ORIGINAL RESEARCH ARTICLE

Assessment of phenotypes, physiological and behavioural responses associated with heat tolerance among Galla goats in North Eastern Kenya.

[1]E. Mutindi, [2]I. Ogali, [1]S. Kuria, [1]G. Moraa, [2]E. Too, [3]J. Kingoo, [1]S. Ommeh

[1]Institute for Biotechnology Research, Jomo Kenyatta University of Agriculture and Technology.

[2]Veterinary Science Research Institute, Kenya Agricultural Livestock and Research Organization.

[3]The Technical University of Kenya.

Corresponding author: sommeh@jkuat.ac.ke

ABSTRACT

Galla goats have great adaptation vigor to different environments. However, the outcomes of the ongoing climate change have subjected livestock including the Galla goats to harsh environmental conditions like high ambient temperatures. In this study, Galla goats were characterized in the selected areas based on phenotypic, physiological, and behavioural responses to high environmental temperature. One hundred and forty-nine Galla goats selected from Isiolo, Garissa and Tana River were scored for various features such as coat colour, horn colour, skin colour, horn shape, horn length, ear orientation, ear length, wattles and horn circumference. Data collected were entered in an excel spread sheet then analyzed in R statistical software version 4.0.4. White was found to be the dominant coat colour with a percentage frequency greater than 60.0% in the studied counties. The study revealed that both male and female Galla goats possess horns with more than 88.9% of goats being horned across the three counties. There was a strong relationship between horn presence and the environmental temperature with p=0.05. A positive correlation was also observed between environmental temperature and rectal temperature, horn length, ear length and horn circumference. The findings show the presence of an important gene pool from which guidelines on conservation of heat stress phenotypes as a result of the ongoing climate change can be put in place.

Keywords: Climate change, diversity, heat stress, pastoral cluster, plasticity

1.0 Introduction

Goats are important in the livelihoods of many pastoralists and agro-pastoralists in developing countries especially in Kenya and Africa at large. In developing countries, goats are a source of food, income and they play crucial socio-cultural roles (Al-Araimi *et al*., 2017).

In Kenya, due to their resilience and adaptability to harsh environmental conditions, goats are kept across all the agro-ecological regions (Nandolo et al., 2019). Majorly, goats are kept in the Arid and semi-arid lands (ASALs) which comprise 80% of Kenya. A major characteristic of the ASALs is the high ambient temperature and the long period of dry seasons. The sale of

URL: https://ojs.jkuat.ac.ke/index.php/JAGST
ISSN 1561-7645 (online)
https://dx.doi.org/10.4314/jagst.v21i1.2

goat milk, meat, and skin contribute to 13% of the national Gross Domestic Product (GDP) and 42% agricultural GDP contributed by the Livestock sector in Kenya (Nyariki and Amwata, 2019).

Goats in Kenya are classified into exotic breeds which include Alpine, Saneen and Toggenburg. The local breeds include the Small East African and the Galla goat (Kivila *et al*., 2018). Galla goat is a hardy breed locally found in the ASALs of Northern and Northeastern Kenya (Otieno *et al*., 2013). They are managed under extensive systems which subject them to extreme temperature changes like heat stress experienced in the horn of Africa as a result of climate change.

Breeds that can withstand the challenges of climate change contribute towards food security (Assan, 2014). Despite being hardy animals, goats like any other animals also suffer from heat stress during extreme high temperatures. This interferes with feeding, immune response and production of meat, milk (Gupta and Mondal, 2021). Galla goats are able to produce and cope in adverse environments due to morphological, genetic, and behavioral adaptation (Sejian *et al*., 2018). Galla goats can grow to a height of 75cm and 66cm for bucks and does respectively. Bucks can gain weight up to70kgs while the does weigh up to 55kgs giving them a pre-eminence in meat production. Several studies have been done to assess the performance of animals, especially in hot areas. A study carried out by Leite (2018) showed that bright coats colours were involved in heat stress alleviation in ewes.

The horn and ear phenotypes have been studied in goats and cattle in hot environments (FAO, 2012). These traits have beneficial effects in heat dissipation during heat stress (Parés-Casanova *et al*., 2014). In addition to the mentioned morphological traits, wattles, ear orientation, hair type, testicles, and skin colour have also been studied in response to heat dissipation in goats (Kolo *et al*., 2014). Behavioral responses like increased standing time and shade seeking have also been linked to high environmental temperatures (Sejian *et al*., 2018). Physiological responses including increased rectal temperature and panting were studied by Niyas (2015) in response to thermoregulation.

Since the characterization of breeds is the first step to sustainable utilization of the animal genetic resources, this study aimed to describe how Galla goats cope in the hot environment of the ASALs by assessing their phenotypic attributes, physiological and behavioural responses. Having a deep understanding of the adaptation of goats may yield markers to assist in the future to keep goat breeds that produce optimally and survive in adverse environmental conditions.

2.0 Materials and Methods

2.1 Study approval

The study was approved by the institutional animal care and use committee (IACUC) of the Veterinary Science Research Institute- Kenya Agricultural and Livestock Research Organization (KALRO). The study was given a clearance reference number (KALRO VSRI/IACUC022/04062021).

URL: https://ojs.jkuat.ac.ke/index.php/JAGST
ISSN 1561-7645 (online)
https://dx.doi.org/10.4314/jagst.v21i1.2

2.2 Study area

We conducted our study in the ASAL regions of Isiolo, Garissa, and Tana River counties in February 2021 during the dry season. These regions are considered as ASALs as they experience high ambient temperatures and rainfall below 600mm per annum. Pastoralism is the main economic activity in the regions (Nyariki and Amwata, 2019). The counties were chosen because Galla goats are local to the region and also based on the Kenya-Climate Smart Agriculture Project which ranked goat production in ASAL areas as a priority. Isiolo county lies between latitude 0°31' 46'' N and longitude 37°41' 33'' E. The county is basically semi-arid with an average annual temperature of about 23.3°C and annual rainfall of about 418 mm. Garissa is located between 0° 19' 27'' S and 39° 35' 3'' E. It has an average annual temperature of 36°C and 280mm rainfall. Tana River County lies between 0°27' 47'' S and 39°36' 27'' E. According to (MoALF (2016) the average rainfall is between 280 mm and 900mm. The climate is hot and dry with an average annual temperature of 30°C (Figure 1).

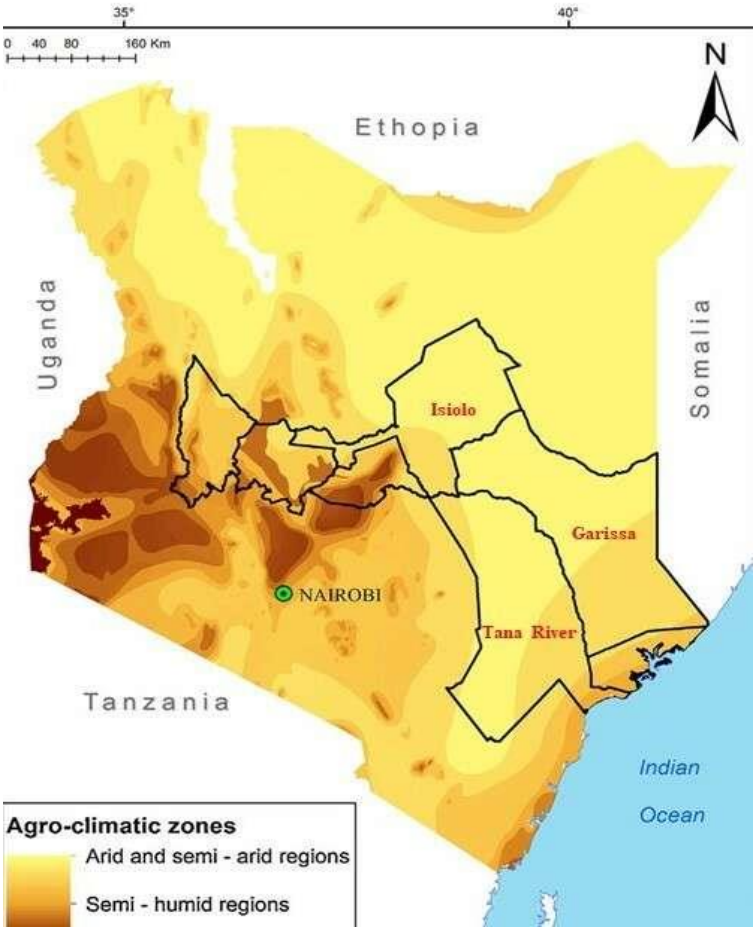

Figure 1. Map of study area source; (Mosomtai et al., 2016)

2.3 Study design and sample size

The design was cross-sectional (one-time study) with a purposive sampling method. Closed-ended questionnaires were administered to farmers to collect phenotypic data. The study was

URL: https://ojs.jkuat.ac.ke/index.php/JAGST
ISSN 1561-7645 (online)
https://dx.doi.org/10.4314/jagst.v21i1.2

carried out within six populations across Isiolo, Garissa and Tana River counties (Table 1).

Table 1. Sampled populations

County	Sub county	Population/ Village	GPS Coordinates	Number of samples	Male	Female
Isiolo	Ngaremara	Ngaremara	0° 21' 0'' N 37° 35' 0'' E	20	10	10
	Ngaremara	Daaba	0°31' 46'' N 37°41' 33'' E	25	11	14
Garissa	Mbalambala	Sankuri	0° 19' 27'' S 39° 35' 3'' E	39	7	32
	Mbalambala	Raya	0° 22' 0'' S 39° 36' 46'' E	25	10	15
Tana River	Madogo	Madogo	0°27' 47'' S 39°36' 27'' E	20	4	16
	Madogo	Adele	- 1° 6' 11.628" 39° 52' 0.66"	20	9	11
Total				**149**	**51**	**98**

2.4 Data collection

We administered closed-ended questionnaires to the farmers to obtain morphological data (physical features which can be observed) and production system information of the Galla goats. The sample size was determined as recommended by Hale *et al*., (2012) where 149 adult Galla goats were characterized from the three counties. Qualitative traits studied via visual appraisal included: horn presence and shape, wattle presence, coat colour (fur colour), skin colour, hair type, ear orientation and presence of beards. Quantitative traits such as horn length, horn circumference, and ear length were taken using a tape measure in centimetres. Physiological responses studied were rectal temperature and panting frequency. Rectal temperature was measured using a thermometer while the frequency of panting and behavioral responses were determined via visual appraisal. Panting (fast open mouth breathing) was scored in the afternoon when temperatures were high. Ambient temperature was taken in each region at the time of sampling. Global positioning systems were also recorded.

2.5 Statistical analysis

We entered raw data in excel spreadsheet package 2016. All the statistical analysis were performed using R software version 4.0.4 (Harris, 2018). The percentage frequency of each trait was computed as follows:

= (Number of individual having the trait / Total number of individual sampled) ×100

The relationship between various traits and the outside temperature in the three regions were determined using ANOVA. Correlation statistics was used to determine the relationship between the body measurements and the rectal temperature. Box plots were used to determine horn length relationship among Galla goats in the three counties.

URL: https://ojs.jkuat.ac.ke/index.php/JAGST
ISSN 1561-7645 (online)
https://dx.doi.org/10.4314/jagst.v21i1.2

3.0 Results

3.1 Phenotypes observed and their percentage frequency among Galla goats

Our study observed six coat colours among the sampled Galla goats across Isiolo, Garissa and Tana River counties. The majority of the sampled Galla goats had white coat colour while a small population had multicolour coats with white having a greater proportion (Figure 2). The percentage frequency for each coat colour and skin colour type across Isiolo, Garissa and Tana River was tabulated. The relationship of coat colours and skin colour expressions to the environmental temperature was also determined (Table 2)

Figure 2. A-Plain white, B- Black stripe on spine, C- Brown spotted, D-Black spotted, E- Brown- black patches, F- Brown patch

Table 2. Proportionate (%) occurrence of coat, skin & ear colour traits among Galla goats and their relationship to outside temperature.

Character	Colour	Isiolo	Garissa	Tana River	*p –value* of outside temperature
Coat color	White	73.3%	68.8%	60.0%	
	White with black stripe on spine	2.22%	7.81%	10.0%	
	White with brown & black patches	0.00%	9.38%	5.00%	
	White with black spots	0.00%	0.00%	2.50%	0.402
	White with brown patches	22.2%	14.1%	20.0%	
	White with brown spots	2.22%	0.00%	2.50%	
Skin colour	Black	84.4%	90.6%	100%	0.076
	Brown	15.6%	9.38%	0.00%%	
Ear colour	White	75.6%	90.6%	70.0%	0.688
	Brown	22.2%	9.38%	25.0%	
	Black	2.22%	0.00%	5.00%	

Significant codes: 0.001 '***' 0.01 '**' 0.05'*'

We observed that both male and female Galla goats possess horns in the three counties. Three different horn shape types and ear orientations were observed among the sampled Galla goats (Figure 3). The percentage frequency of the different horn shapes and ear orientation across Garissa, Isiolo and Tana River and the relationship to ambient temperature was calculated and recorded (Table 3).

URL: https://ojs.jkuat.ac.ke/index.php/JAGST
ISSN 1561-7645 (online)
https://dx.doi.org/10.4314/jagst.v21i1.2

Figure 3. G-polled & horizontal ear, H- curved horn & erect ear, I- straight horn, J- deformed horns, K-floppy ear

Table 3. Proportionate (%) occurrence of horn type, shape and ear orientation traits among Galla goats and their relationship to the outside temperature

Character	Type	Isiolo	Garissa	Tana River	*p* –value of outside temperature
Horn	Horned	88.9%	96.9%	97.5%	0.05*
	Polled	11.1%	3.12%	2.50%	
Horn colour	Black	70.0%	62.9%	69.2%	0.332
	Brown	30.0%	37.1%	30.8%	
Horn shape	Curved	55.0%	45.2%	33.3%	0.257
	Straight	40.0%	35.5%	56.4%	
	Deformed	5.00%	19.4%	10.3%	
Ear orientation	Floppy	55.6%	39.1%	62.5%	0.69
	Horizontal	24.4%	45.3%	2.50%	
	Erect	20.0%	15.6%	12.5%	

Significant codes: 0.001 '**' 0.01 '**' 0.05 '*'

The beard and wattle phenotypes were present in both male and female Galla goats across the counties although the beard phenotype was more dominant in males. Four hair types were also observed across the three counties with the majority having smooth hair (Figure 4). The percentage occurrence of the beard, wattle and hair type phenotypes was determined. The majority of the sampled Galla goats across Isiolo, Garissa and Tana River did not possess beards and wattles and had smooth and glossy hair (Table 4).

Figure 4. L- glossy & smooth hair, M- wattles, N- bearded & dull hair, O- curly rough hair

URL: https://ojs.jkuat.ac.ke/index.php/JAGST
ISSN 1561-7645 (online)
https://dx.doi.org/10.4314/jagst.v21i1.2

Table 4: Proportionate (%) occurrence of beards, hair type and wattle traits among Galla goats and their relation to the outside temperature

Character	Type	Isiolo	Garissa	Tana River	*p* –value of outside temperature
Beard	Bearded	35.6%	15.6%	10.0%	0.00174 **
	Non –bearded	64.4%	84.4%	90.0%	
Hair type	Curly rough hair	2.22%	1.56%	0.00%	0.18
	Straight	15.6%	0.00%	5.00%	
	Smooth	55.6%	48.4%	55.0%	
	Glossy	24.4%	26.6%	25.0%	
	Dull	20.0%	23.4%	15.0%	
Wattles	Wattled	4.44%	6.25%	2.50%	0.438
	Non –wattled	95.6%	93.8%	97.5%	

Significant codes: 0.001 '***' 0.01 '**' 0.05 '*'

3.2 Correlation and box plot analysis

The correlation between different body measurements, rectal and environmental temperature showed either a positive or no relationship at all. The horn length and horn circumference had a high positive correlation (Table 5). We also used a box plot to determine the uniformity and skewness of horn length among the Galla goats across the sampled areas. The horn length sizes were not uniform across the three counties since the box plots were not the same. Isiolo had the majority of Galla goats with horn length greater than the median with the box plot skewed to right. The horn length in Isiolo ranged from two (2) centimetres (cm) to 30cm. Tana River had the least horn sizes ranging from 2cm to 15.8cm with many goats having horn length distributed below the median horn length. Garissa had uniform horn length distribution with no horn length in the extremes. (Figure 5).

Table 5: Correlation between the rectal temperature and body measurements (centimeters)

Parameters	*p-value*	*R-value*
Rectal temp and Outside temp	9.017e-09"***	0.449
Rectal temp and Ear length	0.663	-0.036
Rectal temp and Horn length	0.129	-0.125
Rectal temp and Horn circumference	0.121	-0.127
Ear length and horn circumference	0.05*	0.156
Ear length and horn length	0.093	0.138
Horn length (CM) and Horn circumference	2.2e-16***	0.839

Significant codes: 0.001 '***' 0.01 '**' 0.05 '*'

URL: https://ojs.jkuat.ac.ke/index.php/JAGST
ISSN 1561-7645 (online)
https://dx.doi.org/10.4314/jagst.v21i1.2

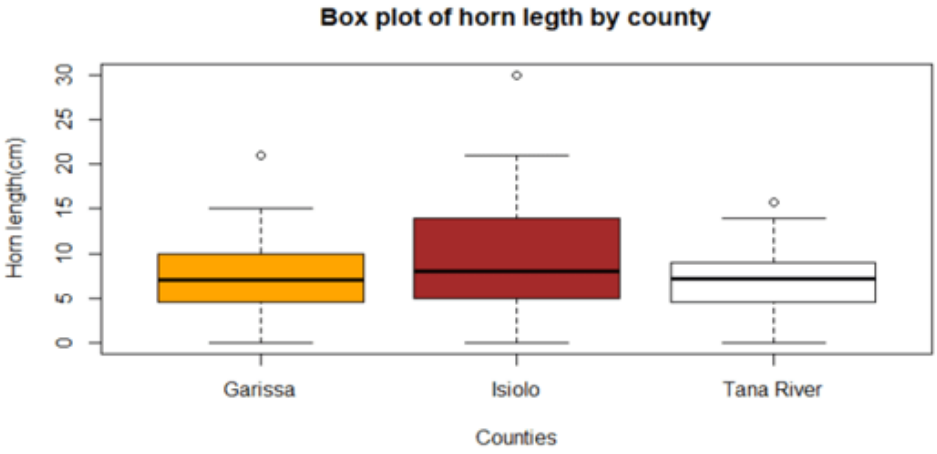

Figure 5. A box plot showing the relationship between horn lengths in sampled area

3.3 Physiological parameter analysis

Open mouth breathing goats were observed during the study as physiological responses to high temperatures. Panting also known as open-mouth breathing of goats was observed in the afternoon when environmental temperatures were high. (Figure 6). The occurrence proportions of panting Galla goats across Isiolo, Garissa and Tana River and the relationship to environmental temperature was calculated and tabulated. Our study observed low frequencies of panting Galla goats (Table 6).

Figure 6, P- Panting goat

Table 6: Proportionate (%) occurrence of physiological trait in Galla goats and the relationship to outside temperature

Character	Expression	Isiolo	Garissa	Tana River	*p–value* of outside temperature
Panting	Yes	35.6%	31.2%	37.5%	0.818
	Absent	64.4%	68.75%	62.5%	

Significant codes: 0.001 '***' 0.01 '**' 0.05 '*'

URL: https://ojs.jkuat.ac.ke/index.php/JAGST
ISSN 1561-7645 (online)
https://dx.doi.org/10.4314/jagst.v21i1.2

4.0 Discussion

4.1 Coat colour

Coat colour is a quickly recognizable appearance colour that may be used to define a breed. It can also be used in characterization and animal selection. In our study, we observed six coat colour patterns: plain white, white with a black stripe on the spine, white with brown spots, white with black spots, white with brown-black patches and white with brown patches. The predominance of white coat colour was reported by Otieno *et al*., (2013) where Galla goats were characterized in Kajiado and Makueni.

4.1.1 Frequency of occurrence of coat and skin colour traits and their relationship to the outside temperature

We observed that plain white was the dominant coat and ear colour among Galla goats across the three counties although there seemed to be no relationship between the predominance of white coat colour to environmental temperature ($p > 0.05$). This may be as a result of sampling one breed. Galla goats with multi-colours coats had a higher portion of white colour mixed with brown patches, black patches, spots, or stripes on the spine. The predominance of the white coat colour among the Galla goats was also reported by Otieno *et al*., (2013). The high proportion of white coat may be linked to the advantageous role of bright coat colour in hot tropical regions where it reflects 60.0% of direct solar radiation in comparison to dark colours (Sejian *et al*., 2018). The reflection of solar radiation results to less absorption of heat. The tendency towards multi-colored goats is also an adaptation to cope with seasonal variation of heat intensity and light (Assan, 2014).

Our study observed that black skin colour is dominant among Galla goats. The occurrence frequency is similar to studies by Otieno *et al*., (2013) where Galla goats were sampled in Makueni and Kajiado. Also, Assan (2014) reported that dark-colored skin played a role in preventing direct penetration of solar radiation. In another study by Darcan *et al*., (2009), pigmented goats showed lower rectal temperature compared to unpigmented since they can maintain normal body temperatures at high environmental temperatures. This is because darkly pigmented skin shields the inner body tissues from the direct ultraviolet short wave by blocking the perforation (Sejian *et al*., 2018).

4.2 The horn and ear phenotypes

Horns refer to pointed structures on the head of several animals and have different shapes. Our study found out that majority of Galla goats were horned with few being polled. The horn phenotype was present in both male and female Galla goats. Studies conducted by Nguluma *et al*., (2016) reported a similar scenario. We observed three different horn shapes among the three counties: curved, straight, and deformed shape. Three ear orientations were also observed in our study similar to Muigai *et al*., (2016).

4.2.1 Frequency of occurrence of horn and ear traits and their relationship to the outside temperature

The horn phenotype was present in more than 88.7% of the Galla goats in the three counties, with Tana River having the highest percentage of 97.5%. This phenotype had a $p<0.05$ in relation to the outside temperature. Studies by Kolo *et al*., (2014) on Nigerian goats reported

URL: https://ojs.jkuat.ac.ke/index.php/JAGST
ISSN 1561-7645 (online)
https://dx.doi.org/10.4314/jagst.v21i1.2

the role of horns in heat dissipation during high temperatures. The horn occurrence was in accordance with studies conducted in Tanzania among the Small East African goats by Nguluma *et al*., (2016) which reported an occurrence frequency of 96.7%. Straight horn phenotype was dominant in Tana River while curved horn shape phenotypes were dominant across Isiolo, Garissa. Similarly, studies carried out by Manzi *et al*., (2011) in Rwanda on goat phenotypic characterization had similar findings. Our study also observed deformed horns in less than 19.4% of Galla goats across the studied regions. Isiolo recorded the lowest frequency of deformed horns at 5.00%.

We observed that ear orientation was majorly floppy (pendulous) in Isiolo and Tana River with a percentage frequency of 55.6 and 62.5 respectively. Garissa recorded the highest frequency of horizontal ear orientation at 43.5%. The same results were reported by Muigai *et al*., (2016) on the characterization of indigenous cattle, sheep and goats in Somalia and northern Kenya.

4.3 Beard, hair type and wattle phenotypes

Beard refers to the hair growing on the chin. Our study observed the presence of beards in both males and females Galla goats. Also, our study scored hair type depending on the nature of the hair; curly and rough, smooth, glossy (shining), and dull hair. All the hair types were observed across the three counties in our study. We observed the dominance of smooth hair in two counties. The hair type, size and structure phenotypes were studied by (Assan, 2014) and they were associated with a heat loss role.

Wattles refers to the hanging appendages on the neck. Our study scored Galla goats as either wattled or non-wattled with the majority being non-wattled. Studies by Adedeji, (2012) linked the presence of wattles in goats to heat dissipation although the mechanism was not explained.

4.3.1 Frequency of occurrence of traits and their relationship to the outside temperature

The majority of goats in our study across the three counties had smooth hair. Curly rough hair recorded the least frequency with Tana River recording 0.00%. Despite this, the relationship between hair type and the ambient temperature had a $p > 0.05$. The occurrence frequency is similar to studies by Castanheira *et al*., (2010) who studied the role of heat tolerance traits in sheep. The study concluded that short and smooth hair facilitated better heat loss to the environment as compared to coarse and dull hair by keeping air between the environment and the skin.

In each county, bearded Galla goats were less than 35.6%. The relationship to environmental temperature had a $p<0.05$. The occurrence frequency is similar to a study carried out by Msemwa *et al.*, (2018) on Pare goats in Tanzania where 38.1% of goats had beards. Similar to a study conducted by Nguluma *et al*., (2016), we observed that both males and females Galla goats had a beard.

Our study observed the wattle phenotype to be less than 6.25% among Galla goats in Garissa, Isiolo, and Tana River counties. Similar findings were reported by Nguluma *et al*., (2016) where the wattle gene was reported to be at the risk of extinction. The wattles colour takes after the

URL: https://ojs.jkuat.ac.ke/index.php/JAGST
ISSN 1561-7645 (online)
https://dx.doi.org/10.4314/jagst.v21i1.2

dominant coat colour just as suggested by studies on heat tolerance features of the West African goats (Adedeji, 2012).

4.4 Correlation analysis between body parameters

Our study observed a positive correlation of 0.45 between environmental and rectal temperature. This confirms that, as the environmental temperature increases, the rectal temperature of the Galla goats increases across the three counties. Similarly, a study involving Swedish goats on the effect of thermal conditions on rectal temperature showed an increase in rectal temperature with high ambient temperature (Hartmann *et al*., 2021).

The association between the rectal temperature and ear length had a negative correlation across the three counties. The ear length measurements are similar to studies involving morphological characterization and selection of Pare goats in Tanzania (Msemwa *et al*., 2018). Our study also reported a p >0.05 for the association between the rectal temperature and horn length.

The association between horn length and horn circumference showed a strong positive correlation value of 0.839. We noted that as horn length increases, the horn circumference also increases similar to studies done on domestic goats to ascertain the role of horns in Bovid. Another study carried out by Parés-Casanova *et al*., (2014) on Watusi cattle reported a positive correlation of 0.92. Horn size and circumference are linked to thermoregulation in animals (FAO, 2012). Reviews have reported the role of horns in heat dissipation among sheep, goats and cattle that are native to Africa where temperatures remain high almost all year round. The Watusi cattle horns grow up to 6 feet long compacted with blood vessels. The consistency in heat regulation among the bovid is due to the physiology and anatomy of their horns. Vasodilation in the highly vascularized inner core has been reported in goats during heat stress allowing the flow of blood close to the surface enabling heat loss (Picard *et al*., 1999).

Ear length and horn circumference had a significant weak positive correlation. It has been shown that ears have a thermoregulatory role even in wild animals (Parés-Casanova *et al*., 2014).

4.5 Uniformity of horn sizes across Isiolo, Garissa, and Tana River counties

To check whether horn size was uniform across the three counties, we drew a boxplot using the R statistical package. Our study found out that horn size was not uniform across the three counties. Horn length among Galla goats in Isiolo was found to be the highest with the distribution of the horn length skewed to the right followed by Garissa with the symmetrical distribution. This showed that horn length in Isiolo had a wide range of values with goats having horn length in the extremes. Tana River was the last with a negatively skewed distribution. The results were in accordance with studies carried out among Small East African goats' populations in several ASAL regions in Tanzania where horn size in different sampled areas was different (Nguluma *et al*., 2016).

4.6 Panting as a physiological response

Panting refers to fast, open-mouth breathing due to increased respiratory rate (Berihulay *et*

URL: https://ojs.jkuat.ac.ke/index.php/JAGST
ISSN 1561-7645 (online)
https://dx.doi.org/10.4314/jagst.v21i1.2

al., 2019). Heat is lost from the body through the evaporation of moisture from the lungs. This evaporative cooling is a mechanism of regulating the normal temperature in goats *(Sejian et al*., 2018).

4.6.1 Occurrence frequency of panting goats in response to environmental temperatures

Tana River recorded the highest percentage of panting/open mouth breathing goats with a percentage of 37.5% in our study. Garissa County had the least with a percentage of 31.2%. Review studies have described panting as a physiological response to elevated temperatures and heat through increased respiration rate. About 66.0% of heat loss is linked to cutaneal evaporation while 34.0% is from the respiration mechanism when goats are exposed to solar radiation (Dmi'el and Robertshaw, 1983).

In addition to morphological and physiological mechanisms, we observed several behavioural responses across Garissa, Isiolo and Tana River counties. They include increased standing time and reduced feeding in the afternoon. Similar findings were reported among farm animals that showed decreased feeding rate when exposed to high ambient temperature by Shaji *et al*., (2017). Reduced intake in feed is an adaptive way to control the released metabolic heat from the body (Berihulay *et al*., 2019).

Our study observed that Galla Goats in the three counties spend most of the time standing especially in the evening when ambient temperatures were high. The same findings were reported in dairy cows in Egypt which spent most of the time standing during summer. This was associated with the orientation of the goats to prevent direct terrestrial and solar radiation (Provolo and Riva, 2009). Standing position also prevents the conductive transfer of heat into the animal body and allow heat dissipation due to direct contact of air across the large body surface area (Sejian *et al*., 2018).

5.0 Conclusion

Our study confirmed that plain white is the dominant coat colour among Galla goats in Isiolo, Garissa, and Tana River. Whitecoat colour plays a role in minimal heat absorbance. The majority of Galla goats possess horns and the phenotype is present in both males and females. Our study confirmed a positive association between environmental and rectal temperature, horn length, and horn circumference. Other morphological characteristics did not correlate with environmental temperatures.

6.0 Recommendations

Our study centred on the adaptation responses to natural hot environments therefore further controlled research should be done to confirm the responses. The findings of our study pave way for further studies to link phenotypes of heat tolerance to the genotypes. Also, similar studies should be carried out in other arid and semi-arid areas of Kenya.

7.0 Acknowledgment

The Authors are very grateful to the Department of Veterinary Services (Isiolo, Garissa, and Tana River counties) for bracing the research, extension officers, community representatives, farmers and colleagues (co-operation towards data collection) and the Kenya Climate-Smart

URL: https://ojs.jkuat.ac.ke/index.php/JAGST
ISSN 1561-7645 (online)
https://dx.doi.org/10.4314/jagst.v21i1.2

Agriculture Project for this scholarship grant award.

8.0 Conflict of Interest

The authors declare no conflict of interest.

9.0 References

Adedeji T. A. (2012). Effect of Some Qualitative Traits and Non-Genetic Factors on Heat Tolerance Attributes of Extensively Reared West African Dwarf (WAD) Goats. *In International Journal of Applied Agricultural and Apicultural Research*. 8.

Al-Araimi N. A., Gaafar O. M., Costa V., Neira A. L., Al-Atiyat R. M and Beja-Pereira A. (2017). Genetic origin of goat populations in Oman revealed by mitochondrial DNA analysis. *PLoS ONE*. 12(12), pp 1–16.

Assan N. (2014). Goat production as a mitigation strategy to climate change vulnerability in semi-arid tropics. *Scientific Journal of Animal Science*. 3(11), pp 258 – 267.

Berihulay H., Abied A., He X., Jiang L and Ma Y. (2019). Adaptation mechanisms of small ruminants to environmental heat stress. *Animals.* 9(3), pp 1– 9.

Castanheira M., Paiva 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. *Tropical Animal Health and Production.* 42(8), pp 1821–1828.

Darcan N. K., Cankaya S and Karakok S. G. (2009). The effects of skin pigmentation on physiological factors of thermoregulation and grazing behaviour of dairy goats in a hot and humid climate. *Asian-Australasian Journal of Animal Sciences*. 22(5): 7–731.

Dmi'el R and Robertshaw D. (1983). The Control of Panting and Sweating in the Black Bedouin Goat: A Comparison of Two Modes of Imposing a Heat Load. *Physiological Zoology* 56(3), pp 404 – 411.

FAO. (2012). Phenotypic characterization of animal genetic resources. *In FAO Animal Production and Health Guidelines.*

Gupta M and Mondal T. (2021). Heat stress and thermoregulatory responses of goats: A review. *Biological Rhythm Research*. 52(3), pp 407– 433.

Hale M. L., Burg T. M and Steeves T. E. (2012). Sampling for Microsatellite-Based Population Genetic Studies: 25 to 30 Individuals per Population Is Enough to Accurately Estimate Allele Frequencies. *PLoS ONE*. 7(9).

Harris R. (2018). An Introduction to R. Quantitative Geography: *The Basics.* 5, pp 250–286.

Hartmann E., Högberg M., Olsson K and Dahlborn K. (2021). Physiological and behavioural responses of Swedish domestic goats and their kids (Capra hircus) to 15 days of heat exposure. *Acta Agriculturae Scandinavica A: Animal Sciences.* 70(1), pp 41– 49.

Kivila J. N., Githui E. K., Amugune N. O., Githaiga J. M and Okwany Z. A. (2018) Mitochondrial DNA Indicate that Kenyan Indigenous Goat (Capra hircus) Population is Diverse. *Agricultural Research & Technology :Open Access Journal*.18(1).

Kolo P. S., Egena S. S. A., Tsado D. N and Adisa-Shehu M. (2014). Phenotypic and genetic categorization of qualitative traits in extensively managed local goat (Capra aegagrus) population of Niger State, Nigeria. *Nigerian Journal of Genetics.* 28(2),pp 38 – 43.

Leite J. H. G. M., Façanha D. A. E., Costa W. P., Chaves D. F., Guilhermino M. M., Silva

URL: https://ojs.jkuat.ac.ke/index.php/JAGST
ISSN 1561-7645 (online)
https://dx.doi.org/10.4314/jagst.v21i1.2

W. S. T and Bermejo L. A. (2018). Thermoregulatory responses related to coat traits of brazilian native ewes: An adaptive approach. *Journal of Applied Animal Research.* 46(1), pp 353–359.

Manzi M., Rutagwenda T., Kanuya N and Chatikobo P. (2011). Phenotypic characterization of goats raised under traditional husbandry systems in Bugesera and Nyagatare districts of Rwanda. *Journal of Animal and Veterinary Advances.* 10, pp 3297–3302.

MoALF. (2016). Climate Risk Profile for Tana River County. Kenya County Climate Risk Profile Series. *The Ministry of Agriculture, Livestock and Fisheries (MoALF)*, Nairobi, Kenya.

Mosomtai G., Evander M., Sandström P., Ahlm C., Sang R., Hassan O. A and Landmann T. (2016). Association of ecological factors with Rift Valley fever occurrence and mapping of risk zones in Kenya. *International Journal of Infectious Diseases*. 46, pp 49–55.

Msemwa J. L and Mbaga S. H. (2018). Physical Characteristics and Selection Criteria of Pare White Goats in Kilimanjaro and Manyara districts, Tanzania. *Tanzania Journal of Agricultural Sciences*. **17**(2), pp 46–53.

Muigai A., Matete G., Aden H. H., Tapio M., Mwai O and Marshall K. (2016). The indigenous farm genetic resources of Somalia: Preliminary phenotypic and genotypic characterization of cattle, sheep and goats. *ILRI Project Report.* Nairobi, Kenya: International Livestock Research Institute (ILRI).

Nandolo W., Mészáros G., Banda L. J., Gondwe T. N., Lamuno D., Mulindwa H. A and Sölkner J. (2019). Timing and Extent of Inbreeding in African Goats. *Frontiers in Genetics*. 10.

Nguluma A. S., Msalya G and Chenyambuga S. W. (2016). Phenotypic variation among four populations of small East African goats of Tanzania. *Livestock Research for Rural Development*:28(8).

Niyas P. A., Chaidanya K., Shaji S., Sejian V and Bhatta R. 2015. Adaptation of livestock to environmental challenges. J Vet Sci Med Diagn. 4 (3), pp 2.

Nyariki D. M and Amwata D. A. (2019). The value of pastoralism in Kenya: Application of total economic value approach. *Pastoralism.* 9(1), pp 9.

Otieno O. G., Junga J. O., Badamana M. S and Amimo J. O. (2013). Indigenous Knowledge Used in Breeding and Management of Capra hircus Populations in Kajiado and Makueni Counties, Kenya. Kenya. *Open Journal of Genetics*. 5, pp 111–135.

Parés-Casanova P. M., Vet P., Caballero M and Lic. (2014). Possible tendency of polled cattle towards larger ears. *Rev Colomb Cienc Pecu.* 27, pp 221-225.

Picard K., Thomas D. W., Festa-Bianchet M., Belleville F and Laneville A. (1999). Differences in the thermal conductance of tropical and temperate bovid horns. *Ecoscience* 6(2): 148–158.

Provolo G and Riva E. (2009). One year study of lying and standing behaviour of dairy cows in a Frestall Barn in Italy. *Journal of Agricultural Engineering*. 40(2), pp 27.

Sejian V., Bhatta R., Gaughan J. B., Dunshea F. R and Lacetera N. (2018). Review: Adaptation of animals to heat stress. *Animal*. 12, pp 431– 444.

Shaji S., Sejian V., Bagath M., Manjunathareddy G. B., Kurien E. K., Varma G and Bhatta R. (2017). Summer season related heat and nutritional stresses on the adaptive capability of goats based on blood biochemical response and hepatic HSP70 gene expression. *Biological Rhythm Research.* 48(1), pp 65–83.

URL: https://ojs.jkuat.ac.ke/index.php/JAGST
ISSN 1561-7645 (online)
https://dx.doi.org/10.4314/jagst.v21i1.2