International Journal of Agricultural Research and Food Production
ISSN: 2536-7331 (Print): 2536-734x (Online)
Volume 4, Number 2, June 2019
http://www.casirmediapublishing.com

Heat Stress as a Source of Infertility in Cattle Production

Torrens, F[1], Marahatta, S[2], Duran, I.L[3] and Ahaotu, E.O[4]
[1]Department of Physical Chemistry, Universitat de València, Spain.
[2]Department of Biological Sciences, Agriculture and Forestry University, Nepal.
[3]College of Graduate Studies, Don Mariano Marcos Memorial State University, Philippines
[4]Department of Animal Production Technology, Imo State Polytechnic Umuagwo, Nigeria.
Email: vieng663@hotmail.com

ABSTRACT

Climate change, with a constant increase in the Earth temperature, negatively affects livestock production and health. Cattle are an important contributor to milk, meat, draught power and leather production in many developing countries. Due to ineffective cooling mechanisms like scanty sweat glands and hair coat they are more predisposed to heat stress causing huge economic losses to the cattle breeders as well as dairy industry. The thermal stress primarily affects the hypothalamic-hypophyseal-ovarian axis and it is the interplay of endocrinological imbalances which affects the reproductive cycle causing seasonality and anoestrus. Hence heat stress needs to be alleviated to maintain the reproductive efficiency in cattle and prevent economic losses.
Keywords: *Reproductive Efficiency, Heat stress, Anoestrus, Cattle, Infertility.*

INTRODUCTION

Animals go through heat stress (HS) when the body temperature is higher than the optimal range specified for the normal activity because the total heat load is greater than the capacity for heat dissipation (Bernabucci *et al.,* 2010). The thermal comfort zone for temperate-region adult cattle is in the range from 5 to 15°C as proposed by Hahn *et al.,* (2003). Nardone *et al.,* (2010) revealed that significant changes in feed intake and physiological processes occur with temperatures greater than 25°C. However, the thermal comfort zone changes as a function of several other factors, including environmental humidity and air speed, genotype, physiological state, thermal susceptibility, acclimation and diet. Animals attempt to maintain the body temperature increasing heat loss and reducing heat production by physiological and behavioural responses. High environmental temperature challenges the animal's ability to maintain energy, thermal, water, hormonal and mineral balance. High ambient temperature and humidity are the major constant on cattle productivity in tropical and subtropical areas. Cattle can withstand for hours an external temperature as high as 43°C during which both sweating and panting are important heat regulating mechanisms. Cattle have immense production potential in terms of milk and meat and act as a source of sustenance to the poor and marginal farmers as well as landless laborers in the developing world (Javaid *et al.,* 2009; Abdolghafour and Sahgir, 2014). It alone contributes approximately 96.8% of the total milk to the dairy industry in Asia and approximately 12.8% of the total world milk production though it forms only 11.6% of the total bovine population in the world (FAOSTAT, 2007).

In tropical and sub-tropical areas, indigenous cattle tend to breed throughout the year, although the sexual activity is restricted to a certain extent to the dry season (Kadim *et al.* 2007). This effect is aggravated when heat stress is accompanied by high ambient humidity. Exposure of cattle to elevated temperatures results in a decrease of body weight, average daily gain, growth rate and body total solids, which is reflected by impaired reproduction (Shelton 2000). Cattle are efficient converter of poor quality and fibrous feeds into high quality protein like meat, milk and valuable by-products (Kaneepan *et al.,* 2013). Agarwal *et al.* (2009) this is due to the better digestive ability of buffaloes than cattle to utilize poor quality roughage and convert into high quality protein. Climatic factors such as air temperature, solar radiation, relative humidity, air flow and their interactions, often limit animal performance (Mishra *et al.,* 2015a), of which air temperature is the most important. Heat stress is a well-known problem in a semi-tropical country like India and amounts to huge economic losses to the cattle breeders as well as dairy industry. Heat stress is the state at which the mechanisms activate to maintain animals body thermal balance, when exposure to elevated temperature.

Elevated body temperatures result due to elevated surrounding temperature causing reduction in gradient between the body and the environment of all the environmental variables, ambient temperature and relative humidity have significant effect on the physiological systems governing thermal balance of the animal and maintaining positive heat loss for efficient cooling. In tropical and subtropical areas, high ambient temperature is the major constraint on animal productivity (Marai *et al.,* 2008; Shelton, 2000). High ambient humidity aggravates the effect of heat stress (Marai *et al.,* 2008) as it prevents evaporative cooling which is the last resort for the animal when ambient temperature rises to a higher level. Exposure of cattle and other animals to the hot conditions evokes a series of drastic changes in the biological functions that include depression in feed intake, efficiency and utilization, disturbances in metabolism of water, protein, energy and mineral balances, enzymatic reactions, hormonal secretions and blood metabolites (Mishra *et al.,* 2015b). Such changes result in impairment of reproduction and production performances. Heat stress directly affects the reproductive efficiency of cows and reduces the intensity and duration of oestrus.

Effect of Heat Stress on the Females Reproductive Traits

Oestrus

Heat stress directly affects oestrus. When the ambient temperature is low in morning and evening, maximum display of sexual activity occur whereas lowest activity is seen in the afternoon. El- Wardani and El-Asheeri (2000) observed that the cows exhibited the signs of oestrus in the early morning (3.00 to 9.00h) and in the evening (15.00 to 21.00h) with a peak in early morning (about 37%), while the lower percentage was at noon (about 12% of oestrous cases started during the period from 9.00 to 15.00h). Ovarian activity decreases in tropical environment as well as, anoestrum is produced (El- Wardani and El-Asheeri, 2000) due to heat stress. The decline in feed intake and in the quantity and quality of feed may, aggravate the negative influence on the adeno-hypophysis during dry season in cattle which result in less gonadotrophic hormone release and weak heat and/or anoestrum. Length of oestrous cycle and degree of expression of oestrus in cows are affected by various factors such as season, climate, photoperiod, temperature and nutrition (El- Wardani and El-Asheeri, 2000). Collier *et al.* (2006) reported that thermal stress increased the ACTH/cortisol level, which caused a change in the endocrine secretion resulting in anoestrus.

Silent Heat

Dokladny *et al.*, (2006) reported that silent heat in cattle may be due to the anoestrus caused by thermal stress. Decrease in estradiol level in the hot season leads to depressed manifestation of oestrus especially on the day of estrous resulting in quiet ovulation and ovarian activity delay in cattle (Collier *et al.*, 2006). Caroprese *et al.*, (2013) reported that higher incidence of the silent heat in cattle calving during the hot season (35.7%) than in those calving in the mild season (27.3%).

Pregnancy Rate

The decrease in estrogen concentration as a function of heat stress and, consequently, the sufficient alteration of environment in the follicle suppresses normal maturation of the egg with depression of LH. Liu *et al.* (2013) showed rising ambient temperature from 12.5 to 35°C was accompanied by decline of CR in cattle from 40 to 31% and an increase in rectal temperature of 1°C at 12h post insemination was found to be associated with a decrease of CR in cattle (45 vs. 61%) (Berman, 2011). The high adverse effects in females are shown on the ova, their fertilization and consequent development of embryos (Berman, 2006).

Effect of Heat Stress on Ovarian Function

Some early studies reported no quiescence of reproductive rhythm (Liu *et al.*, 2013) evident by the presence of follicular growth followed by atresia (Liu *et al.*, 2016). These authors found the presence of smooth quiescent ovaries during hot season without any corpus luteum. Further a recent report on this line indicated the presence of quiescent ovaries in most cattle in hot season months (Nanda *et al.*, 2003). Morphological and histo-chemical studies revealed both normal as well as atretic follicles of variable sizes in atretic cattle ovaries (Calamari *et al.*, 2013). The histological studies reported a reduced follicular growth and plenty of follicular atresia of primary to tertiary follicles in ovarian hypo-function (Caroprese *et al.*, 2013). Neglia *et al.* (2003) reported the higher sensitivity of cattle oocytes than cattle oocytes, to heat stress. It has been reported that season has significant effect on cattle oocyte yield and quality (Zoheir *et al.*, 2007).

Effect of Heat Stress on the Hormonal Profile

Heat stress is directly known to affect the neuroendocrine setup in cattle (Caroprese *et al.,* 2013). They are very susceptible to thermal stress (Calamari *et al.,* 2013) during hot season because of poor evaporative cooling mechanism owing to scanty sweat glands. Scanty hair coat also is unable to provide effective protection against the thermal stress and high relative humidity further aggravates the condition (Ammer *et al.,* 2016). The heat stress causes hyper-prolactinemia, reduced luteinizing hormone (LH) frequency, poor follicle maturation and decreased oestradiol production in anoestrus cattle (Collier *et al.,* 2006) leading to ovarian inactivity. Besides, the circadian secretion of melatonin from the pineal gland adds to the seasonal effects (Ronchi *et al.,* 2001). The following endocrinological factors are influencing seasonal reproduction in cows.

Photoperiodism and Role of Melatonin

Melatonin secretion is the hormonal signal of light dark rhythm. Although cattle are polyestrous, they exhibit seasonality in displaying estrous in which, photoperiod depending on secretion of melatonin plays a major role (Collier *et al.,* 2006). More seasonal cattle are reported to have high concentration of melatonin after sunset (Chase, 2006). Chedid *et al.,* (2014) also reported remarkable changes in melatonin levels in cattle heifers.

Hyperprolactinemia

Seasonal changes in pineal metabolism leads to hyper-prolactinemia during heat stress (Kadim *et al.,* 2007) which prevents LH secretion caused by positive feedback of estrogen at hypothalamic level (Kadim *et al.,* 2006) while at ovarian level it alters the level of LH receptors leading to anoestrus in summer.

Lack of LH Surge and Low Levels of FSH

Peripheral FSH concentrations (Ronchi *et al.,* 2001) and LH levels are affected by weather (Ammer *et al.,* 2016). In cattle, FSH concentrations were reported to be higher at oestrus and during luteal phase in November to December in comparison to March to June (Yousefi *et al.,* 2012). Similarly peak LH levels were found to be higher in cooler months (Dokladny et *al.,* 2006). It is reported that lower basal LH levels and lack of pre-ovulatory surge are associated with ovarian inactivity in summer (Diesel *et al.,* 2007). Decrease in LH peak and lower progesterone concentration may be responsible for silent oestrus in hot season (Ammer *et al.,* 2016).

Role of Progesterone

Significantly higher progesterone concentrations have been found in hot climate than in cold weather (Mondal *et al.,* 2004). These high concentrations could be attributed to release of progesterone from adrenal cortex induced by heat stress under prolonged heat exposure

(Yousefi *et al.,* 2012). Progesterone concentrations are also found to vary with nutritional status of the animal which coupled with heat stress can lead to long anoestrus in cattle. Heat stress causing low level of thyroid hormones or hypothyroidism has been associated with reduced responsiveness of the ovary to FSH and LH leading to hot season anoestrus (Al-Dawood, 2017). Similarly, high level of corticosteroids in serum produced in response to thermal stress leads to change in secretion pattern of pituitary gonadotropins causing a state of anoestrus (Abeni and Galli 2016). Climate change, particularly heat stress, could impact on meat safety as well as organoleptic quality. Global warming could affect microbial burdens on carcasses and meat, especially if the animals carry more enteric pathogens in their gut or on their body surface. Extreme heat provokes an adrenergic stress response. Adrenaline stimulates peripheral vasodilatation and muscle glyco-genolysis, and if exposure is protracted before slaughter it could lead to high pH and darker meat.

CONCLUSION

Heat stress is becoming a serious problem because of the negative impacts on ruminant performance. The negative effect of HS will become more severe in the future, as a consequence of global warming progresses and genetic selection for milk yield continues. Heat-stressed animals change their metabolism and physiology in response to weather change. The direct and indirect effects of HS affect gastrointestinal health and functionality strongly influencing the efficiency of diet utilisation. The changes in nutrient partitioning and the alteration of rumen and intestine functionality should be taken into account. Cattle are perfectly suited to the hot season but they exhibit signs of great distress when exposed to direct solar radiation or when working in the sun during hot season. Heat stress affects male and female reproductive functions deleteriously causing seasonality in reproduction, silent heat coupled with poor expression of estrous and low conception rate. Besides proper management in terms of feeding, housing to alleviate heat stress, a sound knowledge in terms of interplay of hypothalamic, gonadotropic and gonadal hormones in stress conditions, can help to devise means to improve reproductive performance in these animals. An endocrine balance is expected to improve reproductive efficiency.

REFERENCES

Abdolghafour B and Saghir A (2014). Buffalo: a potential animal for quality meat production - a review. *Livestock Research International,* 2(2): 19-29.

Abeni F and Galli A. (2016). Monitoring cow activity and rumination time for an early detection of heat stress in dairy cow. Int J Biometeorol. 61:417–425.

Agarwal N, Shekhar C, Kumar R, Chaudhary LC and Kamra DN (2009). Effect of peppermint (*Mentha piperita*) oil on in vitro methanogenesis and fermentation of feed with buffalo rumen liquor. *Animal Feed Science and Technology,* 148: 321-327.

Al-Dawood A. (2017). Effect of heat stress on adipokines and some blood metabolites in goats from Jordan. Anim Sci J. 88:356–363.

Ammer S, Lambertz C and Gauly M. (2016). Comparison of different measuring methods for body temperature in lactating cows under different climatic conditions. J Dairy Res. 83:165–172.

Berman A. (2006). Extending the potential of evaporative cooling for heat-stress relief. J Dairy Sci. 89:3817–3825.

Berman A. (2011). Invited review: are adaptations present to support dairy cattle productivity in warm climates? J Dairy Sci. 94:2147–2158.

Bernabucci U, Lacetera N, Baumgard LH, Rhoads RP, Ronchi B and Nardone A. (2010). Metabolic and hormonal acclimation to heat stress in domesticated ruminants. Animal. 4:1167–1183.

Calamari L, Petrera F, Stefanini L and Abeni F. (2013). Effects of different feeding time and frequency on metabolic conditions and milk production in heat-stressed dairy cows. Int J Biometeorol. 57:785–796.

Caroprese M, Albenzio M, Marino R, Santillo A and Sevi A. (2013). Dietary glutamine enhances immune responses of dairy cows under high ambient temperature. J Dairy Sci. 96:3002–3011.

Chase LE. (2006). Climate change impacts on dairy cattle. Fact sheet, Climate Change and Agriculture: Promoting Practical and Profitable Responses. http://climate and farming. org/pdf/Factsheets/III.3Cattle.pdf.

Chedid M, Jaber LS, Giger-Reverdin S, Duvaux-Ponter C and Hamadeh SK. (2014). Review: water stress in sheep raised under arid conditions. Can J Anim Sci. 94:243–257.

Collier RJ, Dahl GE and Van Baale MJ. (2006). Major advances associated with environmental effects on dairy cattle. J Dairy Sci. 89:1244–1253.

Diesel B, Kulhanek-Heinze S, Heoltje M, Brandt B, H€oltje HD, Vollmar AM and Kiemer AK. (2007). a-Lipoic acid as a directly binding activator of the insulin receptor: protection from hepatocyte apoptosis. Biochemistry. 46:2146–2155.

Dokladny K, Moseley PL and Ma TY. (2006). physiologically relevant increase in temperature causes an increase in intestinal epithelial tight junction permeability. Am J Physiol – Gastr Liver Physiol. 290:G204–G212?

El-Wardani MA and El-Asheeri K (2000). Influence of season and number of heat checks on detecting of
ovulatory estrus in Egyptian buffaloes. *Egyptian Journal of Animal Production*, 37(1): 18-22.

FAOSTAT (2007). http://faostat.fao.org.

Javaid SB, Gadahi JA, Khaskeli M, Bhutto MB, Kumbher S and Panhwar AH (2009). Physical and chemical quality of market milk sold at Tandojam, Pakistan. *Pakistan Veterinary Journal,* 29: 27-31.

Hahn GL, Mader L and Eigenberg A. (2003). Perspective on development of thermal indices for animal studies and management. EAAP Techn Ser. 7:31–44.

Kadim IT, Mahgoub O, Al-Kindi A, Al-Marzooqi W and Al-Saqri NM (2006). Effects of transportation at high ambient temperatures on physiological responses, carcass and meat quality characteristics of three breeds of Omani goats. Journal of Meat Science, 73: 626–634.

Kadim IT, Mahgoub O, Al-Marzooqi W, Al-Ajmi DS, Al-Maqbali RS and Al-Lawati SM (2007). The influence of seasonal temperatures on meat quality characteristics of hot-boned, *m. psoas major* and *minor,* from goats and sheep. Journal of Meat Science, 80: 210–215.

Kandeepan G, Mendiratta SK, Shukla V and Vishnuraj MR (2013). Processing characteristics of buffalo meat – a review. *Journal of Meat Science and Technology,* 1(1): 01-11.

Liu DY, He SJ, Jin EH, Liu SQ, Tang YG, Li SH and Zhong LT. (2013). Effect of daidzein on production performance and serum anti-oxidative function in late lactation cows under heat stress. Livest Sci. 152:16–20.

Liu F, Cottrell JJ, Furness JB, Rivera LR, Kelly FW, Wijesiriwardana U, Pustovit RV, Fothergill LJ, Bravo DM and Celi P (2016). Selenium and vitamin E together improve intestinal epithelial barrier function and alleviate oxidative stress in heat-stressed pigs. Exp. Physiol. 101:801–810.

Marai IFM, El-Darawany AA, Fadiel A and Abdel-Hafez MAM (2008). Reproductive performance traits as affected by heat stress and its alleviation in sheep – a review. *Tropical and Subtropical Agro ecosystems,* 8: 209-234.

Mishra A, Reddy IJ and Mondal S (2015a). Effect of oxidative stress on animal reproduction. *Livestock*
Research International, 3(4): 103-109.

Mishra A, Reddy IJ and Mondal S (2015b). Modern concept in optimizing reproductive efficiency of seasonal breeders. *Livestock Research International,* 3(3): 51-57.

Mondal S, Palta P and Prakash BS (2004). Influence of season on peripheral plasma progesterone in cycling Murrah buffaloes (*Bubalus bubalis*). *Buffalo Journal,* 1: 95-100.

Nardone A, Ronchi B, Lacetera N, Ranieri MS and Bernabucci U. (2010). Effects of climate changes on animal production and sustainability of livestock systems. Livest Sci. 130:57–69.

Neglia G, Rendina M, Balestrieri A, Grasso FL, Potena A, Russo I and Zicarelli L (2009). Influence of a
Swimming pool on fertility in buffalo species. *Italian Journal of Animal Science,* 8(Suppl. 2): 637-639.

Ronchi B, Stradaioli G, Verini Supplizi A, Bernabucci U, Lacetera N and Accorsi P (2001). Influence of heat stress or feed restriction on plasma P4, oestradiol 17α, LH, FSH, prolactin and cortisol in Holstein heifers. *Livestock Production Science,* 68: 231-241.

Shelton M (2000). Reproductive performance of sheep exposed to hot environments. *In: Sheep Production in Hot and Arid Zones,* RC Malik, MA Razzaque and AY Al-Nasser (eds)*, Kuwait Institute for Scientific Research*. pp. 155-162.

Yousefi AR, Kohram H, Shahneh AZ, Nik-khah A and Campbell AW (2012). Comparison of the meat quality and fatty acid composition of traditional fat-tailed (Chall) and tailed (Zel) Iranian sheep breeds. Journal of Meat Science, 92: 417–422.

Zoheir KMA, Abdoon AS, Mahrous KF, Amer MA, Zaher MM, Li-Guo Y and El-Nahass EM (2007). Effects of season on the quality and in vitro maturation rate of Egyptian buffalo (*Bubalus bubalis*) oocytes. *Journal of Cell and Animal Biology,* 1: 29-33.