Strategies to Improve Livestock Reproduction Under the Changing Climate Scenario

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Abstract

A hot environment impairs production (growth, meat and milk yield and quality, egg yield, weight, and quality) as well as reproductive performance, metabolic and health status, and immune response. Reproductive inefficiency incurred due to heat stress involves changes in ovarian function and embryonic development by reducing the competence of oocyte to be fertilized and the resulting embryo. The ability of an animal to cope up with environmental stress could be improved through strategic management of reproduction by manipulation of folliculogenesis, hormonal alterations, selective breeding, and application of embryo transfer techniques. Intervention of follicular dynamics with a combination of hormones like FSH, GnRH, and progesterone and ovum pick up (OPU) may result in recovery of competent oocytes. Embryo transfer may facilitate extra advantage of *bypassing* the thermosensitive window of oocyte development (maturation) and early embryonic development stages. Selecting thermotolerant breeds of livestock species and their selective breeding may be good strategy for combating heat stress. However, a combination of heat stress ameliorative measures including nutritional management, shelter management, and reproductive strategies is required for getting maximum benefits.

Keywords

BCS • Climate change • Embryo transfer • Follicular dynamics • Livestock • Nutrition • Reproduction • Shelter

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24.1 Introduction

Climate change models predict an increase in the number of extreme weather events, including an increase in the severity and duration of heat waves. Effects of global warming may not be adverse everywhere as areas experiencing severe cold may get beneficial effects in terms of production and reproduction, while a relevant increase of drought is expected across the world affecting forage and crop production, thus adversely affecting production and reproduction. High environment temperatures may compromise reproductive efficiency of farm animals in both sexes and hence negatively affect milk, meat, and egg production and the results of animal selection. High-producing animals are more susceptible to heat stress due to their high metabolic heat production. About 50 % of the bovine population is located in the tropics, and it is estimated that heat stress may cause economic losses in about 60 % of the dairy farms (Wolfenson et al. 2000). Lowered summer fertility is multifactorial in nature due to the fact that various tissues are being affected and their function is disrupted under heat stress conditions. Heat stress compromises oocyte growth in cows by altering progesterone secretion, the secretion of luteinizing hormone and follicle-stimulating hormone, and ovarian dynamics during the estrus cycle (Ronchi et al. 2001). Heat stress has also been associated with impairment of embryo development and increased embryo mortality in cattle (Hansen 2007; Wolfenson et al. 2000). Moreover, heat stress may reduce the fertility of dairy cows in summer by poor expression of estrus due to reduced estradiol secretion from the dominant follicle developed in a low luteinizing hormone environment. Conception rates may drop about a 20–27 % in summer or decrease in 90-day nonreturn rate to the first service in lactating dairy cows. Heat stress during pregnancy slows down growth of the fetus and can increase fetal loss, although active mechanisms attenuate changes in fetal body temperature when mothers are thermally stressed. Roy and Prakash (2007) reported a lower plasma progesterone and higher prolactin concentration during estrus cycle in Murrah buffalo heifers, prolactin and progesterone profiles during the summer and winter months were found to be directly correlated with the reproductive performance of buffaloes, and that hyperprolactinemia may cause acyclicity/infertility in buffaloes during the summer months due to severe heat stress. Pigs are very sensitive to hot conditions while goats are least affected by heat stress. Heat stress impairs embryonic development and affects reproductive efficiency until 5–6 weeks after exposure to hot conditions. An advanced planning of production management systems is required, with an understanding of animal responses to thermal stress and ability to provide management options to prevent or mitigate adverse consequences (Nienaber and Hahn 2007). Various reproductive strategies have been suggested to overcome the adverse effects of heat stress in livestock species, and a combination of these reproductive techniques along with shelter and nutritional management may be more effective in nullifying the effects of heat stress.

24.2 Impact of Climate Change on Livestock Reproduction

Reproductive processes in the male and female animals are very sensitive to disruption by hyperthermia, with the most pronounced consequences being reduced quantity and quality of sperm production in males and decreased fertility in females. Under heat stress the physiological and cellular aspects of reproductive function are disrupted by either the increase in body temperature caused by heat stress or by the physiological adaptations engaged by the animal to reduce hyperthermia.

Heat stress adversely affects ovarian follicle development and compromises oocyte growth by altering progesterone, the secretion of luteinizing hormone (LH) and follicle-stimulating hormone (FSH), and dynamics during the estrus cycle. Heat stress has also been associated with impairment of embryo development and increased embryo mortality in cattle (Hansen 2007). Moreover, heat stress may reduce the fertility of dairy cows by poor expression of estrus due to reduced estradiol secretion from the dominant follicle developed in a low-LH environment. Heat stress can sometimes increase adrenocorticotropin secretion, which itself can block estradiol-induced estrus behavior. It is also likely that estrus expression is reduced by the physical lethargy experienced by heat-stressed animals. Heat stress during pregnancy slows down growth of the fetus and can increase fetal loss, although active mechanisms attenuate changes in fetal body temperature when mothers are thermally stressed.

The detrimental effects of high ambient temperature and relative humidity on reproductive performance are well known. The impact of temperature is direct as a result of increased body temperature or compensatory changes in blood flow. It may be indirect through the hypothalamus involving changes in appetite or feed intake and body metabolism. Figure 24.1 describes the impact of heat stress on goat reproductive processes. In females, heat stress during the first week of pregnancy results in higher embryo mortality and subsequent abortions. The impact of extreme climatic condition leads to most of the reproductive problems. Heat stress alters the normal follicular dynamics pattern. Follicular estradiol levels have shown to be decreased during heat stress, causing disruption of normal folliculogenesis of the first-wave dominant follicle, and the second-wave dominant follicle appears early but functions normally. Furthermore, heat stress alters steroid production and metabolism; in particular progesterone concentration is altered (Sejian et al. 2011). These imbalances affect estrus, embryo survival, and follicular development in the ovary. Conceptus weight is also affected during heat stress since feed intake is affected due to high temperature (Sejian et al. 2012). In males, heat stress impairs spermatogenesis by elimination of spermatogonial germ cells in the seminiferous tubules and degeneration of Sertoli and Leydig cells. The heat damage in the testes is thought to be due to hypoxia causing oxidative stress and consequently germ cell apoptosis and DNA strand breaks mainly in pachytene spermatocytes and round spermatids. Consequently,

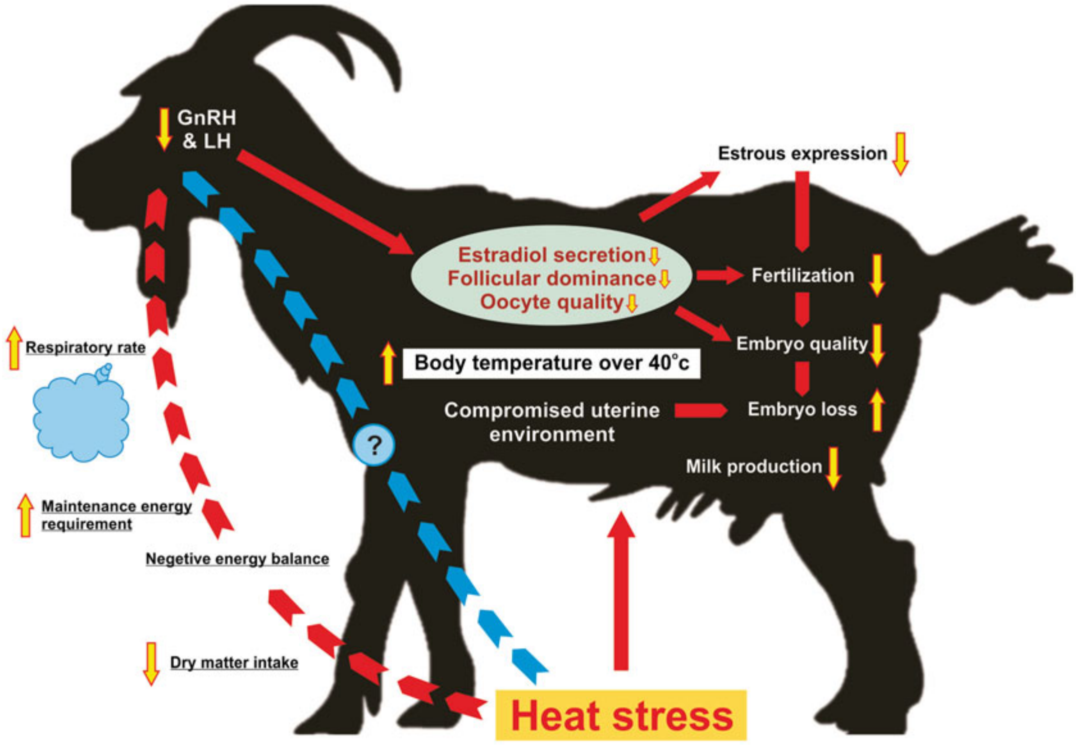

Fig. 24.1 Impact of heat stress on goat reproduction

heat stress has a negative effect on semen attributes. Further, heat stress significantly affects the sexual behavior, scrotal and testicular measurements, semen concentration, seminal volume, and mass activity of semen samples.

Heat stress causes increase in intracellular reactive oxygen species (ROS) and decrease in glutathione (GSH) level which is detrimental to embryo survivability. Oxidative stress due to reactive oxygen species (ROS) produced by cellular metabolism has regulation on various reproductive processes like cyclic endometrial and luteal changes, follicular development, ovulation, fertilization, embryogenesis, implantation, placental differentiation, and growth. Oxidative stress causes several pregnancy-related disorders such as preeclampsia, spontaneous abortion, intrauterine growth retardation leading to pregnancy loss, defective embryogenesis, and teratogenicity (Gupta et al. 2007).

24.3 Strategies to Reduce the Impact of Climate Stress to Improve Livestock Reproduction

There are different strategies available to counter the impact of climate change on livestock reproduction. These strategies can be broadly grouped under two categories: (1) management strategies and (2) advanced reproductive strategies. Figure 24.2 describes the various strategies to counter climate change impact on livestock reproduction.

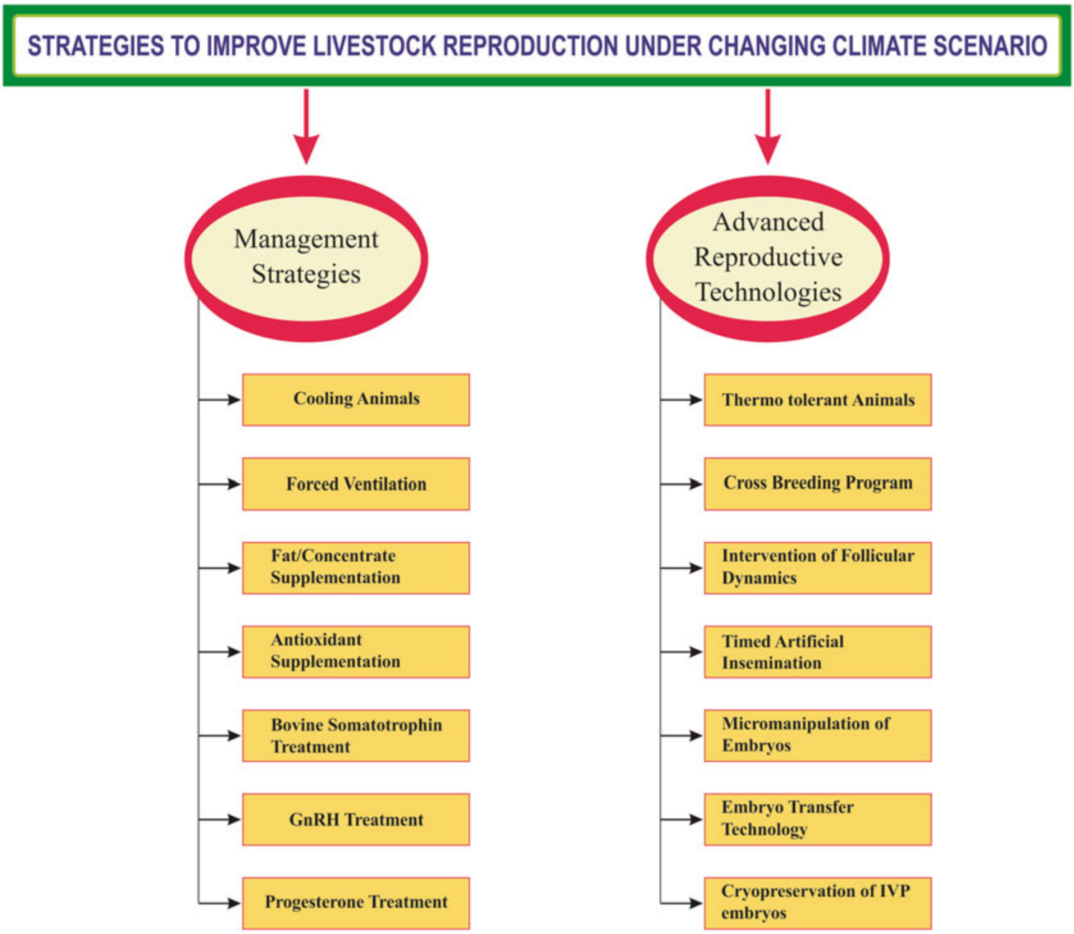

Fig. 24.2 Different strategies to improve livestock reproduction under the changing climate scenario

24.3.1 Management Strategies to Improve Livestock Reproduction

24.3.1.1 Shelter and Other Management Strategies

The time of greatest susceptibility for livestock reproduction is immediately after the onset of estrus and early postbreeding. Heat abatement is essential in the weeks preceding breeding, as well as the first week after breeding. One way to minimize effects of heat stress is to provide housing that alleviates heat stress. This can be expensive. The degree to which housing should be modified to reduce heat stress will depend upon geographical location and extent of heat stress. Providing adequate shade and water to cows on pasture can help keep them cool, resulting in increased embryo survival. The simplest structures for providing cooling are shade structures. These can be inexpensive structures based on the use of shade cloth or more permanent structures. A common and fairly effective system for cooling cows is free stall or loose housing with sprinklers and fans. Including foggers or misters can promote evaporative cooling as air moves through the barn. Flamenbaum and Galon (2010) identified the most appropriate cooling system commonly based on a combination of frequent direct watering of the cows, followed by forced ventilation air blowing onto the cows. A typical cycle is 5 min long and consists of 30 s of watering followed by 4.5 min of forced ventilation. This improved the conception rate in dairy cow. Heat-stressed cows willingly immerse themselves in water, so cooling ponds are sometimes used to allow cows to exhibit this behavior. Bellowing in ponds drop a cow's body temperature and can improve reproductive performance driving heat stress away. These artificially constructed ponds are often built with constant movement of freshwater into the pond.

In the barn and holding areas, the use of fans and sprinklers will help to cool the cow and the air around her. It should be ensured that the sprinklers are set to the appropriate time interval and that the droplet size is large enough to soak the cow to the skin – not a mist, which will sit on top of the hair and insulate the cow. Sprinklers should be running for between 1 and 3 min in every 10–15 min. It is critical that the sprinklers be turned off and fans are running for evaporation to occur, resulting in the cows feeling cooler because some of their body heat is used to evaporate the water. Avoid overcrowding pens and keep up on fly control to prevent bunching.

Another important factor in maintaining reproduction in the summer is nutrition. Research has demonstrated that negative energy balance is correlated with impaired reproductive performance. When cows reduce intake as a result of heat stress and fall into a negative energy balance situation, there are negative effects on plasma concentrations of insulin, insulin-like growth factor-1 (IGF-1), and glucose, which result in poor follicular development, poor quality of oocytes, and reduced expression of heat. Minimizing dry matter intake losses during heat stress is critical. Keeping cows cool will result in more frequent meals and reduce slug feeding. It is a good idea to feed fresh feed more often, place extra waterers in return alleys, and provide shade at the bunk area. Review your ration before the heat hits to make sure there is adequate fiber, potassium, sodium, and buffers if needed. Further, hormonal treatments using bovine somatotropin, GnRH treatment at time of insemination, and elevated progesterone injections post insemination significantly improved summer fertility.

24.3.1.2 Specific Nutritional Strategies to Improve Livestock Reproduction

Properly balanced rations provide adequate energy to reduce problems of herd health and reproduction associated with decreased dry matter intake (DMI) during heat stress. Requirements for specific nutrients appear to differ during thermal stress compared to thermoneutral conditions. Increasing ration energy density with additional grain or fat sources has been shown to be advantageous in improving reproductive efficiency during summer months. Preliminary research has shown fungal cultures can reduce body temperature and respiration rate and beta-carotene has been successful in increasing fertility and pregnancy rate in cows calving during the summer. There is need to establish prediction equations for requirements of all nutrients fed to livestock in different reproductive states at varying degrees of thermal stress. Other logical and relatively simple nutritional management strategies should be instituted on a broader basis. For example, increasing the number of feedings per day may entice animals to take more meals and keep feed fresher, thus increasing total daily consumption. Scheduling feeding strategically with, or right after, other routine events, such as milking, could result in increased daily consumption. As part of a shade management system, placement of feed and water so that they are always in the shade is paramount. Though untested, it is possible that provision of feed and water and perhaps artificial lighting on the dirt lot would result in increased consumption at night. Additionally, it would appear likely that total daily feed intake could be increased if nocturnal feedings were more frequent. This additional feed intake during extreme weather conditions will help the animal to cope up to adapting as well as to reproduce normally.

Dietary fats could favor reproductive processes through actions related to energy balance or through specific actions of individual fatty acids on tissue function. Fats are glyceride esters of fatty acids that can have a direct effect on the transcription of genes that encode proteins that are essential to reproductive events (Mattos et al. 2000). Dietary fats typically increase concentrations of circulating cholesterol, the precursor of progesterone to improve the reproductive efficiency. Fat supplementation has also been shown to stimulate programmed growth of a preovulatory follicle. Reactive oxygen species are a possible source of infertility because ovarian steroidogenic tissue, spermatozoa, and preimplantation embryos become compromised as a consequence of free radical damage. Nutritional tools, such as antioxidant feeding (vit. A, selenium, zinc, etc.) and ruminant-specific live yeast, can help. The use of antioxidants such as vit. E, vit. A, selenium, and selenium-enriched yeast helps in reducing the impact of heat stress on the oxidant balance, resulting in improved reproductive efficiency and animal health (Sejian et al. 2014).

Inclusion of specific nutraceuticals in the diet to improve reproductive function offers an exciting new dimension to dairy cattle management. Pre- and postpartum feedings of organic selenium yeast (0.33 mg/kg), during summer in the selenium-deficient area, improve the selenium status of lactating dairy cows, enhance neutrophil function (i.e., phagocytosis and oxidative burst) and humoral immune/antibody responses, reduce incidence of fever, and improve both uterine health and subsequent fertility to second service. Strategic supplementation of fatty acids accordingly to physiological stage can selectively benefit immune function, maximize production, and improve reproductive responses of lactating dairy cows. Following the transition period, feeding calcium salts of fish oil reduces pregnancy loss after the first service and increases pregnancy per insemination after the second service. This beneficial effect of feeding calcium salts of fish oil is augmented when calcium salts of safflower oil were fed previously in the transition period. Feeding fish oil in the breeding period following safflower oil in the transition period stimulates pregnancy per AI for the second service in the warm season, whereas feeding palm oil in the breeding period following safflower oil in the transition period has no beneficial effect on second service pregnancy per AI. Supplementary feeding of lupine grain for 14 days and the "ram effect" can be combined as a strategy for increasing ovulation rate in sheep. Net reproductive performance of both ewes and rams is improved due to lupine supplementation at mating (Nottle et al. 1997).

24.3.1.3 Body Condition Scoring as a Tool to Optimize Reproduction in Livestock

Body condition scoring (BCS) is a system of describing or classifying breeding animals by differences in relative body fatness. It is a subjective scoring system but provides a fairly reliable assessment of body composition. BCS is a simple but useful procedure, which can help producers in making management decisions regarding the quality and quantity of feed needed to optimize productive and reproductive performance. Under Indian farming condition, a 5-point body condition scoring system similar to the one followed in the United States is preferable. BCS provides a reasonable indicator of nutritional status of ewes at different production phases, which allows to assess ewe's nutrition level and to decide when and how to supplement the flocks. A series of studies conducted on the influence of BCS on sheep reproduction suggests that both ewes and rams belonging to BCS between 3.0 and 3.5 performed much better than lower and higher BCS for most reproductive parameters studied (Sejian et al. 2010; Maurya et al. 2010). This signifies the importance of optimum BCS of ewes for better reproductive performance. Further, the poor performance of 4.0 BCS sheep when compared to 3.0–3.5 BCS reflects the economic importance of the study in terms of wastage of supplementary feeding. This indicates that sheep under a hot semiarid tropical environment should be maintained at moderate (3.0–3.5) BCS both at mating and at lambing stage to ensure optimum return from these animals rather than supplementing to increase the body condition score to a higher level. Further, these studies indicate that active management of breeding sheep flock to achieve the optimum BCS of 3.0–3.5 will ensure optimal reproductive performance of these animals. This will ensure economically viable return from these flocks. Table 24.1 describes the recommended BCS for different reproductive stages in sheep under a hot semiarid tropical environment.

Table 24.1 Some recommended (optimal) condition score values for the various stages of the production cycle of sheep under hot semiarid condition

Class of sheep	Optimum condition score
Breeding	3.0
Mating	3.0–3.5
Early to mid-gestation	3.0
Late gestation	3.5
Lambing	3.5
Twining	3.5–4.0
Lactation	3.0
Rams at mating	3.5
Weaners	2.5 or more

24.3.2 Advanced Reproductive Strategies to Improve Livestock Reproduction

24.3.2.1 Intervention of Follicular Dynamics

The preovulatory follicle is a key component of the reproductive systems, and impairment of its function during thermal stress may affect other reproductive events, such as secretion of gonadotropins, progesterone, and estradiol and subsequently the development of the corpus luteum (CL) and embryo. Aberrant follicular development is observed in hot season. Reduction in plasma inhibin concentration was detected in heat-stressed lactating dairy cows (Wolfenson et al. 1995). The dominance of the large follicle is suppressed during heat stress, and the steroidogenic capacity of theca and granulosa cells is compromised. Reduction in follicular dominance during the period of heat stress is associated with a decrease in inhibin secretion by granulosa cells and subsequent alterations in FSH that leads to an increase in the development of large follicles (e.g., non-ovulatory follicles and cysts) in cattle (Wolfenson et al. 2000).This may happen due to attenuated follicle dominance, but due to elevated ambient temperature, early embryonic losses occur and pregnancy is not sustained. The pool of small antral follicles gets damaged during summer, and as long as these follicles are sustained in the ovaries, fertility will remain low (aftereffect of summer). Sensitivity of the early growing follicles to heat stress is a likely explanation for the fact that oocyte quality is only gradually restored in the autumn and that restoration of oocyte competence for cleavage in the autumn can be hastened by treatments that increase follicular turnover (Roth et al. 2002). It is speculated that fertility may not be restored until all the damaged follicles destined for ovulation have been removed from the ovary that may be the possible explanation of restoration of fertility in the autumn. Actually the follicle is a multi-compartmental structure in terms of biosynthesis of steroids and intrafollicular communication between the oocyte and follicular tissue. Seasonal variations in follicular steroidogenesis may be because of two reasons: first because of low substrate availability due to lowered feed intake which may be said as "indirect effect" and second by alteration in gonadotropin secretion which in turn may affect follicular function. Heat stress can reduce the magnitude of the preovulatory surge of LH and estradiol-17β. There are also direct effects of elevated temperature on nuclear maturation, spindle formation, cortical granule distribution, free radical formation, mitochondrial function, and apoptosis. Estradiol and androstenedione production by granulosa cells and theca cells is decreased due to heat stress, and the theca cells appeared more susceptible to heat stress. Progesterone plays an important role in follicular turnover (de Castro et al. 1999). Progesterone secretion by luteal cells is also lowered during summer. Low plasma progesterone affects steroidogenesis in the dominant follicle and CL and thereby alters reproductive function in the subsequent estrus cycle. Low progesterone may cause aberrant follicular development which may result in abnormal oocyte maturation in the ovulatory follicles.

Delayed effect of heat stress on follicle quality may be overcome by mechanical removal of follicles by OPU from ovaries or by stimulating follicle turnover. FSH treatment increases the number of medium-sized follicles in the follicular waves following heat stress and induced an earlier emergence of high-quality oocytes (Roth et al. 2002; Friedman et al. 2010). Stimulation of gonadal function by GnRH improves follicular function, as frequent follicular waves induced during fall increased follicular estradiol content in preovulatory follicles aspirated from previously heat-stressed cows (Roth et al. 2004). Synchronization with GnRH and PGF2α also improves fertility (Friedman et al. 2011).

The stage of the estrous cycle at the time of the OPU session influences the recovery rate, oocyte quality, and in vitro embryo production (IVP). Conflicting results have been reported regarding the ideal follicular phase to maximize performance of OPU. Greater recovery rates have been reported when the OPU was performed closer to the follicular wave emergence (Machatkova et al. 2004), while greater in vitro competence of oocytes was obtained during the early dominance phase (Hendriksen et al. 2004). Increased IVP was achieved when FSH was used in four equal doses twice daily beginning at the time of follicular wave emergence. In this case, OPU was performed 24 h after the last FSH treatment (Rodriguez et al. 2010).

24.3.2.2 Progesterone and Fertility

Following recruitment of healthy preovulatory follicles which results in a successful postovulatory fertilization are the processes associated with the development of a CL and maintenance of pregnancy. Early embryonic mortality (from fertilization to detection of pregnancy) is the major cause of low conception. The survival of early stage embryos is related to normal luteal progesterone production (Robinson et al. 2008). An association between normally high progesterone concentration and more advanced embryo development has been shown as early as day 5 of pregnancy (Green et al. 2005). Long-term chronic exposure to heat stress decreases plasma progesterone (Chandra et al. 2007), and this decreased progesterone production may be caused by impaired luteinization of CL exhibiting depressed progesterone concentration, depressed synthesis of progesterone from luteal cells, detrimental carry-over effect of heat stress on ovulatory follicle, and subsequent effect on formed CL secreting lower progesterone (Torres-Junior et al. 2008). Concentrations of progesterone before ovulation can affect subsequent fertility (Bisinotto et al. 2010; Denicol et al. 2012), possibly because of actions on oocyte function, and a reduction in circulating progesterone concentrations before ovulation caused by heat stress (Wolfenson et al. 2000) could conceivably compromise the oocyte. The level of endogenous progesterone is widely variable because of several variables: adrenal release of progesterone, metabolism in the liver, hemodilution, degree of thermal stress, age of cow, stage of lactation, and milk yield and type of feeding. Progesterone concentration is lowered mainly in chronic stress and not in acute and short-term stress. Most studies showed that acute exposure to high environment temperature in psychrometric chamber may elevate or does not affect progesterone concentration. This higher concentration of progesterone at acute stress may be attributed to the elevated adrenal secretion of progesterone or to the severity of the thermal stress (Bridges et al. 2005).

Progesterone supplementation during early pregnancy has proven beneficial in some studies. Supplementation of exogenous progesterone under conditions of summer heat stress has the potential to improve fertility, provided that (a) the endogenous level of progesterone secretion is compromised and (b) the thermal stress is at the level that permits embryo survival (mild thermal stress). Accessory CL may be useful in supporting the plasma progesterone which may be facilitated by the induction of ovulation from first-wave dominant follicle by treatment with GnRH agonist or hCG. In general, efficiency to increase progesterone concentration is greatest when accessory CL is induced by hCG. GnRH administration at insemination or 12 days later can improve fertility of lactating cows during heat stress (Lopez-Gatius et al. 2006). Another approach to increase progesterone concentration is by inserting intravaginal devices containing progesterone (CIDR) post AI. A study by Wolfenson et al. (2009) stated that CIDR treatment increased conception rate by 6 % but not significantly. However, the CIDR treatment increased conception rate by 22.5 % in cows with low body condition score at peak lactation, and cows that exhibited uterine disorder at partition had an increase in conception rate from 25.6 to 47.8 % with insertion of the CIDR device.

24.3.2.3 Strategies to Decrease Estradiol

Inskeep (2004) indicated that estrogen secretion from a large follicle from days 14 to 17 of pregnancy may negatively affect embryo survival. Binelli et al. (2001) suggested the attenuation of luteolytic stimuli as a strategy to decrease early embryonic mortality. Moreover, this hormone has a central role in PGF production and luteolysis. Thus, strategies resulting in the absence of dominant follicles, reduction of their steroidogenic capacity, or reduction of endometrial responsiveness to estradiol during the period of maternal recognition of pregnancy should increase the probability of conceptus survival and pregnancy rates. One simple way to reduce plasma concentrations of estradiol is to remove follicles by transvaginal ultrasound-guided aspiration of follicles. Aspiration of the first-wave dominant follicle on day 6 of the estrous cycle decreased PGF release (as measured by plasma concentrations of its metabolite, PGFM) in response to an estradiol injection given on day 17 in comparison with non-aspirated controls. Injection of GnRH on day 5 and hCG on day 13 of a synchronized estrous cycle induced ovulation of the first-wave dominant follicle and an accessory CL, and emergence of the second wave would be synchronous (Bergamaschi et al. 2006). GnRH-hCG approach takes advantage of both the progesterone supplementation and the estradiol reduction strategies to modify uterine function and has the potential to affect positively pregnancy rates in cattle.

24.3.2.4 Administration of Other Antiluteolytic Agents

Strategies like the use of anti-inflammatory drugs, fat feeding, and administration of bovine somatotropin (bST) target the uterus and the conceptus directly. Synthesis of PGF results from a coordinated cascade of intracellular events. A rate-limiting step in this cascade is the conversion of arachidonic acid to prostaglandin-H2 (PGH2) by the enzyme prostaglandin endoperoxidase synthase 2 (PTGS2 or COX-2). The PGH is subsequently converted to PGF. Strategies targeting the inhibition of PTGS2 activity, and consequently PGF synthesis, during maternal recognition of pregnancy should increase embryo survival and pregnancy rates. Treatment of Holstein heifers with flunixin meglumine, an inhibitor of PTGS2 activity, on days 15 and 16 after insemination increased pregnancy rates on days 29 (76.9 vs. 50 %, $P<0.04$) and 65 of gestation (69.2 vs. 46.2 %, $P<0.09$) (Guzeloglu et al. 2007), while administration of flunixin meglumine at 1.1 mg/kg of BW at 13 days after AI did not improve pregnancy establishment in beef cows and heifers (Geary et al. 2010). PTGS2 protein expression in conceptus tissues starts on day 18 of pregnancy. Therefore, inhibition of PTGS2 activity from that moment onwards may in fact be detrimental to conceptus development. Decreasing substrates for PGF synthesis should result in a uterine environment less conducive for luteolysis, which may result in greater embryonic survival. Feeding of long-chain fatty acids can modulate PGF production in the endometrium. Feeding the n-3 fatty acids attenuates PGF production (Mattos et al. 2004), whereas the opposite effect was observed when n-6 fatty acids were fed to cattle (Pettit and Twagiramungu 2004).

Secretion of interferon (IFN) is positively associated with conceptus size (Mann et al. 1999); therefore, larger conceptuses should be better able to block PGF synthesis and luteolysis. One possible way to stimulate conceptus growth is through the administration of bST. bST increases secretion of IGF-1, insulin, and growth hormone (Bilby et al. 2004), and the elevation in the IGF-1 would protect the oocyte and embryos from damage caused by heat stress. In vitro administration of recombinant bST increased fertilization rates, hastened embryo development, and increased embryo quality (Moreira et al. 2002; Santos et al. 2004; Ribeiro et al. 2014).

24.3.2.5 Timed Artificial Insemination

Timed artificial insemination (TAI) programs provide an organized approach to enhance the use of artificial insemination (AI) and the progress of genetic gain and to improve reproductive efficiency in dairy and beef herds. The final follicular growth and the diameter of the dominant follicle at TAI are key factors that may significantly affect the oocyte quality, ovulation, the uterine environment, and consequently pregnancy outcomes. The use of superovulation (SOV) followed by AI is a technique that generates greater numbers of embryos per donor. TAI associated with embryo transfer (ET) is a powerful tool to disseminate high-quality genetics and improve reproductive performance mainly in heat-stressed dairy cattle and repeat breeders (Hansen et al. 2001; Baruselli et al. 2011).

Controlling LH pulsatility and ovarian follicular development by progesterone can influence oocyte quality. During the SOV protocol, low circulating concentrations of progesterone may interfere with follicular growth and oocyte and embryo quality. Higher progesterone concentrations during the SOV protocol may be necessary to regulate LH pulsatility, which avoids the occurrence of premature nuclear maturation, and may be responsible for the improved oocyte/embryo quality following SOV protocols, especially in lactating Holstein cows (Baruselli et al. 2012).

24.3.2.6 Embryo Transfer: Bypassing Damage to Oocytes and Embryos

Major negative effects of heat stress on reproduction may be related to its deleterious effects on the oocyte quality, decreasing fertilization rates, and early embryonic losses. Oocytes are damaged by heat stress during follicular growth and oocyte maturation. Following fertilization, the embryo itself is susceptible to maternal hyperthermia. This way heat stress further enhances preimplantation embryonic mortality. Several attempts have been made to overcome these adverse effects of heat stress in large ruminants by the treatment of GnRH, but in spite of these attempts, pregnancy rate had been low. Thus, successful pregnancy during heat stress requires that anyhow the oocyte is prevented from damaging effects of heat stress to assure successful fertilization and formation of an embryo, and this way, the embryo should escape the stage of developmental block caused by heat stress. One feasible and efficient way to escape this developmental block may be the use of embryo transfer (ET) technology, as bovine embryo transfer has already been shown to be effective in increasing fertility during heat stress.

Minimizing adverse effects by ET is based on the idea that (1) most effects of heat stress on fertility involve actions during folliculogenesis or on cleavage-stage embryos and (2) by the time the embryo is transferred at the morula or blastocyst stage, it has already acquired resistance to elevated temperature. As the embryonic development advances, the embryo progressively acquires resistance to adverse effects of heat stress (Hansen 2007a).

Embryos are typically transferred into recipient females when they reach the morula or blastocyst stages of development, typically at day 7 post ovulation. Thus, transferring day 6–8 embryos may escape these most thermosensitive periods, and pregnancy rate may be improved in summer. The use of ET is considered a potential strategy for minimizing the negative effects of heat stress on bovine reproduction (Baruselli et al. 2011). Embryo transfer can improve pregnancy rate when embryos are produced by superovulation or in vitro fertilization. Embryos produced by superovulation are superior to the embryos produced by in vitro fertilization (Hansen and Block 2004). Pregnancy rates were lower by transferring cryopreserved embryos than by transferring fresh embryos (Stewart et al. 2010), though the embryo culture media used for embryo culture have a significant effect on the success rate of pregnancy. Insulin-like growth factor-1 (IGF-1) acts as a survival factor for preimplantation embryos exposed to heat stress (Hansen and Block 2004), and addition of IGF-1 in the culture media enhances bovine/bubaline preimplantation embryo development (Sirisathein et al. 2003; Chandra et al. 2012) as IGF-1 and IGF-2 receptors are present in all preimplantation stage embryos (Chandra et al. 2011). Treatment with IGF-1 can make embryos resistant to heat shock (Jousan and Hansen 2007), and there might be variation between embryos in the degree of thermotolerance at the blastocyst stage. However, when genetic consideration is secondary, embryos produced from oocytes collected from abattoir ovaries are most cost-effective.

24.3.2.7 Genetic Selection and Proliferation of Thermotolerant Animals

Sustainable livestock production in climate change scenario may be attained through producing heat-resistant strains of animals. It has been seen that certain breeds of beef and dairy cattle are better in regulating body temperature during heat stress than others. Thus, genetic improvement in resistance to heat stress may be achieved by applying genetic selection or crossbreeding. There are wide variations in genetics in resistance to heat stress among livestock species (Hayes et al. 2009). *Bos indicus* breeds have been found to be more heat tolerant than *Bos taurus*. Compared with *B. taurus* cattle, *B. indicus* cattle exhibit increased total numbers of oocytes, increased oocyte viability, increased blastocyst rate, and a reduced rate of nuclear fragmentation in in vitro produced blastocyst (Baruselli et al. 2012).

A beef cow of the Brahman or Nelore breed can maintain productivity in hot environments because it is genetically competent to regulate body temperature during heat stress. There are some genes in Northern European dairy cattle that confer animals with some resistance to heat stress. Genes exist not only for regulation of body temperature during heat stress but also for cellular response to elevated temperature. Identification of the genes controlling cellular thermotolerance or of genetic markers linked to those genes may enable the selection of cattle possessing embryos with increased resistance to disruption by elevated temperature. Basirico et al. (2011) studied the relationship between two single nucleotide polypeptides (SNPs) in the 5′ UTR of the heat shock protein 70 gene and resistance of peripheral blood mononuclear cells from lactating Holsteins to exposure to 43 °C for 1 h in vitro. Moreover, the allele that was associated with increased survival also resulted in increased expression of the heat shock protein 70.1 (HSP70.1) gene. It is worth noting that both of these SNPs were related to calving percentage in seasonal calving in Brahman cows.

“Slick” gene, first described in the Senepol breed of beef cattle that originated in the Virgin Islands, is a dominant gene that causes very short hair growth. Slick Holsteins are found better to regulate body temperature during heat stress than cows with normal hairs (Dikmen et al. 2008). In Venezuela, Olson et al. (2003) found that

Carora-Holstein crossbreds with the slick gene had lower rectal temperatures and higher milk yield than Carora-Holstein crossbreds with normal hair length.

The advantage of selection for thermotolerance is that the reduction in milk yield and fertility during the summer would be minimized. In contrast to these benefits, one must weigh two disadvantages. First, it is to be expected that cows that are more resistant to heat stress will also be less resistant to cold stress. The second possible disadvantage is selection for thermotolerance could accidentally lead to selection against milk yield. An increase in milk yield causes cows to produce more heat and that might make them less thermotolerant.

24.3.2.8 Reducing the Burden of Unproductive Livestock Production of Progenies of Desired Sex

In the coming years, the world will be facing problem of food security for humans as well as for animals due to shortening of available natural resources and cultivable lands. So, the need of the day is that the strategies should be focused upon controlling the population of livestock by increasing the productivity of animals and reducing the number of animals. Farmers should have animals of desired sex, viz., male animals for meat purpose and female animals for milk production. This can be done by using sexed semen or sexed embryos. This will result in excellent replacement for beef and dairy herds. Sexed sperm could be especially useful for superovulation; in that case, it is often desirable to obtain calves of one sex or another for a particular mating. One dose of sexed sperm can be used to produce many embryos. Flow cytometry-mediated sperm sorting is a very effective tool in separating X- and Y-sperm with more than 90 % accuracy.

Sexing of preimplantation embryos is commonly combined with the large-scale commercial embryo production and ET industry, whereas embryos of a predefined sex can definitely allow the application of certain management schemes for dairy or meat production industry (Herr and Reed 1991). Selective sex predetermination together with the multiple ovulation and embryo transfer (MOET) procedures can effectively aid in improvement of the genetic gain of the herd (Colleau 1991). Preimplantation embryo sexing can be achieved by cytogenetic, immunological, and metabolic methods or by using male-specific chromosomal DNA probes. However, the use of SRY gene-specific DNA probes, together with the use of the PCR embryo-derived biopsy samples, is superior in terms of efficiency and running speed (Herr and Reed 1991).

24.4 Conclusion

Although new knowledge about animal responses to the environment continues to be developed, managing livestock to reduce the impact of climate remains a challenge. Among the environmental variables affecting livestock, heat stress seems to be one of the more intriguing factors making difficult animal reproduction of many world areas. There are several strategies that are available to both prevent and counter the adverse impact of climate change on livestock reproduction. These include housing animals in facilities that minimize heat stress, use of timed AI protocols to overcome poor estrus detection, and implementation of embryo transfer programs to bypass damage to the oocyte and early embryo caused by heat stress. There are also several promising avenues of research that may yield new approaches for enhancing reproduction during heat stress. These include administration of antioxidants; intervention of follicular dynamics; hormonal interventions using bST, GnRH, and progesterone; and production of progenies of desired sex. Opportunities also exist for manipulating animal genetics to develop an animal that is more resistant to heat stress. Various reproductive strategies have been suggested in this chapter to overcome the adverse effects of heat stress in livestock species, and a combination of these reproductive techniques along with shelter and nutritional management may be more effective in nullifying the effects of heat stress.

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