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A Review: Growth and Physiological Adaptability of Sheep to Heat Stress under Semi –Arid Environment

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Abstract

Asian countries are characterized with humid subtropical climate, Heat stress is the most important climatic stress which adversely affects the livestock and sometimes even threatens the survival of animals. Among climatic components that may impose stress on many different traits to sheep are ambient temperature, humidity, air movement, photoperiod, solar radiation, wind speed, etc, of which the ambient temperature is the most important variable. Heat stress affects performance and productivity of small ruminants in all phases of production. The degree to which these stress impacts on productivity will differ between the agro-ecological regions and between production systems. The level of production achieved by a particular genotype in harsh environment depends on the contribution and expression of many different traits which may be partitioned into those directly involved with production and adaptation. Growth, such as body weight and physiological performance of animal is affected due to hyperthermia. As the primary non-evaporative means of cooling for the small ruminants (radiation, conduction, convection) become less effective with rising ambient temperature, the animals become increasingly reliant upon evaporative cooling in the form of sweating and panting. Increasing air temperature, temperature-humidity index and rising rectal temperature above the critical threshold levels are related to decreased dry matter intake (DMI) and milk yield. Stress depresses growth rate primarily through the depression of food intake, but also by affecting digestion and metabolism. Alleviation of heat stressed animals by physical, physiological and/or nutritional techniques, in addition to carrying out proper routine management practices at the suitable times, can help the heat stressed animals to express their genetic potentials in tropical and subtropical areas.

Keywords: *Growth, Heat stress, Performance, Sheep, Ambient temperature, Productivity*

Introduction

In the current perspective of global climate change, it is essential to understand the effect of environmental changes on the organism as well as the adaptive mechanisms in their arsenal to combat them. Semi-arid environment is one of the major agro-ecological zones of the tropics. There is a strong relationship between agro-climatic conditions, population density, cropping systems, and livestock production (Maurya et al. 2007).The small and marginal farmers of the semi-arid region earn their livelihood through sheep production. Sheep husbandry has served as sustainable livelihood resource option for people living in the arid and semi-arid region of the world since time immemorial. Sheep can make use of low-quality biomass in times of scarcity and transform it into useful products, such as milk, meat and wool. It is predicted that in coming years, sheep industry will grow further and will play a vital socio-economic role in arid and semi-arid region (Ben Salem and Smith 2008). Therefore, initiatives must be taken to accelerate the sheep production through cheap and simple techniques.

Body weight, growth, physiology of animal is affected due to hyperthermia. Heat stress is defined as the sum of forces external to a homeothermic animal that acts to displace body temperature from the resting state (Yousef 1985). However, when the environmental temperature becomes near the Sheep body temperature, high ambient relative humidity percentage (RH%) reduces evaporation, overwhelms the sheep cooling capability, and the body temperature rises.This is due to the negative effects of high RH% on dissipation of body heat, because of the decline in effectiveness of radiation, conduction and convection, in addition to the decline in the efficiency of evaporative cooling needed to maintain the heat balance. Such stresses can disrupt the physiology and productive performance of an animal (West 2003). Production losses in domestic animals are largely attributed to increases in maintenance requirements associated with sustaining constant body temperature, and altered feed intake (Mader and Davis 2004). In order to maintain body function in steady state homeotherms are required to maintain body temperature within narrow range. Deviation from the set level of body temperature under stressful hot environment, leads to interference with physiological events and consequently negatively impacts animal productivity (Hansen 2004). The properties of the skin and hair, sweating and respiration capacity, tissue insulation, the relationship between surface area per unit body weight or relative lung size, endocrinological profiles and metabolic heat production are factors that influence heat load, but the underlying physiological, behavioural or genetic mechanisms are largely unknown (McManus et al. 2008). Animals can adapt to the hot climate, nevertheless the response mechanisms are helpful for survival but are detrimental to productive and reproductive performance (Rivington et al. 2009). In the present article, sheep growth and physiological traits affected by heat stress are reviewed.

1. Impact of climate change and environmental stress on livestock production

Climate is changing, and with it climate variability and this adds to the already considerable development challenges faced by many countries in the tropics and subtropics. Most climate-related and other environmental impacts on livestock production are closely related to the normal biological functions of animals (food intake, digestion and manure production) (IFDA 2009). The care and feeding of livestock around the world is altered by climate and weather factors (Nienaber and Hahn 2007). Ambient temperature, humidity, wind speed, thermal radiation and precipitation are the major climate parameters which constitute the thermal environment and which are the potential environmental stressors for livestock's with regards to health, growth, yield and reproduction (Nienaber and Hahn 2007; Svotwa et al. 2007; Nwosu and Ogbu 2011). Recently, the negative impacts of human-induced global warming on livestock production systems (Tubiello et al 2007) and the contribution of livestock to climate change (Steinfeld et al. 2006) have been highlighted. There are levels of vulnerability associated with livestock production to the potential risks due to global warming (Hahn 1995; Hatfield 2009). These levels are associated with levels of productivity (Hatfield 2009) as well as other environmental factors and genetic attributes of individual animals, species and breeds. As performance levels increase, the vulnerability of the animal increases and, when coupled with other adverse environmental factors (e.g. poor nutrition), the animal is at greater risk (Hatfield 2009). Inherent genetic characteristics or management scenarios that limit the animal's ability to adapt to or cope with thermal stress also put the animal at risk. At high performance levels, any environment other than near optimum may put the animal at greater risk (Armstrong 1994; Valtorta 2002; Marai and Rashwan 2004; Hatfield 2009; Mader et al. 2009). These stressors meant greater challeng on livestock production in terms of well being, reproduction and performance.

2. Heat stress impact on sheep Production

2.1 Impact of heat stress on growth of sheep

Exposure of sheep to elevated temperatures results in the decrease of body weight, average daily gain (ADG), growth rate and body total solid, which is reflected by impaired reproduction (Marai et al. 2000; Shelton 2000). As a result of thermal challenges associated with climate variability and change, normal behavioural, immunological, and physiological functions of animals are all potentially impacted (Nienaber and Hahn 2007). Under stress, all the physiological and cellular aspects of body function are disrupted by either the effect of stresses (like decreases in body temperature caused but heat stress) or by physiological adaptation engaged by the animal to reduce these effects. In addition, when animals are exposed to thermal stress, metabolic and digestive functions are often compromised due to altered or impaired feeding activity (Mader 2003, Marai et al. 2002, 1994, 2007). High ambient temperature with high direct and indirect solar radiation, wind speed and relative humidity cause the effective temperature of the environment to often exceed the thermal neutral zone of the animals leading to heat stress (Hayes et al. 2003; Kaya 2011). However, under the hot climate conditions, the combined effect of such factors may be more substantial due to the negative effect of elevated ambient temperature on appetite and accordingly on the feed intake that ends with slowing growth and impairment of reproduction (Marai et al. 2002, 2006). The effect of heat stress is aggravated when heat stress is accompanied with high ambient humidity (Marai et al. 2007). Animals exposed to chronic environmental stress undergo metabolic adaptations to elevate them. This include changes in endocrine function, basal metabolism, metabolism of water and electrolytes, acid-base balance and in ruminants an alteration in rumen fermentation. Rumen Volatile Fatty Acid (VFA) production is increased in cold stress, due to increased feed intake and decreased heat stress. Selective forage intake during high environment temperature with alternative rumen fermentation cause a decrease in acetate and alters acetate: propionate ratio, which causes reduced milk fat yield during heat stress. Thermal stress alters the acquisition of potentially absorbable nutrients and energy. The onset of thermal stress results in decline in eating and grazing activities as reducing voluntary feed intake (Hatfield 2009). Dry matter intake is severely reduced. There is also a decrease in the rate of passage of digester through the digestive tract resulting in increase in digestibility (Beede and Collier 1986; Hahn et al. 2003; Mader et al. 2009). Body weight, body condition and level of productivity affect the magnitude of voluntary feed intake and the ambient temperature at which changes in VFI begin to be observed (Mader et al. 2009). Reduction in voluntary feed intake is accompanied by decreases in feed utilization efficiency, rate of body weight gain and general decline in performance (Rowlinson 2008; Mader et al. 2009). Some other studies reported similar performance losses in small ruminants (Sevi et al. 2002; Nwosu and Ogbu, 2011). The biological changes under the hot climate conditions were discussed by Marai et al. (2007) in sheep. Marai et al. (2007) reported that heat stress stimulates the peripheral thermal receptor to transmit suppressive nerve impulse to appetite center in the hypothalamus and thereby causing a decrease in feed intake. The decrease in feed intake could be due to the adaptive mechanism of sheep to produce less body heat. If animals are at a productive stage (growth, lactation), the reduction in feed intake and internal heat production is reflected in a reduction in growth (Silanikove 1992, 2000).

3. Physiological adaptability of sheep to heat stress

Sheep is an important livestock species of arid and semi- arid tropical climate especially in western India. Tropical regions characterized by high levels of solar radiation and temperature are known to adversely affect animal production (McManus et al. 2009). A range of behavioural and physiological changes has been used to identify and quantify stress. These changes may differ qualitatively or quantitatively depending on the stressor so that a range of indices should be used in order to assess the extent of the stress. Measures of rectal temperature (RT), pulse-rate (PR) and respiratory rate (RR) are some of the most important determinants of the adaptation of poultry to the tropical environment. The animal and its environment make up an integrated system, where each acts on the other (Ilori et al. 2011). There is extensive literature developed on the physiological effects of heat stress on the body and the body's mechanisms of achieving heat balance. Physiological adaptation to heat stress is composed of two components: 1) heat load which rises from metabolism, heat exchange, radiation, and convection with the environment; and 2) heat dissipation which is release of the heat load through sweat evaporation. With rising body temperature fluctuation in physiological responses occur, i.e. respiration rate, pulse rate and rectal temperature are the common signs of heat stress in sheep. Such Climate Change negatively affects the sheep performance.

Season cycle of physiological functions to cope with seasonal fluctuations in climate and food availability is common in most of the species (Patkowski et al. 2006; Duarte et al. 2010). These seasonal rhythms reflect the endogenous adaptive mechanism to react in advance to the regular environmental changes associated with the seasons (Piccione et al. 2009). Daily variation of body temperature of endothermic animals is influenced by changes in physiological activity and metabolic changes (Stanier et al. 1984). Environmental factors (ambient temperature, relative humidity, solar radiation and wind speed), animal factors (breed, coat color, stage of lactation and health status) and thermoregulatory mechanisms (circulatory adjustments, sweating and panting) have a significant impact on the energy exchange between the animal and the environment (Nienaber et al. 1999).

3.1 Respiration Rate

Respiration rate is an indicator of heat stress in sheep (Habeeb et al. 1992). Alamer (2011) reported that higher circulating of prolactin during heat stress may modulate some mechanisms of heat dissipation and heat production oriented to support homeothermy it can be used as an indicator of heat stress, and to estimate the adverse effects of environmental temperature. Studies in environmentally-controlled chambers (Wilson et al. 1998; Gaughan et al. 2000; Beatty et al. 2006) have developed valuable models of response to heat stress. There is a range of temperature conditions (thermoneutral zone or optimal zone) within which animals are able to maintain a relatively stable body temperature without significantly altering behavioural or physiological function (Frank et al. 2004). Above this critica body temperature and respiration rate have been described as reliable indicators of heat load (Gaughan et al. 2002; Brown-Brandl et al. 2005.). Sheep respond to heat by panting to increase respiratory evaporation. The animal increases its respiration rate (breaths min^{-1}) in response to the increased rate of respiratory evaporation (Wm^{-2}) required for thermal balance. The increased in RR is an attempt to increase respiratory evaporization and the higher skin temperature can be attributed to the partially to the fact that exposure to heat stress alter the blood flow and redistribution of blood flow and increase blood flow to the surfaces. Similar findings were recently reported by Al-Haidary (2000), Ashutosh and Kundu (2000), Sudarman and Ito (2000), Sunagawa et al. (2002) and Srikandakumar et al. (2003), AL-H aidar (2004).

Fahmy (1994) and Marai et al. (1997c) also described that, during summer, the respiration rate is higher than in winter for sheep. Shalaby (1985), Yousef (1985) and Marai et al. (1997c) observed the trend in RR in Egyptian Rahmani, Ossimi and Ossimi×Suffolk crossbred ewes, they found that RR was markedly lower at 8:00 am than at 12:00 pm and 16:00 pm. Sejian et al. (2012) also found higher respiration rate in afternoon than morning in Malpura sheep of semi-arid region. Further, Silanikove (2000) suggested that respiration rate was a practical and reliable measure of heat load and stated that respiration rate above 80 breath/minute is an indication of high heat stress.

3.2 Pulse rate

The pulse rate reflects primarily the homeostasis of circulation along with the general metabolic status. It is well documented that cardio respiratory system influenced by season, day timings, ambient temperature, humidity and exercise (Marai et al. 2007). Seasonal variation in heart rate is expected because basal metabolic rate (Blaxter and Boyne 1982) and the amount of food consumed per day varied with season (Gordon 1964; Milne et al. 1978; Kay 1979). Pulse rate (PR) are affected by heat stress (Muller et al. 1994a; Wise et al. 1988) So, PR may be used as indicators of heat stress. Pulse rate rhythm exhibit a circadian rhythm and exposure to heat stress reduce the heart rate mainly during the hottest part of the day, Al-haidary *(*2004) reported that exposure to heat stress reduced (P<0.01) the daily average of heart rate (115.7 and 85.8±.11 beat /min for the control and heat stress group, respectively). Several investigators have reported that there is a correlation between heart rate and metabolic heat production (Yamamoto and Ogura 1985; Barkai et al. 2002). On the other hand exposure to heat stress is well known to reduce the metabolic heat production to minimize the heat load and maintain normal body temperature. Therefore, the results from the Al-haidary 2004 showed that heat stress challenges reduce heart rate, and the mark reduction of heart rate occurred during the hottest part of the daily cycle (1200-1700 h). The heart rate rhythm exhibit a circadian rhythm and the exposure to heat stress reduce the heart rate mainly during the hottest part of the day. Aharoni et al. (2003) have suggested that heart rate decreased because the general effort of the animal to decrease heat production. This reduction could be achieved by the animal either by intake reduction or by activity reduction or both. Alexiev et al. (2004), however, reported the heart rate to accelerate during the peak hour of the heat load (15:00) in ewes that had *ad libitum* access to water due to the increased cutaneous blood flow. The same author reported breed differences to exist in the rate of cutaneous cooling. At very high temperatures, the pulse rate may decrease due to a decrease in the metabolic rate. Others (Bhattacharya and Uwayjan 1975; Sunagawa et al. 2002) did not detect any significant changes in hear rate when animals exposed to heat stress. Recent study has showed that heart rate of sheep exhibited circadian rhythm reaching maximum during the middle of day (Lowe et al. 2001). Barkai et al. (2002) working with sheep found heart rate of sheep show a clear diurnal pattern, the lowest value occurred at night and the highest value were recorded during the middle of the day. This increases blood flow from the core to the surface to give a chance for more heat to be lost by sensible (loss by conduction, convention and radiation) and insensible (loss by diffusion water from the skin) means.

3.3 Rectal temperature

The rectal temperature is often used as a representative measurement of animal core temperature (Nieslon 1995). A rise of 1 ºC or less in rectal temperature is enough to reduce performance in most livestock species (Kadzere et al. 2002). Rectal temperature is strongly associated with many physiological attributes associated with heat stress (McManus et al. 2009). Exposure to high ambient temperature induces the animals to try to balance the excessive heat load by using different means to dissipate, as much as possible, their latent heat. If all such means fail, the body rectal temperature rises (Marai and Haeeb 2010). During exposure to heat stress, the hyperthermia is the result of decreased thermal gradient between animal and the surrounding environment, and as a result sensible heat loss becomes less effective. Exposure to heat stress is registered by the temperature–humidity index that includes both ambient temperature and relative humidity (LPHSI 1990; Marai et al. 2001). In winter night's animals remain exposed to extreme cold without any shed, so in the winter THI decreased and animals unable to maintain their core body temperature and their RT decreased. In summer season the THI prevail higher during the evening also, that may cause significantly higher RT in the evening in summer as compared to other season. Rectal temperature increases with exposure to high environmental temperature (Marai et al. 2002; Al-hediary 2004). Srikandakumar (2003) reported that the rectal temperature is generally considered as a good index of deep body temperature even though there is considerable variation at different parts of the deep body core at different times of the day. The higher magnitude of increase in rectal temperature in sheep during the period of heat stress suggests that these animals can store body heat during the periods of heat stress. Rectal temperatures vary between 38.3 and 39.9 ◦C under thermo-neutral conditions. An increase in the ambient air temperature from 18 to 35◦C is accompanied by significant increases in rectal temperature in sheep (Abdel-Samee 1991; Fahmy 1994; Shafie et al. 1994; Marai et al. 1997c, 2000). Rectal temperatures of 42◦C and above are considered as dangerous (Thwaites 1985). Marai et al. (2007) state that sheep as homeotherms maintain their body heat balance by dissipation of the excess heat from their bodies, when exposed to elevated temperatures. Assessment of rectal temperature under summer conditions is relevant, as adaptation to hot conditions or heat tolerance may be evidenced by suppression of body temperature (Turner 1982; Pereira et al. 2008; Riley et al. 2012).While RR, PR and RT are the most popular measures, several studies show that they should not be used in isolation of other factors (Starling et al. 2005, Castanheira et al. 2010) For determining heat stress in sheep Cardoso et al. (2002) found that evaluating adaptation to heat stress using rectal temperature, respiratory frequency and physiological variables under high temperatures was insufficient (Castanheira et al. 2010; McManus et al. 2011**).**

Conclusion

The study indicated that heat stress had impact effect on Sheep as revealed by change in growth, physiological and production characteristics. However, while trying to adapt to heat stress, their growth and physiological performances are compromised. This is evident from the significant changes in body weight, BCS, RR, PR and RT in ewes. The study by various scientists is reviewed extensively and compiled together in the present review article to provide a better understanding of the effect of heat stress on sheep and its adaptability under Semi–arid environment**.** More refinement of the present review can be attempted by further research in this area.

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Reference

1. Abdel-Samee AM. 1991. Detection of heat adaptability of growing lambs in subtropics. Zagazig Vet J. 19 (3):719–731.
2. Aharoni YA, Brosh A, Kourilov P, Ariel A. 2003. The variability of the ratio of oxygen consumption to heart rate in cattle and sheep at different hours of the day and under different heat load conditions. Livest Prod Sci. 79:107–17.

3. Alexiev J, Gudev D, Popova-Ralcheva S, Moneva P. 2004. Thermoregulation in sheep. IV. Effect of heat stress on heart rate dynamics in shorn and inshorn ewes from three breeds. Zhivotnov dni-Nauki. 41(1):16–21.
4. Al-Haidary A. 2000. Effect of heat stress on some thermoregulatory responses of cattle, sheep and goat. Zag Vet J. 28:101–10.
5. Al-haidary AA. 2004. Physiological Responses of Naimey Sheep to Heat Stress Challenge under Semi-Arid Environments. Int J Agr Biol. 6:1560–8530./2004/06–2–307–309.
6. Armstrong DV. 1994. Heat stress interaction with shade and cooling. In: Symposium: Nutrition and heat stress. J Dairy Sci .77:2044 - 2050.
7. Ashutosh D, Kundu R. 2000. Physiological responses of native and crossbred sheep to climate stress under semi-arid conditions. Indian J Anim Sci. 8:857–61.
8. Barkai D, Landau S, Brosh A, Baram H, Molle G. 2002. Estimation of energy intake from heart rate and energy expenditure in sheep under confinement or grazing condition. Livest Prod Sci. 73: 237–46.
9. Beatty DT, Barnes A, Pethick D, McCarthy M, Taylor E, Maloney SK. 2006. Physiological responses of Bos taurus and Bos indicus to prolonged, contin- uous heat, and humidity. J Anim Sci. 84:972–985.
10. Beede DK, Collier RJ. 1986. Potential nutritional strategies for intensively managed cattle during thermal stress. J Anim Sci. 62:543–554.
11. Ben Salem H, Smith T. 2008. Feeding strategies to increase small ruminant production in dry environments. Small Rumin Res. 77:174–194.
12. Bhattacharya AN, Uwayjan M. 1975. Effect of high ambient temperature and low humidity on nutrient utilization and on some physiological responses in Awasi sheep fed different levels of roughage. J Anim Sci. 40:320–328.
13. Blaxter KL, Boyne AW. 1982. Fasting and maintenance metabolism of sheep. J Agri Sci. 99:611-620.
14. Brown-Brandl TM, Eigenberg RA, Nienaber JA, Hahn GL. 2005. Dynamic response indicators of heat stress in shaded and non- shaded feedlot cattle. 1. Analyses of indicators. Biosyst Eng. 90:451–462.
15. Cardoso SJM, Gomes RS, Mario CM. et al. 2002. Analysis of some physiological variables for the evaluation of the degree of adaptation in sheep submitted to heat stress. R Bras Zootec. 31(5): 2070-2077.
16. Castanheira M, Paiva SR, Louvandini H, Landim A, Fiorvanti MCS, Dallago BS, Correa PS, McManus C. 2010. Use of heat tolerance traitss in discriminating between groups of sheep in central Brazil. Trop Anim Health Prod. 42:1821-1828.
17. McManus C, Louvandini H, Paim TP, Martins RFS, Barcellos AO, Cardoso CC, Guimarães RF, Santana OA. 2011. The challenge of sheep farming in the tropics: aspects related to heat Tolerance. R Bras Zootec. 40:107-120.
18. Duarte G, Nava-Hernandez MP, Malpaux B, Delgadillo JA. 2010. Ovulatory activity of female goats adapted to the subtropics is responsive to photoperiod. Anim Reprod Sci. 120:65-70.
19. Fahmy S. 1994. Effect of crossing Romanov with Rahmani sheep on some physiological and productive performance. M.Sc. thesis. Faculty of Agriculture, Al-Azhar University, Cairo, Egypt.
20. Frank KL, Mader TL, Harrington JA Jr, Hahn GL. 2004. Potential climate change effects on warm - season livestock production in the Great Plains. Journal

series no. 14462, Agric Res Div University of Nebraska.

21. Gaughan JB, Holt SM, Hahn GL, Mader TL, Eigenberg R. 2000. Respiration rate: Is it a good measure of heat stress in cattle? In: Proceedings of the 28th Biennial Conference of the Australian Society of Animal Production, Sydney, Australia. CSIRO Publication, Collingwood, Australia, p. 329–332.
22. Gordon JG. 1964. Effect of time of year on the roughage intake of housed sheep. Nature Lond. 204:798-799.
23. Habeeb AA, Marai IFM, Kamal TH. 1992. Heat stress. In: Philips C, Piggens D. (Eds.), Farm Animals and the Environment. CAB Int. pp. 27–47.
24. Hahn GL, Mader TI, Eigenberg RA. 2003. Perspective on development of thermal indices for animal studies and management. In: Interactions between climate and animal production. Wagemigen Academic Publ., Wagemingen, The Netherlands EAAP Technical series No. 7:31-44.
25. Hahn GL. 1995. Environmental management for improved livestock performance, health and well-being. Japanese J Livestk Mang 30:117-127.
26. Hansen PJ. 2004. Physiological and cellular adaptations of zebu cattle to thermal stress. Anim Reprod Sci. 82–83:349–360. doi:10.1016/j.anireprosci.2004.04.01.
27. Hatfield JL. 2009. The effects of Climate Change on Livestock Production. Production Management Feature Articles. USDA Online: http://www.thepigsite.com/articles/2296/the-effects-of-climate-change-on-livestock-production.
28. Hayes BJ, Carrick M, Bowman P, Goddard ME. 2003. Genotype Environment interaction for milk production of daughters of Australian dairy sires from test-day records. J Dairy Sci. 86:3736-3744.
29. IFAD 2009. Livestock and climate change. Livestock thermatic papers. Availableonline at www.ifad.org/irkm/index.tm.
30. Ilori BM, Peters SO, Yakubu A, Imumorin IG , Adeleke MA , Ozoje MO, Ikeobi CON, Adebambo OA. 2011. Physiological adaptation of local, exotic and crossbred turkeys to the hot and humid tropical environment of Nigeria. Acta Agri Scand Sec. A. 61: 204-209.
31. Kadzerea CT, Murphya MR, Silanikoveb N, Maltzb E. 2002. Heat stress in lactating dairy cows: a review. Livest Prod Sci. 77:59–91.
32. Kay RNB. 1979. Seasonal changes of appetite in deer and sheep. Agric Res Comun Res Rev. 5:13-15.
33. Kaya S. 2011.The effects of Outdoor housing and Cafeteria Feeding on growth performance and feeding Behaviour of Awassi Lambs Kept in hot Climate condition. J Anim Vet Adv. 10 (19): 2550-2556.
34. Lowe TE, Christian J, Cook, Ingram JR, Phillip. 2001. Impact of climate on thermal rhythm in pastoral sheep. Physiol Behavior. 74:659–64.
35. LPHSI 1990. Livestock and Poultry Heat Stress Indices Agriculture Engineering Technology Guide. Clemson University, Clemson, SC 29634, USA.
36. Mader TL, Davis MS. 2004. Effect of management strategies on reducing heat stress of feedlot cattle: feed and water intake. J Anim Sci. 82:3077–3087.
37. Mader TL, Frank KL, Arrington Jr. JA, Hahn GL, Nienaber JA. 2009. Potential climate effects on warm season livestock production in the Greats plains. Clim change. 97:529 – 541

38. Mader TL. 2003. Environmental stress in confined beef cattle. J Anim Sci. 81:110–119.
39. Marai IFM, Ayyat MS, Abd El-Monem UM. 2001. Growth performance and reproductive traits at first parity of New Zealand White female rabbits as affected by heat stress and its alleviation, under Egyptian conditions. Trop Anim Health Prod. 33:457–462.
40. Marai IFM, Bahgat LB, Shalaby TH, Abdel-Hafez MA. 2000. Fattening performance, some behavioral traits and physiological reactions of male lambs fed concentrates mixture alone with or without natural clay under hot summer of Egypt. Ann Arid Zone (India) 39:449–460.
41. Marai IFM, El-Darawany AA, Abou-Fandoud EI, Abdel-Hafez MAM. 2006. Tunica dartos index as a parameter for measurement of adaptability of rams to subtropical conditions of Egypt. Anim Sci J. (Japan) 77 (5):487–494.
42. Marai IFM, El-Masry KA, Nasr AS. 1994a. Heat stress and its amelioration with nutritional, buffering, hormonal and physical techniques for New Zealand White rabbits maintained under hot summer conditions of Egypt. In: Baselga, Marai IFM. editors . Hot climate, Proceeding of the 1st Int. Conf. on Rabbit. Prod. Opt Med. 8 (suppl. Cairo, Egypt):475-487.
43. Marai IFM, Habeeb AAM. 2010. Buffaloes reproductive and productive traits as affected by heat stress. Trop Subtrop Agroecosyst. 12:193-217.
44. Marai IFM, Rashwan AA. 2004. Rabbits behavioural response to climate and managerial conditions - a review. Arch Tierz Dummerstorf. 47(5): 469 -482.
45. Marai IFM, Shalaby TH, Bahgat LB, Abdel-Hafez MA. 1997c. Fattening of lambs on concentrates mixture diet alone without roughages or with addition of natural clay under subtropical conditions of Egypt. Physiological reactions. In: Proceedings of International Conference on Animal Production & Health, Dokki, Cairo, Egypt.
46. 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.
47. McManus C, Paluda GR, Louvandini H, Gugel R, Sasaki LCB, Paiva SR. 2009. Heat tolerance in Brazilian sheep: physiological and blood parameters. Trop Anim Health Prod. 41:95–101. doi:10.1007/s11250-008-9162-1.
48. Milne JA, MacRae JC, Spence AM, Wilson S. 1978. A comparison of the voluntary intake and digestion of a range of forages at different times of the year by sheep and the red deer *(Cervus elaphus).* Br J Nutr. 40:347-357.
49. Muller CJC. Botha JA, Smith WW. 1994a. Effect of shade on various parameters of Friesian cows in a Mediterranean climate in South Africa. 1. Feed and water intake, milk production and milk composition. South Afric J Anim Sci. 24:49–55.
50. Nienaber JA, Hahn GL, Eigenberg RA. 1999. Quantifying livestock responses for heat stress management: a review. Int J Biometeorol. 42 (4):183–188.
51. Nienaber JA, Hahn GL. 2007. Livestock production system management responses to thermal challenges. Int J Biometeorol. 52:149–157.
52. Nwosu CC, Ogbu CC. 2011. Climate change and livestock production in nigeria: issues and concerns. Agro-Science J Trop Agri, Food, Environ Extension. 10:41 -60.
53. Patkowski K, Pieta M, Lipecka C. 2006. Effect of maintenance system on the reproduction of sheep as well as the level of some morphological and biochemical blood indicators. Arch Tierz. 49:297-304.

54. Pereira AMF. Baccari Jr. F, Titto EAL, Almeida JAA. 2008. Effect of thermal stress on physiological parameters, feed intake and plasma thyroid hormones concentration in Alentejana, Mertolenga, Frisian and Limousine cattle breeds. Int J Biometeorol. 52:199–208.
55. Piccione G, Giannetto C, Casella S, Caola G. 2009. Annual rhythms of some physiological parameters in Ovis aries and Capra hircus. Biol Rhythm Res. 40:455-464.
56. Riley DG, Chase Jr. CC, Coleman SW, Olson TA. 2012. Genetic assessment of rectal temperature and coats core in Brahman, Angus, and Romosinuano crossbred and straightbred cows and calves under subtropical summer conditions. Livest Sci. 148:109–118.
57. Rivington M, Matthews KB, Buchan K, Miller D, Russell G. 2009. Investigating climate change impacts and adaptation options using integrated assessment methods. Aspects Appl Biol. 93:85–92.
58. Rowlinson P. 2008. Adapting livestock production systems to climate change - Temperate zones. Livestock and global change conference proceeding. May 2008, Tunisia.
59. Sejian V, Maurya VP, Kumar K, Naqvi SMK. 2012. Effect of multiple stresses on growth and adaptive capability of Malpura ewes under semi-arid tropical environment. Trop Anim Health Prod. 45(1):107-16.
60. Sevi A, Albenzio M, Annicchiarico G, Caroprese M, Marino R, Taibi L. 2002. Effects of ventilation regimen on the welfare and performance oflactating ewes in summer. J Anim Sci. 80:2341 - 2361.
61. Shafie MM, Murad HM, El- Bedawy TM, Salem SM. 1994. Effect of heat stress on feed intake, rumen fermentation and water turnover in relation to heat tolerance response by sheep. Egypt J Anim Prod. 31 (2): 317–327.
62. Shalaby TH. 1985. Performance and adaptation of local sheep to varied environmental and managerial conditions. Ph.D. thesis. Faculty of Agriculture, Cairo University, Cairo, Egypt.
63. Shelton M. 2000. Reproductive performance of sheep exposed to hot environments. In: Malik RC, Razzaque MA, Al-Nasser AY. Editors. Sheep Production in Hot and Arid Zones. The Kuwait Institute for Scientific Research; p. 155–162.
64. Silanikove N. 1992. Effect of water scarcity and hot environment on appetite and digestion in ruminants: a review. Livest Prod Sci. 30:175-194.
65. Silanikove N. 2000. Effects of heat stress on the welfare of extensively managed domestic ruminants. Livest Prod Sci. 67:1 - 18.
66. 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 Rumin Res. 49:193–8.
67. Stainer MW, Mount LE, Bligh J. 1984. Energy balance and temperature regulation. In: Yousef MK. editor. Stress physiology in livestock. Cambridge: Cambridge university press Ungulates. Boca Raton: CRC Press, 1985. v.2.
68. Starling JMC, Silva RG, Negrão JA, Maia ASC, Bueno AR. 2005. Variação estacional dos hormônios tireoideanos e do cortisol em ovinos em ambiente tropical. R Bras Zootec. 34:2064-2073.
69. Steinfeld H, Gerber P, Wassener T, Castel V, Rosales M, de Haan C. 2006. Livestock's long shadow. Environmental issues and options, FAO, Rome.
70. Sudarman, Ito T. 2000. Heat Production and Thermoregulatory Responses of Sheep

Fed Different Roughage Proportion Diets and Intake Levels When Exposed to a High Ambient Temperature. Asian-Austalasian J Anim Sci. 13:325–629.

71. Sunagawa K, Arikawa Y, Higashi M, Matsuda H, Takahashi H, Kuriwaki Z, Kojiya Z, Uechi S, Hong F. 2002. Direct effect of a hot environment on ruminal motility in sheep. Asian Austalasian J Anim Sci. 6:859–65.
72. Sunagawa, K., Y. Arikawa, M. Higashi, H. Matsuda, H. Takahashi, Z. Kuriwaki, Z. Kojiya, S. Uechi and F. Hong, 2002. Direct effect of a hot environment on ruminal motility in sheep. Asian Austalasian J Anim Sci. 6: 859–65
73. Svotwa E, Makarau A, Hamudikuwanda H. 2007. Heat tolerance of Mashona, Brahman and Simmental cattle breeds under warm humid summer conditions of natural region II area of ZImbabew. J Environ Agri Food Chem. 6(4): 1934 - 1944.
74. Tubiello FN, Soussana JF, Howden SM. 2007. Crop and pasture response to climate change. Proc Natl Acad Sci *U S A.* 104:19 686 -19 690. doi:10.1073/ pnas.0701728104.
75. Turner HG. 1982. Genetic variation of rectal temperature in cows and its relationship to fertility. Anim Prod Sci. 35:401–412.
76. Valtorta SE. 2002. Animal production in a changing climate: Impacts and mitigation. Paper 15th conf. on Biometeorology/Aerobiology and 16th Int congress of Biometeorol. 28 October 2002 Kansas City, M.O.
77. West JW. 2003. Effects of heat-stress on production in dairy cattle. J Dairy Sci. 86: 2131–2144. doi:10.3168/jds.S0022-0302(03)73803-X.
78. Wilson SJ, Marion RS, Spain JN, Spiers DE, Keisler DH, Lucy MC. 1998. Effects of controlled heat stress on ovarian function of dairy cattle. 1. Lactating cows. J Dairy Sci. 81:2124–2131.
79. Wise ME, Armstrong DV, Huber JT, Hunter R, Wiersma F. 1988. J Dairy Sci. 71:2480-2485.
80. Yamamoto S, Ogura Y. 1985. Variations in heart rate and relationship between heart rate and heat production of breeding Japanese Black Cattle. Japanese J Livestock Manag. 3: 109–18.
81. Yousef HM. 1985. Studies on some environmental factors affecting production and reproduction in some farm animals. MSc Thesis, Faculty of Agriculture, Zagazig University, Zagazig.
82. Yousef HM. 1985. Studies on some environmental factors affecting production and reproduction in some farm animals. M.Sc. thesis. Faculty of Agriculture, Zagazig University, Zagazig, Egypt.