EFFECT OF HEAT STRESS ON THERMOREGULATORY, LIVE BODYWEIGHT AND PHYSIOLOGICAL RESPONSES OF DWARF GOATS IN SOUTHERN NIGERIA

M.I. Okoruwa
Department of Animal Science, Ambrose Alli University,
EKpoma, Edo State. Nigeria

Abstract

The study was conducted to investigate the effect of heat stress on thermoregulatory, live bodyweight and physiological responses of dwarf goats in southern Nigeria. Twenty-four West African dwarf goats, aged between 8 and 9 months with average bodyweight of 8.00$\pm$0.53kg were used for the study. The goats were assigned to three (T_1, T_2 & T_3) treatment groups in a completely randomized design with eight goats per treatment group. T_1 goats were confined in their pens throughout the study. T_2 goats were opened from their pens to the open yard between 8.00am and 1.00 pm daily, while T_3 goats were opened from their pens to open yard between 1.00pm and 6.00pm daily. The results obtained showed that morning time was significantly (P<0.05) highest in relative humidity (62.51%), while afternoon time was highest (P<0.05) in ambient temperature (33.01^{0}C) and temperature-humidity index (83.97). Final and change in live bodyweight (8.66 and 0.04kg), white blood cell $\left(12.60\times10^9/L\right)$ and serum calcium $\left(12.66\,mmol/L\right)$ were significantly (P<0.05) best in T_1 compared to T_2 and T_3. Rectal and skin temperature (41.02 and 40.68^{0}C), respiratory rate (23.01 breaths/min), pulse rate (91.04 beats/min), packed cell volume (32.34%), haemoglobin (9.09g/dl), red blood cell $\left(10.37\times10^{12}/L\right)$, total protein (5.12g/dl), albumin (3.88g/dl), albumin and globulin ratio (3.13%), glucose (71.01mg/dl), sodium (104.35mmol/L) and potassium (6.22mmol/L) were significantly highest in T_3. No significant (P>0.05) different was observed in initial live bodyweight and serum globulin. It is concluded that heat stress had significant effect on thermoregulatory, live bodyweight and physiological responses of dwarf goats in southern Nigeria.

Keywords: Heat stress, thermoregulatory, bodyweight, physiology, goats.

Introduction

Goats and sheep are important small ruminant resources in the tropics, where they play a predominant role in the sustenance of the livelihoods of impoverished families especially in the rural areas. They are widely distributed in Africa with 31.7% of the goats and 16.3% of the sheep population (Ozung *et al*., 2011). Yakubu *et al*. (2010) also reported that goats and sheep population represent about 63.70% of the total grazing domestic animal across the rainforest belt of southern Nigeria. Goats and sheep can be reared for various reasons which contribute significantly to the economy of the people in form of income generation, religious purpose, household consumption and hobby as well as security against crop failure. Hirpa and Abebe (2008) indicated that goats and sheep have served as means of ready cash and a reserved against economic and agricultural production hardship in rural areas. Ozung *et al* (2011) also noted that goats contribute 16.0% and sheep 5.0% of the total domestically produced meat in Nigeria, which has been estimated at 813,000 tonnes annually.

Goats are generally compacted and able to expose large surface per unit weight in order to dissipate heat. The diversity of different climatic conditions within tropics has given rise to differential adaptive mechanisms that enable goats to cope effectively with a variety of stressful tropical environmental conditions. The physiological response of goats to environmental stress during the dry and wet season with their energy balance showed that seasonal heat and cold stress have profound effects on some thermoregulatory live bodyweight and physiological parameters. Several authors (Helal *et al*., 2010; Sanusi *et al*., 2010) have indicated that the best thermo-physiological parameters to objectively monitor animal welfare in harsh environment are rectal temperature, respiratory rate and blood indices. Hence, the ability of goats to maintain heat adaptation capacity to harsh environment need to be studied.

Heat stress is more common in the dry season and especially when the environmental temperature and relative humidity are high with prolonged exposure to direct sunlight. Thus, heat stress has been generally associated with detrimental effects on physiological equilibriums of goats and their various systems (nervous, endocrine and immune) have been implicated with specific responses and reciprocal regulatory influences (Castanheira *et al*., 2010). Blood profile of animals are particularly sensitive to changes in the environmental temperature, being important indicator of physiological responses to stressing agent in goats. The present study was therefore designed to determine the effect of heat stress on thermoregulatory, live bodyweight and physiological responses of dwarf goats in southern Nigeria.

Materials and Methods

Study Area: The study was conducted during the dry season (between January and February) at sheep and goat Unit of the Teaching and Research Farm, Ambrose Alli University, EKpoma. The area lies between latitudes 6.42^0N and longitudes 6.09^0E, which is about 3km from Ekpoma town. Geographically, Ekpoma is within the south-south geo-political zone of Nigeria. The vegetation represents an interface between the tropical rainforest and the derived savannah. The area has mean annual rainfall and ambient temperature of about 1556mm and 31^0C respectively.

Animals, Housing and Feeding: A total of 24 West African dwarf male goats (bucks), aged between 8 and 9 months with mean body weight of 8.00 ± 0.53kg were used for the study. The dwarf goats were procured from sheep and goats weekly market located at Ekpoma. The animals proved to be free from internal and external parasites and were kept under close clinical observation throughout the experimental period. The goats were housed individually in a partially shaded pen with open yard. The dwarf goats were divided into three treatment groups (T_1, T_2 and T_3) with eight dwarf goats per treatment group in a completely randomized design. T_1 goats were confined in their individual pens throughout the experimental period. T_2 goats were opened from their individual pens to the open yard at 8.00am (morning) and returned to their pens at 1.00pm (afternoon). T_3 goats were opened from their individual pens to the open yard at 1.00pm (afternoon) and returned to their pens at 6.00pm (evening). This enables each animal on T_2 and T_3 to receive direct solar radiation for 5 hours at different time daily throughout the experimental period.

However, the experimental goats were fed on guinea grass with concentrates as total mixed ration (ME 1950Kcal/Kg, crude protein 13%, crude fat 2%, crude fibre 10%, ash 8%) on dry matter (DM) basis to meet their metabolic energy maintenance requirement. The feeds at a level of 2.5% of their body weight was offered twice daily at 8.00am and 4.00pm. Clean fresh water was given to the goats once daily *ad. libtum*. The experiment lasted for 4 weeks excluding the 2 weeks for adaptation period.

Collection of Data

Climatic Data: Ambient temperature (AT, ^{0}C) and relative humidity (RH%) were measured three times daily at 9.00am (morning), 1.00pm (afternoon) and 5.00pm (evening) using a thermometer and barometer respectively, throughout the study. Temperature-humidity index (THI) was calculated using the formula below as reported by Amundson *et al*. (2006); Helal *et al*. (2010).

$$THI = 0.8 \times AT^0C + (RH,\%) \times \left(AT^0C - 14.4\right)/100) + 46.4$$

Thermoregulatory and Live Bodyweight Data: Rectal temperature, skin temperature, respiratory rate and pulse rate in each goat were measured three times (morning, afternoon and evening) at 9.00, 13.00 and 16.00 hr daily. Rectal temperature was measured using digital thermometer. The sensory tip was disinfected and inserted into the rectum at the display of L^0C by the thermometer (which indicated that the thermometer is set for the temperature reading). This was removed after the sound of the alarm signal. The displayed body temperature was then recorded. Skin temperature was measured with infrared thermometer in four shaved regions (right and left shoulder with right and left hips). Respiratory rate was determined by counting the number of abdominal movement per minute. Pulse rate was recorded by placing the finger tips on the femoral arteries of the hind limb for one minute and read from the stopwatch as reported by Sanusi *et al*. (2010).

Live bodyweight (LBW, Kg) of goats in each treatment group was measured at the beginning and the end of the experimental period. The rate of change in live bodyweight of each goat was calculated.

Physiological Data: Blood samples (two weeks interval) were taken from jugular vein from each goat in the morning before access to feed and water. The blood samples were placed into two different 5ml vacuum tubes. One of the 5ml set of blood tubes contained ethylene diamine tetra-acetic acid (anti-coagulant) for haematological studies. The packed cell volume (PCV, %), haemoglobin (Hb, g/dl), red blood cell $\left(RBC \times 10^{12}/L\right)$ and white blood cell $\left(WBC \times 10^{9}/L\right)$ were analysed as described by Al-Eissa and Alkahtani (2011); Okoruwa and Ikhimioya (2014).

The second 5ml vacuum set of blood tubes without anticoagulant were centrifuged for 20 minute at 3500rpm to collect plasma and stored at -20^0C for chemical analysis. Total plasma proteins (TP, g/dl), albumin concentration (Al, g/dl) was determined according to the method reported by Helal *et al*. (2010). Total plasma globulins concentration (Gl, g/dl) was calculated as the difference between total plasma proteins and plasma albumin, then albumin: globulin ratio (Al/GL, %) was calculated. Glucose (Glu, mg/dl), sodium (Na^+, mmol/L) potassium (K^+, mmol/L) and calcium (Ca^{+2}, mmol/L) were estimated according to the method reported by Sanusi *et al*. (2010); Al-Haidary *et al*. (2012).

Statistical Analysis: Data obtained from thermoregulatory, live bodyweight and physiological indices were analyzed using the Generalized Liner Model (GLM) of SAS (2003) software package. Statistical means were compared using Duncan Multiple Range Test (DMRT).

Results and Discussion

The mean climatologically values of ambient temperature (AT, ^{0}C), relative humidity (RH, %) and temperature-humidity index (THI) for the experimental period are shown in Table 1. Ambient temperature for afternoon (33.01^{0}C) was significantly ($P<0.05$) highest compared to morning (21.98^{0}C) and evening (23.24^{0}C). The observed ambient temperature for afternoon in this study was higher than the critical temperature of 24 to 27^{0}C for most species as indicated by Helal *et al*. (2010). The relative humidity that ranged between 59.98 and 62.51% was significantly ($P<0.05$) lower in the afternoon compared to morning and evening. Relative humidity values obtained in this study was higher than the reported ranged of values (9.20 to 33.93%) by Al-Haidary *et al*. (2013). Temperature-humidity index values of 68.72, 83.97 and 69.98 were recorded for morning, afternoon and evening respectively. Temperature humidity index observed in the morning and evening were significantly ($P<0.05$) lower than the afternoon. The temperature humidity index of 74 or less is considered normal, 75 to 78 is alert status, 79 to 83 is danger status and a temperature-humidity index equal to or above 84 is an emergency as reported by Helal *et al*. (2010). In this present study, the temperature-humidity index was higher than 83 in the afternoon during the experimental period and classified as severe heat stress. Thus, the obtained climatic data revealed that goats exposed to solar radiation in the afternoon during this experimental period were extreme heat stressed.

Table 1. Climatic data prevailed during the experimental period

Climatic parameters	Time			SEM$\pm$
	Morning	Afternoon	Evening	
Ambient temperature (^{0}C)	21.98^b	33.01^a	23.24^b	0.31
Relative humidity (%)	62.51^a	59.98^b	61.00^a	1.06
Temperature humidity index	68.72^b	83.97^a	69.98^b	1.64

$^{a, b}$ means within the same row with different superscripts differ significantly ($P<0.05$). SEM = Standard error of mean.

Table 2. Thermoregulatory and live bodyweight parameters of dwarf goats as affected by heat stress in southern Nigeria.

Parameters	Treatments			SEM$\pm$
	T_1	T_2	T_3	
Thermoregulatory				
Rectal temperature (^{0}C)	37.98^c	39.07^b	41.02^a	0.54
Skin temperature (^{0}C)	36.63^b	38.99^b	40.68^a	0.76
Respiratory rate (breaths/min)	16.04^b	18.98^b	23.01^a	0.96
Pulse rate (beats/min)	78.38^c	82.01^b	91.04^a	1.89
Live bodyweight (Kg)				
Initial live body weight	8.62	8.54	8.42	0.29
Final live body weight	8.66^a	7.80^b	6.40^c	0.16
Change in live body weight	0.04^a	–0.74^b	–2.02^c	–0.12

$^{a, b, c}$ means within the same row with different superscripts differ significantly ($P<0.05$). SEM = Standard error of means.

Table 2, presents the effect of heat stress on thermoregulatory and live bodyweight parameters of dwarf goats in southern Nigeria. Rectal temperature was significantly ($P<0.05$) highest in T_3 (41.02^0C) followed by T_2 (39.07^0C) before T_1 (37.98^0C). Otoikhian *et al* (2009) reported that the increase in rectal temperature of animal has been considered as a good indicator to the level of heat stress upon the animal. Therefore the observed elevation in the rectal temperature for goats on T_3 indicated that, they were heat stressed. Skin temperature values of 36.63, 38.99 and 40.68^0C that were obtained for T_1, T_2 and T_3 respectively, was significantly ($P<0.05$) highest in T_3 and lowest in T_1. The observed increase in skin temperature for goats on T_3 was also attributed to the exposure to heat stress, which has been reported to cause vasodilatation of skin capillary bed and consequently increase the blood flow to the skin surface to facilitate heat dissipation (McManus *et al*., 2009). Skin temperature could also be elevated due to solar radiation, as skin temperature has been shown to be directly related to ambient solar radiation levels (Schutz *et al*., 2011). Respiratory rate was not significantly ($P>0.05$) different between T_1 (16.04 breaths/min) and T_2 (18.98 breaths/min) but T_3 (23.01 breaths/min) was significantly ($P<0.05$) higher than T_1 and T_2. Al-Haidary *et al*. (2012) stated that respiration rate can be used to estimate the adverse effects of environmental temperature and as an indicator of heat stress. Okourwa *et al*. (2013) also reported that respiratory rate is practical and reliable measure of heat load and stated that respiratory rate above 12 to 20 breath/minute in sheep and goats is an indicator of heat stress. Thus the observed acceleration of respiratory rate of goats on T_3 indicated that, they were exposed to severe heat stress which increased their panting. Panting is the major evaporating heat loss mechanism and respiratory frequencies tend to follow closely the heat loss by evaporation (Marai *et al*., 2007). Pulse rate which was significantly ($P<0.05$) highest in T_3 (91.04 beats/min) and lowest in T_1 (78.38 beats/min) showed the same pattern of variation concurrently with that of rectal temperature. The higher significant ($P<0.05$) pulse rate obtained in T_3 could be due to the redistribution of blood to peripheral tissues during heat exposure in goats. This finding supports the previous reports of McManus *et al*. (2009) for sheep.

The initial live bodyweight at the commencement of the study was not significantly ($P>0.05$) affected by treatment groups. The final live bodyweight had significantly ($P<0.05$) effect on treatment groups, the goats on T_1 (8.66kg) had the highest final live bodyweight, followed by T_2 (7.80kg) and then T_3 (6.40kg). Regarding the effect of heat stress on live bodyweight, exposure of goats to solar radiation for different time daily declined final live bodyweight in this study. The rates of change in live bodyweight recorded were 0.04, –0.74 and –2.02kg for goats on T_1, T_2 and T_3 respectively. This revealed that the rate of decreased for change in live bodyweight was higher in T_3 compared with T_2. Similar observation was reported by Helal *et al*. (2010), who found that exposure of goats to solar radiation for 12 hours increased loss in live body weight and packed cell volume (PCV) of the goats. Ocak *et al*. (2009) also attributed that loss of live bodyweight during exposure to solar radiation increase energy expended for heat dissipation through respiratory evaporation and subsequently to reduction in the amount of water available for storage.

Table 3. Effects of heat stress on haematological and serum biochemical indices of dwarf goats in southern Nigeria.

Parameters	Treatments			SEM±
	T_1	T_2	T_3	
Haematology				
$PCV(\%)$	27.56^{b}	30.42^{a}	32.34^{a}	0.72
$Hb(g/dl)$	6.99^{b}	9.06^{a}	9.09^{a}	0.04
$RBC(\times 10^{12}/L)$	5.98^{b}	8.79^{a}	10.37^{a}	0.12
WBC ($X10^9$/L)	12.60^{a}	10.25^{a}	5.96^{b}	0.20
Serum biochemistry				
$TP(g/dl)$	3.99^{b}	4.02^{b}	5.12^{a}	0.68
$AL(g/dl)$	2.89^{b}	2.90^{b}	3.88^{a}	0.03
$GL(g/dl)$	1.10	1.12	1.24	0.01
$AL/GL(\%)$	2.63^{b}	2.59^{b}	3.13^{a}	0.06
$GLU(Mg/dl)$	55.60^{c}	60.73^{b}	71.01^{a}	1.67
$Na^{+}(mmol/L)$	89.72^{b}	92.64^{b}	104.35^{a}	2.13
$K^{+}(mmol/L)$	3.16^{b}	4.98^{b}	6.22^{a}	0.75
$Ca^{+2}(mmol/L)$	12.66^{a}	10.42^{a}	8.97^{b}	0.08

$^{a, b, c}$ means within the same row with different superscripts differ significantly (P<0.05). SEM = Standard error of means.

Table 3, indicates haematological and serum biochemical indices of dwarf goats as affected by heat stress in southern Nigeria. All the haematological parameters observed were significantly (P<0.05) affected by treatment groups. Packed cell volume (PCV) was significantly (P<0.05) higher in T_3 (32.34%) and T_2 (30.42%) than T_1 (27.65%). This observation could be influenced by the higher rectal temperature and respiratory rate resulted from severe heat for goats on T_3 and T_2. Al-Haidary *et al*. (2012) reported that higher PCV values are an adaptive mechanism of animals to provide the necessary water required for evaporative cooling process. The concentration of haemoglobin (Hb) and red blood cell (RBC) were significantly (P<0.05) higher in T_3 (9.09 g/dl and $10.37x10^{12}$/L) and T_2 (9.06 g/dl and $8.79x10^{12}$/L) compared with T_1 (6.99 g/dl and $5.98x10^{12}$/L). This observed difference could be attributed to the higher heat load for goats on

T_3 and T_2 which brought physiological need for increase in haemoglobin and red blood cell to cope with oxygen circulation during panting. This explanation was in harmony with the result found by Sanusi *et al*. (2010) who reported that heat stress increased haemoglobin and red blood cell concentration in sheep. White blood cell (WBC) was significantly ($P<0.05$) lower in T_3 ($5.96x10^9$/L) compared to T_2 ($10.25x10^9$/L) and T_1 ($12.60x10^9$/L). This variation in WBC could be the effect of rectal temperature and immunological challenged of the studied goats that attributed to physiological adjustment that presented against negative antigenic effect. Similar observation was reported by Okoruwa *et al*. (2013) who observed significant ($P<0.05$) lower in white blood cell for studied dwarf bucks of higher rectal temperature.

Serum biochemical parameters were also significantly ($P<0.05$) affected by treatment groups, except globulin (GL, g/dl) that was not significantly ($P>0.05$). The significant ($P<0.05$) increased in the serum concentration of total protein (TP, 5.12g/dl), albumin (AL/GL, 3.13%) and sodium (Na^+, 104.35mmol/L) for goats on T_3 could be due to dehydration which has been reported to occur as a result of increased breathing rate (Erickson and Poole, 2006). Moreover, glucose (Glu) and potassium (K^+) varied significantly ($P<0.05$) between treatment groups with T_3 (71.01mg/dl and 6.22mmol/L) recorded the highest and T_1 (55.60mg/dl and 3.16mmol/L) the lowest. This observed elevation of serum Glu and K^+ in T_3 could be due to the stress induced activation of cortical secretion and the consequent stimulation of gluconegenesis and potassium with inhibition of cellular glucose uptake and utilization (Marai *et al*., 2007). On the other hand, the observed significant ($P<0.05$) reduction in serum calcium (Ca^{+2}) concentration in T_3 (8.97mmol/L) could be attributed to the reduction in the dietary intake which has been reported under heat stress condition (Al-Haidary *et al*., 2012).

Conclusion

It was observed that the variation on thermoregulatory, live bodyweight and physiological traits in the studied goats were associated with the different in time of their exposure to environmental heat load. Therefore, the results of this study indicate that goats on T_3 were susceptible to heat stress than T_2 and T_1. However goat production under such condition in southern Nigeria and other parts of the world would require environmental and/or nutritional modification to alleviate the impact of heat stress on goats.

References:

Al-Eissa, M.S. and Alkahtani, S. (2011). Seasonal influence on some blood and biochemical parameters of Jerboa (*Jaculus jaculus*) in Saudi Arabia. *J. Res. Opin Anim. and Vet. Sci*., 1(5): 51–54.

Al-Haidary, A.A., Aljumaah, R.S., Alshaikh, M.A., Abdoun, K.A., Samara, E.M., Okah, A.B. and Aluraiji, M.M. (2012). Thermoregulatory and physiological responses of Najdi sheep exposed to environmental heat load prevailing in Saudi Arabi. *Pak. Vet. J*., 32(4): 515–519.

Al-Haidary, A.A., Samara, E.M., Okah, A.B. and Abdoun, K.A. (2013). Thermophysiological responses and heat tolerance of Saudi camel breeds. *Int. J. Chem. Environ. and Bio. Sci*., 1(1): 173–176.

Amundson, J.L., Mader, T.L., Rasby, R.J. and Hu, Q.S. (2006). Environmental effects on pregnancy rate in beef cattle. *J. Anim. Sci*., 84: 3415–3420.

Castanheira, M., Parva, S.R., Louvandini, H., Landim, A., Fiorvanti, M.C.S., Dallago, B.S., Correa, P.S. and McManus, C. (2010). Use of heat tolerance traits in discriminating between groups of sheep in central Brazil. *Trop. Anim. Health Prod*., 42: 1821–1828.

Erickson, H.H. and Poole, D.C. (2006). *Fisiologia do exercicio. In: Dukes fisiologia dos animal domesticos*. 12th Ed. (reece.wo.ed.). Rio de Janerio: Guanabara Koogan.

Helal, A., Hashem, A.L.S., Abdel-Fattah, M.S. and El-Shaer, H.M. (2010). Effects of heat stress on coat characteristics and physiological responses of Balady and Damascus goats in Sinai, Egypt. *American-Eurasian J. Agric. and Environ. Sci*., 7(1): 60–69.

Hirpa, A. and Abebe, G. (2008). Economic importance of sheep and goats. In: Sheep and goat production handbook for Ethiopia, Addis Ababa. Pp. 1–4.

Marai, I.F.M., El-Darawany, A.A., Fadiel, A. and Abdel-Hafez, M.A.M. (2007). Physiological traits as affected by heat stress in sheep. A review. *Small Rumin. Res*., 71: 1–12.

McManus, C., Prescott, E., Paludo, G.R., Bianchini, E., Louvandini, H. and Mariante, A.S. (2009). Heat tolerance in naturalized Brazilian cattle breeds. *Livest. Sci*., 120: 256–264.

Ocak, S., Darcan, N., Cankaya, S. and Inal, T.C. (2009). Physiological and biochemical responses in German fawn kids subjected to cooling treatments under mediterranean climatic conditions. *Turk J. Vet. Anim. Sci*. 33(6): 455–461.

Okoikhian, C.S.O., Ovheruata, J.A., Imasuen, J.A. and Akporhuarho, O.P. (2009). Physiological response of local (West African dwarf) and adapted switndzerla (white bornu) goat breed to varied climatic conditions in south-south Nigeria. *Afr. J. Gen. Agric*. 5: 1–6.

Okoruwa, M.I. and Ikhimioya, I. (2014). Haematological indices and serum biochemical profiles of dwarf goats fed elephant grass and varying levels of combined plantain with mango peels. *American. J. Exp. Agric*., 4(6): 619–628.
Okoruwa, M.I., Adewumi, M.K. and Igene, F.U. (2013). Thermophysiological responses of West African dwarf (WAD) bucks fed *Pennisetum purpureum* and unripe plantain peels. *Nig. J. Anim Sci*. 15: 168–178.
Ozung, P.O., Nsa, E.E., Ebegbulem, V.N. and Ubua, J.A. (2011). The potentials of small ruminant production in Cross River rainforest zone of Nigeria: A review. *Continental Journal of Animal and Veterinary Research*, 3(1): 33–37.
Sanusi, A.O., Peter, S.O., Sonibare, A.O. and Ozojie, M.O. (2010). Effects of coat colour on heat stress among West African dwarf sheep. *Nig. J. Anim. Prod*., 38(1): 28–36.
SAS (2003). *Statistical analysis system user's guide: Statistical version*. 8 edition. Cary. Nc.: SAS Institute.
Schutz, K.E., Roger, A.R., Cox, N.R., Webster, J.R. and Tucker, C.B. (2011). Dairy cattle prefer shade over sprinkler effects on behaviour and physiological. *J. Dairy Sci*., 94: 273–283.
Yakubu, A., Raji, A.O. and Omeje, J.N. (2010). Genetic and phenotypic differentiation of qualitative traits in Nigerian indigenous goat and sheep populations. *ARPN Journal of Agricultural and Biological Science*. 5(2): 58–59.