Genetic Variation in Thermotolerant Traits of Three Nigerian Goats Reared in the Humid Environment

Oguntade, D. O[1].; Isidahomen, C. E[1].; Loyinmi, I[1].; Igene, F. U[1].; Okoruwa, M. I[1].; Agboghidi, O[1]. and Ajewole, A[2].

[1]Department of Animal Science, Faculty of Agriculture Ambrose Alli University, Ekpoma, Edo State.

[2]Department of Animal Breeding and Genetics, Federal University of Agriculture, Abeokuta Ogun State.

Corresponding author: oguntadedo@aauekpoma.edu.ng; +2348154163003

Abstract

Heat stress is a major stressor that affects the production performance of livestock species in tropical region. There is need to examine the relative adaptability to heat stress of the major goat breeds in Nigeria for optimization of rearing environment which can enhance their productivity. Genetic variation in thermo-tolerant traits of three major Nigerian goats (West African Dwarf (WAD), Red Sokoto and Sahel goats) were investigated at the Sheep and Goat Unit, Teaching and Research Farm, Ambrose Alli University, Ekpoma, Edo State, Nigeria for a period of twelve weeks between December and February. A total of 60 just weaned goats of about 12 weeks old and 10-12 kg body weight comprising 20 each of West African Dwarf (WAD), Sahel and Red Sokoto goats were used for this experiment. The sex of each animal was determined by physical examination of the reproductive organs. Meteorological data of the environment including the ambient temperature, relative humidity and temperature-humidity index (THI) were taken in the morning (7:00 am) and afternoon (1:00pm) on daily basis. The thermo-tolerant traits such as rectal temperature (RT), respiratory rate (RR) and pulse rate (PR) were measured while the heat stresse index (HSI) was calculated biweekly. There was no significant difference (p>0.05) in the meteorological parameters examined with respect to the period of the day. The WAD goat had significantly higher RT and RR (p<0.05) in most of the weeks of the study. Likewise, the PR and HSI were higher and frequently fluctuated among the WAD goats than Sahel and Red Sokoto goats. There exist sexual dimorphisms in thermo-tolerant traits among the three breeds of indigenous goats. The Sahel and Red Sokoto goats showed minimum variations in RT, RR, PR and HSI and therefore could be upgraded to obtain high performance tropically adapted goat breeds.

Keywords: Thermotolerant; WAD goat; Sahel goat; Red Sokoto goat; Respiratory rate; heat stress index.

Variation Génétique des Caractéristiques Thermotolérantes de Trois Chèvres Nigérianes Élevées dans un Environnement Humide

Résumé

Le stress thermique est un facteur de stress majeur qui affecte la performance de production des espèces d'élevage dans les régions tropicales. Il est nécessaire d'examiner l'adaptabilité relative au stress thermique des principales races de chèvres au Nigeria afin d'optimiser l'environnement d'élevage, ce qui peut améliorer leur productivité. La variation génétique des traits thermotolérants de trois principales chèvres nigérianes (la chèvre West African Dwarf (WAD), la chèvre Sokoto rouge et la chèvre du Sahel) a été étudiée à l'Unité de Moutons et de Chèvres, à la Ferme d'Enseignement et de Recherche de l'Université Ambrose Alli, à Ekpoma, dans l'État d'Edo, au Nigeria, pendant une période de douze semaines entre décembre et février. Un total de 60 chèvres récemment sevrées d'environ 12 semaines et pesant entre 10 et 12 kg, comprenant 20 individus de chaque race (WAD, Sahel et Red Sokoto), a été utilisé pour cette *expérience. Le sexe de chaque animal a été déterminé par l'examen physique des organes reproducteurs. Les données météorologiques de l'environnement, y compris la température ambiante, l'humidité relative et l'indice température-humidité (ITH), ont été recueillies le matin (7h00) et l'après-midi (13h00) chaque jour. Les traits thermotolérants tels que la température rectale (TR), le taux respiratoire (TR) et le rythme cardiaque (RC) ont été mesurés, tandis que l'indice de stress thermique (IST) a été calculé toutes les deux semaines. Aucune différence significative (p>0,05) n'a été observée dans les paramètres météorologiques examinés par rapport à la période de la journée. La chèvre WAD a présenté des TR et TR significativement plus élevés (p<0,05) pendant la plupart des semaines de l'étude. De même, le RC et l'IST étaient plus élevés et fluctuaient fréquemment chez les chèvres WAD par rapport aux chèvres du Sahel et Sokoto rouge. Des dimorphismes sexuels dans les traits thermotolérants existent entre les trois races de chèvres indigènes. Les chèvres du Sahel et Sokoto rouge ont montré des variations minimales dans la TR, TR, RC et IST et pourraient donc être améliorées pour obtenir des races de chèvres adaptées aux tropiques et à haute performance.*

Mots-Clés : Thermotolérant ; Chèvre WAD ; Chèvre du Sahel ; Chèvre Red Sokoto; Taux respiratoire; Indice de stress thermique.

Running title: Thermotolerant Traits of Three Nigerian Goats in the tropics

Introduction

Livestock is an asset and basis of the livelihood for the majority of Nigerians (Herrero *et al.*, 2013). Their roles are evidenced in economic, social and cultural development of the country. Among the small ruminants in Nigeria, goat plays a significant economic role for the farming communities living in different parts of the country. This is probably as a result of it smaller body size and high prolific nature. In addition, goats have lower requirements in terms of management, capital and maintenance costs. They are a good source of revenue in case of emergency cash requirement such as children welfare and other purposes (Jorgen *et al.*, 2007). Goats have the ability to produce milk and meat under harsh environmental conditions that might limit productivity of sheep and cattle (Getachew *et al.*, 2000). Generally, the major constraints to proliferation of livestock sector in Nigerian could be summarized as shortage of animal feeds, grazing land, livestock health problems and low genetic potential (Oyeyemi *et al.*, 2011).

The Nigerian indigenous breeds of goats are well adapted to the agro-climatic conditions of the country and are generally hardy enough to grow well on poor forage and stressful conditions than high yielding exotic and crossbred animals (Nyamushamba *et al.*, 2017). Although Nigerian goats are relatively smaller in size, however, it is a genetic adaptive tactic for surviving under limited nutrient resources (Adedeji *et al.*, 2011). The indigenous breeds of goat are generally expected to adapt better due to their inherent genetic potential. However, variations exist among them due to wide range of climatic variations in the tropical environment.

The Red Sokoto goat together with the Sahel goats, make up the Savannah group of West African goats. The Red Sokoto goat in particular gained global recognition due to its high quality skin which is used for the production of Morocco leather. However, the most popular breed of goat in the humid region of West Africa is the West African Dwarf (WAD) goat. It is short, small and well adapted to the hot-humid coastal climate of West Africa, a climate established to have a relatively high annual ambient temperature that is hardly below 25 °C and a high annual relative humidity, ranging from 60% in the morning to 80% in the afternoon hours (Adedeji *et al.*, 2011). Indeed, growth of an animal is influenced by environmental and genetic factors. Growth is a major selection criterion for the meat-type animals and is considered a crucial factor which determines the meat production (Pragna *et al.*, 2018). Small ruminants (goat and sheep) are often faced with weather vulgar each year, especially during the harmattan period of the year usually called cold-dry season or the “West African cold season” (Habibu *et al.*, 2017). This period usually spans from late November to the middle of March in Nigeria.

Reduction in growth performance due to the variation in the climatic factors is thus an important limiting factor that threatens the meat industry in the tropical region (Mpofu *et al.*, 2017). This is because among the various environmental stressors, heat stress (which may arise from climate change) is a major stressor that affects the production performance of livestock species, particularly in the tropical region. The heat stressed animals always display slow growth, low production and reproductive performances in order to adapt to elevated ambient temperature conditions (Pragna *et al.*, 2018). This phenomenon is associated with animals under heat stress in the tropical and subtropical regions of the globe. The slow growth rate in livestock under heat stress could be attributed to decreased anabolic activity due to the reduced feed intake and enhanced tissue catabolism. Several researches have reported alteration in the growth parameters during thermal exposure (Popoola *et al.*, 2014; Habibu *et al.,* 2016). Among the several growth variables, body weight is mostly affected by heat stress in livestock. In addition, in a study conducted in West African dwarf goats exposed to summer heat stress (32.9°C), average daily gain (ADG) was reported to be reduced which could be attributed to the decrease in feed intake (Habibu *et al.*, 2016). Further, Habibu *et al.* (2016) reported a significant reduction in body mass index (BMI) in Sahel and Red Sokoto kids after thermal (38.8°C) exposure while Sejian *et al.* (2010) reported a significant reduction in body condition score (BCS) in heat stressed (40°C) Malpura ewes. It has been generally established that different indigenous breeds exhibit superior adaptive capabilities in their respective agro-ecological zones and among these, only few breeds possess the ability to thrive well in different agro-ecological zones due to their higher genetic merit (Helal *et al.,* 2010). Nevertheless, there is paucity of information on thermo-tolerant traits in major breeds of goats in Nigeria. Nigeria is a tropical country characterised by constant high temperatures throughout the year. The survivability and productivity of any livestock species in Nigeria is relatively dependent on the ability of such livestock to cope under heat stressed environment. Therefore, understanding some physiological parameters like pulse rate, respiratory rate and rectal temperature could be used to monitor heat stress in livestock. This is because the combine effects of these parameters could be used to determine their adaptability in a particular environment.

Therefore, this study is conducted to investigate variation in thermo-tolerant traits of three different indigenous breeds of goats reared in hot humid environment.

Materials and Methods

***Experimental Location and Climate*:** The experiment was carried out at the Poultry Unit of the Teaching and Research Farm, Ambrose Alli University, Ekpoma, Edo State of Nigeria. The farm is located in the tropical zone and rain forest vegetation belt in Nigeria. It lies between latitude 6.44°N and longitude 6.8°E in Esan West Local Government Area Ekpoma, Edo State, Nigeria. Ekpoma is within the South - South geo-political zone of Nigeria. The annual rain fall ranges from 1500mm – 2000mm. The mean ambient temperature ranges from 26°C in December to 34°C in February, relative humidity ranges from 61% in January to 92% in August with yearly average of about 82%.

***Experimental animals and management*:** A total of 60 goats comprising 20 each of West African Dwarf (WAD), Sahel and Red Sokoto goats were used for this experiment. The WAD goats were purchased from a reputable farm within Ekpoma

Edo State while the Sahel and Red Sokoto goats were sourced from Northern part of Nigeria where they are predominantly found.

Determination of the experimental goat age: The goats used for this study were just weaned and of similar age bracket (between 2 to 3 months) and body weights (between 10 to 12kg).

Determination of sex: The sex of each animal was determined by physical examination of the reproductive organs. Those with testes were grouped as males while those with mammary gland females. A total of 10 males and 10 females were identified in each of the three breeds.

Management of Experimental Animals: The goats were housed in pens for a period of 12 weeks. Adequate ventilation was ensured within the pens. The three breeds of goats were housed together at a stocking density of 20 goats per pen and properly tagged for identification and data collection purposes. All the experimental goats were routinely screened for ectoparasites and endoparasites. The goats were allowed to graze freely on *Digitaria smutsi* as basal diet and supplemented with concentrate ration of crushed maize (25%), Soya bean meal (30%), wheat offal (37%), bone meal (4%) and salt (4%) at 300 g/head/ day. Cool drinking water was provided *ad libitum*.

***Determination of thermotolerant trait*s: The respiratory rate** was determined by counting each movement of the flank around the para-lumbar fossa per unit time, and expressed in number of breaths per minute. **The Pulse rate or Heart rate** was determined by counting the beats of the heart using a stethoscope per unit time, and expressed in number of beats per minute. **The body temperature of the goats** was recorded by determining the rectal temperature of the goats using a digital thermometer (Tro-Digitatherm, Hamburg Germany) and presented in degree Celsius (°C) (Habibu *et al.,* 2016; Yaqub *et al.,* 2017).

***Determination of meteorological parameters*:** Dry and wet-bulb temperatures were obtained at 07:00 am and 1:00 pm in the morning and afternoon, respectively, on daily basis during the experimental period. Relative humidity (RH) values were measured using hydrometer in percentage.

The temperature humidity index (THI) was used to evaluate the level of heat stress induced by the environment and was calculated using the equation reported by Ravagnolo *et al.* (2000):

$$THI = (1.8 \times T + 32) - \{(0.55 - 0.0055\,RH)(1.8 \times T - 26)\}$$

Where: T = ambient temperature (°C) and RH = relative humidity (%)

Statistical Analysis: The data obtained were subjected to one way analysis of variance (ANOVA) using Statistical Analytic System (SAS, 2004). Means were separated using Duncan's multiple range test of the same software.

Results

Table 1 shows the meteorological data recorded in the course of the study. The results showed that the meteorological parameters measured in the morning and the afternoon throughout the study period were not significantly different ($p>0.05$). The ambient temperature ranged from 31.40 °C in the morning to 34.19 °C in the afternoon. The highest mean relative humidity (35.50%) was obtained during the morning while the least (32.14%) was obtained in the afternoon. The temperature humidity index (THI) ranged from 77.52 in the morning to 80.09 in the afternoon.

The effect of breed on Thermotolerant traits of WAD, Sahel and Red Sokoto goats are presented in Table 2. Breed had significant effect ($p<0.05$) on all the measured thermotolerant traits. The WAD goat had the highest ($p<0.05$) rectal temperature (RT), respiratory rate (RR) and heat stress index (HSI) at week one. The pulse rate (PR) was significantly ($p<0.05$) highest in Red Sokoto (183.25 beats/minute) however not significantly ($p>0.05$) different from the PR of WAD (172.52 beats/minute) at week one. Similarly, the WAD goat had the highest

($p<0.05$) values of RT (41.52 °C), RR (84.62 breaths/minute) and HSI (2.34) at week 2 of the experiment. There were no significant difference ($p>0.05$) in the RT, RR and HSI of Sahel and Red Sokoto goats at week 2. At week 4, the Red Sokoto goat had the highest ($p<0.05$) values of RR (55.25 breaths/minute) and HSI (1.62) which were not significantly ($p>0.05$) different from the values (47.78 breaths/minute and 1.46 for RR and HSI, respectively) obtained in WAD goat. The Sahel goats had the least RR (35.50 breaths/minute) and HSI (1.06) at week 4. There was a significantly ($p<0.05$) influence of genotype on the RT and PR of the three goat breeds at week 6. The WAD goats had the highest ($p<0.05$) values of RT (39.81 °C) and PR (182.58 beats/minute) at week 6 of the study. At week 8, there was no significant ($p<0.05$) influence of breed on the RT, RR and HSI of the Sahel, WAD and Red Sokoto goats but the WAD goats had a significantly ($p<0.05$) highest value of PR (158.82 beats/minute); which was comparable to the value of PR (149.50 beats/minute) obtained in Sahel goats at week 8. The value of RR was significantly ($p<0.05$) highest in Sahel (72.50 breath/minute) and WAD (67.13 breath/minute) goats at week 10 of the experiment. The PR on the other hand was significantly ($p<0.05$) highest in Red Sokoto goats (183.25 beats/minute) but comparable to 171.79 beats/minute obtained in WAD goats. The Sahel and WAD goats also had statistically similar ($p>0.05$) values of PR at week 10. The values of HSI for the three genotypes of goats used for this study were significantly highest in Sahel goats (2.23) and WAD goats (1.95) than the Red Sokoto goats (1.37) at week 10 of the study. At week 12, the WAD goats had the highest ($p<0.05$) value of RR (62.83 breath/minute), which was statistically similar ($p>0.05$) to 50.50 breaths/minute recorded for the Sahel goats at week 12. More so, the Red Sokoto goats had significantly ($p<0.05$) highest value of PR (190.25 beats/minute) but comparable with 188.83 beats/minute recorded for WAD goat at week 12. The values of HSI were highest ($p<0.05$) in WAD (1.65) and Sahel (1.63) goats at week 12, whereas the Red Sokoto goats had the least HSI (1.27) week 12 of the experiment

Table 3 showed the effect of sex on Thermotolerant traits of Sahel, WAD and Red Sokoto goats. There are significant ($p<0.05$) effects of sex on the heat tolerant traits considered among the three breeds of goats used in this study. At week 2, the male Sahel goat had significantly ($p<0.05$) higher RT (41.05 °C) than the female Sahel (40.00 °C) counterpart while the HSI was significantly ($p<0.05$) influenced in female Red Sokoto goat (1.63) than the male Red Sokoto goat (1.09). All the heat tolerant traits (except RR in WAD) were not significantly affected by sex of the goats across the three genotypes at week 4. Only the male and female WAD goats differ significantly ($p<0.05$) in RR values at week 4 (i.e 52.00 and 43.56 breaths/minute for male and female WAD respectively). The higher ($p<0.05$) RR (50.25 breaths/minute) and HSI (1.29) were recorded in male WAD goat at week 6. In addition, there was significant ($p<0.05$) effect of sex on RT of male and female Red Sokoto male Red Sokoto goat had a higher ($p<0.05$) value of RT (39.75 °C) at week 6.

The male Sahel goat had significantly ($p<0.05$) higher values of RT (40.95 ^{O}C), RR (76.76 breaths/ minute) and HSI (2.58) than the female Sahel goats at week 8. More so, the male WAD goat had a significantly ($p<0.05$) higher RT (40.83 °C) at week 8. The male Red Sokoto goat had the higher ($p<0.05$) values of RR (66.25 breaths/minute) and PR (150.25 beats/minute) than the female counterpart at week 8. The male WAD goat had the higher ($p<0.05$) RT (40.45 °C) while the female WAD had the higher ($p<0.05$) values of RR (76.75 breaths/minute) and HSI (2.21) at week 10. The female Sahel goat significantly ($p<0.05$) had a higher RT (39.50 °C) at week 12, however, the RR, PR and HSI were not varied significantly ($p>0.05$) between male and female Sahel goats at week 12 of the study. The male and female Red Sokoto goats only differed significantly (p<0.05) with respect to RR and HSI at week 12. The male Red Sokoto goat had higher values of RR (54.25 breaths/minute) and HSI (1.44) as compared to the female counterpart at week 12.

Table 1: Meteorological parameters recorded in the pen during the study

Parameters	Morning	Afternoon
Ambient temperature (ºC)	31.40±0.94	$34.19±1.27^{NS}$
Relative humidity	35.50±3.47	$32.14±3.74^{NS}$
Temperature humidity index (THI)	77.52±2.04	$80.09±3.36^{NS}$

NS means Non-significant

Table 2: Effect of breed on thermotolerant traits of WAD, Sahel and Red Sokoto goats

Week	Breed	Rectal temperature (RT) ºC	Respiratory rate (RR) Breaths/minute	Pulse rate (PR) beats/minute	Heat stress index (HSI)
1	Sahel	$39.80±0.19^{b}$	$54.25±2.51^{b}$	$151.25±9.34^{b}$	$1.86±0.17^{ab}$
	WAD	$40.80±0.14^{a}$	$84.19±4.67^{a}$	$172.52±4.09^{ab}$	$2.46±0.14^{a}$
	Red Sokoto	$39.80±0.19^{b}$	$52.25±8.07^{b}$	$183.25±12.98^{a}$	$1.56±0.34^{b}$
2	Sahel	$40.53±0.27^{b}$	$52.50±4.51^{b}$	$181.50±11.22^{a}$	$1.50±0.16^{b}$
	WAD	$41.52±0.24^{a}$	$84.62±5.46^{a}$	$178.31±6.20^{a}$	$2.34±0.10^{a}$
	Red Sokoto	$40.13±0.14^{b}$	$45.25±2.90^{b}$	$169.25±11.28^{a}$	$1.36±0.10^{b}$
4	Sahel	$40.13±0.18^{a}$	$35.50±0.73^{b}$	$167.50±0.73^{a}$	$1.06±0.02^{b}$
	WAD	$40.55±0.14^{a}$	$47.78±1.78^{a}$	$165.33±3.49^{a}$	$1.46±0.07^{a}$
	Red Sokoto	$39.98±0.24^{a}$	$55.25±4.94^{a}$	$171.25±6.08^{a}$	$1.62±0.14^{a}$
6	Sahel	$38.78±0.18^{b}$	$43.50±3.33^{a}$	$168.50±6.61^{b}$	$1.32±0.13^{a}$
	WAD	$39.81±0.23^{a}$	$52.92±2.48^{a}$	$182.58±0.66^{a}$	$1.45±0.07^{a}$
	Red Sokoto	$38.95±0.36^{ab}$	$46.25±4.07^{a}$	$179.25±6.54^{a}$	$1.27±0.07^{a}$
8	Sahel	$40.35±0.28^{a}$	$56.50±8.30^{a}$	$149.50±2.69^{ab}$	$1.88±0.28^{a}$
	WAD	$40.37±0.20^{a}$	$64.17±2.91^{a}$	$158.83±3.83^{a}$	$2.01±0.07^{a}$
	Red Sokoto	$39.68±0.40^{a}$	$54.25±6.10^{a}$	$136.25±5.95^{b}$	$1.99±0.20^{a}$
10	Sahel	$39.55±0.20^{a}$	$72.50±7.54^{a}$	$161.50±4.26^{b}$	$2.23±0.20^{a}$
	WAD	$39.98±0.22^{a}$	$67.13±3.33^{a}$	$171.79±1.67^{ab}$	$1.95±0.09^{a}$
	Red Sokoto	$39.43±0.15^{a}$	$49.25±3.91^{b}$	$183.25±8.51^{a}$	$1.37±0.14^{b}$
12	Sahel	$38.58±0.40^{a}$	$50.50±4.33^{ab}$	$156.50±2.68^{b}$	$1.63±0.17^{a}$
	WAD	$39.23±0.21^{a}$	$62.83±3.47^{a}$	$188.83±2.40^{a}$	$1.65±0.08^{a}$
	Red Sokoto	$38.95±0.15^{a}$	$48.25±3.21^{b}$	$190.25±2.27^{a}$	$1.27±0.08^{b}$

Mean in the same group with different superscripts (a, b) are significant different (p<.0.05)

Table 3: Effect of sex of goats on thermotolerant traits of WAD, Sahel and Red Sokoto goats

Week	Breed	Sex	Rectal temperature (RT) ºC	Respiratory rate (RR) Breaths/minute	Pulse rate (PR) Beats/minute	Heat Stress index (HSI)

1	Sahel	Male	39.65±0.23^{a}	52.25±2.31^{a}	170.25±12.70^{a}	1.58±0.19^{a}
		Female	39.95±0.32^{a}	56.25±4.62^{a}	132.25±2.31^{b}	2.14±0.21^{a}
	WAD	Male	40.72±0.21^{a}	86.29±9.38^{a}	164.29±6.26^{b}	2.63±0.27^{a}
		Female	40.88±0.18^{a}	82.08±1.51^{a}	180.75±4.30^{a}	2.28±0.07^{a}
	Red Sokoto	Male	39.70±0.20^{a}	38.25±3.47^{a}	180.25±13.86^{a}	1.10±0.18^{a}
		Female	39.90±0.35^{a}	66.25±12.70^{a}	186.25±24.25^{a}	2.01±0.60^{a}
2	Sahel	Male	41.05±0.32^{a}	48.75±0.32^{a}	160.75±0.32^{a}	1.52±0.01^{a}
		Female	40.00±0.20^{b}	56.25±9.24^{a}	202.25±17.32^{a}	1.48±0.36^{a}
	WAD	Male	41.19±0.32a	82.93±8.42^{a}	182.64±11.27^{a}	2.23±0.13^{a}
		Female	41.90±0.33^{a}	86.58±6.95^{a}	173.25±3.14^{a}	2.47±0.16^{a}
	Red Sokoto	Male	40.15±0.23^{a}	40.25±4.62^{a}	184.25±20.79^{a}	1.09±0.01^{b}
		Female	40.10±0.20^{a}	50.25±1.16^{a}	154.25±3.47^{a}	1.63±0.01^{a}
4	Sahel	Male	40.35±0.32^{a}	36.75±0.32^{a}	168.75±0.32^{a}	1.09±0.01^{a}
		Female	39.90±0.15^{a}	34.25±1.16^{a}	166.25±1.16^{a}	1.03±0.03^{a}
	WAD	Male	40.53±0.0.19^{a}	52.00±2.53^{a}	167.56±5.64^{a}	1.58±0.11^{a}
		Female	40.57±0.21^{a}	43.56±1.61^{b}	163.11±4.33^{a}	1.35±0.08^{a}
	Red Sokoto	Male	40.25±0.14^{a}	46.25±3.47^{a}	168.25±11.55^{a}	1.42±0.20^{a}
		Female	39.70±0.46^{a}	64.25±6.93^{a}	174.25±5.78^{a}	1.83±0.14^{a}
6	Sahel	Male	38.95±0.32^{a}	48.75±0.32^{a}	172.75±0.32^{a}	1.41±0.01^{a}
		Female	38.60±0.15^{a}	38.25±5.78^{a}	164.25±13.86^{a}	1.24±0.28^{a}
	WAD	Male	40.05±0.43^{a}	58.58±1.93^{a}	182.58±0.90^{a}	1.60±0.05^{a}
		Female	39.57±0.17^{a}	47.25±4.01^{b}	182.58±1.00^{a}	1.29±0.11^{b}
	Red Sokoto	Male	39.75±0.18^{a}	50.25±5.78^{a}	190.25±5.78^{a}	1.31±0.11^{a}
		Female	38.15±0.38^{b}	42.25±5.78^{a}	168.25±9.24^{a}	1.24±0.10^{a}
8	Sahel	Male	40.95±0.32^{a}	76.75±0.32^{a}	148.75±0.32^{a}	2.58±0.01^{a}
		Female	39.75±0.16^{b}	36.25±6.93^{b}	150.25±5.78^{a}	1.18±0.19^{b}
	WAD	Male	40.83±0.16^{a}	64.58±5.89^{a}	153.92±7.13^{a}	2.06±0.13^{a}
		Female	39.90±0.32^{b}	63.75±0.78^{a}	163.75±2.46^{a}	1.95±0.04^{a}
	Red Sokoto	Male	39.40±0.79^{a}	66.25±8.08^{a}	150.25±5.78^{a}	2.25±0.36^{a}
		Female	39.95±0.23^{a}	42.25±3.47^{b}	122.25±1.16^{b}	1.72±0.13^{a}
10	Sahel	Male	39.25±0.32^{a}	52.75±0.32^{b}	152.75±0.32^{b}	1.73±0.01^{b}
		Female	39.85±0.16^{a}	92.25±2.31^{a}	170.25±5.78^{a}	2.73±0.16^{a}
	WAD	Male	40.45±0.24^{a}	57.50±2.81^{b}	170.17±2.53^{a}	1.68±0.07^{b}
		Female	39.50±0.33^{b}	76.75±4.66^{a}	173.42±2.19^{a}	2.21±0.12^{a}
	Red Sokoto	Male	39.55±0.23^{a}	56.25±2.31^{a}	190.25±17.32^{a}	1.53±0.20^{a}
		Female	39.30±0.20^{a}	42.25±5.78^{a}	176.25±2.31^{a}	1.21±0.18^{a}
12	Sahel	Male	37.65±0.32^{b}	48.75±0.32^{a}	160.75±0.32^{a}	1.52±0.01^{a}
		Female	39.50±0.30^{a}	52.25±9.24^{a}	152.25±4.62^{a}	1.75±0.36^{a}
	WAD	Male	39.48±0.18^{a}	64.58±6.00^{a}	189.92±2.90^{a}	1.68±0.14^{a}
		Female	38.98±0.36^{a}	61.08±3.73^{a}	187.75±3.92^{a}	1.63±0.09^{a}
	Red Sokoto	Male	39.15±0.16^{a}	54.25±3.47^{a}	188.25±4.62^{a}	1.44±0.06^{a}
		Female	38.75±0.23^{a}	42.25±3.47^{b}	192.25±0.14^{a}	1.10±0.09^{b}

Mean in the same group with different superscripts a and b are significantly different ($p<0.05$)

Discussion

In the study's environment, the meteorological data recorded were not significantly different with respect to the period of the day. All the values obtained are within the range previously reported in the study area during the morning and afternoon of the dry season. The THI obtained in this study ranges from 77.52 to 80.09 which can constitute heat stress on animals. According to McDowell (1972) model, the THI above 75 was considered extremely severe heat stress to animals. The THI mean values of 77.52 and 80.09 recorded during morning and afternoon hours during entire experimental period clearly indicated that the experimental animals were reared under extreme severe heat stressed environment.

In the current study, the results of heat tolerant traits in three major genotypes of goats in Nigeria (namely; Sahel, WAD and Red Sokoto goats) showed that the WAD goats have higher rectal temperature at weeks 1, 2 and 6 of the study. The values of RT range from 38.58 ºC in Sahel goats at week 12 to 40.80 ºC in WAD goats at week 1 of the study. The RT range obtained for the goats used in this study is below and above the minimum and maximum values suggested as the normal RT (39.00-40.00 ºC) for goat by American Institute for goat research (AIGR, 2000). The rectal temperature is often used as a representative measurement of animal core temperature: a rise of 1 ºC or less in rectal temperature is enough to reduce performance in most livestock species (Kadzere *et al.,* 2002). Since rectal temperature is strongly associated with many physiological attributes associated with heat stress (McManus *et al.,* 2009), therefore, 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 Habeeb, 2010). This may accounts for the reason WAD goats are characterized with slow growth rate and milk yield (Williamson and Brinkmann, 1997). According to the results obtained in this study, the WAD goats showed higher RT in most of the weeks of the experiment than the Sahel and Red Sokoto goats.

The Sahel and Red Sokoto goats on the other hand have relatively low rectal temperature which suggests better adaptability in them than the WAD goats. This may further be attributed to the WAD goats predominantly found in Southern and Western part of the country (rain forest zone) unlike the Sahel and Red Sokoto that are predominant in the Northern part (Savannah zone). This result indicates that the adaptability of the WAD goats may depends on their ability to adapt and reproduce under heat stressed environment and they have been naturally selected to thrive in humid tropics such as the study's environment. Thus, assuming all other factors are constant, Sahel and Red Sokoto goats would fit selection for heat stressed environment in the tropics.

Altan *et al*. (2003) reported that high ambient temperature and relative humidity of the environment are responsible for the increase in rectal/body temperature (RT) of animals. Also, Kaya (2011) reported that high ambient temperature with high direct and indirect solar radiation, wind speed and relative humidity (which are the characteristics of the tropical environment) 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). Further, 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.,* 2006) which are traits attributed to WAD goats.

Moreover, the respiratory rates were highest in WAD goats at weeks 1, 2, 6, 8 and 12 although not statistically significant at week 8. The pulse rates are relatively higher in WAD and Red Sokoto goats than in Sahel goats in most of the weeks of the experiment. The heat stress index was higher in WAD and Sahel goats in most of the weeks of the study. Respiration rate is an indicator of heat stress in small ruminants (Indu *et al.,* 2015). 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). Respiration rates have been described as reliable indicators of heat load above this critical body temperature (Brown-Brandl *et al.,* 2005). The higher respiratory rate in WAD goats collaborate the report of Habibu *et al.* (2021) that irrespective of the hour of day, the WAD goats had higher respiratory rate than the Red Sokoto and Sahel goats. Ngere *et al.* (1984) reported that the higher respiratory rate in the WAD goats may be genetically related to their miniature body size as compared with the other breeds (Ngere *et al.,* 1984). Also the Red Sokoto and Sahel goats, unlike the WAD goats were able to minimise the variation in the diurnal fluctuation of respiratory rate and rectal temperature. These wide fluctuations in biological rhythms are induced by the wide difference between the morning and afternoon ambient temperatures and may be the major challenge to the survivability of WAD goats during the West African cold season in the Northern Guinea Savannah climate of Nigeria (Habibu *et al.,* 2021). Generally the respiratory rates for all the breeds of goats in this study fell below 80 breaths/minute except at weeks 1 and 2 of the experiment, where the WAD goats showed higher respiratory rates. 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. This implies that the WAD goats are prone to heat stress than the Sahel and Red Sokoto in the study environment. The values of respiratory rates recorded in this study are generally higher than 12-20 breaths/minute suggested by American Institute for goat research (AIGR, 2000) as normal respiratory rate for goat. 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 (Kay, 1979). Pulse rate (PR) may be used as indicators of heat stress as they are affected by heat stress. The results on pulse rate in this study agreed with the findings of Habibu *et al.* (2017) who reported a decrease in pulse rate of Red Sokoto and Sahel goats during the West African cold season as compared to the hot-dry season. In addition, the high pulse rate observed in WAD goats agreed with the well-established high heart rate (>87 beats per min.) in WAD goats (Sodipe *et al.,*2014; Azeez *et al.,* 2018) attributed to their small body size (Detweile, 1922).

The high heat stress index obtained in WAD goat in most of the weeks of the experiment may be attributed to the high RT recorded. Altan *et al*. (2003) reported that high ambient temperature and relative humidity, increases heat stress and are responsible for the increase in rectal/body temperature (RT) of animals. This implies RT is a major determinant of heat stress in animals. Therefore, the high HSI recorded in WAD may be due to the high RT recorded among this breed. Further, the results on heat stress index in this study imply that susceptibility of livestock to heat stress differs with species and genetic potential

(Das *et al.,* 2016) and production environment among other factors.

Sexual dimorphism plays significant roles in Thermotolerant traits of the three indigenous breeds of goats in this study. The RT was higher in male Sahel than female at week 2 and 8 while at week 12, the female Sahel had the higher RT. At weeks 8 and 10, the male WAD goat had the higher RT than the female. The male Red Sokoto showed higher RT at week 6 than the female. This current study therefore demonstrates higher RT in male goats than their female counterparts. This result agreed with Habibu *et al.* (2021) who observed higher circulating thyrotropin concentration in bucks than does during hot dry season. Further, the respiratory rate was observed to be higher in male WAD (at weeks 4 and 6) and male Sahel (at week 8) and male Red Sokoto (at weeks 8 and 12). The female Sahel and WAD goats had higher RR at week 10 of the study. This results show concurrent changes in RR between male and female goats in different weeks of the study. This may be attributed to changes in physiological functions as a result of changes in environmental temperature. Habibu *et al.* (2021) revealed that low ambient temperature is responsible to reduction in respiratory frequency and a decrease in body surface and core body temperatures. Also, the higher RR among the bucks in some of the weeks may be attributed to hyper-activeness of the bucks, which implies increase respiratory rate as a result of increase activities such as fighting. The pulse rate higher in bucks Sahel at week 1 whereas in WAD, the does had the higher PR. In Red Sokoto goat, the bucks had the higher PR than the does at week 10. The variation in PR was not significant between the two sexes of the three genotypes of goats in most of the weeks of the study. Although goats are generally tolerant to heat stressed conditions, there exist sexual dimorphism in their responses as demonstrated in some of the weeks of this study. The Sahel buck had a higher heat stress index at week 8 while the Sahel doe showed a higher HSI at week 10 of the study. The Red Sokoto doe had a higher HSI at week 2 while the Red Sokoto buck had the higher HSI at week 12. The WAD buck had the higher HSI at week 6 and the WAD doe at week 10. The variations in HSI between male and female of goats in some of the weeks of the study may be attributed to sexual dimorphisms in animal physiology.

Conclusion

The THI obtained in this study revealed that the study's environment as at the period of the study; is extremely heat stressed for the experimental animals. The WAD goat had higher RT and PR than the Sahel and Red Sokoto goats in most of the weeks of the study. The Sahel and Red Sokoto goats showed minimum variation in RR as compared to the WAD goats. The HSI was higher and fluctuate more frequently in WAD goat than in Sahel and Red Sokoto goats. There exist sexual dimorphisms in thermo-tolerant traits among the three goat breeds used in this study. The Sahel and Red Sokoto goats can adapt to heat stressed environment, therefore could be upgraded to obtain improved tropical goat breeds**.** The WAD goat performance in the tropics could be improved through management of the rearing environment.

Conflict of interest

The authors have declared no conflict of interests.

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