Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2019; 7(2): 342-345

Received: 19-01-2019
Accepted: 23-02-2019

Devi P
National Dairy Research Institute, Karnal, Haryana, India

Debbarma S
National Dairy Research Institute, Karnal, Haryana, India

Kumar G
National Dairy Research Institute, Karnal, Haryana, India

Thakur P
Indian Veterinary Research Institute, Izzatnagar, Bareilly, Uttar Pradesh, India

Correspondence
Debbarma S
National Dairy Research Institute, Karnal, Haryana, India

Effect of heat stress on reproduction in farm animals and its mitigation: A review

Devi P, Debbarma S, Kumar G and Thakur P

Abstract
Reproductive success in farm animals is a key driver of livestock based industries. Understanding the underlying mechanisms of reproduction under various circumstances is an essential aspect for maintaining reproductive success. Under the current scenario of global warming, heat stress have been identified as a serious challenge for the welfare, reproduction and production of animals. To improve reproductive efficiency under environmental challenges involving heat stress, it is essential to identify thermal sensitive reproductive responses coupled with reproductive technologies and their application to manage infertility associated with heat stress. This review outlines the various physiological aspects of effects of heat stress in farm animals; and to intervene these deleterious effects, mitigation strategies for sustainable farm productivity are discussed.

Keywords: Heat stress, reproduction, mechanism, mitigation

Introduction
The impact of environmental stress on animal health and productivity is significant [34]. Reproduction is essential for continuity of species and multiplication. Most components of the reproductive system including the oocyte, granulose, uterine environment and the developing embryo and are affected by heat stress. Studies on the effect of heat stress indicate the necessity of cooling animals during summer in order to raise summer fertility [37]. Two general mechanisms through which heat stress can lead to disruptions in reproductive processes, the first one includes regulation of body temperature involving redistribution of blood flow from the body core to the periphery to increase sensible heat loss and reduced feed intake to reduce metabolic heat production can lead to changes in energy balance and nutrient availability that can influence negatively on reproduction. Another mechanism for heat stress induced disruption of reproduction is the failure of homeokinetic systems to regulate body temperature [15]. Reproduction is a complex process involving the interplay of several factors including gametes, hormones, genetic factors, etc. and the balance of the intricate relationships between these factors is essential for successful reproduction. The understanding the role of heat stress in influencing the reproductive capacity of farm animals is therefore imperative to ensure sustainable farm productivity.

Male: Potential fertility of an individual bull is more important than of an individual cow because one bull can influence pregnancy rate of 30 or 40 cows with natural mating, or thousands of cows with artificial insemination [17]. Most of the mammals must have cooler testicular temperature than core body temperature for normal sperm production. The developmental processes of the male gamete may be affected by various factors, including heat stress, causing the production of low quality sperm and thus affecting fertility. Sperm cells are vulnerable to heat stress and respond by undergoing apoptosis [31] and loss of DNA integrity [1]. The primary site of action of heat in testes is the Sertoli cell and thereby have profound effect on the developmental process of the germ cells [29]. During summer, the spermatozoa produced are either intrinsically less active at the time of production or that, though normal at the time of genesis, suffered deterioration during their passage down the reproductive tract prior to their release in the ejaculate [3]. Heat stress result in significant decrease in mass motility of sperm [25]. The acrosome integrity percent is lowest during summer as compared to winter season [3]. Decrease in acrosomal function leads to reduction in sperm fertility [4]. During summer, the sperm abnormalities are higher than winter season [3] suggesting the adverse effects of heat stress on sperm morphology.

In a study, when bulls were exposed to increased ambient temperature (31 and 35 ^{0}C for 8 weeks) there was reductions in the percentage of motile sperm and percentage of normal sperm with non-aged acrosomes, and it took 8 week after the end of heat stress to return to the levels of control bulls [22]. In a study on heat stressed bull; the reaction time, total time taken for successful ejaculate and dismount time were found to be prolonged and was accompanied with low libido score [20].

Female: Cows exposed to heat stress have shorter periods of estrous cycle and had a delayed deleterious effect on ovarian follicular dynamics and oocyte competence [11]. Heat stress leads to reduction in the number of mounts [23], and consequently poor detection of estrus. In a study on lactating dairy cows, the accompanying metabolic and hormonal changes were attributed to the reduction of the proestrus concentrations of estradiol [10], which is further aggravated by heat stress [13]. Heat stress inhibits the expression of gonadotropin receptors in granulosa cells and attenuates the estrogenic activity of growing follicles [30]. Thus the impaired estrogen production may lead to abnormal estrous cycle in animals. High temperature-induced malproduction of ovarian hormones and a reduction in the response of ovarian cells to hormonal stimulators can have deleterious effect on the reproduction processes [32]. During ovarian follicular development, the granulosa cells multiply, secrete hormones, and support the growth of the oocyte. Heat stress induces alteration of gene expression and apoptosis in granulosa cells, and reduces the steroidogenic gene messenger RNA (mRNA) expression which in turn affects the estrogen synthesis leading to ovarian dysfunction [19]. Heat stress alters follicular dominance pattern resulting in disruption of normal follicular dynamics which may contribute to depressed summer fertility [38]. In a study, Gir cows when exposed to heat stress did not reveal any immediate effect on reproductive function, but exerted a delayed deleterious effect on ovarian follicular growth, hormone concentrations and oocyte competence [11]. Heat shock during oocyte maturation can promote apoptotic response leading to disruption of the oocyte's capacity to support early embryonic development [27]. The pre-implantation developmental capacity of an oocyte is determined by cytoplasmic rather than nuclear components, and the cytoplasmic maturation of oocyte is more susceptible to heat stress than nuclear maturation [36]. In a study, it was observed that summer calved cows had greater number of services per conception and lower conception rates than cows calved in other seasons [12]. High yielding dairy cows are sensitive to heat stress either few days before, during, or shortly after breeding which may affect the breeding success of the animal. The impact of heat stress on Pregnancy rate/AI (artificial Insemination) ratio is clearly manifested at THI>70 [21]. In another study conducted on the effect of THI on pregnancy rates of Murrah buffaloes, THI 75 was identified as the threshold THI affecting pregnancy rates with the lowest pregnancy rate occurring between THI values 80.3 to 81.6. The decline in fertility was found to be linearly associated with an increase in combination of both temperature and humidity [9]. Thermal stress affects the uterine blood flow [26] which may alter the uterine environment disrupting embryonic development. Although heat stress may not affect the cleavage rate, but it reduces blastocyst development [11]. The deleterious effects of heat stress induced at the germinal vesicular-stage oocyte is carried over to subsequent embryonic developmental stages and compromise oocyte competence and quality of developed blastocysts [28]. Heat stress affecting dam results in reduced placental weight and fetal growth retardation [2]. Heat stressed dam have shortened gestation length with the calves having decreased body weight at the time of birth and weaning. The fetal growth and immune function of offspring of dam induced with heat stress during dry period is compromised from birth through weaning [35] In a study, it was found that pigs from dams that experienced heat stress during the first half of gestation had increased (13.9%) subcutaneous fat thickness compared to pigs from dams exposed to thermo neutral conditions indicating altered metabolic and body composition parameters during future development and in biological responses to a subsequent heat stress challenge [5].

Mitigation strategies

1. Physical modification of animal housing-Implementation of heat abatement facilities can enhance both pregnancy rates and milk production. Heat abatement is dependent upon the efficient heat exchange of animals with the environment via radiation, evaporation, conduction and convection. Artificial shades are to be provided at appropriate areas of animal shed to prevent the direct heating from sunlight. Tree shades are cost effective natural means in reducing the heating effect of direct sunlight on animal house. Spray along with fan can be used in animal sheds to minimize stress-induced decline in milk production [16] to enhance evaporative cooling. The impact of heat stress can be minimized with either natural or mechanical ventilation to supplement the natural ability of a cow's evaporative cooling mechanism [6]
2. Genetic selection of heat tolerant breeds - Certain breeds of animals are more tolerant to heat stress as compared to other breeds [24]. Cattle from zebu breeds regulate body temperature in response to heat stress more efficiently than *B. taurus* breeds of European origin. The ability of Zebu cattle to regulate of body temperature during heat stress is attributed to their lower metabolic rates as well as better heat loss mechanisms [14]. While selection of heat tolerant breeds for production, the economic aspect should be taken into consideration.
3. Nutritional management- To combat the decreased feed intake during heat stress, increasing diet energy concentration, protein supply and essential amino acids should be the strategy [7]. Night time feeding of dairy cattle with selenium-vitamin E can alleviate the effects of heat stress [33]. Feeding of niacin supplement decreases skin temperatures during heat stress in cows [8]. Animals should be provided ad lib clean drinking water during periods of high ambient temperature to maintain water homeostasis.
4. Hormonal treatments-Use of gonadotropins to induce follicular development and ovulation can decrease the severity of seasonal postpartum infertility in dairy cows [18].

Conclusion

Heat stress affects the reproductive capacity of both male and female animals. The effect of heat stress on reproduction is multidimensional. The intricate reproductive pattern required for a successful reproduction is disrupted by heat stress at various stages of reproduction. The deleterious effects of heat

stress on reproduction are profound from the stage of gamete development to the growth of offspring. Advanced reproductive technologies, hormonal treatments and management practices involving modification of animal environment and nutritional strategies are tools for abatement for heat stress related reproductive problems.

References

1. Banks S, King SA, Irvine DS, Saunders PTK. Impact of a mild scrotal heat stress on DNA integrity in murine spermatozoa. Reproduction. 2005; 129:505-514.
2. Bell AW, McBride BW, Slepetis R, Early RJ, Currie WB. Chronic heat stress and prenatal development in sheep: I Conceptus growth and maternal plasma hormones and metabolites. J Anim. Sci. 1989; 67:3289-3299.
3. Bhakat M, Mohanty TK, Gupta AK, Abdullah. Effect of season on semen quality of crossbred (Karan Fries) bulls. Adv. Anim. Vet. Sci. 2014; 2(11):632-637.
4. Birck A, Christensen P, Labouriau R, Pedersen J, Borchersen S. *In vitro* induction of the acrosome reaction in bull sperm and the relationship to field fertility using low-dose inseminations. Theriogenology. 2010; 73:1180-1191
5. Boddicker RL, Seibert JT, Johnson JS, Pearce SC, Selsby JT *et al*. Gestational heat stress alters postnatal offspring body composition indices and metabolic parameters in pigs.2014.PLoS ONE 9(11):e110859. doi:10.1371/journal.pone.0110859
6. Collier RJ, Collier JL. Environmental physiology of livestock: Strategies to reduce the impact of heat and cold stress in dairy cattle facilities.2012.John Wiley & Sons, Inc. Print ISBN: 9780813811765 |Online ISBN:9781119949091 |DOI:10.1002/9781119949091.
7. Conte G, Ciampolini R, Cassandro M, Lasagna E, Calamari E, Bernabucci Uand Abeni F. Feeding and nutrition management of heat- stressed dairy ruminants. Italian Journal of Animal Science. 2018; 17(3):604-620.
8. Di Constanzo A, Spain JN, Spiers DE. Supplementation of nicotinic acid for lactating Holstein cows under heat stress conditions. J Dairy Sci. 1997; 80:1200-1206.
9. Dash S, Chakravarty AK, Sah V, Jamuna V, Behera R, Kashyap N *et al*. Influence of temperature and humidity on pregnancy rate of murrah buffaloes under subtropical climate.2015.Asian-Australas J Anim Sci. 28(7):943-950.
10. De la Sota RL, Lucy MC, Staples CR, Thatcher WW. Effects of recombinant bovine somatotrophin (Sometribove) on ovarian function in lactating and nonlactating dairy cows. J Dairy Sci. 1993; 76:1002-1013.
11. de S Torres-Júnior JR, de F A Pires M, de Sá WF, de M Ferreira A, Viana JH, Camargo LS *et al*. Effect of maternal heat stress on follicular growth and oocyte competence in Bos indicus cattle. Theriogenology; 2008; 69(2):155-66.
12. Ghavi Hossein-Zadeh N, Mohit A, Azad N. Effect of temperature-humidity index on productive and reproductive performances of Iranian Holstein cows. Iranian Journal of Veterinary Research. 2013; 14(2):106-112.
13. Gwazdauskas FC, Thatcher WW, Kiddy CA, Paape MJ, Wilcox CJ. Hormonal patterns during heat stress following PGF2α-Tham salt induced luteal regression in heifers. Theriogenology; 1981; 16:271-285
14. Hansen PJ. Physiological and cellular adaptations of zebu cattle to thermal stress. Anim. Reprod. Sci. 2004; (82, 83):349-360.
15. Hansen PJ. Effects of heat stress on mammalian reproduction. Phil. Trans. R. Soc. B; 2009; 364:3341-335.
16. Igono MO, Johnson HD, Stevens BJ, Krause GF, Shanklin MD. Physiological, productive and economic benefits of shade, spray, and fan system versus shade for Holstein cows during summer heat. Journal of Dairy Science. 1987; 70:1069-1079
17. Kastelic JP. Male involvement in fertility and factors affecting semen quality in bulls. Animal Frontiers. 2013; 3(4):20-25.
18. Khodaei-Motlagh M, Zare Shahneh A, Masoumi R, Derensis F. Alterations in reproductive hormones during heat stress in dairy cattle. African Journal of Biotechnology; 2011; 10(29):5552-5558.
19. Li L, Wu J, Luo M *et al*. The effect of heat stress on gene expression, synthesis of steroids, and apoptosis in bovine granulosa cells. Cell Stress and Chaperones; 21 2016; (3):467-475.
20. Mandal DK, Nagpaul PK, Gupta AK. Seasonal variation in seminal attributes and sexual behaviour of Murrah buffalo bulls. Indian Journal of Dairy Science; 2000; 53(4):278-283.
21. Mellado M, Sepulveda E, Meza-Herrera C, Veliz FG, Arevalo JR, Mellado J *et al*. Effects of heat stress on reproductive efficiency of high yielding Holstein cows in a hot-arid environment.2013.RevistaColombiana de Ciencias Pecuarias; 26(3):193-200.
22. Meyerhoeffer DC, Wettemann RP, Coleman SW, Wells ME. Reproductive criteria of beef bulls during and after exposure to increased ambient temperature. J Anim. Sci. 1985; 60:352-357.
23. Pennington JA, Albright JL, Diekman MA, Callahan CJ. Sexual activity of Holstein cows: seasonal effects. J Dairy Sci. 1985; 68:3023-30.
24. Pereira AM, Baccari Jr F, Titto EA, Almeida JA. Effect of thermal stress on physiological parameters, feed intake and plasma thyroid hormones concentration in Alentejana, Mertolenga, Frisian and Limousine cattle breeds. Int. J Biometeorol. 2008; 52:199-208.
25. Ram KL, Tiwari RP, Mishra GK, Sahasrabudhe SA and Nair AK. Effect of heat stress on seminal characteristics of murrah buffalo bull semen. Buffalo Bulletin; 2017; 36(2):369-378.
26. Roman-Ponce H, Thatcher WW, Caton D, Barron DH, Wilcox CJ. Thermal stress effects on uterine blood flow in dairy cows. Journal of Animal Science. 1978; 46(1):175-180.
27. Roth Z, Hansen PJ. Involvement of apoptosis in disruption of developmental competence of bovine oocytes by heat shock during maturation. Biology of Reproduction; 2004; 71:1898-1906.
28. Sadeesh EM, Sikka P, Balhara AK, Balhara S. Developmental competence and expression profile of genes in buffalo (*Bubalus bubalis*) oocytes and embryos collected under different environmental stress. Cytotechnology; 2016; 68(6):2271-2285.
29. Setchell BP. The Parkes lecture Heat and the testis. J Reprod. Fertil; 1998; 114:179-194.
30. Shimizu T, Ohshima I, Ozawa M, Takahashi S, Tajima A, Shiota M *et al*. Heat stress diminishes gonadotropin

receptor expression and enhances susceptibility to apoptosis of rat granulosa cells. Reproduction. 2005; 129(4):463-72.
31. Sinha Hikim AP, Lue Y, Yamamoto C, Vera Y, Rodriguez S, Yen PH *et al*. Key apoptotic pathways for heat-induced programmed germ cell death in the testis. Endocrinology. 2003; 144:3167-3175.
32. Sirotkin AV, Kacaniova M. The effect of high temperature on swine ovarian function in vitro. Veterinarni Medicina. 2010; 55(8):377-382.
33. Tahmasbi AM, Kazemi M, Moheghi MM, Bayat J, Shahri AM. Effects of selenium and vitamin E and night or day feeding on performance of Holstein dairy cows during hot weather. J Cell Anim. Biol. 2012; 6:33-40.
34. Tao S, Dahl GE. Invited Review: Heat stress effects during late gestation on dry cows and their calves. J Dairy Sci. 2013; 96:4079-4093.
35. Tao S, Monteiro AP, Thompson IM, Hayen MJ, Dahl GE. Effect of late gestation maternal heat stress on growth andimmune function of dairy calves. J Dairy Sci. 2012; 95:7128-7136.
36. Wang JZ, Sui HS, Miao DQ, Liu N, Zhou P, Ge L, Tan JH. Effects of heat stress during in vitro maturation on cytoplasmic versus nuclear components of mouse oocytes. Reproduction. 2009; 137:181-189
37. Wolfenson D, Roth Z, Meidan R. Impaired reproduction in heat-stressed cattle: basic and applied aspects. Animal reproduction science. 2000; 60-61(2):535-547.
38. Wolfenson D, Thatcher WW, Badinga L, Savio JD, Meidan R, Lew BJ *et al*. Effect of Heat Stress on Follicular Development during the Estrous Cycle in Lactating Dairy Cattle. Biology of Reproduction. 1995; 52:1106-1113.