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Sudhanshu Pratap Singh
Department of Veterinary Gynaecology and Obstetrics, BVC, Bihar Animal Sciences University (BASU) – Patna, Bihar, India

Ankesh Kumar
Department of Veterinary Clinical Complex, BVC, Bihar Animal Sciences University (BASU) – Patna, Bihar, India

Nitu Sourya
BVC, Bihar Animal Sciences University (BASU) – Patna, Bihar, India

Corresponding Author:
Sudhanshu Pratap Singh
Department of Veterinary Gynaecology and Obstetrics, BVC, Bihar Animal Sciences University (BASU) – Patna, Bihar, India

Effects of heat stress on animal reproduction

Sudhanshu Pratap Singh, Ankesh Kumar and Nitu Sourya

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Abstract
Heat stress during the summer disturbs reproductive processes in farm animals as it affects the physiology of reproductive tract by several means like hormonal imbalance, decreased oocyte and semen quality, and decreased embryo development and survival. Heat causes decreased secretion of the luteinizing hormone and oestradiol which causes reduced length and intensity of estrus expression, increased incidence of anoestrus and silent heat in farm animals. Oocytes exposed to thermal stress lose its competence for fertilization and development into the blastocyst stage, which results in decreased fertility because of the production of poor-quality oocytes and embryos. Furthermore, low progesterone secretion limits the endometrial functions, and subsequently embryo development. In addition, the increased secretion of endometrial prostaglandin F2 alpha during heat stress threatens the maintenance of pregnancy. The effects of heat stress on livestock can be minimized via adapting suitable scientific strategies comprising physical modifications of the environment, nutritional management and genetic development of breeds that are less sensitive to heat stress. In addition, the summer infertility may be countered through advanced reproductive technologies involving hormonal treatments, timed artificial insemination, and embryo transfer, which may enhance the chances for establishing pregnancy in farm animals.

Keywords: Summer, Buffalo, Cattle, Infertility, THI

Introduction
Climate affects the performance, health, and well-being of livestock. Among the environmental variables affecting livestock, heat stress seems to be one of the most intriguing factors hampering animal production in many regions of the world. Heat stress due to high ambient temperatures, high direct and indirect solar radiation and humidity are environmental stressing factors leads to strain on animals. Even though new knowledge on the animal responses to the environment continually arises, managing livestock to reduce the impact of climate remains a challenge. Considerable efforts are, therefore, needed from livestock researchers to counter the impact of environmental stresses on livestock production. Besides ensuring the livelihood security to our poor and marginal farmers, stress mitigation can also improve the economy of livestock industry. Hence, it is crucial to understand the impact of environmental stress on livestock production and reproduction. These efforts may help in identifying the appropriate targets for developing suitable mitigation strategies [1].

Thermal stress effects on livestock are of multifactorial nature. It directly alters and impairs the cellular functions in various tissues of the body and the redistribution of blood flow, as well as the reduction in food intake, which ultimately results in reduced production performance. Reproductive functions of livestock are particularly vulnerable to climate change; it has been established that large ruminants are more prone to heat stress compared with small ruminants. Heat stress is the major cause for infertility and reproductive inefficiency in livestock, resulting in profound economic losses. Heat stress reduces the libido, fertility, and embryonic survival in livestock and favours the occurrence of diseases in neonates with reduced immunity. Heat stress affects the fertility and reproductive performance of livestock species through compromising the functions of the reproductive tract, disrupting the hormonal balance, decreasing the oocyte quality, and thereby decreasing embryo development and survival [2]. The threshold level of temperature humidity index (THI) for the high performance in terms of milk yield and reproduction is around THI 72 in tropical and subtropical climates. However, recent studies on THI in temperate climate emphasized that the THI lower than 68 is suitable for cattle performance and welfare [3].

Effects of heat stress on animals

High environmental temperatures impair the female reproductive process at various stages of pubertal development, conception and embryonic mortality. Stress inhibits the reproductive performance of livestock species by activating the hypothalamic-pituitary-adrenal (HPA) axis, which subsequently excites the pituitary gland to release adrenocorticotropic hormone (ATCH). The ACTH stimulates the release of glucocorticoids and catecholamines, which act extensively to alleviate the effect of stress. However, ACTH-stimulated glucocorticoid release is responsible for an inhibitory effect on the reproductive axis. Heat stress reduces the length and intensity of estrus, alters follicular development and increases the rate of apoptosis in the antral and pre-antral follicles. Extreme environmental temperatures delay the onset of puberty in male and female animals. Furthermore, heat stress during follicular recruitment suppresses the subsequent growth and development to ovulation [4]. Changes in the follicular growth disturb further progress and function of the oocytes. The chronic release of ACTH, such as the associated with heat stress, inhibits the ovulation and follicular development by altering the efficiency of follicular selection and dominance and glucocorticoids are critical to mediating this inhibitory effect on reproduction [5]. Further, high level of glucocorticoids during heat stress directly inhibits the meiotic maturation of oocytes, and, in addition, corticotrophin releasing hormone (CRH) inhibits the ovarian steroid genesis, derived of the decrease in the secretion of luteinizing hormone (LH). The consequent decrease in oestradiol results in reduced length and intensity of estrus expression [6].

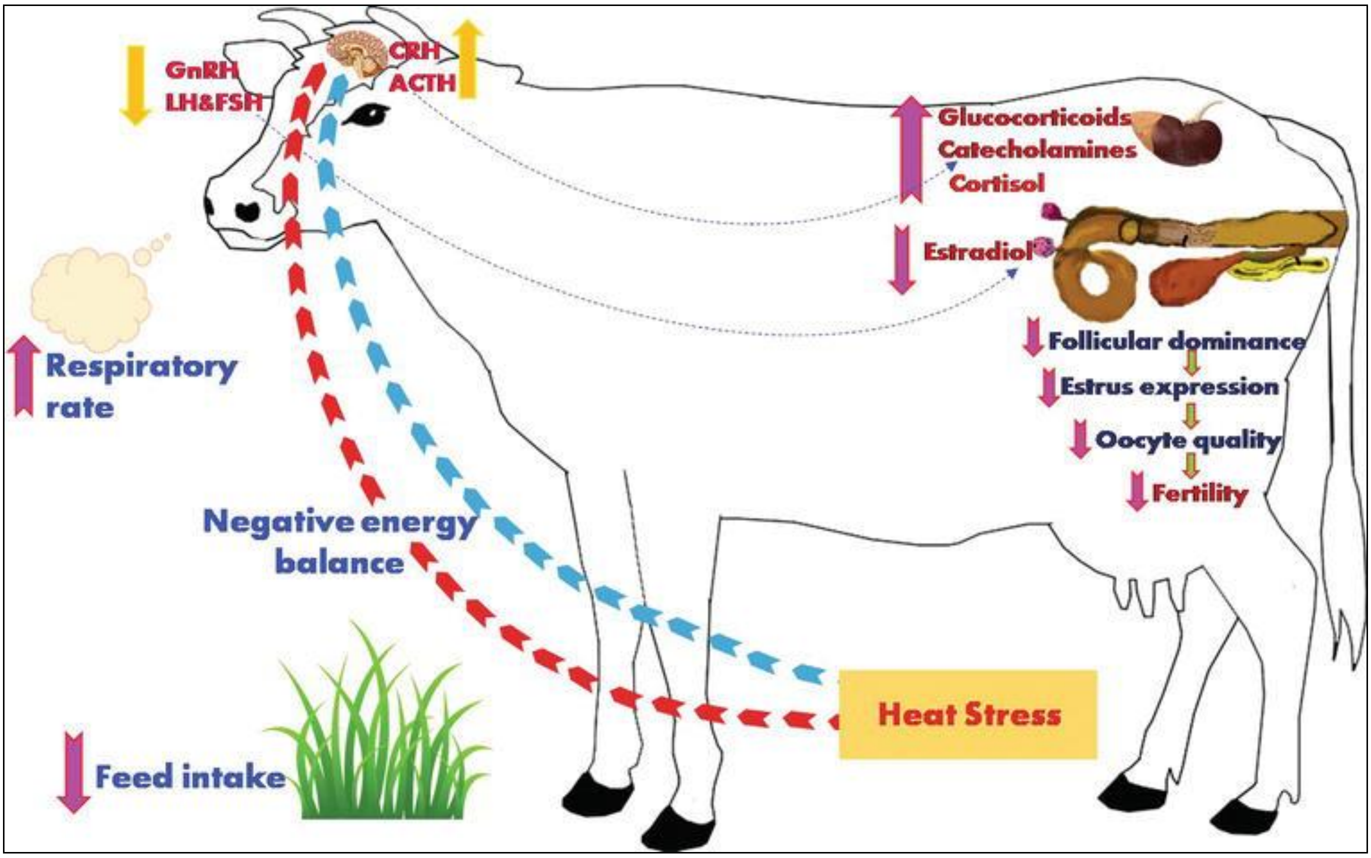

Fig 1: Effects of heat stress on animal (Adopted from [1])

Impact of heat stress on pregnancy

Heat stress negatively affects the ability of an animal to become pregnant through many mechanisms affecting fertilization, follicular development, and early embryonic development. When the rectal temperature of the animals increased from 38.5 to 40°C at 72 h after insemination, pregnancy rate decreased up to 50% [7]. A significant reduction in the pregnancy rate in beef cattle during summer (62%) when the THI was equal to or above 72.9 [8]. There is 3.2% decrease in pregnancy rates in *Bos Taurus* cattle for each unit increase in THI above 70, and a decrease of 3.5% for each degree increase in ambient temperature above 23.4°C. Further, heat stress during pregnancy slows down the growth of the foetus, which was attributed to the decreased uterine blood supply [8]. Each additional raise of 1.05 unit in the THI over 72, during the peri–implantation period, during 21–30 days and up to 90 days of gestation, increases the chance of pregnancy losses [9].

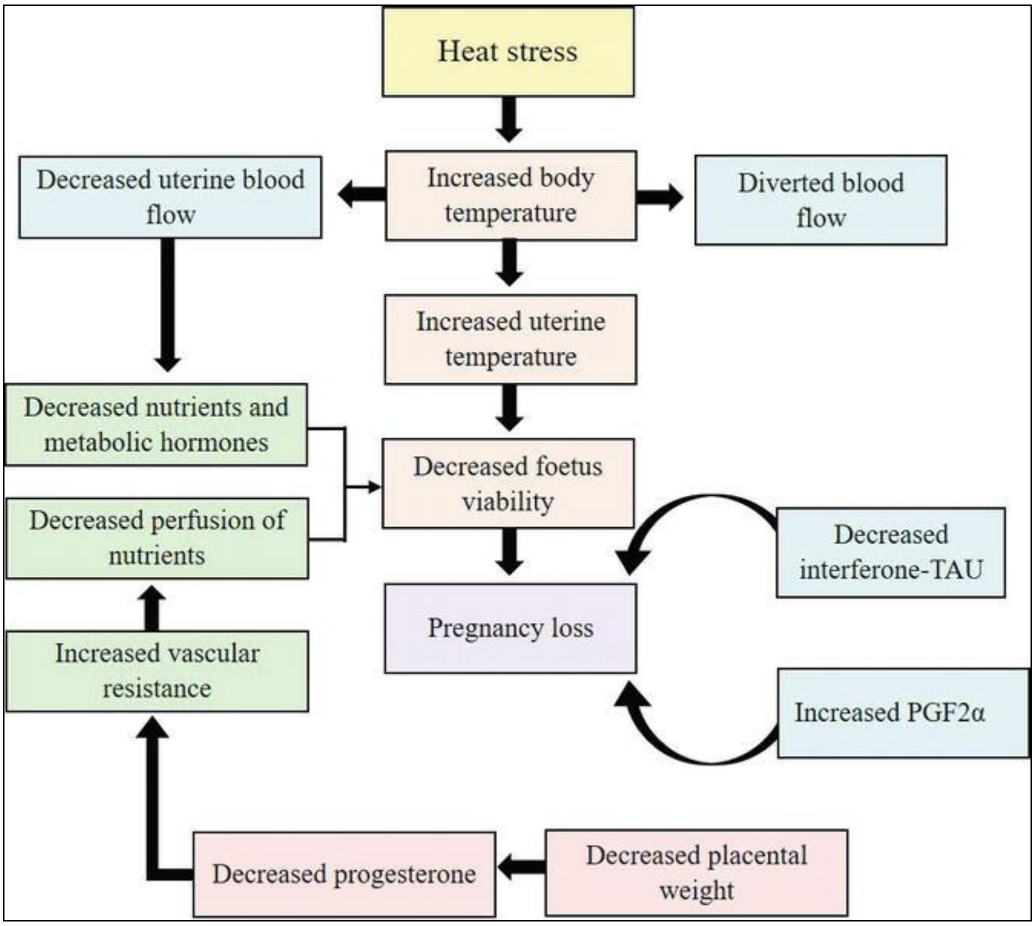

Fig 2: Impact of heat stress on pregnancy in livestock [1].

Impact on maternal recognition of pregnancy

The maximum pregnancy losses due to heat stress occur during the early embryonic period of 8–17 days of pregnancy [10]. In addition, heat stress compromises the embryonic growth up to day 17, which was considered a critical period for production of interferon-tau by the embryo. The quantity of interferon-tau is crucial to reduce the pulsatile secretion of PGF2α thus facilitating the persistence of the corpus luteum for the maintenance of pregnancy. Hence, low-quality embryo and poor-quality CL are important causes of early embryonic death during heat stress. The heat stress during late gestation period in dairy cows resulted in lower birth weight calves with reduced milk yield, which is associated with a reduced thyroxine, prolactin and growth hormone [11].

Impact on male reproduction

Bulls are generally considered to be half of the herd and its fertility is directly associated with the fertilization of oocyte to produce a good, viable and genetically potential concepts. In mammalian species, the males have a unique physiological mechanism of testicular thermoregulation to maintain its reproductive activity in adverse environmental conditions. The increased density of sweat glands in the scrotum of ruminants is crucial to the efficiency of local thermoregulation. The testicular temperature in bulls must be 4–5°C below the rectal temperature, and this difference in temperature is essential for an efficient sperm production [12]. Also, high temperatures interfere with the oxidative metabolism of glucose in spermatic cells as a result of mitochondrial dysfunctions and the accumulation of reactive oxygen species and increase lipid peroxidation which is reflected in an increase of sperm primary defects [13].

Because of heat stress in males, the biological phenomena such as sexual activity, endocrine secretions and testicular function, spermatogenesis and physical and chemical characteristics of semen are affected. Extremes of environmental temperature may cause low sperm quality, which is closely related to female low fertility, as a result of low fertilization rates and increased embryonic mortality. High temperature can also affect semen production and quality during epididymal maturation or spermatogenesis, not only at the moment of semen collection but up to 70 days before collection [1].

Mitigation strategy to minimize impacts of heat stress

The effects of heat stress on livestock cause huge economic losses to the farmers, but there are few opportunities to recover some of the losses by adapting suitable strategies to mitigate heat stress. There are three major key components to sustain the productivity of animals in hot environment: through physical modifications of environment, nutritional management and genetic development of breeds that are less sensitive to heat stress. These strategies may either be used individually or in combination to obtain better results by providing optimum productive environment for farm animals. In addition, summer infertility may also be treated with advanced reproductive technologies comprising gonadotropins, timed artificial insemination and embryo transfer. Strategies that are cost effective and involve indigenous knowledge have the better success rate in adopting those strategies by the farmers.

Physical modification of environment

In general, livestock environmental management is an emerging area in animal science, which is getting more attention in the era of climatic change, attempting to provide a suitable microclimate to ensure optimum production by preventing the adverse environmental impacts on animal production systems. Primary means of altering the environment may be broadly divided into two categories comprising…

1. Provision of shade
2. Evaporative cooling techniques [14]. Fogging and misting systems use fine droplets of water, which are immediately dispersed into the air stream by quick evaporation and cool the surrounding environment.

Nutritional management of heat stress

Ensuring appropriate nutritional level to the livestock is crucial to optimize livestock production in the changing climatic condition. Importance should be given for providing balanced nutrition to ensure optimum reproduction in animals as the energy balance are closely associated with their fertility [15]. The environmental temperatures are highest in arid and semi-arid regions where the available feed resources are both of low quality and quantity which directly affect the reproductive performance of the livestock species. Combating the heat stress effects on the metabolism is therefore very essential, as animals subjected to mild to severe heat stress needs to be supplemented 7–25% extra maintenance requirements [16]. Feeding of betaine, a trimethyl form of glycine, ameliorate heat stress in sheep. Feeding buffers during heat stress is highly beneficial to animals, since buffers assist in the prevention of low rumen pH and rumen acidosis [17]. Inclusion of ascorbic acid in the feed ameliorates, heat stress induced problems like poor immunity, feed intake, weight gain, oxidative stress, body temperature, fertility and semen quality [18].

Genetic selection of heat-tolerant breeds

Scientific advances allow improving the environmental modifications and nutritional management in the view of alleviating the impacts of thermal stress on animal performance. However, long-term strategies are foreseen for adaptation to climate change, namely regarding the differences in thermal tolerance existing between livestock breeds, endowed with tools to select thermo-tolerant animals. However, the selective breeding of dairy cows for higher milk production has increased the susceptibility of cows to heat stress by compromising the summer production and reproduction. Furthermore, selection for high milk yield reduced the thermoregulatory range of the dairy cow and resulted in heat stress which has magnified the seasonal depression in fertility [15]. Identification of heat-tolerant animals within high-producing breeds will be useful only if these animals are able to maintain high productivity and survivability when exposed to heat stress conditions. Cattle with shorter hair, hair of greater diameter and lighter coat colour are more adapted to hot environments than those with longer hair coats and darker colours [19].

Hormonal treatment and assisted reproductive technologies (ART)

Hormonal treatments have the potential to minimize the heat stress effects in animals. The administration of GnRH in the early stages of estrus coincides with the endogenous LH surge and improves the conception rate successfully. GnRH agonist or hCG injected on day 5 of the estrous cycle results in ovulation or luteinisation of the first wave dominant follicle and forms an accessory corpus luteum (CL) that enhances the plasma progesterone levels to compensate its decrease in chronic heat stress [2]. The timed artificial insemination (AI) program also improves summer fertility when associated with an injection of GnRH to induce a programmed recruitment of the ovulatory follicle. This protocol should be followed by PGF2α injection 7days later to regress the CL which permits the final maturation of ovulatory follicles. Further, a second dose of GnRH 48 h after PGF2α may induce ovulation and the insemination of cows at 16 h to ensure successful conception [20].

Conclusion

Heat stress is the major challenge in the optimal reproductive performances in the animals, especially in the tropical countries. Heat stress causes physiological and hormonal imbalances and compromise male and female fertility in the farm. Various manage mental practices and dietary interventions and supplementations helps in minimizing the heat stress. Genetic parameters and use of the ART will help to improve the scenario.

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