presence of  $\text{P}_4$ . However, after calving, FSH increases rapidly allowing the recruitment and selection of the dominant follicle (WILLIAMS, 1990; WETTEMANN *et al.* 2003) while this follicle will ovulate only when there is a restoration of LH pulse frequency (MIHM, 1999). Typically, anestrus is a consequence of a number of dominant follicles that fail to ovulate due to low LH concentrations (ROCHE *et al.* 1992; JOLLY *et al.* 1995). After about 30 days postpartum, GnRH discharges increase and consequently, of LH pulses (GARCIA-WINDER *et al.* 1986). Increased LH pulse amplitude makes the follicles to become dominant and start to secrete large quantities of  $\text{E}_2$ , thus activating the positive feedback in the hypothalamus.

The pituitary gland of anestrous cows presents gonadotropin concentrations similar to that of cyclic cows about 30 days postpartum, responding normally to exogenous GnRH. Thus, researchers are concentrating efforts to identify metabolic and endocrine signals that influence central mechanisms that act on LH secretion (LUCY, 2003; WETTEMANN *et al.* 2003). The use of supplementation pre and postpartum can result in shorter postpartum anovulatory period. Bellows *et al.* (2001) supplemented pre-first calving cows with different oilseeds and observed a higher pregnancy rate in the treated animals (91.7 vs. 79%). This same group, in a second experiment, were fed two diets, the first supplemented with sunflower seed and the second, a control diet containing 6.5 and 2.2% fat, respectively, for 68 days pre-partum; however, the subsequent

pregnancy rates were similar. After estimating the quantity and quality of available forage, it was concluded that the lack of response of the second experiment was due to the high quality and abundance of available forage, which masked any possible effect of supplementation.

Wehrman *et al.* (1991) supplemented calved cows, BCS = 4, with cottonseed and observed an increase of up to 18% in the number of cyclic cows, when the mating initiated 30 days after the beginning of the supplementation period. The response was more evident when the experimental conditions resulted in loss of body condition during the postpartum period, regardless of supplementation.

According to Thomas *et al.* (1997) fat consumption is able to avoid decreasing GH serum levels in the postpartum period. Supplementation with rice grain, 5.2% ether extract (E.E.) in the experimental diet and 3.7% E.E. in the control diet for 50 days postpartum showed a trend towards better pregnancy rate in animals treated with fat (DE FRIES *et al.* 1998). Gong (2002) demonstrated that feeding diets that increase circulating insulin in dairy cows, during early lactation, may speed up the first postpartum ovulation and increase pregnancy rate in first service.

However, for some authors, energy supplementation in postpartum period is costly and often ineffective to stimulate cyclicity and, therefore, reduce the interval between births. Filley *et al.* (2000) supplied 0.23 kg/d of protected fat for heifers with ECC = 5; 30 days after delivery and found no difference in pregnancy rate or in the number of days to first service. Grant *et al.* (2003) supplemented high amounts of linoleic acid as safflower seeds for postpartum beef cows and reported an increase in metabolite of PGF from postpartum day 25 to 80, as well as a tendency of decreasing pregnancy rate at first service.

## FINAL CONSIDERATIONS

Lipid supplementation effects on reproductive performance of cows are extensive and there is a clear need for further studies. The use of diets with higher fat content for beef cattle, especially in the postpartum, has shortened the postpartum anovulatory period since it improves the functional ability of the ovaries, as well as steroid production and luteal hormones activity.

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