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Effect of microclimate on feeding, drinking and physiological parameters of buffalo: A review

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Abstract
Homeostasis plays a vital role in endotherms, largely dependent on the climatic factor. A harsh and warranted climate deteriorates the animal's performance which is reflected by changes in water and feed intake, besides showing the fluctuations in the physiological parameters. Buffalo being an endothermic animal follow the same principles, but with a more profound response as the species is having its peculiar character of dark colour with the presence of fewer sweat glanads sparse across the body. An increased ambient temperature reflected on varied physiology *viz.* rectal temperature, respiration rate and heart rate, besides affecting the feeding and water intake. This review paper focuses on the effect of microclimate on the feeding, drinking and physiological parameters of livestock species including buffalo as a prime species.

Keywords: buffalo, microclimate, feeding, drinking, physiological parameters

Introduction
Amongst different environmental conditions, it is the hot weather that ubiquitously compromises the productive and reproductive performance of livestock species. The plains, coast-line and foot-hill regions of the Indian subcontinent, home to over 90% of the worlds' buffaloes, experience varied and extreme weather conditions, with temperatures reaching up to 48°C in summers and as low as minus 2°C in winters. The presence of a large buffalo population in such diverse climatic conditions indicates that buffaloes are well-adapted to such climatic extremes. These peculiar morphological and anatomical characteristics make buffalo poor the rmoregulator, thereby tending to increase the internal body heat, which in turn, takes its toll on food intake, productivity as well as reproductive performance of the animal. Thus it is no surprise that there is a scarcity of milk in this region during summer months, while most of the calvings are concentrated during rainy and winter months of the year. In Spite of these facts, which tend to suggest susceptibility of buffalo to heat stress due to its unique thermoregulatory mechanisms, the presence of large population of buffaloes in such harsh hot climates could possibly be due to some of the special anatomical, Behavioral and morphological features of the skin in this species. Such features include the characteristic black skin that contains numerous melanin granules, which provide protection against UV rays component of sunlight. UV rays are abnormally high in the typical hot climates of the tropics. Further, buffalo dermis has well-developed sebaceous glands and their oily secretions make skin slippery for water and mud. This possibly acts as a defence against harmful ingredients present in mud and water while wallowing. The oil secretions from skin make it more lustrous during summer to reflect solar radiations more effectively.

Feed and Water intake
Microclimate of the house has a significant effect on the DMI, milk yield and water intake of the animal. Heat is generated by Nutrient metabolism which must be dissipated in a warm climate by physiological processes to maintain thermal-neutrality. Dairy cows are in the comfort zone when environmental temperatures are between 5º and 25ºC (Roenfeldt, 1998) [46]. At 26ºC or more, animal thermoregulatory capacity is surpassed and goes into heat stress. Physiological mechanisms start functioning to overcome this state, such as decreasing dry matter consumption, reducing metabolic heat generation and increase in water intake.

Dry Matter Intake (DMI) and Feed Conversion Efficiency (FCE)

According to NRC (2001) [38], with an environmental temperature of 40ºC, consumption of dry matter decreases by 40%. The first noticeable response of ruminants to heat stress is a decrease in food intake (Mc Dowell, 1972) [32]. As the environment temperature approaches or goes above body temperature, animals find it difficult to dissipate heat. Due to this difficulty, animals reduce feed intake with increasing environmental temperature in order to avoid the extra heat increment that accompanies feed intake. Heat tolerant species will reduce their feed intake less than those which are adapted to cooler conditions. Misra *et al*. (1963) [36] found the feed intake significantly ($P<0.05$) lower during summer months in unprotected Murrah buffaloes than those protected from hot winds and solar radiation. Highly significant negative correlation was observed between feed consumption and ambient temperature. In the unprotected group of buffaloes depression in feed intake was 30.5 percent over that of the protected group. Corbett *et al*. (1963) [15] noticed that intake of dry matter lowered by about 10 per cent during summer. Fahimuddin (1975) [17] conducted trials on buffaloes and reported a significant decline in their feed consumption at high environmental temperature. Ostergaard *et al*. (1989) [39] concluded that FCE is not affected by housing i.e., loose housing or stall. Baccari *et al*. (1990) [6] reported lower DM intake in buffalo bulls which were kept under thermal stress as compared to those under thermo neutral conditions. Patel *et al*. (1995) [40] concluded that there was no significant difference in feed intake in buffalo heifers kept under tree, thatch roof and brick walled shed. Singh (2000) [53] concluded that heifers kept in aluminium foil pasted roof (T3) and thatch roof (T4) consumed more DM as compared to those in asbestos (T1) but the difference was non-significant but the corresponding values for per kg metabolic body size were differing significantly between the treatments. Similarly, he also found that the heifers under asbestos consumed significantly more DM per kg body weight gain as compared to T3 and T4. However no significant difference was observed between white painted roof (T2), T3 and T4 and between T1 and T2.

Jat *et al*. (2005) [23] reported that calves reared under that (3.89 kg) and mud plaster roof (3.95 kg) consumed more ($P<0.05$) dry matter per day than those reared in asbestos (3.68 kg) roof. Kamal (2013) [26] recorded significantly ($P<0.05$) higher total DMI in calves kept in agro-net compared with those in asbestos; however, the DMI through green fodder and FCE didn't differ significantly between the treatments and values were found to be lower for asbestos. Barman *et al*. (2017) [8] found higher DMI of concentrate feed and dry fodder in buffalo calves kept in asbestos roofs with significant ($P<0.05$) difference from all other groups but there was no significant difference between galvanized iron and CGI sheet roofs. However, the DMI of green fodder did not differ significantly among the groups throughout the fortnights. Sinha *et al*. (2017, a) [54] observed significant ($P<0.05$) differences of dry matter intake of cows and higher mean values were recorded in modified sheds as compared to existing sheds.

Water intake

Water is the most functional agent in the body, playing an important role in mastication, digestion, absorption, distribution of nutrients and disposal of harmful end products of metabolism through various excretory channels. Water also has a high latent heat of evaporation (2400 J/g) and its evaporation from the lungs and skin gives it a further role in the regulation of body temperature (Mc Donald *et al*., 1995). The total water requirement of ruminant is met from different sources such as, (i) Voluntary Water Intake (VWI) (ii) water consumption as part of forages and feeds and (iii) metabolic water. Total Water Intake (TWI) is the combination of VWI and water consumed as part of roughages. There are studies that indicate the direct association between water intake and environmental temperature (Arias *et al*., 2008) [4]. A number of factors like dry matter intake, the nature of ration, milk yield, age, breed, availability of water, temperature of water, air temperature and other environmental factors influence the water intake of dairy calves (ARC, 1965). Fahimuddin (1975) [17] observed a significant ($P<0.05$) increase in water intake of buffalo under high environmental temperature. Radadia (1979) studied water consumption in four groups of lactating murrah buffaloes in summer *viz*. control, showering, provision of cold water for drinking, and showering plus provision of cold water for drinking. There was a positive correlation ($P<0.05$) between water intake and atmospheric temperature in the control group and a negative correlation ($P<0.05$) between water intake and relative humidity,

Korsun (1993) [29] reported that water consumption increases when air temperature is above 24°C. Patel *et al*. (1995) [40] studied the effect of different housing patterns on water intake in mehsana buffalo heifers under semi-arid conditions. The heifers were subjected to three types of housing patterns *viz*. (i) Brick walled RCC shed; (ii) Thatched roof shed and (iii) Under tree and observed that the water intake per 100 kg body weight were significantly ($P<0.05$) different for housing and months and was highest in group (iii) and lowest in group (ii) animals. Singh (2000) [53] reported that mean VWI and TWI was not significantly influenced by treatment, but both VWI and TWI per kg DMI and per kg metabolic body size was significantly influenced between the treatments with higher values for heifers under asbestos roof and lowest for those in thatch roof. Jat *et al*. (2005) [23] reported that the average daily voluntary water intake was significantly ($P<0.05$) more in animals kept in asbestos roofs as compared to thatch and mud plaster roof. Khongdee (2008) [27] reported lower water intake by the animals kept under open wall polypropylene shade structure. Chauhan *et al*. (2011) [13] reported higher water intake by cows kept under RCC roof as compared to thatched roof and tree shelter. Kamal (2013) [26] concluded that Vrindavani calves under asbestos consumed more ($P<0.05$) quantity of water followed by those in thatch roof and least in agro-net. Barman (2016) [7] observed that the buffalo calves kept under galvanized iron sheet roof consumed significantly ($P<0.05$) more quantity of water followed by those in CGI sheet roof, asbestos roof and least in thatch roof.

Effect on physiological parameters

Temperature and humidity are to a considerable extent responsible for the variation of the physiological reaction of animals and the reactions vary widely in different breeds and species. Animals do acclimatize by gradually adapting to such stressors within their natural environment (Willmer *et al*. 2000) [56], yet the level of adaptation is not well documented in most situations. Buffalo is very sensitive to high ambient temperature and direct exposure to sun. Heat stressed buffaloes tend to have increased body temperatures (core and rectal) and as a result they will decrease DMI and increase water intake. Its body temperature is normally lower than cattle which may account for lower heat tolerant coefficient. This low heat tolerance coefficient in buffaloes may also be due to their large body size, dark skin color and less number of sweat glands (Sastry and Thomas, 2012) [48]. Heat loss in the environment occurs by two main routes. Firstly, non-evaporative heat transfer to the air and surrounding surface by convection, conduction and radiation. Secondly, evaporative heat transfer, associated with loss of water vapor from the body. Since evaporative cooling doesn't depend upon temperature gradient, during severe summers when ambient temperature surpasses animal body temperature at that time most animals rely on evaporation of water from the body as a means to dissipate body heat. Since the bovine does not possess an efficient sweating mechanism, the primary process of heat dissipation is via evaporation through the respiratory tract (Clark and McArthur, 1994) [14]. During thermal stress, several physiological rearrangements occur in buffalo heifers as they attempt to facilitate heat dissipation and/or reduce metabolic heat production. The major physiological changes involved in this acclimation and acclimatization are discussed below.

Respiration Rate (RR), Pulse Rate and Rectal temperature (RT)

The simplest method to modify the effect of environmental conditions is shade structures. The main function of shade is to reduce the heat load of the animal (Ittner and Kelly, 1951) [22]. Yousef (1997) [57] estimated that total heat load could be reduced from 30 to 50% with a well-designed shade. The ability of an animal to withstand the rigor of climatic stress under warm conditions has been assessed physiologically by changes in body temperature, respiration rate and pulse rate. Normal respiration rate is approximately 10-30 breaths/min (Hafez, 1968) [21] and the respiration rate increases when environmental temperature increases (Mc Dowell, 1958; Bond and McDowell, 1972; Singh and Bhattacharya, 1991) [32, 34]. Riek and Lee (1948) [44] observed that an increase in RR is one of the first visible reactions when ruminants are exposed to ambient temperature above the thermal-neutral zone. Mc Dowell, (1958) [34] reported that an evaporative heat loss from the respiratory tract is one of the primary mechanisms for maintenance of heat balance. This respiratory response arises from direct heat stimulation of peripheral receptors which transmit nervous impulses to the heat centre in the hypothalamus. The cardio-respiratory centre is then stimulated to send impulses to the diaphragm and intercostal muscles for further respiratory activity (Findlay and Ingram, 1961) [18]. A high RR in most cases does not necessarily indicate the animal is successful in keeping its temperature balance, but rather that it is already overheated and trying to restore normal heat balance (Mc Dowell, 1958) [34]. The significance of an increase in RR under heat stress is that it enables the animals to dissipate excess body heat by vaporizing more moisture in the expired air, which accounts for about 30% of total heat dissipation (McLean, 1963) [35]. Similarly, the normal pulse rate of buffalo is 40-60 per minute, a rate which reflects primarily the homeostasis of circulation along with the general metabolic level (Bianca, 1965; Habeeb *et al*., 1992) [9, 20]. It increases on exposure to high ambient temperature at 32- 38° C (Mullick and Kehar, 1959; Bianca, 1965) [37, 9], and associated changes in capillary flow cause an increase in blood flow from core to surface and thus allow more heat to be lost by sensible (conduction, convection and radiation) and insensible (evaporative) ways.

Raghavan and Mullick (1962) [42] reported that change in air temperature appeared to be the major cause for affecting variations in the respiration rate, pulse rate and body temperature of buffaloes. They further observed that the relationship between ambient temperature and respiration rate can be taken as an index to assess the heat tolerance in the species. Sastry *et al*. (1973) [47] concluded that provision of shelter and water sprinklers significantly reduced thermal strain expressed by murrah buffalo heifers and aided them in maintaining higher metabolic rate as evidenced by rectal temperature and pulse rate. Amakiri and Funsho (1979) [3] observed that daily variations are known to exist with the maximum temperature occurring in the early afternoon and the minimum in the early hr. of the morning. Robertshaw (1985) [45] reported that the normal range in RT is very narrow in most domestic animals; not more than about 2.5°C. Baccari *et al*. (1988) [6] observed higher rectal temperature in buffaloes subjected to heat stress than those kept under thermo neutral condition. Kabunga (1992) [24] observed that RR is a mode of thermoregulation while RT is the result of thermal equilibrium. Singh (1996) [34] studied the effect of summer management practices on physiological parameters of buffalo calves. The evening respiration rate and rectal temperature was significantly ($P<0.05$) higher in T1 (loose house) and T3 (thatched roof and screen) as compared to T2 (three time body wetting) and T4 (thatched roof + body wetting). T1 also shows significantly ($P<0.05$) higher evening respiration rate and rectal temperature as compared to T3.

Singh (2000) [52] observed that morning respiration rate, pulse rate and rectal temperature of buffalo heifers belonging to different treatment groups were not significantly different from each other, but evening values of these physiological parameters were significantly ($P<0.01$) low in aluminium pasted roof and thatch roof as compared to asbestos and white painted roof. Evening values during the experiment were always high as compared to morning values. Singh *et al*. (2008) [52] reported that the respiration rate was not influenced by providing shed (asbestos, agro-net, and tree). Khong Dee *et al*. (2010) [27] observed significantly lower mean rectal temperature (38.56°C) in shade cloth than that of the cows housed under normal roofing (39.86°C). Kamal *et al*. (2014) [25] concluded that provision of agro-net followed by thatch during the summer as shade materials in an open paddock provided favorable micro-environment to the crossbred calves resulted in keeping physiological responses in normal range. Asbestos sheets could not provide proper microclimate to calves that were witnessed to have high physiological values. Calves kept under tree also had high physiological values which indicate that tree was also insufficient to provide better micro-environment to calves during the summer. Chaudhary *et al*. (2015) [12] conducted his research on surti buffaloes and concluded that there was a significant increase in RR and thus THI with an increase in ambient temperature and the relative humidity in hot dry season and hot humid season, respectively. Barman (2016) [7] divided 24 buffalo calves in four groups kept under different roof modifications *viz.* Asbestos roof (T1), Pre painted CGI Sheet roof (T2), Thatch with polythene shading roof (T3) and Galvanized iron sheet roof (T4) and observed that the respiration rate and rectal temperature of calves at 2:00 PM was significantly ($P<0.05$) higher than at 9:00 AM in all the groups throughout the experiment. Respiration rate of T3 was lowest and showed significant ($P<0.05$) difference from T1, T2 and T4 whereas; rectal temperature at 9:00AM was higher in T1, T2 and T4 grouped calves whereas at 2:00PM T1 and T2 showed higher ($P<0.05$) rectal temperature. The overall rectal temperature of T3 showed significance ($P<0.05$) difference from all other groups with lower values. Kumar *et al*. (2018) [31] concluded that housing modifications of dairy animals are linked to overall physiological parameters and production performance. Cooling mechanism is useful to maintain normal physiological parameters during thermal load conditions.

Skin Surface Temperature

It is well known that environmental temperature affects skin surface temperature (Arp *et al*. 1983). The body extremities are recognized as the main locations for regulating heat loss or storage (Klir and Heath, 1992 and Vanden Heuvel *et al*. 2004) [28, 55]. The changes in skin temperature at various sites indicate that temperature of skin surface not only varies with the change in the environmental temperature but it also varied in different parts of the body at a particular period of time (Singh and Singh, 2006) [51]. The ability of the animal to maintain normal body temperatures by cutaneous and respiratory heat dissipation plays a predominant role in adaptation of cattle in hot climate (Gebremedhin and Wu, 2001) [19]. If the skin surface temperature is below 350C, the temperature gradient between the core and skin is large enough for the animals to effectively use all routes (i.e., convection, conduction, radiation, and evaporation) of heat exchange (Cappola *et al*. 2002) [11]. Above this surface temperature, animals begin to store heat, rectal temperature rises and cutaneous heat loss plays the major role in body temperature control mechanism besides increased respiration rates (Pollard *et al*. 2004) [41]. Surface temperature measured by Infrared thermometer at different sites of the buffalo heifer body can be used as an indicator of animal welfare under different production conditions. Das *et al*. (1997) observed in buffaloes that skin temperature increases as the intensity of solar radiation increases and skin temperature is highly correlated with RT. Singh and Singh (2006) [51] observed the difference between maximum and minimum peripheral skin temperature in crossbred cattle exposed to solar radiation and unexposed cattle at forehead (14.54 and 7.010C), ear (19.50 and 19.120C), dewlap (16.34 and 7.590C) and flank (14.50 and 14.040C), respectively and also found that temperature were lower at different locations of fore and hind leg than other body parts. The forehead surface temperature was higher at 14:00 hr in both protected and unprotected cattle. The feet temperatures were the lowest and similar results were also observed at other extremities of cattle (Kotrba *et al*. 2007) [30]. Rhoads *et al*. (2009) [43] found an increase in the surface temperature in dairy cattle on exposure to heat stress. Alam *et al*. (2011) [2] observed that no differences in skin temperature. Kamal (2013) [26] observed that the mean body ST of calves showed significant difference ($P<0.05$) between 9:00 AM and 2:00 PM under all the shades except those under asbestos roof. Calves kept under tree shade showed maximum body ST at all the body points at 2:00 PM.

Conclusion

In hot-humid climates, although buffalo attempts to acclimatize through physiological changes including cutting down on feed intake and heat production, but this does not come without sacrificing part of its productivity. In order to prevent this economic loss to the farmer, there is need to understand and effectively combat heat stress by minimizing its impact on animal body and its productivity. Over generations, continued genetic selection for improved dry matter intake and milk yield under adverse climates, will pave the way for producing buffaloes that are better equipped for heat tolerance. In the short term, there is no substitute to good management practices to ameliorate heat stress, which include nutritional management and infrastructure facilities for providing comfort to the animal in the event of harsh hot climate. There is little doubt that a buffalo shall repay the investment in due course of time through continued high milk productivity and maintaining good reproductive efficiency for higher life-time productivity.

Reference

1. ARC (Agricultural Research Council). The nutrient requirements of farm Ruminants, A.R.C. London, 1965.
2. Alam MM, Hasnem MA, Rahman MM, Hossain MM, Haque MR, Sobhan Z *et al*. Effect of heat stress on behaviour, Physiological and blood parameters of goat. Progress. Agric 2011;22:37-45.
3. Amakiri SF, Funsho ON. Studies of rectal temperature, respiratory rates and heat tolerance in cattle in the humid tropics. Anim. Prod 1979;28:329-335.
4. Arias RA, Mader TL, Escobar PC. Factores climáticos que afectan el desempeño productivo del ganado bovino de carne y leche. Arch. Med. Vet 2008;40:7-22.
5. Arp SC, Owens FN, Armbruster SL, Laudert S. Relationship of coat color, body surface temperature and respiration rate in feedlot steers. Anim. Sci. Res. Rep., 1983;114:82-86.
6. Baccari F. (Jr.), Blasi AC, Muniz LMR, Fre CA. Effect of therrnal stress on feed intake and senlrn trj..jdothyronine in young buffalo calves. *Proc. Lind* World Buffalo Congress, New Delhi, India 1990;2:139-143.
7. Barman RSD. Studies on the effect of different shade materials on the performance of buffalo calves. PhD thesis submitted to Bihar Agricultural University, Bhagalpur, Bihar, 2016.
8. Barman RSD, Chaudhary MK, Anjay Verma RK, Jha DK. Growth performance and feed intake of buffalo calf under different shade materials during summer season. International Journal of Science, Environment and Technology 2017;6(1):640-649.
9. Bianca W. Reviews of the progress of dairy science. Section A. Physiology. Cattle in a hot environment. J Dairy Res 1965;32:291-345.
10. Bond J, McDowell RE. Reproductive performance and physiological response of beef female as affected by a prolonged high environmental temperature and humidity. J Anim. Sci 1972;35(4):820-829.
11. Cappola CL, Collier RJ, Enns RM. Evaluation of thermal status of cattle using infrared technology. In: Proc., Western Section, American Soc. of Anim. Sci. Colorado State University, Fort Collins, 2002, 53.
12. Chaudhary SS, Singh VK, Upadhyay RC, Puri G, Odedara AB, Patel PA. Evaluation of physiological and biochemical responses in different seasons in Surti buffaloes, Veterinary World 2015;8(6):727-731.
13. Chauhan HD, Prajapati KB, Rajpura RM, Modi RJ. Feed and water intake of Kankrej cows under different housing systems. Indian J. Dairy Sci 2011;64(2):176-177.
14. Clark JA, Mc Arthor AJ. Thermal Exchange In: Watches, C.M and Charles, D.R. (Eds) Livestock Housing. CAB International, Wallingford. U.K, 1994.

15. Corbett JL, Langlandas JP, Reid GW. Effect of season on growth and digestibility of herbags intake by grazing dairy cows. Anim. Prod 1963;5:119.
16. Das SK, Upadhyay RC, Madan ML. Changes in skin temperature and physiological reactions in Murrah buffalo during solar exposure in summer. Asiatic Aust. J. Anim. Sci 1997;10(5):478-483.
17. Fahimuddin M. Domestic water buffalo. Oxford and IBH publishing Go., New Delhi, 1975, 79.
18. Findlay JD, Ingram DL. Brain temperature as a factor in the control of thermal polypnea in the ox (*Bos taurus*). J Physiol. (Lond.) 1961;155:72-85.
19. Gebremedhin KG, Wu B. Sensible and latent heat losses from wet-skin surface and fur layer. *ASAE Annual international Meeting, Sacramento,* CA. ASAE ASABE, St. Joseph, MI, USA. Paper No. 01-4040. 2001.
20. Habeeb AAM, Marai IFM, Kamal TH. Heat stress in farm animals and the environment. CAB International [C.J.C Phillips and D. Piggins (eds.)].Wallingford. 1992, 27-47.
21. Hafez ESE. Adaptaion of Domestic Animals. *Lea and Febiger,* Philadelphia, USA 1968, 415.
22. Ittner NR, Kelly CF. Cattle shades. J Anim. Sci 1951;10:184-194.
23. Jat RP, Gupta LR, Yadav BL. Effect of roof modification in loose house on intake and utilization of nutrients in buffalo calves during rainy season. Indian J Anim. Sci 2005;58(1):54-57.
24. Kabunga JD. The influence of thermal conditions on rectal temperature, respiratory rate and pulse rate of lactating Holstein-Friesian cows in the humid tropics. Int. J Biometeor 1992;36:146-150.
25. Kamal R, Dutt T, Patel BH, Dey A, Chandran PC, Barari SK *et al*. Effect of shade materials on microclimate of crossbred calves during summer, Veterinary World 2014;**7**(10):776-783.
26. Kamal RK. Effect of different shade material on Performance of Vrindavani calves. PhD thesis submitted to Deemed University IVRI, Izatnagar, U.P 2013.
27. Khongdee S. The effects of high temperature and housing modification on the productive and reproductive performance of dairy cows. Thesis submitted to graduate school, Kasetsart University, 2008.
28. Klir JJ, Heath JE. An infrared thermographic study of surface temperature in relation to external thermal stress in 3 species of foxes- the red fox (Vulpes vulpes), arctic fox (Alopex lagopus), and kit fox (Vulpes macrotis). Physiol Zool 1992;65:1011-1021.
29. Korsun BA. Feeding cows under shaded awnings during summer. Molochno Mysane skotarstvo 1993;82:52-54.
30. Kotrba R, Kny zikova I, Kunc P, Bartosi L. Comparison between the coat temperature of the eland and dairy cattle by infrared thermography. J Therm. Biol 2007;32:355-359.
31. Kumar A, Kamboj ML, Chandra S, Kumar C, Singh D, Rather HA. Physiological parameters of cattle and buffalo in different seasons under different housing modification systems - A review. Agricultural Reviews 2018;39(1):62-68.
32. Mc Dowell RE. Improvement of livestock production in warm climates. W.H. Freeman and Co., San Francisco 1972, 66-110.
33. Mc Donald P, Edwards RA, Greenhalgh JFD. Animal Nutrition. *5th ed*., Longman Group Ltd., England 1995.
34. Mc Dowell RE. Physiological approaches to animal climatology. J. Heredity 1958;2:52- 61.
35. McLean JA. The partition of insensible losses of bodyn weight and heat from cattle under various climatic conditions. *J*. Physiol. (Lond.) 1963;167:427-44.
36. Misra MS, Sen Gupta BP, Roy A. Physiological reactions of buffalo cows maintained in two different housing conditios during summer months. Indian J Dairy Sci 1963;17:203-215.
37. Mullick DN, Kahar ND. Seasonal Variations in the pulse rate, respiratory rate, body temperature and haemoglobin level of dairy cows. Indian J Dairy. Sci 1959;12:56-62.
38. NRC. Nutrient requirements of dairy cattle. 7th revised ed. National Research Council, Natl. Acad. Press, Washington D.C., USA 2001, 178-183.
39. Ostergaard V, Christensen Thysen LG. Effects of genotype, production system and level of nutrition on feed conversion efficiency in Danish dairy cattle herds in 1961-86. (fide Dairy Sci. Abstract 1989;59(1):109.
40. Patel JB, Patel JP, Pande MB. Effect of Different Housing Patterns on Feed and Water Intake in Mehsana Buffalo under Semi-arid conditions. Indian J Anim Sci 1995;65:88-90.
41. Pollard BC, Dwyer ME, Fitzgerald AC, Genty PC, Henderson D, Collier RJ. Effect of ambient temperature and solar radiation on skin evaporative water loss in dairy cattle. J Dairy Sci. (Abst.) 2004;87(Suppl. 1):198.
42. Raghavan GV, Mullick DN. Effect of air temperature and humidity on the pulse rate, respiration rate and rectal temperature in buffalo bulls. Indian Vet. J 1962;38:391-396.
43. Rhoads ML, Rhoads RP, VanBaale MJ, Collier RJ, Sanders SR, Weber WJ *et al*. Effects of heat stress and plane of nutrition of lactation Holstein cows: I. Production, metabolism, and aspects of circulation somatotropin. J Dairy Sci 2009;9(5):1986-1997.
44. Riek RF, Lee DHK. Reaction to hot atmosphere of Jersey cows in milk. J Dairy Res 1948;15:219-226.
45. Robertshaw D. Heat loss of cattle, In: M.K. Yousef. (ed.). Stress Physiology in Livestock. CRC Press, Inc., Boca Raton 1985;1:55-66.
46. Roenfeldt S. You can't afford to ignore heat stress. Dairy Manage 1998;35(5):6-12.
47. Sastry NSR, Thomas CK, Gupta LR, Tripathi VN, Pal RN. Effect of shelter and water sprinkling during summer and autumn on some physiological reactions of Murrah buffalo heifers. Indian J Anim. Sci 1973;33:95-99.
48. Sastry NSR, Thomas CK. Dairy bovine production. Kalyani Publisher. New Delhi, 2012.
49. Singh DN, Wadhmani KS, Arya JS, Sarvaiya NP, Patel AM. Effect of blood constitute of ewes during summer in a subtropical climate. Indian J Small Rumi 2008;14(1):252-254.
50. Singh K, Bhattacharya NK. Themosensistivity of Bos indicus cattle and their F1crosses with three breeds of Bos taurus. Anim. Prod 1991;52:57-65.
51. Singh R, Singh SV. Circadian changes in peripheral temperature and physiological responses under solar exposure and shed during summer in Karan Fries heifers. Indian J of Anim. Sci 2006;76(8):605-608.
52. Singh Y. Studies of certain summer management practices on performance of growing buffalo calves. M.V.Sc. thesis, submitted to CCS Haryana Agricultural University, Hisar, India, 1996.

53. Singh Y. Effect of certain managemental practices on the performance of buffalo heifers. PhD thesis, submitted to C.C.S. Haryana Agricultural University, Hisar, India 2000.
54. Sinha R, Kamboj ML, Lathwal SS, Ranjan A. Effect of housing management on production performance of crossbred cows during hot-humid season. Indian J Anim. Res 2017, a;3316:1-4.
55. Vanden Heuvel CJ, Ferguson SA, Gilbert SS, Dawson D. Thermoregulation in normal sleep and insomnia: the role of peripheral heat loss and new applications for digital thermal infrared imaging (DITI). J Therm. Biol 2004;29:457-461.
56. Willmer P, Stone G, Johnston I. Environmental Physiology of Animals. *Blackwell Science*, Ltd., Oxford, England 2000;644:112.
57. Yousef HM, Habeeb AAM, El-Kousey H. Body weight gain and some physiological changes in Friesian calves protected with wood or reinforced concrete sheds during hot summer season of Egypt. Egypt. J Anim. Prod 1997;34(2):89-101.