

## HEAT STRESS, DIETARY FAT AND REPRODUCTIVE MANAGEMENT OF DAIRY COWS

Arlindo de Alencar Araripe MOURA<sup>1</sup>, Airton Alencar de ARAUJO<sup>2</sup> & Patricia Guimarães PIMENTEL<sup>3</sup>

<sup>1</sup>UFC (amoura@ufc.br)

<sup>2</sup>UECE (aaaraujo@hotmail.com)

<sup>3</sup>EnUFC (pgpimentel@hotmail.com)

### ABSTRACT

The present review discusses some of the effects of heat stress and dietary fat on reproductive criteria. Females raised under high temperatures have low estradiol, small follicles and a longer luteal phase. Thermal stress also alters gonadotrophin, inhibin and PGF2a secretion, quality of sperm cells and oocytes, as well as the ability of embryos to develop into blastocysts. Thus, pregnancy rates are usually low in hot seasons. In Brazil, most dairy cows are still crosses between Holstein and Zebu but, although these type of cattle are expected to be more adaptable to hot climates, their capacity to produce under certain levels of heat stress may be altered if cows are managed to reach high levels of milk yield. As a strategy for nutritional management, the use of dietary fat could lower the heat load for dairy cows. Moreover, fat supplementation may not only increase milk yield but also influence concentrations of cholesterol and progesterone, synthesis of PGF2a, follicle growth and pregnancy rates. Therefore, dietary fat could be used as a strategy for nutritional management and may also help dairy cows cope with heat stress.

### INTRODUCTION

The dairy industry demands rapid progress in milk production of individual cows and management strategies that must be cost effective. However, synthesis of milk depends on the ability of cows to start a new lactation every year (or close to this interval). Therefore, cows should present estrus and become pregnant while

they are in the first third of lactation, a period when intake of dry matter and nutrients need to be maximized. At post-partum, animals are also more susceptible to certain types of diseases (metritis, retained placenta, mastitis, etc.), variations in the quality of diets and heat stress. In tropical regions, air temperature is always close to body temperature and this makes animals more susceptible to the effects of climate conditions. Therefore, this review emphasizes some of the effects of heat stress on reproduction and how the results obtained with high-producing purebred animals might be applied to the conditions of dairy herds in the semi-arid region of Brazil. Moreover, the article discusses the potential effects of dietary fat on reproductive criteria and as a tool for management of heat-stressed cows.

### Heat stress, fat supplementation and reproductive performance

Heat stress induces several changes on physiology, milk production and reproductive performance of dairy cows. Females raised in temperatures between 31 and 33.5 °C and 60 % of humidity (Columbia, USA) had lower estradiol in the follicular phase of the cycle and small size of the growing and ovulatory follicles. Somehow, the length of the luteal phase in heat -stressed cows was longer than in females kept in thermoneutral environment. It seems that the uterus secreted less PGF2a because of the reduction in estradiol synthesis and/or because high temperatures can interfere with the release of PGF2a by endometrial cells (MALAYER et al., 1990). It's well known that the uterine endometrium must be "primed" by estradiol to produce enough

prostaglandin and trigger luteolysis (SILVIA et al., 1991). Thermal stress also alters the concentrations of FSH and inhibin (BADINGA et al., 1994; ROTH et al., 2000; WOLFENSON et al., 1997) and corpus luteum function (WILSON et al., 1998), as well as decreases the fluid content of follicles (BADINGA et al., 1993). High temperatures reduce the number of granulosa cells and aromatase activity and secretion of androstenedione by theca cells (WOLFENSON et al., 1997).

Ambient conditions influence oocyte and embryo quality of dairy cows. Oocytes exposed to high temperatures between the onset of estrous and insemination produced lower number of viable embryos (PUTNEY et al., 1989). Moreover, the temperature and humidity 2 days before insemination appears to be more critical to conception rates than at any other phase of the cycle, including the period from breeding to 2 days after breeding (INGRAHAM et al., 1974). When rectal temperatures rise, there is a shift in blood flow from the visceral organs to the peripheral circulation and this could reduce perfusion of nutrients and hormones to the endometrial and oviductal tissues (HANSEN & ARÉCHIGA, 1999). It has been suggested that the early stages of embryo development (8 to 16-cell stage) are more susceptible to heat stress but there is also a high risk of embryonic loss at days 13 and 14 of pregnancy (BIGGERS et al., 1987; RYAN et al., 1993). Also, conceptuses cultured in high temperatures reduced the secretion of Interferon: (PUTNEY et al., 1988), an event that impairs implantation and maintenance of corpus luteum. As a consequence of these effects, it is expected that ambient with high temperatures significantly influence pregnancy rates in dairy herds. Results from a study conducted in a 12-year period in Australia shows that pregnancy rates of cows and heifers were reduced from 80 to 55 % (after 3 inseminations) as the daily maximum temperature increased above 27°C (ORR et al., 1993). In USA, associations have been found between, season and pregnancy rates in commercial dairy herds (THOMPSON et al., 1996; BADINGA et al., 1985; AL-KATANANI et al., 1999).

Thermal stress affects male reproductive function. High temperatures cause degeneration

of meiotic germ cells in the seminiferous tubules (LUE et al., 1999), influence the structure of spermatozoa DNA (LOVE et al., 1999) and lower sperm counts and motility (SETCHELL, 1998). Also, it seems that the progressive motility is more sensitive to temperature variation than the number of spermatozoa produced at each ejaculation (MOREIRA et al., 2001). Furthermore, premature embryonic death occurs if heat-damaged sperm cells are used to fertilize normal oocytes (BURFENING et al., 1968). Unfortunately, the consequences of heat stress on reproductive performance of dairy herds do not seem to be overcome by the substitution of natural service by artificial insemination because, when spermatozoa are retrieved from heat-stressed females and used in other animals (kept in thermoneutral temperatures), there is a decrease in embryonic survival (HOWARTH et al., 1965).

Although heat stress has a direct effect on reproduction, it is important to emphasize, however, that results from all studies depend on the magnitude and duration of the thermal stress, milk yield and lactation status, breed, composition of diet dry matter intake and physical activity of the animals. Although heat stress would be a major concern of dairy producers in tropical countries, few studies have been conducted in Brazil, where most dairy cows are still crosses between Holstein and Zebu. These animals are expected to be more adaptable to hot climates because of the *Bos indicus* heritage. In fact, oocytes collected from Brahman cows during the warm season exhibited normal morphology and produced a higher proportion of blastocysts in comparison with oocytes obtained from Angus x Holstein cows (ROCHA et al., 1998). However, selection has increased milk production even in Brazilian zebu cows and this may also affect their capacity to reproduce under certain levels of temperature and humidity.

The semi-arid region of the Northeast of Brazil has unique climate conditions, usually with a long dry season (7 months), high temperatures (> 30°C) and low humidity (< 50%) during the day, but lower temperatures at night. In a study conducted in the semi-arid (Ceara, Brazil), Oliveira Neto et al. (2001) showed that, in the summer, crossbred cows raised in shaded pens

were under low stress (in the morning and at night) or moderate stress (afternoon), based on values of THI (temperature and humidity index). In another study carried out in the semi-arid, similar values of THI have been found (79,7 in the morning; 82,5 in the afternoon and 76,6 at night), most of them associated with moderate heat stress (PIMENTEL et al., 2002). Cows used in those studies had an average production of 15 kg of milk/day and showed an increase of 0.4° C (from 39.6 to 40°C) in rectal temperatures between morning and afternoon. Apparently, such ambient conditions do not limit calf crop although there are few results to fully support this hypothesis. Unpublished data from a Brown Swiss herd in a semi-arid region (Experimental Station - Federal University of Ceara) show that, over a 5.5 year period, pregnancy rate at first insemination was 59.4 % for heifers and 50.5 % for cows. However, reproductive indexes may be different if cows are managed to reach high levels of milk production because of the expected increase in dry matter intake and heat load. Fertilization of oocytes at 41°C (a value for rectal temperature that is expected for heat-stressed cows) had reduced the cleavage rate and development of blastocysts compared to oocytes fertilized at 38.5 °C (RIVERAN & HANSEN, 2001). Also, Holstein cows had longer post-partum interval and lower response to superovulation and number of good quality embryos when they were brought from Europe (with a temperate climate) to the Northeast of Brazil (BENYEI et al., 2001). After 1.5 years, however, these animals showed reproductive criteria that were similar to local Holstein cows, suggesting that adaptation to a tropical environment may take a long time for purebred animals, despite the efficiency of nutritional and housing conditions.

Stressful ambient conditions cause decrease in dry matter intake (SILVA, 2000) and this may interfere with reproductive performance because of the lower intake of nutrients. The reduction in feed intake depends on several factors, including the proportion of concentrate and forrage of the diet and milk yield. It has been suggested that, in tropical regions, substitution of certain ingredients of the diets may minimize the effects of heat stress on the performance of dairy

cows (KNAPP & GRUMMER, 1991). The use of fat in diets for dairy cows could lower the heat load of dairy cows because of the high energy density and lower metabolic heat when compared with other ingredients such as fiber and carbohydrate (MORRISON, 1983). Inclusion of fat in diets may therefore increase milk yield but results about these effects are not conclusive yet and depends on the environment where cows are raised (HUBER et al., 1993; SKAAR et al., 1989; CHAN et al., 1992, 1993). Moreover, studies suggest that certain types of fat have significant effects on concentrations of cholesterol (WEHRMAN et al., 1991), progesterone (STAPLES et al., 1998), rate of synthesis and metabolism of PGF<sub>2a</sub> (JENKINS, 1988; KADUCE et al., 1982; DANET-DESNOYERS et al., 1993; THATCHER et al., 1994; OLDICK et al., 1997), follicle growth (LUCY et al., 1991a,b; THOMAS & WILLIAMS, 1996; BEAM & BUTLER, 1997; LAM MOGLIA, 1997), and pregnancy rates in dairy herds (STAPLES et al., 1998; PETIT et al., 2001). However, some experiments failed to detect significant correlations between conception rates and fat supplementation in dairy herds. The reason for these contradictory results is not clear but could be related to differences in management of cows, energy "status" of the animals the amount and type of fat added to the diets (CARROL et al., 1994; LUCY et al., 1992; SKLAN et al., 1994).

## CONCLUSIONS

Reproductive efficiency depends on several factors including milk production, housing conditions, nutrition, disease control, inbreeding and heat stress tolerance. In tropical countries, like Brazil, milk yield per cow is still low in comparison with dairy units of other regions of the world but there is a demand for progress in genetic selection and management for greater productivity. Probably, as a consequence of this progress, the capacity of cows (even the crossbred ones) to synthesize milk and reproduce under hot climates will change and management strategies should be re-evaluated. Also, the use of milk production systems based on grazing reduces the

costs per kg of milk but also expose the animals to greater heat load. Most of the information about the effects of heat stress come from studies carried out with animals raised in conditions that are totally different from those found in tropical regions. Therefore, studies are needed to better understand the associations between climate conditions and reproductive physiology and to evaluate the efficacy of nutritional strategies in those regions.

## REFERENCES

- AL-KATANANI, Y. M.; WEBB, D. W.; HANSEN, P.J. Factors affecting seasonal variation in 90-day nonreturn rate to first service in lactating Holstein cows in a hot climate. *J. Dairy Sci.* v. 82, p. 2611-2616, 1999.
- BADINGA, L.; THATCHER, W. W.; DIAZ, T.; DROST, M.; WOLFENSON, D. Effect of heat stress on follicle development and steroidogenesis in lactating dairy Holstein cows. *Theriogenology*, v. 39, p. 797-810, 1993.
- BADINGA, L.; COLLIER, R. J.; THATCHER, W. W.; WILCOX, C. J. Effects of climate and management factors on conception rate of dairy cattle in subtropical environment. *J. Dairy Sci.*, v.68, p.78-85, 1985.
- BEAM, S.; BUTLER, W. R. Energy balance and ovarian follicular development prior to the first ovulation post-partum in dairy cows receiving three levels of dietary fat. *Biol. Reprod.*, v. 56, p. 133-142, 1997.
- BÉNYEI, B.; GÁSPÁRDY, A.; BARROS, C. W. C. Changes in embryo quality results and ovarian recrudescence during the acclimatisation to the semiarid tropics of embryo donor Holstein-Friesian cows raised in a temperature climate. *Anim. Reprod. Sci.*, v. 68, p. 57-68, 2001.
- BIGGERS, B. G.; GEISERT, R. D.; WETTEMAN, R. P.; BUCHANAN, D. S. Effect of heat stress on early embryonic development in the beef cow. *J. Anim. Sci.*, v. 64, p. 1512-1518, 1987.
- BURFENING, P. J.; ULBERG, L. C. Embryonic survival subsequent to culture of rabbit spermatozoa at 38°C and 40°C. *J. Reprod. Fertil.* v. 15, p. 87-92, 1968.
- CARROLL, D. J.; HOSSAIN, F. R.; KELLER, M. R. Effect of supplemental fish meal on the lactation and reproductive performance of dairy cows. *J. Dairy Sci.*, v. 77, p. 3058-3072, 1994.
- CHAN, S. c.; HUBER, J. T.; WU, Z.; CHEN, K. H., SIMAS, J. Effect of fat supplementation and protein source on performance of dairy cows in hot environment temperatures. *J. Dairy Sci.*, v. 75, Suppl. 1, p. 175, 1992. (Abstract).
- CHAN, S. c.; HUBER, J. T.; WU, Z.; SIMAS, J.; CHEN, K. H.; SANTOS, F.; RODRIGUES, A.; VARELA, J. Effect of supplementation of fat and evaporative cooling of dairy cows subjected to hot temperatures. *J. Dairy Sci.*, v. 76, Suppl. 1, p. 184, 1993. (Abstract).
- DANET-DESNOYERS, G.; JOHNSON, J. W.; O'KEEFE, S. F.; THATCHER, W. W. characterization of a bovine endometrial prostaglandin synthesis inhibitor (EPSI). *Biol. Reprod.*, v. 48, Suppl. 1, p. 115 1993, (Abstract).
- HANSEN, P. J.; ARECHIGA, C. F. Strategies for managing reproduction in the heat-stressed dairy cow. *J. Anim. Sci.*, v. 77, Suppl. 2, p. 36-50, 1999.
- HOWARTH, B.; ALLISTON, C. W.; ULBERG, L. C. Importance of uterine environment on rabbit sperm prior to fertilization. *J. Anim. Sci.*, v. 24, p. 1027-1032, 1965.
- HUBER, J. T.; WU, Z.; CHAN, S. C.; SIMAS, J. Feeding of fat during heat stress conditions and combinations of fat source. *J. Dairy Sci.*, v. 68, Suppl. 1, p. 122, 1993. (Abstract).
- INGRAHAM, R. H.; GILLETE, D. D.; WAGNER, W. D. Relationship of temperature and humidity to conception rate of Holstein cows in subtropical climate. *J. Dairy Sci.*, v. 57, p. 476-481, 1974.
- JENKINS, K. J. Factors affecting poor performance and scours in preruminant calves fed corn oil. *J. Dairy Sci.*, v. 71, p. 3013-3020, 1988.
- LUE, Y. H.; IDKIM, A. P. S.; SVERDLOFF, R. S.; IM, P.; TAING, K. S.; BUTT, T.; LEUNG, A.; WANG, C. Single exposure to heat stress induces stage-specific germ cell apoptosis in rats: Role of intratesticular testosterone on stage specificity. *Endocrinology*, v. 140, n. 4, p. 1709-1717, 1999.
- LOVE, C. c.; KENNEY, R. M. Scrotal heat stress altered sperm chromatin structure associated with a decrease in protamine disulfide bonding in the stallion. *Biol. Reprod.*, v. 60, n. 3, p. 615-620, 1999.
- KADUCE, T. L.; SPECTOR, A. A.; BAR, R. S. Linoleic acid metabolism and prostaglandin production by cultured bovine pulmonary artery endothelial cells. *Arteriosclerosis*, v. 2, p. 380-389,

- 1982.
- KNAPP, D.M.; GRUMMER, R. R. Response of lactating dairy cows to fat supplementation during heat stress. *J. Dairy Sci.*, v. 74, p. 2573-2579, 1991.
- LAMMOGLIA, M. A.; WILLARD, S. T.; HALLFORD, D. M.; RANDEL, R. D. Effects of dietary fat on follicular development and circulating concentrations of lipids, insulin, progesterone, estradiol 17 $\beta$ , 13,14-dihydro-15-keto-prostaglandin F<sub>2</sub> and growth hormone in estrous cyclic Brahman cows. *J. Anim. Sci.*, v. 75, p. 1591-1600, 1997.
- LUCY, M. c.; STAPLES, C. R.; MICHEL, F. M.; THATCHER, W. W. Effects of feeding calcium soaps to early post-partum dairy cows on plasma prostaglandin F<sub>2</sub>alpha, luteinizing hormone and follicular growth. *J. Dairy Sci.*, v. 74, p. 483-489, 1991a.
- LUCY, M. C.; STAPLES, C. R.; MICHEL, F. M.; THATCHER, W. W. Energy balance and size and number of ovarian follicles detected by ultrasonography in early postpartum dairy cows. *J. Dairy Sci.*, v. 74, p. 473-482, 1991b.
- LUCY, M. c.; STAPLES, C. R.; THATCHER, W W; ERICKSON, P. S.; CLEADE, R. M.; FIRKINS, J. L.; CLARK, M. R.; MURPHY, M. R.; BRODIE, B. O. Influence of diet composition, dry matter intake, milk production and energy balance on time of postpartum ovulation and fertility in dairy cows. *Anim. Prod.*, v. 54, p. 323-331, 1992.
- MALAYER, J. R.; HANSEN, P. J. Differences between Brahman and Holstein cows in heat-shock induced alterations of protein secretion by oviducts and uterine endometrium. *J. Anim. Sci.*, v. 68, p. 266-280, 1990.
- MOREIRA, E. P.; MOURA, A. A.; ARAUJO, A. A. Efeitos da insulação escrotal sobre a biometria testicular e parâmetros seminais em carneiros raça Santa Inês. *Rev. Bras. Zootec.*, v. 30, n. 6, p. 1704-1711, 2001.
- MORRISON, S.R. Ruminant heat stress: effect on production and means of alleviation. *J. Anim. Sci.*, v. 57, p. 1594, 1983.
- OLDICK, B. S., STAPLES, C. R., THATCHER, W W., GYAWU, P. Abomasal infusion of glucose and fat - effect on digestion, production, and ovarian and uterine function of cows. *J. Dairy Sci.*, v. 80, p. 1315-1328, 1997.
- OLIVEIRA NETO, J. B.; MOURA, A. A.; NEIVA, J. N. M.; GUILHERMINO, M. M. Efeitos da somatotropina bovina (bst) sobre a produção de leite e indicadores de estresse térmico (temperatura retal e temperatura do leite) em vacas *Bos taurus* x *Bos indicus* criadas no semi-ando do Nordeste. *Rev. Bras. Zootec.*, v. 30, n. 2, p. 360-367, 1999.
- ORR, W N.; COWAN, R T; DAVISON, T M. Factors affecting pregnancy rate in Holstein-Friesian cattle mated during summer in a tropical upland environment. *Austl. Vet. J.*, v. 70, n. 7, p. 256-278, 1993.
- PETIT, H. V; DEWHURST, R. J.; PROULX, J. G.; KHALID. M.; HARESIGN, W.; TWAGIRAMUNGU, H. Milk production, milk composition and reproductive function of dairy cows fed different fats. *Can. J. Anim. Sci.*, v. 81, n. 2, p. 263-271, 2001.
- PIMENTEL, P. G.; MOURA, A. A.; NEIVA, J. N. M. Efeitos da adição de castanha de caju sobre o consumo de matéria seca e nutrientes, produção de leite e indicadores de estresse térmico em vacas criadas no semi-árido. *Revista Brasileira de Zootecnia* .... Anais. (Em CD). 2002.
- PUTNEY, D. J.; MULLINS, S.; THATCHER, W W; DROST, M.; GROSS, T. S. Embryonic development in superovulated dairy cattle exposed to elevated ambient temperatures between the onset of estrus and insemination. *Anim. Reprod. Sci.*, v. 19, p. 37-51, 1989.
- PUTNEY, D. I.; MALAYER, I. R.; GROSS, T. S.; THATCHER, W W; HANSEN, P. J.; DROST, M. Heat stress-induced alterations in the synthesis and secretion of proteins and prostaglandins by cultured bovine conceptuses and uterine endometrium. *Biol. Reprod.*, v. 39, p. 717-728, 1988.
- RIVERA, R. M.; HANSEN, P. J. Development of cultured bovine embryos after exposure to high temperatures in the physiological range. *Reproduction*, v. 121, n. 1, p. 107-115, 2001.
- ROCHA, A.; RANDEL, R. D.; BROUSSARD, J. R.; LIM, J. M.; BLAIR, R. M.; ROUSSEL, J. D.; GODKE, R. A.; HANSEL, W. High environmental temperature and humidity decrease oocyte quality in *Bos taurus* but not in *Bos indicus* cows. *Theriogenology*, v. 49, p. 657-665, 1998.
- RYAN, D. P.; PRICHARD, J. F.; KOPEL, E.; GODKE, R. A. Comparing early embryo mortality in dairy cows during hot and cool seasons of the year. *Theriogenology*, v. 39, p. 719-737, 1993.
- SETCHELL, B.P. The Parkers Lecture - Heat and the testis. *J. Reprod. Ferri.*, v. 114, p. 179-194, 1998.
- SILVA, R.G. Um modelo para determinação do equilíbrio térmico de bovinos em ambientes tropicais. *Rev. Bras. Zootec.*, v. 29, n. 4, p. 1244-1252, 2000.
- SILVIA, W J.; LEWIS, G. S.; MCCracken, J. A.; THATCHER, W W; WILSON JR, L. Hormonal regulation of uterine secretion of prostaglandin F<sub>2</sub>a during luteolysis in ruminants. *Biol. Reprod.*, v. 45,

p. 655-663, 1991.

SKAAR, T. c.; GRUMMER, R R; DENTINE, M. R.; STUFFACHER, R. H. Seasonal effects of prepartum and postpartum fat and niacin feeding on lactation performance and lipid metabolism. *J. Dairy Sci.*, v. 72, p. 2028-2039, 1989.

SKHAN, D.; KAIM, M.; MOALLEM, U.; FOLMAN, Y. Effect of dietary calcium soaps on milk yield, body weight, reproductive hormones and fertility in first parity and older cows. *J. Dairy Sci.* . 77, p. 1652-1660, 1994.

STAPLES, C. R, BURKE J. M., THATCHER, W. W. Influence of supplemental fat on reproductive tissues and performance of lactating cows. *J. Dairy Sci.*, v. 81, p. 856-871, 1998.

THATCHER, W W; STAPLES, C. R.; DANET-DESNOYERS, G.; OLDICK, B. S.; SCHMITT, E. P Embryo health and mortality in sheep and cattle. *J Anim. Sci.*, v. 72, Suppl. 3, p. 16. 1994.

THOMAS, M. G.; WILLIAMS, G. L. Metabolic hormone secretion and FSH-induced superovulatory responses of beef heifers fed dietary fat supplements containing predominantly saturated and polyunsaturated fatty acids. *Theriogenology*, v. 45,

p. 451-458, 1996.

THOMPSON, J. A.; MAGEE, D. D.; TOMASZEWSKI, D. L.; WILKS, D. L.; FOURDRINE, R. H. Management of summer infertility in Texas Holstein dairy cattle. *Theriogenology*, v. 46, p. 547-558, 1996. WEHRMAN, M. E., WELSH, T. H. JR., WILLIAMS, G. L. Diet induced-hyperlipidemia in cattle modifies the intrafollicular cholesterol environment, modulates ovarian follicular dynamics and hastens the onset of postpartum luteal activity. *Biol. Reprod.* v. 45, p. 514-522, 1991.

WILSON, S. J.; MARION, R S.; SPAIN, J. N.; SPIERS, D. E.; KEISLER, D. H.; LUCY, M. C. Effects of controlled heat stress on ovarian function of dairy cattle. I. Lactating cows. *J. Dairy Sci.*, n. 81, p. 2124-2131, 1998.

WOLFENSON, D.; THATCHER, W W; BADINGA, L SAVIO, J. D.; MEIDAN, R; LEW, B. J.; BRAWTAL.; R, BERMAN, A. Effect of heat stress on follicle development during the estrus cycle in lactating dairy cattle. *Biol. Reprod.*, v. 52, p. 1106- 1113. 1995.