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Research Article

Impact of Climate Change on Small Ruminants Production: A Review

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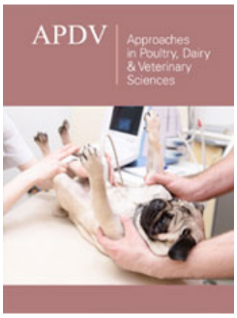

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Abstract

Sheep and goats, known as small ruminants, are an important component group of livestock, representing 58% of the global domestic ruminant population. Both sheep and goats are adapted well under varied climatic conditions including harsh climates. The large-scale presence of these animals in the arid regions indicates the adaptability of these animals to the hotter climatic conditions. the impact of climate change and consequential heat stress conditions, however, has been found to affect the growth and production, milk yield, feed intake, reproductive performance, and other biological functions of these animals. Through the present paper, an effort has been made to review the impact of the elevated environmental temperatures on the production performance of sheep and goats and provide certain alleviation strategies to overcome the climatic extremes.

Keywords: Climate change;Heat stress; Small ruminants;Sheep;Goat

Introduction

The adverse impact of climate change and consequential heat stress affecting the well-being of the livestock and further their production and reproduction efficiency is well known at present. As per the prediction of the intergovernmental panel on climate change, by the year 2100, the global surface temperature may be increased by 3.7-4.8 **°C** [1]. At a time when the emphasis is being laid on the increasing production and productivity of livestock to meet the increasing demand for animal protein at global levels, climate change has been posing a major threat to the sustainability of livestock production systems. It has been an established consensus that animal domestication began with goats and then sheep [2], which happened in the 'Fertile Crescent' of the Middle East about 10, 500 years ago before established worldwide [3]. Globally sheep and goats represent 58% of the domestic ruminant population, with 1209 million sheep and 1045 million goats [4].

Both sheep and goats are found to be well adapted under different environmental conditions including harsh climates showing better performance than other domesticated ruminants [5-7]. As per the available information, more than 1,000 sheep and 600 goat breeds are available worldwide [8] and these breeds possess the varied capacity to overcome extreme climatic conditions [9]. The adaptability of small ruminants to the hotter climatic condition can be recognized from their large-scale (over 50%) presence in the arid region, which further indicates the suitability of these animals to higher temperature regimes in the future too [10]. Further, it has been recognized that sheep is one of the most resistant species against any extreme climatic condition, particularly to high environmental temperatures [11]. Heat stress, however, is one of the complex factors which makes the task of sheep management and husbandry a challenging one in several geographical regions in the world [12,13].

Impact on Growth and Production

Sheep has been one of the most resistant species to climatic extremes, especially to elevated environmental temperatures [11]. However, the biological functions of the sheep were found to undergo several changes with higher ambient temperature, which include reduced feed intake and utilization, disturbances in the metabolism of protein, energy, and minerals, and secretion of hormones [14], which lead to reduced growth. Further, it is known that the growth of animals occurs due to cell multiplication, which is controlled by genetic and environmental factors. According to [12] exposure to higher temperatures (30-40 °C, 40% humidity) during the early embryonic life stage in sheep results in a significant reduction of total cell number and placentome size, and also a marginal decrease in cell size, compared to thermo-neutral temperatures (18-20 °C, 30% humidity). The heat exposure during placental growth further restricts early foetal development.

Exposed to heat stress, the animals, in general, reduce feed intake and increase water intake, and further increase their maintenance requirements, thereby leading to reduced growth performance [15]. The production potential and physiological functions of native sheep breeds were found to be less affected at higher environmental temperatures or solar radiation during hot summer months in the hot semi-arid areas compared to the non-adapted exotic and crossbred sheep [16,17]. Working with Bharat Merino sheep, [17] observed increased respiration rate and body temperature at higher ambient temperature. [18] also reported temperatures of over 31 °C lead to increases in rectal temperature and also heartbeat rate in Santa Ines sheep. Studies of three different Indian sheep breeds, viz., Chokla, Magra, and Marwari of the arid zone under heat stress conditions showed that the Magra breed had the highest adaptability followed by Marwari and Chokla, although they did not differ significantly [19].

High environmental temperature has been the major constraint for the productivity of sheep in tropical and sub-tropical areas. Higher temperature leads to a reduction in feed intake and an increase in energy demands due to activation of thermoregulation mechanisms, which negatively affect the development and productivity in sheep [20]. The high temperature together with high humidity found to aggravate the effect of heat stress [21,22]. The Temperature-Humidity Index (THI), therefore, is considered a major indicator of heat stress. Working on Mediterranean dairy sheep (Valle del Belice), [23] reported heat stress to result in decreased production, although the breed originated from the hot environment. In this case, the THI ≥23 was found to affect the production. A study on Comisana dairy sheep and Australian Merino sheep showed the effects of heat stress at THI of ≥27 and ≥32 respectively [24,25]. [26] reported a reduction in production performance in Sarda sheep by 20% with THI passing from 60-65 to 72-75. Working under a semi-arid tropical environment, [27,28] reported a more detrimental effect of combined stressors of heat and nutritional factors on growth and reproductive performance in Malpura ewes, compared to animals subjected to separate stressors.

The extent of the heat stress impact on the productivity in sheep largely depends on the adaption level of the breed to higher temperature regimes. Studies have shown that the tolerance level to heat stress, in general, are found to be more in hair breeds [29,30]. Similarly, [31,32] reported a higher level of heat tolerance in the hair sheep breeds in hot agro-ecological regions in Mexico and the authors did not find a substantial adverse effect on the growth and reproductive capacity in lambs. Adapted to hot climates, such breeds exhibit physiological and metabolic plasticity, which do not impact the productivity of these animals [33]. In the case of hair sheep, the phenotypic characteristics provide them the adaptability to heat stress [20]. The presence of hair is an advantage in terms of heat loss both by non-evaporative and evaporative means, compared to that of wool [29,33]. [34] reported a significant reduction in body weight and height in different sheep and goat breeds from north to south of the Mediterranean area connected to the period of dry months. Such an impact of high ambient temperature on size reduction is further expected to pose a huge risk on the reduction in average carcass weight in the ruminants in European, Asian, and African Mediterranean areas with global warming [35]. Further, the increased climatic variability and high ambient temperature are projected to exert a strong influence on pastoral systems, particularly in Africa, Australia, Central America, and Southern Asia. Further, the reduction of availability of biomass is expected to have a direct impact on the production system of the small ruminants.

Impact on Milk Production

There have been several studies demonstrating the adverse effect of heat stress on yield and quality of milk in ewes and goats, which include the decrease of milk yield, reduction in total protein, fat and casein contents, increase of saturated fatty acids and decrease of oleic, rumenic, vaccenic, linoleic and linolenic acids, and reduction of milk coagulating ability [24,36-43]. Studying the impact of heat stress on Mediterranean dairy sheep, [23] reported the milk production and fat-plus-protein yields were consistently negatively correlated with temperature and THI. Further, the extent of the decline in milk production was quite different among different sheep breeds.

The physiological and production performance of lactating sheep is found to be affected at temperatures higher than the upper critical point [11]. [24] recorded a reduction of milk yield in Comisana ewes exposed to temperatures over 35 °C, even for a short period. The sheep subjected to the heat-stressed condition found to have a significant reduction of fat and protein contents in milk, affecting the production of high-quality cheese which is the principal product [11]. Working with Sarda ewes, [26] recorded a 15% reduction in milk yield at maximum environmental temperatures of over 21-24 °C, and a reduction of 20% milk yield with an increase of minimum temperatures from 9-12 °C to 18-21 °C. [35] reported the reduction of milk yield and the content of milk components in goats at high air temperature. [42] reported a decrease of milk yield in dairy goats with an increase of THI index value, and with the increase of 1-unit t of THI, there was a decrease of 1% in milk yield. The lactating Saanen goats exposed to moderately hot (30±2 °C) and severe hot (35±2 °C) environments for 4 days at Relative Humidity of 70±5% reported the reduction of the milk yields by 3% and 13% respectively in moderate and severe heat exposure as against thermos-neutral (20±2 °C) environments [44]. Experimenting with Murciano-Granadina dairy goats in the late lactation stage, [45], however, did not observe any variation in the milk yield between the heat-stressed and a thermo-neutral group of animals. But the milk of the heat-stressed goats resulted in a reduction of protein and casein levels by 12.5% and 11.5% respectively than the thermo-neutral ones. Under heat stress conditions, a reduction of protein content and protein fractions in the milk of goat was reported by [45]. Further, dairy goats under heat stress conditions have been also observed to produce milk with less fat content [42]. Studying the effect of heat stress on dairy goats, [46] observed a modest effect on milk yield at THI 80-85, the severe effect at THI 85-90, and extreme with the threat of death at THI≥90. With the exposure of dairy goats to moderate heat stress conditions (34 **°C**, THI=79) for 5 weeks, [47] reported a reduction in milk yield, solids, fat, and N levels in Alpine goats compared to Nubian goats, indicating a response to the heat stress is breed-specific.

Impact on Reproduction

The heat stress was shown to affect both the male and female reproductive functions in livestock in several ways, viz., fertilization rate, estrous activity, embryonic survival, sperm motility, and abnormalities and mortality in spermatozoa [12,48,49]. According to [50], most of the reproductive processes are influenced by environmental stressors, either by directly affecting the functions of reproductive organs or blocking the cellular functions of the hypothalamic-pituitary-gonadal axis. Working with Australian merino ewe, [49], reported heat stress to result in a reduction in embryo production during artificial insemination or embryo transfer, which was attributed to the disruption of the physiological and cellular features of the reproductive function of the animals and early embryo development. The ewes exposed to a hot condition during the first 3 days after artificial insemination shown to affect the oocyte and/or embryo quality [51].

The susceptibility of pregnant and lactating ruminants to heat stress is found to be much higher than those of non-pregnant and non-lactating ones [52,48]. [53] reported heat stress affecting the reproductive performance in sheep through impaired reproduction. [54] observed thermal stress to harm the embryo quality during the pre-ovulatory period in Bharat Merino sheep. With the induction of heat stress to Malapura ewes in a climatic chamber at 40 **°C** and RH of 55% for 6h per day for two estrous cycles and restricted feeding, [28] observed reduced body weight, oestrus duration, birth weight of lambs and oestradiol 17-**β**, and increased oestrus cycle length and progesterone levels.

Exposure of Ossimi ram to severe heat stress during hot summer and at THI of over 84, reported increasing the rectal and scrotal skin temperature, abnormalities in sperm and semen, and further reduction of conception rate and lambing [55]. Studies with ewes of different breeds viz., Ossimi, Rahmani, and Ossimi x Suffolk have shown to have negative relationships between conception rate, and ambient temperature and daylight length [55-57]. Further, exposed to high ambient temperature, the reproductive functions of the females are found to be adversely affected, with a reduction in the length of the estrous cycle and effect on ovulation [14]. The authors further reported the production of dwarfed lambs and hairy appearance in ewes subjected to elevated ambient temperatures during early pregnancy, especially in the case of lambs of the wool breeds. [58] reported an increase in early embryonic mortality and a decrease in fecundity in ewes subjected to heat stress. Studying crossbred ewes of Targhee x Suffolk under heat stress conditions for a short and long duration of 25 days and 53 days respectively, [59] observed a smaller size of lambs at birth for both duration of treatments.

Meta-analyses carried out by [22] with 20, 626 ewes through 36 studies demonstrated that heat stress decreased the duration of estrus in cycling in ewes by 7.09h but increased the cycle length by 0.57 days. The study further showed that the heat-stressed cycling ewes resulted in higher embryo mortality and decreased impregnation. Such heat-stressed pregnant ewes also resulted in reduced placental and fetal weights. [60], however, reported decline of the susceptibility of embryos to maternal heat stress with the progress of the development.

Impact on Body Physiology

Several studies have been carried out to understand the impact of heat stress on changes in rectal temperatures, respiration rates, and other physiological functions in sheep [11,24,25,45,61-65]. Higher body temperature and increased respiration rate are the important indicators of heat stress in sheep and goats [66,67]. At higher ambient temperature, the physiological responses of sheep largely comprise increases in rectal temperature, respiration rate, and heart rate [11]. [12] reported the rectal temperatures of sheep to vary between 38.3 °C and 39.9 °C under thermo-neutral conditions. Owing to the presence of a wool coat that hinders sweating, the heat loss in sheep, is largely taken place through the increase in respiratory rate [12]. In the case of hair sheep, the phenotypic characteristics provide them the adaptability to heat stress [20]. The presence of hair is an advantage in terms of heat loss both by non-evaporative and evaporative means, compared to that of wool [29,33]. The ewes and goats subjected to heat-stress were found to decrease the feed intake in an attempt to create less metabolic heat [42,44,45,68,69]. According to [70], heat stress not only depresses the growth rate of sheep through the reduction of food intake but also by affecting digestion and metabolism.

Study to assess the effect of multiple stresses viz., thermal, nutritional, and walking stress on the adaptive capability of Malpura ewes showed these stresses to affect significantly on the body weight, respiration rate, pulse rate, rectal temperature, sweating rate and several other biochemical parameters [71]. Experimenting with a new heat stress model, i.e., subjecting the Malapura sheep to a different temperature ranging 38-44 **°C** at different hours of the day and thereby simulating the natural heat stress condition for the sheep reared under a hot semiarid environment, [72] found less severe physiological strain, which could be seen from lower variations in the heat stress markers such as respiration rate, rectal temperature, and plasma cortisol. The authors further suggested the present model for heat stress study to be more ethical than that of the constant heat stress model. [48] reported the heat stress is qualified as cytotoxic, as it alters biological molecules, disturbs cell functions, modulates metabolic reactions, induces oxidative cell damage and activates both apoptosis and necrosis pathways.

Alleviation Strategies for Heat Stress

Several methods are suggested for the small ruminant farmers to combat the negative effects of heat stress, which include the use of proper shades, selection of the appropriate site for animals' housing, use of fans and evaporative cooling, availability of adequate drinking water and adoption of appropriate feeding and grazing strategies. [73] suggested possibility reduction of the effect of thermal stress through three basic management schemes, viz., physical modification of the environment, improving thermos-tolerance by genetic modifications and improving nutritional regimes.

Provision of shade, especially during the summer months, is the simplest, effective and economical method to minimize the heat stress for the animals [9,74-76]. In extreme heat periods of the day, the animals were reported to decrease their grazing time and spend more time in the shade [7]. The trees and shrubs often serve as shelters for these animals in case of extensive grazing systems. It is well known that the sheep and goat flocks are rarely housed permanently, while most of them are housed only during the night hours [69]. Simple shelter with straw or hay or aluminum sheets as the rooftop can be very effective for even semi-intensive rearing practices. Provision of shade to the sheep and goats was found to improve body weight gain, milk production, and reproductive performance [77]. Installation of fans or other cooling systems in the sheds can minimize heat stress [77]. Because the water requirements of sheep and goats increase under heat stress conditions, access to adequate cool freshwater, therefore, is one of the best practices to reduce heat stress [74,77]. Experimenting with German Fawn × Hair crossbred dairy goat genotypes, [78] reported consumption of 18% more feed, 7% more water intake and 21% more milk yield in experimental group which was sprayed and ventilated for 1 h a day to reduce the heat stress over the control group.

Ration modifications, including changes in feeding schedules and feed composition, also reported helping in reducing the adverse impact of heat stress. [79] reported that increased feeding frequency helps to minimize the diurnal fluctuation in ruminal metabolites and increase feed utilization efficiency in the rumen of the animals. While appropriate management measures including that of nutritional strategies can be important remedial measures to overcome heat stress conditions, it would be appropriate to give increase emphasis on the development of more heat-resistant varieties through the approach of genetic selection for wider adaptability in the scenario of climatic change.

Conclusion

The ever-increasing demand for meat, in particular, necessitates the increased emphasis on sheep and goat farming in the coming years. In this context, the understanding of the negative impact of heat stress on the productivity and well-being of sheep and goats is of paramount importance today to take up appropriate alleviation strategies. It is, therefore, necessary that the livestock keepers are given adequate exposure for improved understanding of the impact of such elevated ambient temperature which is likely to be intensified further in the coming years with the increasing impact of climate change. In this endeavor, there is a need to intensify the linkage between the associated researchers, extension workers, and the livestock keepers to improve the knowledge and skills of the later for ensuring all necessary measures of good management practices, and for taking appropriate strategic and operational management decisions to improve production systems in such heat stress condition. It would be also necessary to continue the research efforts on the subject to improve our understanding of such climate extreme situations for providing necessary guidance to the stakeholders associated with the farming of these small ruminants for harnessing maximum production and ensuring the wellbeing of the animals.

References

1. IPCC 2014 (2014) Intergovernmental panel on climate change. Summary for policymakers. In: Climate Change 2014: Mitigation of climate change. Contribution of working group III to the fifth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 30.
2. Zeder MA (2018) Domestication and early agriculture in the Mediterranean basin: Origins, diffusion, and impact. PNAS 105(33): 11597-11604.
3. Alberto FJ, Boyer F, Terwengel PO, Streeter I, Servin B, et al. (2018) Convergent genomic signatures of domestication in sheep and goats. Nature Commun 9: 813.
4. FAOSTAT (2020) Food and agriculture organizations of the United Nations.
5. Haidary AAA, Aljumaah RS, Alshaikh MA, Abdoun KA, Samara EM, et al. (2012) Thermoregulatory and physiological responses of Najdi sheep exposed to environmental heat load prevailing in Saudi Arabia. Pak Vet J 32(4): 515-519.
6. Banerjee D, Upadhyay RC, Chaudhary UB, Kumar R, Singh S, et al. (2014) Seasonal variation in expression pattern of genes under HSP70 family in heat and cold-adapted goats (*Capra hircus*). Cell Stress Chap 19(3): 401-408.
7. Sarangi S (2018) Adaptability of goats to heat stress: A review. Pharma Innovation J 7(4): 1114-1126.
8. Dwyer CM (2009) The behavior of sheep and goats. In: Jensen P (Ed.), The ethology of domestic animals: An introductory text, CABI, Wallingford, UK, (2nd edn), pp. 161-174.
9. Dawood AA (2017) Towards heat stress management in small ruminants- A review. Ann Anim Sci 17(1): 59-88.
10. Gowane GR, Gadekar YP, Prakash V, Kadam V, Chopra A, et al. (2017) Climate change impact on sheep production: Growth, milk, wool, and meat. In: Sejian V (Ed.), Sheep production adapting to climate change, pp. 31-69.
11. Sevi A, Caroprese M (2012) Impact of heat stress on milk production, immunity and udder health in sheep: A critical review. Small Ruminant Res 107(1): 1-7.

12. Marai IFM, Darawany AAE, Fadiel A, Abdel Hafez MAM (2007) Physiological traits as affected by heat stress in sheep- A review. Small Ruminant Res 71(1-3): 1-12.
13. Sawyer G, Narayan EJ (2019) A review on the influence of climate change on sheep reproduction. In: Narayan EJ (Ed.), Comparative Endocrinology of Animals, England, UK, pp. 1-21.
14. Marai IFM, Darawany AAE, Fadiel A, Abdel Hafez MAM (2008) Reproductive performance traits as affected by heat stress and its alleviation in sheep. Tropical and Subtropical Agroecosystems 8(3): 209-234.
15. Gaughan JB, Cawsell Smith AJ (2015) Impact of climate change on livestock production and reproduction. In: Sejian V (Ed.), Climate change impact on livestock: Adaptation and Mitigation, Verlag GMbH Publisher, India, pp. 51-60.
16. Naqvi SMK, Hooda OK (1991) Influence of thermal, nutritional and exercise stress on some blood parameters of native and crossbred sheep. Indian J Anim Sci 61: 660-662.
17. Naqvi S, Maurya V, Gulyani R, Joshi A, Mittal J (2004) The effect of thermal stress on superovulatory response and embryo production in Bharat merino ewes. Small Ruminant Res 55(1-3): 57-63.
18. Cezar MF, Souza BB, Souza WH (2004) Evaluation of physiological parameters of sheep from Dorper, Santa Inês and their crosses in climatic conditions of northeast semi-arid. Ciência e Agrotecnologia 28: 614-620.
19. Singh KM, Singh S, Ganguly I, Ganguly A, Nachiappan RK, et al. (2016) Evaluation of Indian sheep breeds of arid zone under heat stress condition. Small Ruminant Res 141: 113-117.
20. Pérez RV, Cruz UM, Reyes LA, Calderón AC, Baca MAL, et al. (2020) Heat stress impacts in hair sheep production- Review. Rev Mex Cienc Pecu 11(1): 205-222.
21. Marai IFM, Bahgat LB, Shalaby TH, Abdel Hafez MA (2000) Fattening performance, some behavioural traits and physiological reactions of male lambs fed concentrates mixture alone with or without natural clay, under hot summer of Egypt. Ann Arid Zone 39(4): 449-460.
22. Barron CBR, Daniel Diaz, Loera JJP, Rubio JAR, Trejo FJ, et al. (2019) Impact of heat stress on the reproductive performance and physiology of ewes: A systematic review and meta-analyses. Int J Biometeorol 63: 949-962.
23. Finocchiaro R, Van Kaam JBCHM, Portolano B, Misztal I (2005) Effect of heat stress on production of Mediterranean dairy sheep. J Dairy Sci 88(5): 1855-1864.
24. Sevi A, Annicchiarico G, Albenzio M, Taibi L, Muscio A, et al. (2001) Effects of solar radiation and feeding time on behavior, immune response and production of lactating ewes under high ambient temperature. J Dairy Sci 84: 629-640.
25. Srikandakumar A, Johnson EH, Mahgoub O (2003) Effect of heat stress on respiratory rate, rectal temperature, and blood chemistry in Omani and Australian Merino sheep. Small Ruminant Res 49(2): 193-198.
26. Peana I, Fois G, Cannas A (2007) Effects of heat stress and diet on milk production and feed and energy intake of Sarda ewes. Ital J Anim Sci 6: 577-579.
27. Sejian V, Maurya VP, Naqvi SMK (2010) Adaptability and growth of Malpura ewes subjected to thermal and nutritional stress. Tropical Animal Health and Production 42: 1763-1770.
28. Sejian V, Maurya VP, Naqvi SM (2011) Effect of thermal stress, restricted feeding and combined stresses (thermal stress and restricted feeding) on growth and plasma reproductive hormone levels of Malpura ewes under semi-arid tropical environment. J Anim Physiol Anim Nutr 95(2): 252-258.
29. Correa MPC, Dallago BSL, Paiva SR, Canozzi ME, Louvandini H, et al. (2013) Multivariate analysis of heat tolerance characteristics in Santa Inês and crossbred lambs in the Federal District of Brazil. Trop Anim Health Pro 45(6): 1407-1414.
30. McManus C, Louvandini H, Gugel R, Sasaki LC, Bianchini E, et al. (2011) Skin and coat traits in sheep in Brazil and their relation with heat tolerance. Trop Anim Health Prod 43(1): 121-126.
31. Cruz UM, Estrada TJS, Delgado MÁG, Reyes LA, Calderón AC, et al. (2015) Seasonal reproductive activity of Pelibuey ewes under arid conditions of México. Arch Med Vet 47(3): 381-386.
32. Cruz UM, Gastélum MA, Álvarez FD, Correa A, Díaz R, et al. (2016) Effects of summer heat stress on physiological variables, ovulation and progesterone secretion in Pelibuey ewes under natural outdoor conditions in an arid region. Anim Sci J 87(3): 354-360.
33. Cruz UM, Baca MAL, Vicente R, Mejia A, Álvarez FD, et al. (2016) Effects of seasonal ambient heat stress (spring vs. summer) on physiological and metabolic variables in hair sheep located in an arid region. Int J Biometeorol 60(8): 1279-1286.
34. Nardone A (2000) Weather conditions and genetics of breeding systems in the Mediterranean area. In: Enne G (Eds.), Proc of the XXXX International Symposium of Società Italiana per il Progresso della Zootecnia, Italy, pp. 67-92.
35. Nardone A, Ronchi B, Lacetera N, Ranieri MS, Bernabucci U (2010) Effects of climate changes on animal production and sustainability of livestock systems. Livestock Sci 130(1-3): 57-69.
36. Sevi A, Albenzio M, Annicchiarico G, Caroprese M, Marino R, et al. (2002) Effects of ventilation regimen on the welfare and performance of lactating ewes in summer. J Anim Sci 80(9): 2349-2361.
37. Sevi A, Rotunno T, Caterina RD, Muscio A (2002) Fatty acid composition of ewe milk as affected by solar radiation and high ambient temperature. J Dairy Res 69(2): 181-194.
38. Sevi A, Taibi L, Albenzio M, Annicchiarico G, Marino R, et al. (2003) Influence of ventilation regimen on micro-environment and on ewe welfare and milk yield in summer. Ital J Anim Sci 2(3): 197-212.
39. Albenzio M, Santillo A, Caroprese M, Marino R, Centoducati P, et al. (2005) Effect of different ventilation regimes on ewe milk and Canestrato Pugliese cheese quality in summer. J Dairy Res 72(4): 447-455.
40. Nudda A, McGuire MA, Battacone G, Pulina G (2005) Seasonal variation in conjugated linoleic acid and vaccenic acid in milk fat of sheep and its transfer to cheese and ricotta. J Dairy Sci 88(4): 1311-1319.
41. Caroprese M, Albenzio M, Bruno A, Fedele V, Santillo A, et al. (2011) Effect of solar radiation and flaxseed supplementation on milk production and fatty acid profile of lactating ewes under high ambient temperature. J Dairy Sci 94(8): 3856-3867.
42. Salama AAK, Caja G, Hamzaoui S, Badaoui B, Costa AC, et al. (2014) Different levels of response to heat stress in dairy goats. Small Rum Res 121(1): 73-79.
43. Todaro M, Bonanno A, Scatassa ML (2014) The quality of Valle del Belice sheep's milk and cheese produced in the hot summer season in Sicily. Dairy Sci Technol 94: 225-239.
44. Sano H, Ambo K, Tsuda T (1985) Blood glucose kinetics in whole body and mammary gland of lactating goats exposed to heat. J Dairy Sci 68(10): 2557-2564.
45. Hamzaoui S, Salama AAK, Albane IIE, Such X, Caja G (2013) Physiological responses and lactational performances of late-lactation dairy goats under heat stress conditions. J Dairy Sci 96(10): 6355-6365.
46. Silanikove N, Koluman N (2015) Impact of climate change on the dairy industry in temperate zones: Predications on the overall negative impact

and on the positive role of dairy goats in adaptation to earth warming. Small Rumin Res 123(1): 27-34.

47. Brown DL, Morrison SR, Bradford GE (1988) Effects of ambient temperature on milk production of Nubian and Alpine goats. J Dairy Sci 71(9): 2486-2490.
48. Belhadj SI, Najar T, Ghram A, Abdrrabba M (2015) Heat stress effects on livestock: Molecular, cellular and metabolic aspects, a review. J Anim Physiol Anim Nutr 100(3): 401-412.
49. Narayan E, Sawyer G, Parisella S (2018) Faecal glucocorticoid metabolites and body temperature in Australian merino ewes (Ovis aries) during summer artificial insemination (AI) program. PLoS One 13(1): e0191961.
50. Kumar D, De K, Sejian V, Naqvi S (2017) Impact of climate change on sheep reproduction. In: Sheep Production Adapting to Climate Change. Sejian V (Eds.), pp. 71-93.
51. Sawyer G (1979) The influence of radiant heat load on reproduction in the Merino ewe II. The relative effects of heating before and after insemination. Australian J Agric Res 30(6): 1143-1149.
52. Alliston CW, Ulberg LC (1961) Early pregnancy loss in sheep at ambient temperatures of 70° and 90°F as determined by embryo transfer. J Anim Sci 20(3): 608-613.
53. Dobson H, Fergani C, Routly JE, Smith RF (2012) Effects of stress on reproduction in ewes. Anim Reprod Sci 130(3-4): 135-140.
54. Naqvi S, Maurya V, Gulyani R, Joshi A, Mittal J (2004) The effect of thermal stress on superovulatory response and embryo production in Bharat merino ewes. Small Ruminant Res 55(1-3): 57-63.
55. Darawany AAE (1999) Improving semen quality of heat stressed rams in Egypt. Indian J Anim Sci 69: 1020-1023.
56. Naga AMA, Ela MBA, Nakhla SM, Mehrez AZ (1987) Oestrous and ovarian activity of sub-tropical fat-trailed Rahmani sheep and their response to light treatment. J Agric Sci 108: 617-621.
57. Marai IFM, Darawany AAE, Fandoud EIA, Hafez MAMA (2004) Reproductive traits and the physiological background of the seasonal variations in Egyptian Suffolk ewes under the conditions of Egypt. Annals Arid Zone 42(2): 1-9.
58. Chemineau P (1993) Environment and animal production. World Anim Rev 77: 135-147.
59. Brown DE, Harrison PG, Hinds FC (1977) Heat stress effects on fetal development during late gestation in the ewe. J Anim Sci 44(3): 442-446.
60. Dixon AB, Knights M, Winkler JL, Marsh DJ, Pate JL, et al. (2007) Patterns of late embryonic and fetal mortality and association with several factors in sheep. J Anim Sci 85(5): 1274-1284.
61. Ames DR, Nellor JE, Adams T (1971) Energy balance during heat stress in sheep. J Anim Sci 32(4): 784-788.
62. Lowe TE, Cook CJ, Ingram JR, Harris PJ (2001) Impact of climate on thermal rhythm in pastoral sheep. Physiol Behav 74(4-5): 659-664.
63. Maurya VP, Naqvi SMK, Joshi A, Mittal JP (2007) Effect of high temperature stress on physiological responses of Malpura sheep. Indian J Anim Sci 77: 1244-1247.
64. Gupta M, Kumar S, Dangi SS, Jangir BL (2013) Physiological, biochemical and molecular responses to thermal stress in goats. Int J Livestock Res 3(2): 27-38.
65. Sharma S, Ramesh K, Hyder I, Uniyal S, Yadav VP, et al. (2013) Effect of melatonin administration on thyroid hormones, cortisol and expression profile of heat shock proteins in goats (*Capra hircus*) exposed to heat stress. Small Rumin Res 112(1-3): 216-223.
66. Haidary AAA (2004) Physiological responses of Naimey sheep to heat stress challenge under semi-arid environments. Inter J Agric Biol 6(2): 307-309.
67. Alam MM, Hashem MA, Rahman MM, Hossain MM, Haque MR, et al. (2011) Effect of heat stress on behavior, physiological and blood parameters of goat. Prog Agric 22(1-2): 37-45.
68. Abdalla EB, Kotby EA, Johnson HD (1993) Physiological responses to heat-induced hyperthermia of pregnant and lactating ewes. Small Rumin Res 11(2): 125-134.
69. Kandemir C, Kosum N, Taskin T (2013) The effects of heat stress on the physiological traits in sheep. Macedonian J Anim Sci 3(1): 25-29.
70. Indu S, Pareek A (2015) A review: Growth and physiological adaptability of sheep to heat stress under semi-arid environment. Int J Emerging Trends Sci Tech 2(9): 3188-3198.
71. Sejian V, Maurya VP, Kumar K, Naqvi SMK (2013) Effect of multiple stresses on growth and adaptive capability of Malpura ewes under semi-arid tropical environment. Trop Anim Health Prod 45(1): 107-116.
72. Indu S, Sejian V, Naqvi SMK (2015) Impact of simulated semiarid tropical environmental conditions on growth, physiological adaptability, blood metabolites and endocrine responses in Malpura ewes. Anim Prod Sci 55(6): 766-776.
73. Sejian V (2013) Climate change: Impact on production and reproduction, Adaptation mechanisms and mitigation strategies in small ruminants: A review. Indian J Small Ruminants 19(1): 1-21.
74. Silanikove N (2000) Effects of heat stress on the welfare of extensively managed domestic ruminants. Livestock Prod Sci 67(1-2): 1-18.
75. Tamimi HJA (2007) Thermoregulatory response of goat kids subjected to heat stress. Small Rumin Res 71(1-3): 280- 285.
76. Berger Y, Billion P, Bocquier F, Caja G, Cannas A, et al. (2004) Principles of sheep dairying in North America. Cooperative Extension Publishing, A3767, University of Wisconsin-Madison, USA, pp. 156.
77. Samara EM, Abdoun KA, Okab AB, Badwi MAA, ElZarei MF, et al. (2016) Assessment of heat tolerance and production performance of Aardi, Damascus, and their crossbred goats. Int J Biometeorol 60(9): 1377-1387.
78. Darcan N, Güney O (2008) Alleviation of climatic stress of dairy goats in Mediterranean climate. Small Rumin Res 74(1-3): 212-215.
79. Sejian V, Hyder I, Malik PK, Soren NM, Mech A, et al. (2015) Strategies for alleviating abiotic stress in livestock. In: Malik PK (Eds.), Livestock Production and Climate Change, CAB International, Wallingford, UK, pp. 25-60.