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Thermoregulatory response of Yankasa sheep with distinct thick-coarse and short-slick hair types during hot-dry season in tropical Savannah

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Abstract

The skin has the closest contact with the environment and, thus, the role of body coat in adaptation to the changing environmental conditions cannot be over emphasised. The study was aimed at comparing the thermoregulatory response of Yankasa rams with distinct thick-coarse and short-slick hair types at the peak of the hot-dry season in tropical Guinea Savannah. A total of 10 Yankasa rams with thick-coarse (n=5) and short-slick (n=5) hair types, balanced for age and body condition score were used. The meteorological and thermoregulatory parameters were measured four times at 2 days interval at 9:00, 13:00 and 17:00 h. In the afternoon, the temperature humidity index and ambient temperature were higher than the thermoneutral zone for sheep. Yankasa sheep with thick-coarse hair had higher ($P < 0.05$) hair length than those with short-slick hair type. Respiratory rate at all hours, body surface temperature in the morning hours, eye and inter-digital surface temperature in the afternoon hours were lower in thick-coarse hair than short-slick hair sheep. Significant rise ($P < 0.05$) in respiratory rate, skin and rectal temperatures from morning to afternoon hours were observed in both hair types. Subsequently, in the evening hours, the rectal temperature in the thick-coarse hair sheep returned to values comparable to those of the morning hours; while the values in short-slick hair sheep remained higher ($P < 0.05$) than that of the morning hours.It was concluded that Yankasa sheep with thick-coarse hair type had lower thermoregulatory demand to maintain homeostasis in the afternoon hours, and cooled faster in the evening hours relative to their short-slick hair type counterpart during the tropical hot-dry season.

Keywords: Rectal temperatures, Respiratory rate, Inter-digital surface temperature, Afternoon hours, Morning hours, homeostasis

La Réponse thermorégulatrice des moutons 'Yankasa' avec des types distincts de cheveux épais-grossiers et courts-lisses pendant la saison chaude-sèche dans la savane tropicale

Résumé

La peau a le contact le plus facile avec l'environnement et, par conséquent, le rôle du pelage dans l'adaptation aux conditions environnementales changeantes ne peut pas être trop souligné. L'étude visait à comparer la réponse thermorégulatrice des béliers yankasa avec des types distincts de cheveux épais-grossiers et courts au plus fort de la saison chaude et sèche dans la savane tropicale de Guinée. Un total de 10 béliers Yankasa avec des types de cheveux épais-grossiers (n=5) et short-slick (n=5), équilibrés pour l'âge et le score d'état corporel ont été utilisés. Les paramètres météorologiques et thermorégulateurs ont été *mesurés quatre fois à intervalles de 2 jours à 9 h, 13 h et 17 h. Dans l'après-midi, l'indice d'humidité de la température et la température ambiante étaient plus élevés que la zone thermonéutrale pour les moutons. Les moutons Yankasa aux cheveux épais et grossiers avaient une longueur de cheveux plus élevée (P < 0,05) que ceux de type cheveux courts. La fréquence respiratoire à toute heure, la température de surface du corps le matin, la température des yeux et de la surface inter-numérique dans les heures de l'après-midi étaient plus faibles dans les cheveux épais-grossiers que les moutons cheveux courts lisses. Des hausses significatives (P < 0,05) des températures respiratoires, cutanées et rectales du matin à l'après-midi ont été observées dans les deux types de cheveux. Par la suite, le soir, la température rectale chez les moutons aux cheveux épais-grossiers est revenue à des valeurs comparables à celles des heures du matin; tandis que les valeurs chez les moutons à poils courts sont restées plus élevées (P < 0,05) que celles des heures du matin. Il a été conclu que les moutons Yankasa de type cheveux épais-grossiers avaient une demande thermorégulatrice plus faible pour maintenir l'homéostasie dans les heures de l'après-midi, et refroidi plus rapidement dans les heures du soir par rapport à leur homologue de type cheveux courts lisses pendant la saison chaude-sèche dans la savane tropicale.*

Mots-clés: Températures rectales, Taux respiratoire, Température de surface inter-numérique, Heures de l'après-midi, Heures du matin, homéostasie

Introduction

In the tropics, high ambient temperature and relative humidity is the most challenging environmental condition that reduce the productivity of livestock, especially those with morphometric and genetic features that make them poorly adapted to thermal stress (Dikmen *et al*., 2014; Sejian *et al*., 2014; Rout *et al*., 2016; Habibu *et al*., 2016; 2019). It is believed that the wild ancestors of today's domestic breeds of sheep had long and coarse hair with a short and downy undercoat. After domestication, however, the sheep were selected to become woolly and the long hair was lost (Schoenian, 2019). Most sheep have both hair and wool fibres and the main difference between hair wool sheep is in the ratio of hair to wool fibres. Hair sheep have more hair fibers and wool sheep have more wool fibres (Barth, 2017**;** Schoenian, 2019). Hair sheep tend to grow more wool fibers in cold climates, thus making them adaptable to different climate extremes (Schoenian, 2019). Like the wool breeds, there is considerable difference between and within breeds in hair sheep, with respect to the fibre contents. Thus, the two basic features of the hair sheep that have been identified include; breeds or individuals that have short, slick hair coats with no wool, and other breeds or individuals that grow thicker coarse coats containing a mixture of hair and wool fibers that shed naturally each year **(**Yakubu *et al*., 2010; Akpa *et al.,* 2011**).** These two groups could be termed "short-slick hair sheep" and "thick-coarse hair sheep", respectively. The role of coat in the adaptation of animals to changing environmental conditions cannot be over emphasised as it is the best delineation of the boundary between the animals' internal and the surrounding physical environments (Cruz Junior *et al*., 2015; McManus *et al*., 2020). Morphometric variations in the features of hair fibre, colour of the skin and hair markedly influence thermoregulatory adaptation in all tropical livestock (Daramola and Adeloye, 2009; McManus *et al*., 2011a). Since Yankasa sheep have a uniform coat colour which is predominantly white with black patches on the eyes, muzzle and ears, one major morphometric feature of thermoregulatory significance is the hair fibre. Thus, to adequately adapt and remain productive in the extremely dynamic

West African climate characterised by a range of hot-humid to cold-dry seasons, different coat morphometric features have developed in the Nigerian sheep; with natural selection favouring the development of hair coat that is smooth and short over the long hair coat (Ozoje, 2002; Yakubu *et al*., 2010). However, both short and long hair coats are trade-offs between efficient thermoregulation and protection from solar radiation (Castanheira *et al*., 2010; Cruz Junior *et al*., 2015). Heat stress, particularly in sheep, diverts physiological efforts from growth and reproduction to the maintenance of homoeothermy through increasing respiratory, sweating and pulse rates (Sejian *et al* ., 2014; Indu *et al* ., 2014; Habibu *et al* ., 2019). Studies on the physiology of sheep have contributed immensely in improving livestock productivity through identifying and understanding traits of economic importance that can enhance adaptation (Crawford *et al.,* 1995; Yakub *et al*., 2019). Although great genetic diversity exists in West African sheep, several phenotypic traits, including morphometric features for thermoregulation are yet to be exploited (Kemp *et al*., 2007; Olufunmilayo et al., 2003). Despite the fact that almost all hair sheep are of tropical or sub-arid origin and majority of them are found in the tropics or sub-arid regions where heat stress is a major challenge to production; there is paucity of information on the physiology of thermal adaptation in the two types of hair sheep (short-slick and thick-coarse). If available, this information could be useful in genetic selection and management of thermal stress. The aim of this study was to compare the diurnal thermoregulatory responses in Yankasa rams with thick-coarse and those with short-slick hair during the peak of the hot-dry season in Zaria, Nigeria.

Materials and methods

Animal management

The experiment was performed at Large Animal pen of the Department of Veterinary Surgery and Radiology, Faculty of Veterinary Medicine, Ahmadu Bello University, Samaru Zaria (11^0 12' N, 7^0 33' E); located in the Northern Guinea Savannah zone of Nigeria during the hot-dry season. The animals were managed intensively in a well-ventilated pen in east–west orientation with dimension of 3.0, 3.0 and 3.0 ft for length, width and height, respectively. The roof of the pen was made of galvanized metal sheets, while the floor was made of concrete. Each pen had a maximum stocking density of 4 sheep. Health status of the sheep was evaluated based on behaviour, appetite and faecal consistency. The animals were dewormed 4 weeks prior to the commencement of the study and were routinely screened by a trained personnel for helminths (using floatation and sedimentation tests) and haemoparasites. Only clinically healthy animals were used for the study. The rams were fed *Digitaria smutsi* as basal diet and supplemented with concentrate (Table1; AOAC. 1990) – ration of ground maize (30 %), cotton seed cake (36 %), maize offal (20 %), wheat offal (10 %), bone meal (2.5 %) and salt (1.5 %) at 3% body weight per day. Feed and portable drinking water were provided to the rams *adlibitum* during the experimental period. Standard farm management protocol was adopted in the management the experimental rams.

Table 1: Bromatological analysis of the hay and concentrate

Parameters (%)	Hay (*Digitaria smutsi*)	Concentrate ration
Moisture	3.50	4.21
Fibre	2.77	18.11
Carbohydrate	89.85	81.04
Protein	2.93	5.15
Lipid	1.85	7.06
Ash	1.87	2.47

Experimental design and measurement of parameters

A total of 10 Yankasa rams with distinct thick-coarse (n=5) and short-slick (n=5) hair types, balanced for body condition score and age were selected from a flock of sheep. The study was conducted during the peak of hot-dry season in the month of April. Body condition was scored by the same person adopting a 6-point scale (0–5) method with 0.5 increment or decrease as the body condition changes (Santucci *et al*., 1991). Both hair types were balanced for age (2.80 ± 0.46) and body condition score (3.00 ± 0.13). During the experimental period, ambient temperature and relative humidity inside the pen was recorded at 0:90, 13:00, and 17:00 h using wet and dry bulb thermometer (Brannan, UK). Relative humidity (RH) was obtained from the wet-bulb and dry-bulb temperature values using conversion tables, condensed from the Bulletin of the US Weather Bureau No. 1071. Temperature humidity index (THI), an indicator of thermal comfort, was calculated using the following formula:

THI= 0.72(W + D) + 40.6 (Silanikove, 2000)

Where: W = Wet-bulb temperature (˚C) and D = Dry-bulb temperature (˚C)

To prevent additional stress, each of the experimental animals was restrained and calmed before taking the readings. The physiological parameters were measured four times at 2 days interval in the morning, afternoon and evening hours at 9:00 h, 13:00 and 17:00. For each thermoregulatory parameter, a total of 60 numerical values were obtained in each hair type. Eye, skin, hair and inter-digital space temperatures were measured using a pistol-type infrared thermometer(VMR Scientific Horiba) fixed 2 cm away from the target sites and the reading displayed recorded in ˚C (Minka and Ayo, 2016a).The target sites for determination of eye, skin, hair and inter-digital space temperatures were the sclera of the eye, a shaved area on the lateral surface of the abdomen, the lateral surface of the thorax and the less hairy space between the digits of the fore limb, respectively. Rectal temperature was measured using digital thermometer (Wilson-Supreme, Japan). The sensory tip was disinfected and inserted into the rectum at the display of ˚*C* by the thermometer (which indicates that the thermometer is set for the temperature reading). This was removed after the sound of the alarm signal and the displayed body temperature was then recorded. Heart rate was measured using stethoscope on the left side of the thorax between the third and fifth ribs and represented as number of beats per minute (Sanusi *et al.,* 2010; Yaqub *et al*., 2017).Respiratory rate was recorded based on the movements of the flank at the paralumber fossa of the rams using a stop watch and represented by number of breaths per minute (Habibu *et al*., 2017; Yaqub *et al*., 2017).The temperature difference between rectal and ambient temperatures as well as the skin and ambient temperatures for each ram were determined in all hours of the day. Similarly, the difference between the highest and lowest rectal temperature was determined. The hair length was determined as the length of the hair around the dorso-cranial region of the thorax in upright and stretched position using a ruler (Iddriss and Abdul Rahim**,** 2018). The study protocol and animal experimentation were approved by the Animal Use and Welfare Committee of Ahmadu Bello University, Zaria; and the research followed the international guidelines for animal welfare.

Data analysis

The Statistical Package for Social Sciences (SPSS) version 20 was used to analyse the data and values were expressed as means (±SEM). Comparisons of all data between different hair types andhours of the day were done using repeated measure one-way analysis of variance (ANOVA) followed by the Duncan multiple range test. Discriminate analysis was performed to identify variables with greater discriminatory power between the two hair types. This was followed by the discriminate analysis option of variable classification. Values of $P < 0.05$ were considered significant.

Results and discussion

Table 2 shows the values of meteorological parameters recorded during the study period. The ambient temperature significantly increased ($P < 0.05$) from morning to afternoon hours with insignificant decrease ($P > 0.05$) in the evening hours. The ambient temperature in the evening hours was significantly higher than in the morning hours. The relative humidity significantly decreased ($P < 0.05$) from morning to afternoon hours. There was no significant change ($P > 0.05$) in THI between hours of the day from 9:00 to 17:00 h. On the basis of THI with respect to sheep, Khalifa *et al.* (2002) reported a thermoneutral zone of 60 and 70, while moderate heat stress ranged from 70 to 85 and severe heat stress is observed at THI $\geq$ 85. On the basis of ambient temperature, Fuqauy (1981) reported a thermoneutral zone of 18 – 27°C for tropical sheep. Thus, the sheep in the current study were exposed to moderate heat stress from 9:00 to 17:00h, especially in the afternoon hours when both the ambient temperature and THI were at the upper limit of the thermoneutral zone. The ambient thermal load markedly increased from morning to afternoon hours as indicated by rise in ambient temperature. The lack of significant increase in THI during the afternoon hours, despite marked increase in ambient temperature was due to the higher relative humidity during the morning hours. Higher THI due to increase in humidity in tropics is commonly reported and pose less thermoregulatory challenge if not accompanied by higher ambient temperature (Habibu *et al.*, 2016; 2017). The differences between rectal and ambient temperature as well as between skin and ambient temperature (Table 3) in both hair types significantly decreased ($P < 0.05$) from morning to afternoon hours with an insignificant change ($P > 0.05$) in the evening hours. This suggests that despite thermoregulatory efforts in the afternoon hours, the ambient temperature still had marked impact on core body temperature. Moreover, the significantly positive correlation between ambient temperature and all thermoregulatory variables (Table 4) assert the impact of ambient temperature on all thermoregulatory variables. All thermoregulatory variables showed significantly negative correlation with difference between ambient and rectal as well as skin temperatures (Table 4).

Table 2: Meteorological parameters during the study period (hot-dry season)

Hours of the day	Ambient temperature (ºC)	Relative humidity (%)	THI
Morning (9:00 h)	28.57 ± 1.00 a	21.86 ± 1.74 a	77.50 ± 1.35
	(23.00–31.00)	(18.00 –30.00)	(73.72–83.80)
Afternoon (13:00 h)	36.43 ± 1.07 b	14.71 ± 1.27 b	77.42 ± 1.09
	(32.00–40.00)	(8.00–19.00)	(72.28–80.92)
Evening (16:00 h)	33.71 ± 0.68 b	18.00 ± 1.62ab	77.83 ± 1.21
	(31.00–36.00)	(14.00–25.00)	(73.00–82.36)

a,b indicates significant effect of hour of the day (P<0.05)

Table 3: Mean (±SEM) value of differences between rectal and ambient temperature and between skin and ambient temperature in Yankasa sheep with the two hair types

Temperature difference	Morning	Afternoon	Evening
Rectal and ambient			
Thick-coarse	10.20 ± 1.68 x	3.70 ±0.55 y	6.46 ±0.57
Smooth-slick	10.34 ±1.76 x	4.05 ±0.44 y	6.82 ±0.54
Skin and ambient			
Thick-coarse	10.27 ±1.68 x	4.18 ±0.32 y	6.64 ±0.56
Smooth-slick	10.38 ±1.77 x	4.24 ±0.47 y	6.50 ±0.46

x,y indicates significant diurnal changes (P<0.05).

Table 4: Pearson's correlation between the thermoregulatory and environmental parameters

	ST	RT	RAT	SAT	BST	ET	RR	HR	IDT	AT
ST	1	0.41**	-0.36**	-0.10	0.65**	0.64**	0.15	0.48**	0.63**	0.40**
RT	0.41**	1	-0.38**	-0.44**	0.45**	0.41**	0.31**	0.35**	0.30**	0.53**
RAT	-0.36**	-0.38**	1	0.95**	-0.39**	-0.32**	-.404**	-0.32**	-0.16	-0.97**
SAT	-0.10	-0.44**	0.95**	1	-0.26**	-0.19*	-0.41**	-0.23*	-0.01	-0.95**
BST	0.65**	0.45**	-0.39**	-0.26**	1	0.69**	0.34**	0.47**	0.78**	0.44**
ET	0.64**	0.41**	-0.32**	-0.19*	0.69**	1	0.35**	0.49**	0.65**	0.37**
IDT	0.63**	0.30**	-0.16	-0.01	0.78**	0.65**	0.34**	0.46**	1	0.20*
RR	0.15	0.31**	-0.40**	-0.41**	0.34**	0.35**	1	0.28**	0.34**	0.43**
HR	0.48**	0.35**	-0.32**	-0.23*	0.47**	0.49**	0.28**	1	0.46**	0.36**
AT	0.40**	0.53**	-0.99**	-0.95**	0.44**	0.37**	0.43**	0.36**	0.20*	1

Values with asterisk indicates significant correlation * (P<0.05) and ** (P<0.01). ST (Skin temperature), RT (rectal temperature), RAT (difference between rectal and ambient temperature), SAT (difference between skin and ambient temperature), BST (body surface temperature), ET (eye temperature), RR (respiratory rate), HR (heart rate), IDT (inter-digital space temperature) and AT (ambient temperature)

Effects of diurnal changes and hair type on respiratory rate, heart rate, body surface, eye, skin, inter-digital space and rectal temperatures of Yankasa sheep during the hot-dry season are presented on Fig. 1, 2, 3, 4, 5, 6 and 7, respectively. Due to rise in ambient temperature in the afternoon hours, both hair types showed significant (P < 0.05) diurnal fluctuation by an afternoon rise and an evening decline in respiratory rate, skin and rectal temperatures, while there was no significant diurnal fluctuation in eye temperature in both hair types. On the other hand, body surface temperature showed significant (P < 0.05) diurnal fluctuation by an afternoon rise only in thick-coarse hair sheep; and inter-digital space temperature and heart rate showed significant (P < 0.05) diurnal fluctuation by an afternoon rise only in Short-slick hair sheep. In condition of high ambient thermal load, most especially in the afternoon hours, body temperature increase due to decreased thermal gradient between the sheep and their environment, and as a result sensible heat loss becomes less effective (Butswat *et al.,* 2000; Habibu *et al*., 2016; Hartmann *et al*., 2021). Under these conditions the animal must rely more on evaporative cooling mechanisms from the skin and the respiratory tract (Sevi *et al*., 2001; Habibu *et al*., 2019). This explains the rise in respiratory rate, rectal and skin temperatures in both Thick-coarse and Short-slick hair sheep and agrees with the findings of previous studies in sheep (Ayo *et al*., 2011; Silva *et al*., 2016; Cruz Junior *et al*., 2015).

In agreement with the current study, higher body surface temperature has been reported in sheep with great heat burden (Paim *et al*., 2014; Maurya *et al*., 2017; Macias-Cruz *et al*., 2018). The lower body surface temperature in thick-coarse hair sheep than short-slick hair sheep in the morning hours indicates that at lower degree of moderate heat stress (THI: 72.28; Paim *et al*., 2014) as observed at 9:00 h, short-slick hair sheep already had an elevated body surface temperature that was higher than that of thick-coarse hair sheep. This is higher enough that with subsequent increase in ambient heat load in the afternoon hours, no further significant rise in body surface temperature was observed in short-slick hair sheep, but the value rose (Seixas *et al*., 2017; de Souza *et al*., 2018) in thick-coarse hair sheep to equate the values in short-slick hair sheep (Fig. 8). Plausibly, the difference may be due to greater coat cover and more effective reflection of solar radiation (Dikmen *et al* . 2008) in thick-coarse hair sheep than in short-slick hair sheep. This suggests greater sensitivity of the hair in short-slick hair sheep to rise in ambient heat load as compared with that of the thick-coarse hair sheep.

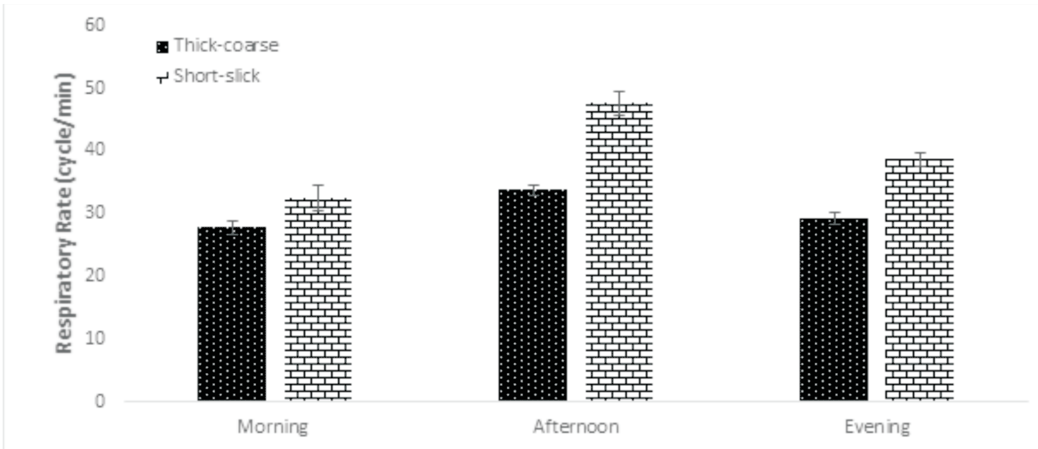

Fig. 1: Diurnal variation in respiratory rate of thick-coarse and smooth-slick hair Yankasa ram during hot-dry season. x,y and a,b indicate significant diurnal and hair type difference, respectively (P<0.05).

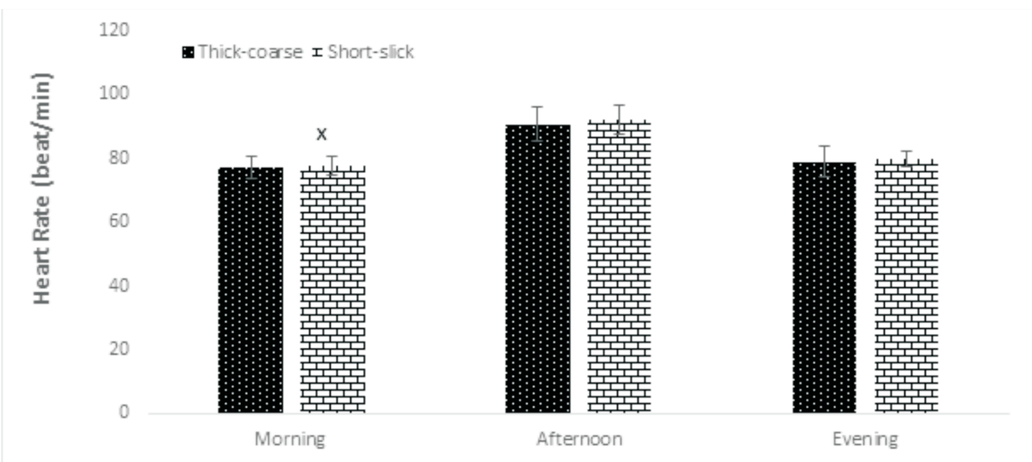

Fig. 2: Diurnal variation in heart rate of thick-coarse and smooth-slick hair Yankasa rams during hot-dry season. x, y indicates significant diurnal changes (P<0.05).

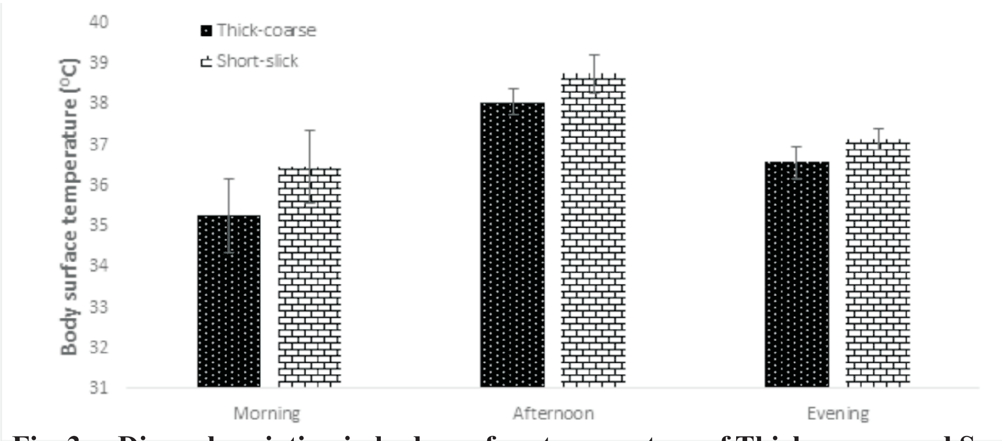

Fig. 3: Diurnal variation in body surface temperature of Thick-coarse and Smooth-slick hair Yankasa rams during the hot-dry season. x,y and a,b indicate significant diurnal and hair type difference, respectively (P<0.05).

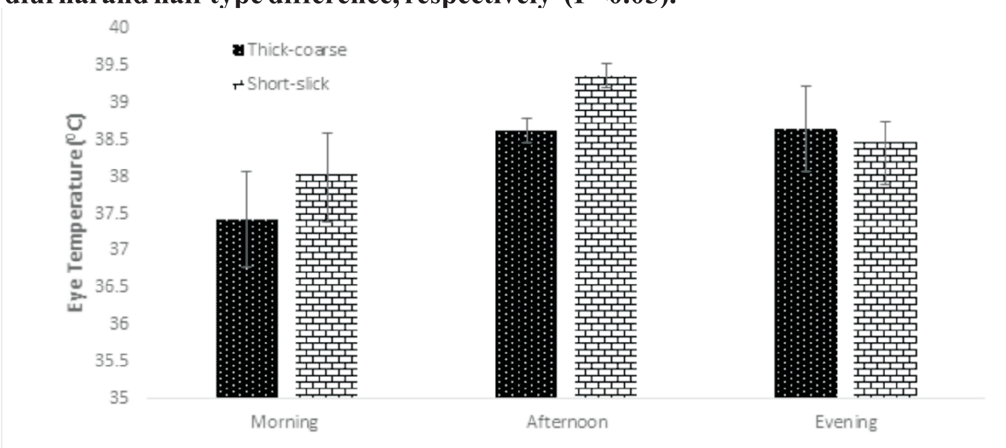

Fig. 4: Diurnal variation in eye temperature of Thick-coarse and Smooth-slick hair Yankasa rams during the hot-dry season. a,b indicates significant effect of hair type (P<0.05).

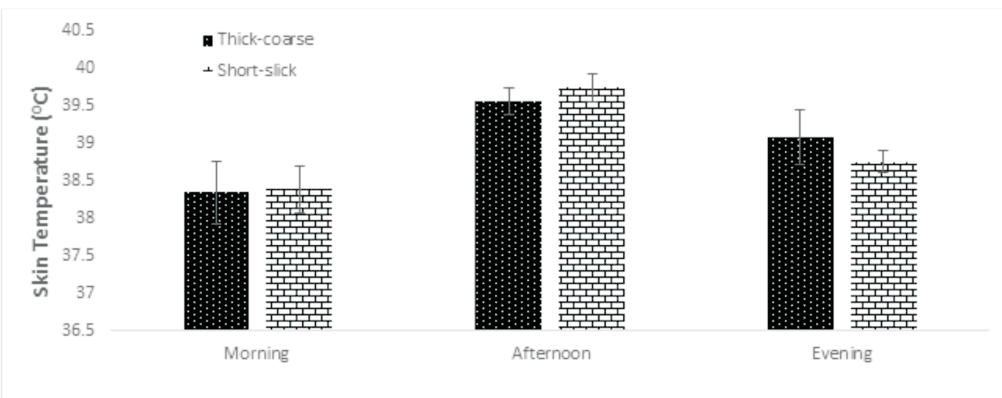

Fig 5: Diurnal variation in skin temperature in Thick-coarse and Smooth-slick hair Yankasa rams during hot-dry season. x, y indicates significant diurnal changes (P<0.05).

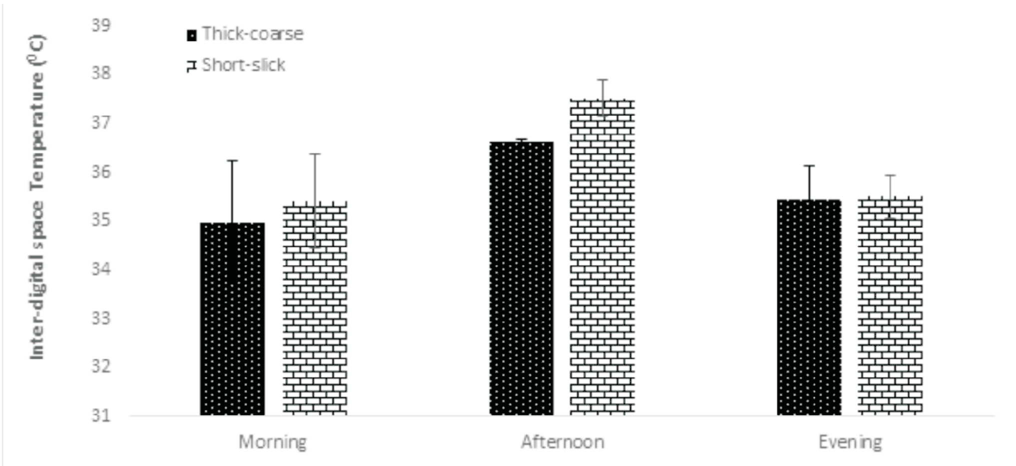

Fig. 6: Diurnal variation in Inter-digital space temperature of Thick-coarse and Smooth-slick hair Yankasa rams during hot-dry season. x,y and a,b indicate significant diurnal and hair type difference, respectively ($P<0.05$).

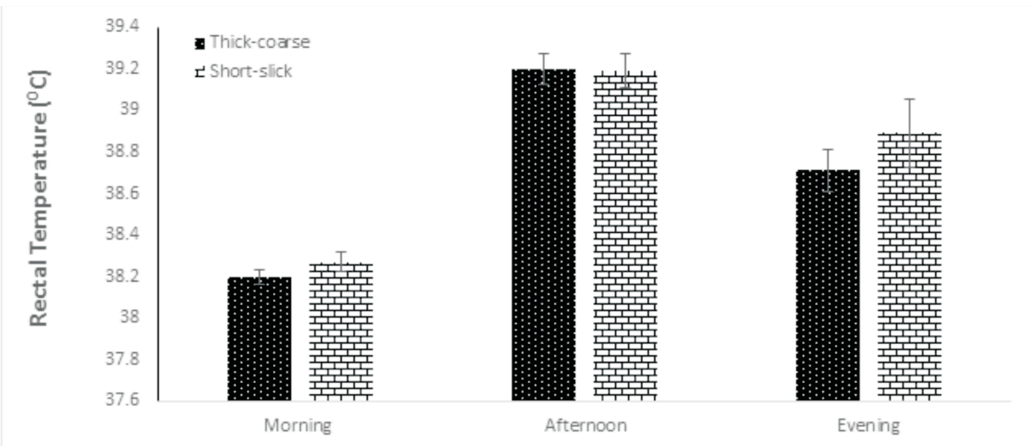

Fig. 7: Diurnal variation in rectal temperature of thick-coarse and smooth-slick hair Yankasa rams during hot-dry season. x,y,z indicates significant diurnal changes ($P<0.05$).

Moreover, the inter-digital space temperature and heart rate showed a significant afternoon rise only in short-slick hair sheep and also, the value of the inter-digital space temperature was higher in short-slick hair sheep than thick-coarse hair sheep in the afternoon hours. Increase in inter-digital space temperature is a reliable indicator of increased physiological effort to dissipate body heat, since during heat stress, a peripheral vasodilation and visceral vasoconstriction occur to pump larger volume of blood to peripheral structures like the limbs and skin for heat dissipation (D'Alterio *et al*., 2011; Minka and Ayo, 2016a; Habibu *et al*., 2018). This is in addition to the existence of a rich arteriovenous anastomoses on the limbs, which adjust the blood flow to enhance the efficiency of heat loss (D'Alterio *et al*., 2011).Irrespective of the degree of moderate heat stress (THI: 70-85), as indicated in the morning (THI: 72.28±1.79), afternoon (THI: 77.88±1.39) and evening (76.98±1.23) hours, respiratory rate was higher in Yankasa sheep with short-slick hair than those with thick-coarse hair. Hence from the discriminant test, respiratory rate contributes largely to the difference in thermoregulatory performance of the two hair types. Generally, sheep with greater propensity for heat stress adopt evaporative heat loss earlier and more intensely by increasing respiratory rate (Sevi *et al*., 2001; Seixas *et al*., 2017; Habibu *et al*., 2019). This may also explain the higher thermoregulatory demand in short-slick hair sheep that resulted in high rectal temperature in the evening as compared to the morning hour; indicating slow cooling after the afternoon rise in ambient temperature. Furthermore, the eye temperature was higher in short-slick hair sheep than thick-coarse hair sheep which agree with previous studies that demonstrated higher eye temperature in heat-stressed lambs (Paim *et al*., 2014). Collectively, the higher respiratory rate, eye and inter-digital space temperatures as well as marked diurnal changes in inter-digital space temperature and heart rate in short-slick hair sheep indicate greater physiological investment, and subsequently, higher energy expenditure to dissipate body heat, especially in the afternoon hours. Nonetheless, this mechanism seems efficient as the short-slick hair sheep were able to maintain similar body temperature as compared with the thick-coarse hair sheep.

The current study reported significantly higher hair length in Thick-coarse sheep than those with the Short-slick hair type (Fig. 8). Several studies in the tropics have demonstrated superior in terms of thermoregulatory (McManus *et al*., 2011a; Cruz Junior *et al*., 2015; Seixas *et al*., 2017), weight gain and lactation(Dikmen *et al*., 2008; 2014; Daure *et al*., 2013; Lukefahr, 2017) in sheep and cattle with short and smooth hair coat as compared with other types of hair coats.This may explain why natural selection favours the development of hair coat that is smooth and short over the long hair coat in different tropical breeds of sheep, including Yankasa sheep (Odubote, 1994; Ozoje, 2002; Daramola and Adeloye, 2009; Yakubu *et al*., 2010). However, in the study of Iddriss and Abdul Rahim (2018) for the Guinea Savannah climate of Ghana, both hair length nor coat depth affected the rectal temperature, respiratory and pulse rates in West African Dwarf (Djallonke) sheep. The current study observed lower thermoregulatory efficiency in Yankasa sheep with thick and wooly hair coat as compared to those with short and slick hair coat during the hot-dry season of Nigerian tropical Savannah. The higher thermoregulatory challenge in short-slick hair sheep is probably due to their large body size (Akpa *et al*., 2011; Correa *et al*., 2012). Yankasa rams with shorthair have been reported to be relatively longer, broader, deeper and heavier than those with thick hair (Akpa *et al*., 2011; Daure *et al*., 2013). Similarly, higher respiratory rate and greater thermoregulatory challenge have been reported in breed of sheep with larger body size than smaller breeds during heat stress (Seixas *et al*., 2017). Heat dissipation is more difficult in larger animals because of the lower proportion of body surface contact available for heat loss (McManus *et al*., 2011b; 2020). This low body size and weight in Yankasa rams with thick-coarse hair may be an adaptive feature to prevent accumulation of excess heat during heat stress; since they have a compromised heat dissipation capacity caused by thick hair coat (Maia *et al*., 2005; Cruz Junior *et al*., 2015; McManus *et al*., 2020). Moreover, Pacifici *et al*. (2017) reported that small body size is an adaptation to warmer climate and Singh *et al*. (2017) reported that, comparatively small size and white coat are among the traits that enhance heat tolerance in Indian sheep.

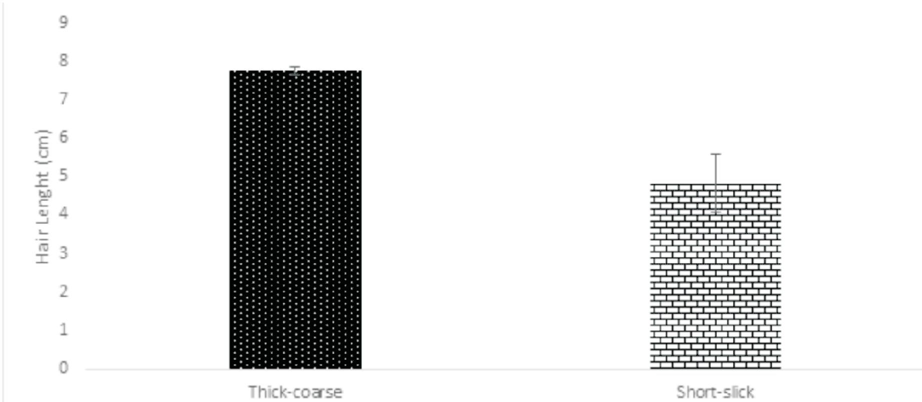

Fig. 8: Mean values of hair length in thick-coarse and smooth-slick hair Yankasa rams during hot-dry season. a,b indicates significant effect of hair type ($P<0.05$).

The discriminant analysis (Table 5) was conducted to predict which of the 9 thermoregulatory parameters measured best distinguish the two hair types into categories. Out of the 9 parameters measured, only temperature difference between skin and ambient temperatures was not included in the analysis. Respiratory rate had the strongest discriminating power, followed by hair and inter-digital space temperatures. Classification of rams into their predicted group membership (Table 6) showed distinct separation in thermoregulatory responses between the two hair types with higher number of Yankasa sheep with short-slick hair type (33.30%) been wrongly classified as having thick-coarse hair type. Whereas, only 11.70% of the sheep with thick-coarse hair type were wrongly classified as having short-slick hair type. Higher number of cases correctly classified into their respective groups indicates a distinction in the thermoregulatory responses of the two hair types to the challenge of heat stress. The thermoregulatory responses were more distinct in Yankasa sheep with thick-coarse hair type due to theirs low classification error into the short-slick category. This may imply uniqueness in the thermoregulatory performance of the thick-coarse hair sheep to heat stress during the hot-dry season. This agrees with previous studies in sheep and goats in which animals were correctly classified into membership groups based on their thermoregulatory responses to thermal stress (McManus *et al*., 2011b; de Alvarenga *et al*., 2013; Ribeiro *et al*., 2015).

Table 5: Structural matrix with discriminant function for the sheep

Variable	
Respiratory rate	0.773
Body surface temperature	0.293
Inter-digital temperature	0.206
Eye temperature	0.200
Rectal temperature	0.089
Heart rate	0.041
Skin temperature	-0.018
Rectal-ambient	0.017

Rectal-ambient indicates temperature difference between rectal and ambient temperatures

Table 6. Number and percentage of sheep classified into the different hair types

Group	Predicted Group Membership		Total
	Thick-coarse	Short-slick	
Count			
Thick-coarse	53.00	7.00	60.00
Short-slick	20.00	40.00	60.00
%			
Thick-coarse	88.30	11.70	100.00
Short-slick	33.30	66.70	100.00

Conclusion

The study showed that Yankasa rams with thick-coarse hair type had lower respiratory rate than those with short-slick hair type irrespective of hour of the day. Similarly, rams with thick-coarse hair type had lower body surface, eye and inter-digital space temperatures when compared to those with short-slick hair in the afternoon hours. Despite the higher thermoregulatory demand in short-slick hair sheep during the afternoon hours, they were able to maintain a comparable rectal temperature with their thick-coarse hair counterpart at all hours of the day; likely through increasing respiratory rate and vasodilation, especially of the limb blood vessels. Additional studies will be needed to evaluate the role of hair type in the thermoregulation of sheep during the cold-dry season, when thick coat is necessary to protect against loss of body heat.

Conflict of interest

The authors have no conflict of interest to declare.

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