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**Comparative assessment of growth performance of three different indigenous goat breeds
exposed to summer heat stress**

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Running Head: Superior adapted goat breed

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SUMMARY

A study was conducted to assess comparatively the growth performance of three different indigenous goat breeds during exposure to summer heat stress. The primary objective of the study was to observe the heat stress impact on the growth performance based on the body weight changes, allometric measurements, growth hormone (GH) concentration and peripheral blood mononuclear cell (PBMC) Insulin-like growth factor-1 (IGF-1) mRNA expression pattern during the summer season in comparison to the local breed (Osmanabadi). Thirty six ten months to one year old female goats of Osmanabadi, Malabari and Salem Black breeds were randomly divided into six groups, OC (n=6; Osmanabadi control), OHS (n=6; Osmanabadi heat stress), MC (n=6; Malabari control), MHS (n=6; Malabari heat stress), SBC (n=6; Salem Black control) and SBHS (n=6; Salem Black heat stress). Body weight was recorded at weekly intervals, whereas other growth and allometric measurements and blood collection was carried out at fortnightly intervals. Breed factor significantly ($P<0.05$) influenced only few growth variables such as body weight, body mass index (BMI), body condition score (BCS). However, heat stress treatment significantly ($P<0.05$) reduced all growth parameters except BMI. Further, the heat stress significantly ($P<0.01$) increased plasma GH concentration in goats with significantly higher ($P<0.05$) concentration recorded in OHS. Among the stress groups, the lower ($P<0.05$) PBMC IGF-1 mRNA expression was recorded in OHS, while the higher ($P<0.05$) expression was observed in SBHS indicating the extreme adaptive capability of Salem Black breed. Thus, the

results indicated that the Salem Black breed performed much better compared to both Osmanabadi and Malabari breeds indicating the superior ability of this breed to adapt to heat stress challenges. The results also indicated that plasma GH and IGF-1 gene may act as ideal biomarkers for assessing the heat stress impact on growth performance in indigenous goats.

Keywords: Heat stress, indigenous goat, growth, growth hormone, allometric variables, IGF-1.

Introduction

Indigenous breeds are well adapted to the agro-climatic conditions where they have evolved and are hardy enough to thrive well on poor forage and stressful conditions where high yielding exotic and crossbred animals succumb (Akinyi, 2008). Further, the indigenous breeds play a vital role in the economy and food security of poor and marginal farmers in developing countries in particular. In addition, the smaller size of indigenous goat breeds as compared to exotic and crossbred goats is a genetic adaptive strategy synchronized with the available nutrient resources (Nyamushamba et al., 2017). Although the indigenous breeds are expected to adapt better due to their inherent genetic potential, still this superior adaptive ability was not yet validated in several indigenous breeds. Eventhough the production potential of indigenous breeds are less compared to exotic and crossbred goats they possess a stable production during testing conditions where high producing animals fail to maintain their productive performance.

Growth of an animal is influenced by environmental and genetic factors. Importance of growth performance in livestock has gained wider attention from the researchers around the

world since last two to three decades (Bourdon, 2000). Growth is a major selection criterion for the meat breed animals, particularly the pre-weaning growth, and is considered a crucial factor which determines the meat production. Reduction in growth performance due to the variation in the environmental factors is an important limiting factor that threatens the meat industry in the tropical region (Mpofu et al., 2017).

Among the various environmental stressors, heat stress is a major stressor that affects the production performance of livestock species, particularly in the tropical region. Generally the heat stressed animals reduce their growth, production and reproductive performances in order to adapt to elevated ambient temperature conditions. Reduced growth performance associated with summer heat stress is a common phenomenon in the tropical and sub-tropical regions of the globe. Decreased anabolic activity due to the reduced feed intake and enhanced tissue catabolism are the major reasons for the growth retardation in livestock. Several researches have reported alteration in the growth parameters during thermal exposure (Popoola et al., 2014; Habibu et al., 2016; Sejian et al., 2010). Among the several growth variables, body weight is the first and foremost factor which gets affected due to the heat stress in livestock. 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 can be attributed to the decrease in feed intake in these animal (Popoola et al., 2014). 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. Furthermore, Sejian et al. (2010) reported a significant reduction in body condition score (BCS) in heat stressed (40 °C) Malpura ewes.

It has been widely 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). However, not many reports available on comparing the productive responses of different indigenous breeds subjected to heat stress challenges in a single locality. These efforts can help the researchers to identify the appropriate breed which can survive in multiple environmental conditions. This may pave way for disseminating most suitable breed which can cope to the climate change oriented environmental extremes and produce optimally in a specific location. Therefore, the present study was conducted to assess the growth performances of three

different indigenous goat breeds exposed to summer season heat stress. The primary objective of the study was to compare the productive performances in terms of changes associated with various growth variables between these breeds.

Materials and methods

Study site

The experiment was conducted in the experimental livestock unit of the ICAR-National Institute of Animal Nutrition and Physiology, Bengaluru, India located on latitude 77°36'25.3"E, longitude 12°57'04.3"N and altitude of 920 m above mean sea level. The mean annual maximum and minimum ambient temperature of this regime ranges between 15 to 36°C respectively. The mean annual relative humidity ranges from 20 to 85%. The average annual precipitation in this region varies between 200 to 970 mm with erratic distribution. The average annual minimum and maximum temperature ranges between 15-22°C and 27-34°C respectively. The study was conducted during the months of April to May which falls in the mid summer season. The maximum-minimum temperatures, relative humidity, dry and wet bulb temperature, pen surface temperature and temperature-humidity index (THI) during the study period (45 days) are listed in table 1. THI was calculated by the formula described by McDowell (1972).

Animals

A total of 36 ten months to one year old female goats comprising Osmanabadi, Malabari and Salem Black breeds weighing between 12-19 kg were used. Osmanabadi is a dual purpose (meat and milk) hardy goat breed, which originated in the semi-arid areas of central tropical India, whereas, Malabari breed originated in hot humid tropics and Salem Black goat breeds originated in the wet and dry tropical region of southern India. The animals were brought from different locality and acclimatized to the current experimental location for a period of 45 days. These animals were maintained in well ventilated sheds following standard farm management procedures.

Experimental design

The study was conducted for a period of 45 days during mid summer season. Thirty six animals were used in this study. The animals were randomly allocated into six groups of six animals each, OC (n=6; Osmanabadi control), OHS (n=6; Osmanabadi exposed to summer

season heat stress), MC (n=6; Malabari control), MHS (n=6; Malabari exposed to summer season heat stress), SBC (n=6; Salem Black control) and SBHS (n=6; Salem Black exposed to summer season heat stress). The animals were stall fed with a diet consisting of 60% roughage (Hybrid Napier) and 40% concentrate (Maize 36kg, wheat bran 37kg, soybean meal 25kg, mineral mixture 1.5kg, common salt 0.5 kg/ 100kg). The OC, MC and SBC animals were maintained in the shed in comfort condition while OHS, MHS and SBHS animals were exposed outside to summer season heat stress between 10:00 h to 16:00 h during the experimental period. The OC, MC and SBC animals were fed and watered inside the shed while OHS, MHS and SBHS animals were fed and watered while they are exposed to summer heat stress in the outside environment. All cardinal weather parameters were recorded twice daily both inside and outside the shed throughout the study period. Body weight was recorded at weekly intervals, whereas other growth, allometric measurements and blood collection was carried out at fortnightly intervals. The study was conducted after obtaining approval from the institute ethical committee for subjecting the goats to summer heat stress.

Variables studied

Growth and allometric variables

The animals were individually offered feed at 8.00 h in the morning and the left over feed residues were recorded before feeding in subsequent day to calculate the daily feed intake by subtracting the residues with the total amount of feed offered. Body weight was measured at weekly intervals using a hanging weighing balance. All allometric variables were measured by means of a measuring tape. From these measurements, growth variables such as ADG (Ermias and Rege, 2003), kleiber ratio (KR; Kleiber, 1947), relative growth rate (RGR; Fitzhugh and Taylor, 1971) and BMI (Tanaka et al., 2003) were calculated. Further, the BCS described method as by Russel et al. (1969) was used to condition score the goats. BCS was assessed by careful palpation of the spinous and transverse process in the loin area, immediately behind the last rib. The BCS was scored by an operator who has considerable previous experience in condition. BCS is the subjective way of assessment of body condition of the animals based on measurement of the amount of soft tissue (meat and fat) over the bones of the animal in the loin area. For accuracy, care was taken that the BCS was scored only when the animals were standing in a relaxed position. The muscle and fat cover around the ends of the short ribs and over the

backbone were assessed by palpation. The degree of roundness of the ends of the bones, the amount of tissue between the bones and the fullness of the latissimus muscle determines the condition or finish of the animal condition score.

Blood collection and plasma separation

Blood samples were collected at fortnightly intervals after feeding using 21-gauge sterile needles and plastic syringes from the external jugular vein in tubes with heparin anticoagulant. Plasma was separated from blood by centrifugation at 3,500 rpm at room temperature for 15 minutes. The plasma was transferred in to micro centrifuge tubes and kept frozen at -20°C till further analysis.

Endocrine variable

Plasma growth hormone (GH) was estimated at fortnightly intervals. Plasma GH analytical sensitivity, 0.2 ng/ml; intra-assay and inter-assay coefficient of variations were 5.8 and 9.0%, respectively. Plasma GH was estimated using enzyme linked immunosorbent assay (ELISA) using a micro plate reader (Thermo Scientific, Finland) by ELISA kits (LDN kit, Nordhorn, Germany).

Expression of IGF-1 mRNA in PBMC

The total RNA was isolated from the PMBC pellet using GeneJET Whole Blood RNA Purification Mini Kit (Thermo Scientific, Lithuania). The total RNA was reverse transcribed into complementary DNA (cDNA) using Maxima first strand cDNA synthesis kit for real-time quantitative polymerase chain reaction (RTqPCR) (Thermo Scientific, Lithuania). Sequences of the primer used for amplifying the target regions of Insulin-like growth factor-1(IGF-1) and Glyceraldehyde 3-phosphate dehydrogenase (GAPDH) were based on published reports of Bagath et al. (2016) and Shaji et al. (2016) respectively. The primer sequences are described in Table 2. The relative expression of selected genes was studied using SYBR green chemistry (Maxima SYBR green qPCR master mix, Fermentas, USA). The peripheral blood mononuclear cell (PBMC) IGF-1 messenger RNA (mRNA) expression was quantified as per the published procedure (Bagath et al., 2016) The glyceraldehyde 3-phosphate dehydrogenase (GAPDH) gene was used as an internal control, and the relative expression was analyzed using the formula, $2^{-\Delta\Delta CT}$ (Shaji et al., 2016).

Statistical analysis

The experimental data were analysed using general linear model (GLM) repeated measurement analysis of variance (SPSS 18). Effect of fixed factors, namely breed (Osmanabadi, Malabari and Salem Black) and group (OC, OHS, MC, MHS, SBC and SBHS) were taken as between subject factor and days (longitudinal time over which experiment was carried out; Day 0, Day 15, Day 30 and Day 45) were taken as within subject factor and also the interaction between breed, treatment and experimental days were analysed on the various parameters studied. Comparison of means of the different subgroups was made by Duncan's multiple range tests as described by Kramer (1957). The changes in relative expression of PBMC IGF-1 mRNA in relation to GAPDH as the house keeping gene were analyzed by one-way analysis of variance (ANOVA) with Tukey's post hoc analysis to compare the means among the groups.

Results

THI Index

The THI values to depict the level of heat stress are described in table 1. The THI values both inside and outside the shed in the morning are 69.9 and 73.5 respectively while in the afternoon the values were 74.9 and 86.5 respectively. The THI index inside shed proved that the animals were not stressed while in the outside environment they were extremely distressed. This difference in THI between inside and outside the shed were highly significant ($P < 0.01$). The THI values description as per McDowell (1972) are: the values 72 and less are considered comfortable; THI values between 75-78 are considered stressful and THI above 78 considered extreme distress.

Feed intake

The effect of heat stress on the feed intake was described in table 3. Breed factor did not influence the feed intake in present study. However, the treatment significantly ($P < 0.01$) influenced the feed intake of the animals. Among the breeds, heat stress significantly reduced the feed intake only in MHS group. But the interaction between breed, treatment and experimental days did not influence the feed intake of the animals.

Growth parameters

The effect of heat stress on growth parameters in Osmanabadi, Malabari and Salem Black goats are presented in table 3. Body weight showed significant variation for both the breed ($P<0.01$) and treatment ($P<0.05$). Comparing the body weight changes between the breeds, control group of Malabari breed showed lower body weight than the control group of other two breeds. Further, the body weight did not differ between the control group of Osmanabadi and Salem Black breeds. Within the breeds, body weight did not differ between the control and heat stress groups in all three breeds. The rates of reduction in body weight at the end of study period were 3.4 kg, 2.69 kg and 2.65 kg in OHS, MHS and SBHS groups respectively. However, both the experimental days and interaction between breed, treatment and experimental days did not influence the body weights of all three indigenous goats. The ADG did not show any significant difference between the breeds. But heat stress treatment significantly ($P<0.01$) reduced the ADG in all the heat stress groups as compared to their respective control groups. KR showed similar trend as that of ADG for both the breed and treatment. The heat stress treatment significantly ($P<0.01$) reduced the KR in all the heat stress groups as compared to their respective control groups. Further, RGR also did not exhibit any significant variation between the breeds. However, the RGR was significantly ($P<0.01$) lower in both OHS and MHS groups as compared to their respective control groups. Further, the RGR did not differ between SBC and SBHS. In addition, the BMI showed significant ($P<0.05$) variation for the breed factor. However, the heat stress treatment did not influence the BMI in all three breeds. The BCS showed significant ($P<0.05$) variation for both breed as well as treatment. Further, the experimental days significantly influenced only BMI ($P<0.05$) and BCS ($P<0.05$) in the study. In addition, the interaction between breed, treatment and experimental days did not influence any of the growth variables.

Allometric variables

The effects of heat stress on allometric measurements of three different indigenous breeds are presented in table 4. The breed factor significantly ($P<0.01$) influenced all the allometric measurements. However, the heat stress treatment did not influence most of the allometric variables except chest depth (CD). The heat stress treatment significantly ($P<0.01$) influenced the CD in all the three breeds. Further among the allometric variables, the experimental days significantly ($P<0.05$) influenced only heart girth (HG). In addition, the interaction between breed, treatment and experimental days did not influence any of the allometric variables.

Endocrine parameter

Breed factor did not influence the plasma GH level in the experimental goats. However, heat stress treatment significantly ($P<0.01$) increased the plasma GH level only in OHS group (Fig.1). But the GH level did not differ between the control and heat stress groups of both Malabari and Salem Black breed. Further, both the experimental days and interaction between breed, treatment and experimental days did not influence plasma GH concentration.

IGF-1 gene expression

The PBMC IGF-1 expression pattern did not differ between the OC, MC and SBC groups (Fig.2). However, among the stress groups PBMC IGF-1 expression differed significantly ($P<0.05$) only between OHS and SBHS groups. Among the stress groups, the lower ($P<0.05$) IGF-1 mRNA expression was recorded in OHS, while the higher ($P<0.05$) expression was observed in SBHS. The SBHS group behaved in contrast to OHS and MHS for IGF-1 mRNA expression with significantly ($P<0.05$) higher value in SBHS as compared to SBC. However, only in Malabari breed, heat stress did not influence the expression pattern of IGF-1 mRNA between MC and MHS groups.

Discussion

The breed factor did not alter the feed intake in the study indicating the potential of these breeds being indigenous in nature and they can thrive well on any feeding patterns. However for heat stress factor, the feed intake reduced significantly only in the Malabari breed. It is known that heat exposed animals will reduce their feed intake as an adaptive mechanism in order to reduce the metabolic heat production by transmitting suppressive nerve impulses to appetite center of the hypothalamus (Marai et al., 2007; Sejian et al., 2010). The significantly lower feed intake in Malabari breed on exposure to heat stress indicates the severity of heat stress in inducing reduced feed intake probably in an effort to reduce the metabolic heat production to cope with external hot environment (39.9°C).

Body weight is an important parameter for explaining the adaptive capability of goats. Breed difference was significantly evident in the body weight of goats. Further, the significantly reduced body weight of Malabari breed as compared to that of other two breeds could be attributed to the breed differences in body weight as generally it is believed that Malabari is categorized under small sized breed whereas Salem Black and Osmanabadi are considered as medium sized breeds (Shettar, 2011). Further, significant differences in the body weight among

the treatment groups shows the influence of heat stress on the growth performance in goats. This body weight reduction could be attributed to the deviation of energy for adaptation mechanisms rather than for production pathways (Hamzaoui et al., 2013). Similarly Indu et al. (2014) also observed a significant body weight reduction in Malpura ewes subjected to thermal stress and they attributed this to the collective effects of increased energy allocation for altered gut physiology, metabolic activity and thermoregulation. However, in the current study rate of body weight reduction was higher in Osmanabadi breed compared to other two breeds. This relatively low rate of body weight reduction in Malabari and Salem back goats could be attributed to their superior adaptability to heat stress as these breeds are brought from the humid tropical agro-climatic zones and therefore the stress level could have been less severe for these breeds in the current locality. Similarly, Helal et al. (2010) also reported significant body weight reduction in heat exposed Balady and Damascus goats with higher rate of reduction in Damascus goats as Balady goats are indigenous breed while Damascus is an exotic breed. This literature clearly shows the superior adaptive capability of indigenous goat breeds from exotic and crossbred goats.

Average daily gain did not show any significant variation for the breed factor indicating all the three breeds behaved in the similar pattern for gaining body weight in this study. However, heat stress significantly reduced the ADG in all three breeds indicating that the production potential is compromised even in indigenous breeds while trying to adapt to the harsh climatic condition. This may not be a contradiction as again the breed factor did not influence ADG in any of the breed like feed intake. But the difference was established for heat stress factor in all three breeds for ADG as compared to only in Malabari breed for feed intake. This difference could be attributed to the depletion in body reserves in Osmanabadi and Salem Black as a result of supporting adaptive mechanisms which might have reflected in reduction in ADG in these two breeds. This result coincides with the findings of Popoola et al. (2014) who reported significant ADG reduction in West African dwarf goats subjected to high ambient temperature and they attributed this reduction to the decreased feed intake in heat stressed goats. Similar results reduced feed intake was also observed in Alpine x Beetle cross goats (Hooda and Upadhyay, 2014).

The KR is a type of growth parameter to measure the growth efficiency in animals irrespective of their body weight (Kleiber, 1947). Several researchers studied the KR in goats to

relate it to their growth performance (Shettar, 2011; Supakorn and Pralomkarn, 2012). However, there is no report explaining the impact of heat stress on KR in goats. Therefore, this study is the first to establish the impact of heat stress on KR in three different indigenous goats. Breed factor did not influence the KR of all three indigenous breeds. However, the significantly lower KR in heat stressed goats may serve as an indicator for reduction in growth efficiency especially during prolonged heat exposure in these breeds. The RGR also showed similar trend as that of KR indicating its significance in assessing the growth performance in indigenous goat breeds. Similarly, Sharma and Pathodiya (2006) indicated that RGR can be a good indicator for assessing the growth performance in Sirohi goats. Further, they observed that RGR was determined by genetic variance and this explanation could be the reason for treatment differences among the breeds for RGR in the current study. In addition, Singh et al. (2002) also reported seasonal influence on RGR with significantly lower values recorded during summer season in Black Bengal goats. This was in agreement in the current study with significantly lower RGR recorded in all heat stress groups as compared to that of respective controls.

The BMI was also considered to be a reliable growth indicator in animals (Habibu et al., 2016). Further, the nutritional statuses of the animals are indicated based on relative changes in the BMI (Estrada-Cortes et al., 2009). Breed factor significantly influenced BMI in the current study. Similar report of genotype influencing BMI was established in Red Sokoto and Sahel kids by Habibu et al. (2016). However, heat stress did not influence BMI in the current study and this could be attributed to the indigenous nature of all three goat breeds.

The BCS is an important growth parameter that influences the productivity and health of the animals (Sejian et al., 2010). In the present study treatment showed significant influence on the BCS of all three (Osmanabadi, Malabari and Salem Black) breeds. According to Sejian et al. (2010) this decline in BCS in the heat stressed animals could be due to higher rate of mobilization of fat storage for energy synthesis to support life sustaining activities. Further, the significant reduction in BCS of heat stressed Osmanabadi goats as compared to that of heat stressed Malabari and Salem Black goats indicates the superiority of maintaining body condition in Malabari and Salem Black breeds during heat stress exposure. However, the non-significant interaction between breed, treatment and experimental days for all the growth variables indicates that the effects of heat stress persisted on these variables throughout the study period.

Allometric measurements generally reflect the growth potential of animals. The highly significant effect of breed on all the allometric measurements in the current study establishes the genotype influences on these measurements (Hagan et al., 2012). Further, these body measurements are typical to a particular goat breed of indigenous nature in a specific agro-ecological zone (Hagan et al., 2012). This could be the reason for wide variation for the allometric measurements among the three breeds in the current study, as these animals are indigenous breeds and well known for their survival in three different agro-ecological zones of southern India. These differences in the allometric measurements among the Osmanabadi, Malabari and Salem Black breeds in this study indicates that these animals possess typical morphologically adaptable characteristics which might help them to survive in their specific agro-ecological zone.

Further, body length (BL) did not show significant variation between both heat stress and control group. Our results coincided with the reports of Rana et al. (2014) who established a non-significant influence of heat stress on the BL of indigenous Bangladesh sheep. The, HG did not varied significantly among both the control and heat stress groups. Similar results of non-significant influence of heat stress on HG were also established in Bengal goats (Hashem et al., 2013) and native Bangladesh sheep (Rana et al., 2014). This non-significant difference in HG could be attributed to the adaptive capability of indigenous goats to heat stress conditions.

The wither height (WH) did not vary significantly among control and heat stress groups in this study. This indicates that the magnitudes of heat stress these animals were subjected did not influence the body confirmation changes as these breeds are well known for their thermo-tolerant capability. However, Nardone et al. (2006) reported negative influence of thermal environment on the WH in Holstein Friesian calves. Generally the BL and WH reflect the animal's skeletal size and body condition (Hagan et al., 2012). The non-significant effect of HS on BL and WH in the current study indicates the extreme adaptive capability of the three indigenous breeds in the current study. Further, heat stress also did not influence the hip width (HW) of all three indigenous goats in the current study. In contrary to our findings Nardone et al. (2006) reported significant reduction in HW of Holstein Friesian calves subjected to thermal stress than calves kept under thermo-neutral conditions.

Among the three indigenous goat breeds Salem Black breed showed higher rump height (RuH). Increased RuH and limb length could be an adaptive mechanism to survive in the hot

tropical climatic condition (Shettar, 2011). Further, it was reported by Chacón et al. (2011) that goats in hot arid conditions generally possess longer limbs to reduce the heat from the surface radiation. These authors explained this as an evolutionary adaptation in these animals by keeping their body at an elevated position to avoid the reflected solar radiation from the ground. The higher RuH in Salem Black goats could be attributed to thin and longer legs of this particular breed to avoid the ground radiation during grazing condition in hot humid tropics.

The CD significantly varied among control and heat stress groups. The CD is the only allometric measurement that was influenced by heat stress treatment in the study. Similar result of diminished CD was also established in the heat stressed fat-tailed Farafra sheep (Ali and Hayder, 2008).

The GH is a major peptide hormone that promotes the growth, cell multiplication and cell regeneration. It has been observed in goats that the balance between the rate of energy production and utilization determines the concentration of plasma GH (Hirayama and Katoh, 2004). In the current study, significantly increased GH concentration was observed in the heat stress group of all the three breeds indicating the severity of heat stress on growth performance as generally the level of plasma GH was found to be significantly increased in heat stressed animals in ruminant species (Pulina et al., 2012; Bagath et al., 2016). Similar heat stress induced increase in GH concentration was established by Sejian et al. (2014) in sheep and they attributed the increased GH secretion to the reduced feed intake of the heat stressed animals. Similar observation was made by Pulina et al. (2012) in dairy sheep and they attributed the heat stress induced increase in plasma GH to the reduced binding of GH to its receptor as well as to the marked reduction in GH receptor synthesis. Further the increased GH secretion in OHS as comparison to Malabari and Salem Black goats indicates the higher magnitude of heat stress experienced by Osmanabadi breed. Based on the above findings, it could be inferred that circulating GH level can serve as a good indicator for growth performance during heat stress exposure in different breeds of goats.

The IGF-1 is an endocrine, autocrine and paracrine growth factor that plays a major role in the cell growth, development and differentiation (Delafontaine et al., 2004). Significantly reduced PBMC IGF-1 mRNA expression in OHS group could be attributed to the reduction in protein synthesis and higher level of protein breakdown in these animals (Gasparino et al., 2014).

Lower rates of IGF-1 mRNA expression in OHS animals indicate the compromised growth performance in Osmanabadi breed. However, Bagath et al. (2016) in a study conducted in Osmanabadi bucks to assess the different level of feed intake on IGF-1 mRNA expression pattern did not observed any variation between the groups. These authors attributed this no difference between the groups to the minimum number of animals in each group rather than the nutritional status. Nutritional deprivation has been shown to decrease hepatic IGF-1 production by diminishing IGF-1 gene expression in cells (Jaquiere et al., 2012). The heat stress induced compromised dry matter intake (DMI) might have brought down the expression pattern of IGF-1 mRNA in OHS group in the current study. Bossis et al. (2000) attributed the reduced IGF-1 mRNA expression to the decreased GH binding to hepatocellular membranes. Reduction in the IGF-1 mRNA expression can also be due to the decrease in the GHR level in the liver as a consequence of reduced DMI in heat stressed animals (Jaquiere et al., 2012). The significantly high IGF-1 mRNA expression in SBHS group could be attributed to the ability of this breed to maintain growth performance even in adverse environmental conditions. This establishes the superior ability of Salem Black breed over other two breeds for maintaining growth during heat stress exposure. Thus, IGF-1 gene expression may act as an important indicator for growth performance of the different indigenous breeds of goats when they are exposed to high ambient temperature.

Conclusion

The current study provided an insight into the impact of heat stress on growth performance in indigenous goats. Based on the changes observed on various growth variables during heat stress exposure, it was observed that the Salem Black breed performed much better compared to both Osmanabadi and Malabari breeds indicating the superior ability of this breed to adapt to heat stress challenges. The results also indicated that plasma GH and IGF-1 gene may act as ideal biomarkers for assessing the heat stress impact on growth performance in indigenous goats. These findings are of higher significance as the scientific community battles in its effort to identify suitable thermo-tolerant breeds for sustaining livestock production in the changing climate scenario.

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Table 1: Average weather parameters for the entire study period

	Time of Recording	DBT (°C)	WBT (°C)	MaxT (°C)	MinT (°C)	RH (%)	AT (°C)	PST (°C)	THI
Inside	Morning (8:00 h)	23.2 ±0.11	17.5 ±0.17	41.5 ±1.40	22.5 ±0.92	56.7 ±1.76	26.6 ±0.31	25.5 ±0.20	69.9 ±0.16
	Afternoon (14:00 h)	26.0 ±0.16	21.6 ±0.15	44.6 ±0.94	24.1 ±1.02	37.1 ±1.62	34.2 ±0.22	30.6 ±0.46	74.9 ±0.14
Outside	Morning (8:00 h)	24.5 ±0.55	21.2 ±0.30	44.0 ±1.27	23.0 ±0.93	58.6 ±2.54	28.8 ±0.61	29.5 ±0.61	73.5 ±0.56
	Afternoon (14:00 h)	34.6 ±0.37	29.1 ±0.43	44.9 ±0.81	24.4 ±1.27	29.1 ±1.75	39.9 ±0.63	47.4 ±0.76	86.5 ±0.39

DBT- Dry Bulb Temperature, WBT- Wet Bulb Temperature, MinT- Minimum Temperature, MaxT- Maximum Temperature, RH- Relative Humidity, AT- Ambient Temperature, PST- Pen Surface Temperature, THI- Temperature Humidity Index.

Table 2: Primers used for IGF-1 expression. GAPDH used as reference gene to normalize the gene expression of target genes

Gene ID	Primers	Primer sequence (5"–3")	Primer length (bp)	Product size (bp)	Accession no.
IGF-1	F	CTTGAAGCAGGTGAAGATGCC	21	132	NM_001285697.1
	R	AGAGCATCCACCAACTCAGC	20		
GAPDH	F	GGTGATGCTGGTGCTGAGTA	20	265	AF030943
	R	TCATAAGTCCCTCCACGATG	20		

IGF-1 - Insulin-like growth factor- 1, GAPDH - Glyceraldehyde 3-phosphate dehydrogenase, bp-base pair

Table 3: Comparative assessment of growth parameters in three different indigenous goat breeds subjected to heat stress

Attributes	Days	Treatments						Effects			
		OC	OHS	MC	MHS	SBC	SBHS	BREED	TRT	DAY	BREED* TRT*DAY
Feed intake (DMIg/kg ^{0.75} *Day)	0	51.03	48.21	46.64	42.04	50.97	48.86				
	15	48.48	38.71	39.72	39.07	37.06	42.76				
	30	43.90	31.25	31.83	25.99	44.32	33.47	NS	**	**	NS
	45	40.84	40.47	47.59	34.55	45.62	31.61				
	Mean	46.06 ^a	39.66 ^{ab}	41.45 ^{ab}	35.41 ^b	44.49 ^a	39.18 ^{ab}				
	Pooled SE	±4.47	±4.47	±4.47	±4.47	±4.47	±4.47				
Body weight (kg)	0	16.78	17.07	13.43	13.45	16.85	16.53				
	7	17.13	16.07	13.45	12.88	17.08	17.50				
	15	17.57	15.77	13.43	12.86	17.21	17.42				
	21	17.53	15.73	13.72	13.17	17.52	17.17				
	30	18.10	15.03	13.73	12.50	17.72	15.88	**	*	NS	NS
	37	18.45	14.77	14.37	12.12	18.05	15.28				
	45	18.80	15.40	15.08	12.40	18.30	15.65				
Average daily gain (g)	Mean	17.77 ^a	15.69 ^{ab}	13.89 ^{bc}	12.77 ^c	17.53 ^a	16.49 ^a				
	Pooled SE	±0.83	±0.83	±0.83	±0.83	±0.83	±0.83				
	7	50.00	-142.86	2.38	-80.95	33.33	138.10				
	15	61.91	-42.86	-2.38	-3.57	17.86	-11.91				
	21	-4.76	-4.762	40.48	44.05	44.05	-35.71				
	30	80.95	-100.00	2.38	-95.24	28.57	-183.33				
	37	50.00	-38.10	90.48	-54.76	47.62	-85.71	NS	**	NS	NS
	45	50.00	90.48	102.38	40.48	35.72	52.38				
	Mean	48.02 ^a	-39.68 ^b	39.29 ^a	-25.00 ^b	34.53 ^a	-21.03 ^b				
	Pooled SE	±16.68	±16.68	±16.68	±16.68	±16.68	±16.68				

Kleiber ratio	7	6.07	-18.39	-0.67	-13.03	3.76	15.85	NS	**	NS	NS
	15	6.54	-5.61	-0.40	-0.66	1.84	-1.60				
	21	-0.30	-0.75	6.15	6.72	5.08	-4.06				
	30	9.20	-13.36	0.21	-14.17	3.20	-24.05				
	37	5.62	-5.26	12.24	-9.38	5.56	-10.76				
	45	5.76	11.18	13.51	5.18	4.00	6.82				
	Mean	5.48^a	-5.37^b	5.17^a	-4.22^b	3.91^a	-2.97^b				
	Pooled SE	±2.11	±2.11	±2.11	±2.11	±2.11	±2.11				
Relative growth rate	7	0.19	-0.51	-0.01	-0.41	0.12	0.55	NS	**	NS	NS
	15	0.20	-0.17	-0.00	-0.02	0.06	-0.05				
	21	-0.01	-0.02	0.22	0.23	0.16	-0.12				
	30	0.28	-0.41	0.03	-0.46	0.10	-0.73				
	37	0.17	-0.17	0.41	-0.31	0.17	-0.33				
	45	0.18	-0.36	0.44	0.17	0.12	0.22				
	Mean	0.17^a	-0.27^c	0.18^a	-0.13^c	0.12^{ab}	-0.08^{bc}				
	Pooled SE	±0.07	±0.07	±0.07	±0.07	±0.07	±0.07				
Body mass index (g)	0	1.41	1.48	1.21	1.26	1.48	1.41	*	NS	*	NS
	15	1.54	1.41	1.24	1.13	1.44	1.52				
	30	1.60	1.33	1.32	1.12	1.49	1.39				
	45	1.71	1.37	1.49	1.14	1.64	1.30				
	Mean	1.57^a	1.40^{ab}	1.32^{ab}	1.16^b	1.51^a	1.41^{ab}				
	Pooled SE	±0.09	±0.09	±0.09	±0.09	±0.09	±0.09				
Body condition score	0	2.42	2.33	2.00	2.25	2.33	2.42	*	*	**	NS
	15	2.75	2.42	2.00	1.92	2.33	2.17				
	30	2.92	2.33	2.08	2.00	2.00	2.00				
	45	3.08	2.42	2.67	2.00	2.92	2.17				
	Mean	2.79^a	2.38^{ab}	2.19^b	2.04^b	2.40^{ab}	2.19^b				
	Pooled SE	±0.16	±0.16	±0.16	±0.16	±0.16	±0.16				

OC- Osmanabadi control, OHS- Osmanabadi heat stress, MC- Malabari control, MHS- Malabari heat stress, SBC- Salem Black control, SBHS- Salem Black heat stress, TRT- Treatment, BREED*TRT*DAY- Breed, treatment and day interaction, SE- Standard error.

**P<0.01, *P<0.05, NS- Non-significant

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Table 4: Comparative assessment of allometric parameters in three different indigenous goat breeds subjected to heat stress

Attributes	Days	Treatments						Effects			
		OC	OHS	MC	MHS	SBC	SBHS	BREED	TRT	DAY	BREED*TRT *DAY
Body length (cm)	0	55.55	56.72	51.60	53.65	58.92	59.88				
	15	56.85	57.12	52.23	52.40	55.15	59.57				
	30	58.67	56.13	53.13	51.95	56.70	59.43				
	45	60.22	57.07	55.78	52.53	58.47	57.17	**	NS	NS	NS
	Mean	57.82^a	56.76^{ab}	53.19^{bc}	52.63^c	57.31^a	59.01^a				
	Pooled	±1.35	±1.35	±1.35	±1.35	±1.35	±1.35				
	SE										
Heart girth (cm)	0	61.35	60.63	58.15	57.88	61.85	63.67				
	15	60.88	57.63	58.73	57.53	59.95	62.30				
	30	59.52	57.03	59.87	56.87	60.90	60.60				
	45	59.25	57.98	60.48	57.23	60.43	61.17	**	NS	*	NS
	Mean	60.25^{ab}	58.32^b	59.31^{ab}	57.38^b	60.78^{ab}	61.94^a				
	Pooled	±1.13	±1.13	±1.13	±1.13	±1.13	±1.13				
	SE										
Wither height (cm)	0	66.31	64.97	57.23	57.37	67.20	70.38				
	15	65.43	64.13	56.63	59.85	66.33	68.55				
	30	66.73	63.68	55.57	58.05	67.60	68.00				
	45	66.92	64.33	56.40	57.52	65.20	69.07	**	NS	NS	NS
	Mean	66.35^{ab}	64.28^b	56.46^c	58.20^c	66.58^{ab}	69.00^a				
	Pooled	±1.03	±1.03	±1.03	±1.03	±1.03	±1.03				
	SE										
Hip width (cm)	0	19.13	17.83	17.67	16.85	18.10	18.87				
	15	18.50	17.73	17.00	17.05	18.37	18.85				
	30	19.63	17.43	17.12	16.27	18.85	18.30				
	45	18.30	17.87	17.58	16.55	19.10	18.83	**	NS	NS	NS
	Mean	18.89^a	17.72^{abc}	17.34^{bc}	16.68^c	18.61^{ab}	18.71^{ab}				
	Pooled	±0.45	±0.45	±0.45	±0.45	±0.45	±0.45				
	SE										
Rump	0	70.30	69.07	60.95	61.15	72.70	73.77	**	NS	NS	NS

height	15	69.87	66.35	61.70	62.92	70.18	73.18				
(cm)	30	70.13	65.82	61.80	61.42	70.98	72.60				
	45	70.42	67.60	61.72	61.67	72.20	72.57				
	Mean	70.18^{ab}	67.21^b	61.54^c	61.79^c	71.52^a	73.03^a				
	Pooled SE	±1.17	±1.17	±1.17	±1.17	±1.17	±1.17				
Chest	0	29.42	30.03	24.62	24.10	25.00	25.80				
depth	15	28.97	25.30	24.08	23.95	26.58	22.78				
(cm)	30	27.45	24.37	24.63	23.63	28.17	26.32				
	45	27.07	26.48	23.88	23.43	28.83	26.65	**	**	NS	NS
	Mean	28.23^a	26.55^{abc}	24.30^c	23.78^c	27.15^{ab}	25.39^{bc}				
	Pooled SE	±0.61	±0.61	±0.61	±0.61	±0.61	±0.61				

OC- Osmanabadi control, OHS- Osmanabadi heat stress, MC- Malabari control, MHS- Malabari heat stress, SBC- Salem Black control, SBHS- Salem Black heat stress, TRT- Treatment, BREED*TRT*DAY- Breed, treatment and day interaction, SE- Standard error.

**P<0.01, *P<0.05, NS- Non-significant.

Fig. 1 Comparative assessment of plasma growth hormone in three different indigenous goat breeds **exposed** to heat stress. Values bearing different alphabets differ significantly with each other at $P < 0.01$

Fig. 2 Comparative assessment of Relative PBMC IGF-1 mRNA Expression in three different indigenous goat breeds subjected to heat stress. Values bearing different alphabets differ significantly with each other at $P < 0.05$

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