Effect of summer environment on growing lambs under hot semi-arid tropical region

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Research Article

Keywords: Behavior, environment, hot, lamb, sheep, summer

Posted Date: January 24th, 2022

DOI: <https://doi.org/10.21203/rs.3.rs-1140384/v1>

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Abstract

Extended hot summer is a major constrain in animal production in the semi-arid tropical region. However, the adult native sheep is well-adapted to this climatic condition. Nonetheless, the adaptability of growing lambs in summer conditions is yet to be explored for sustainable sheep production. Therefore, the present study was carried out to assess the effect of summer environment on the growing lambs under hot semi-arid region. For this purpose, sixteen Malpura weaner lambs of 3-4 months of age were selected and equally distributed into two groups, viz. C and T. The lambs of T groups were kept inside the psychometric chamber in different temperature and humidity schedules simulated with the summer average temperature and humidity of the last 10-year of the semi-arid tropics. The lambs of C groups were kept inside the pen in a thermocomfort environment with the same space availability of T group lambs. The lambs of both the groups were provided with adlibitum feed and water. The water intake, respiration rate (RR), pulse rate (PR), rectal temperature (RT) and skin temperature of T group lamb was significantly ($P<0.05$) higher as compared to C group lambs. The summer exposure (T) reduced ($P<0.01$) the feeding and rumination time whereas increased ($P<0.01$) the panting in lambs as compared to C group. The endocrine profile did not varied ($P>0.05$) with the simulated summer exposure of semi-arid region in lambs. The present study reflected that the native Malpura growing lamb modifies their behavior and thermoregulatory responses to counter the extreme summer of the semi-arid region.

Introduction

An excessive hot and dry environment with irregularity in precipitation and vegetation is a common feature of the semi-arid region (da Silva et al., 2017; Façanha et al., 2020). Furthermore, with climate change, these regions are becoming much hotter with less rainfall that threatens agricultural production (Yadav and Lal, 2018). This situation will lead to more uncertainty for food, occupational options for the rural population, farm yield and grazing system ("AR5 Climate Change 2014," n.d.; Ndiritu, 2020). Earlier studies suggested that the small ruminants can tolerate and thrive in the harsh environment of the arid and semi-arid zone (Samara et al., 2016). Sheep rearing is a common occupation for the people residing in the arid and semi-semi-arid region and it serves as vital economic activity (Gowane et al., 2020) for the small and marginal farmers. The sheep are mostly managed without any input, depending on a completely grazing system (De et al., 2020) in available rangelands in this region.

The physiology, reproduction and behavior of the animal influence the thermoregulation that ultimately decides the suitable environment for production (Façanha et al., 2020). Despite the excessive hot environment in the arid and semi-arid regions, sheep able to keep their thermal balance through dissipation of extra heat (De et al., 2017a). The heat tolerance and adaptability of different sheep breeds secure their sustenance in such adverse environments (de França Carvalho Fonsêca et al., 2019). All the previous studies in these region ensure the adaptability of the different sheep breeds in their adult stage. However, the success of sheep husbandry not only depends on the adult stock; the growing lambs also play an important part in making it beneficial and sustainable (De et al., 2017c) as growing lambs are the future flock. However, there always remained a chance for lambs to get exposed to the higher temperature

during hot semi-arid regions which may affect their performance. It is well-established fact that the exposure of sheep to the high ambient temperature induces alteration in body physiology (Dias e Silva et al., 2016) and behavior (De et al., 2017b) as an adaptive measure in the hot-semi-arid region. The animals maintain their thermal balance through behavioral adaptation by changing their timing in daily activities and physiological adjustment (Cain et al., 2008). Although several studies are available defining physiological and behavioral parameters under thermal exposure of semi-arid region; however, scanty literature is available stating the behavioral and physiological response of lamb under heat exposure. Therefore, the present study aimed to evaluate the effect of summer environment on the growing lambs under hot semi-arid tropical region.

Material And Methods

Study site, animal and experimental design

The research was carried out on the lambs of the experimental flock of the physiology division of the ICAR-Central Sheep and Wool Research Institute (ICAR-CSWRI), Avikanagar, India. The institute (75°25' E, 26°18' N) is located in the semi-arid region of Rajasthan state in western India. The present study was undertaken with the approval of the institutional animal ethical committee. For the present study, sixteen Malpura lambs aged 109.9 ± 1.70 days having a bodyweight of 16.3 ± 0.38 kg were selected from the experimental animal flock. The Malpura sheep is a native of the semi-arid region possesses a good adaptable capacity in this environment. The selected lambs were evenly distributed in two groups. One group was termed as C were the control group the other group termed as T were given thermal exposure. The lambs of the T group were exposed to a summer environment inside the psychometric chamber. For twenty-one days. The lambs of the C group were maintained in a thermocomfort environment (Fig. 1). The lambs inside the psychometric chambers were exposed to 30° C temperature and 60% relative humidity (RH) at 0500 h, 35° C temperature and 50% RH at 0800 h, 37° C temperature and 46% RH at 1000 h, 40° C temperature and 45% RH at 1100 h, 41° C temperature and 45% RH at 1200 h, 42° C temperature and 40% RH at 1400 h, 41° C temperature and 45% RH at 1500 h, 37° C temperature and 45% RH at 1700 h, 32° C temperature and 50% RH at 2000 h, and 28° C temperature and 65% RH at 2200 h. The temperature and humidity were scheduled based on the last ten-year average maximum and minimum temperature and humidity during summer. The lambs of the C were maintained outside the psychometric chamber in a similar management system. Both the groups were kept on the plastic slated floor. The animals of the C were maintained inside a corrugated iron sheet roofed building inside which the psychometric chamber was constructed. Prior to the beginning of the heat exposure, the lambs of the C and T groups were kept for fifteen days in their allocated respective place without temperature control to get adjusted with the experimental condition and handling.

Management of lambs

The psychometric chamber was constructed in a complete outer building of 40' X 20' area with galvanized thin iron roof shed. The shed height at the center was 15' and at the side was 10'. Inside the

building, three climate-controlled chambers were constructed through an 80 mm thick puff panel with an outer wall made up of prepainted GI sheet and the inner wall was of stainless steel. Doors were also made up of the same puff panel. The doors of each chamber having a glass window of 1' X 1' to take observation and see the activities of the animals. Each chamber was of 5'6" X 5'6" X 6' and in between the chamber 4' x 4' glass window (see-through) was there, so that the lambs of one chamber can see the lambs of the next chamber. The floor of each chamber was plastic slated type. Inside the climatic chamber, the lambs of the T group were kept where temperature can be controlled between +5° C to 48° C and humidity can be controlled between 20–90%. In front of the climate control chamber three same-sized (5'6" X 5'6") pens were constructed with a chain-linked fence and plastic slated floor where C group lambs were kept. The lambs of each allotted group were kept in their respective chamber and pen regularly during the experimental period from morning 0800h to the next day 0700h. The lambs were allowed to roam outside the building from 0700 h to 0800 h to clean the shed and measure the feed and water intake. The lambs were provided with ad libitum *Cenchrus* hay (*Cenchrus ciliaris*) and wholesome drinking water during their stay inside the chambers and pens. The lambs were offered with 350 g of concentrate mixture for each lamb in the group. The 1 kg of concentrate mixture was composed of 650 g barley, 320 g groundnut cake, 20 g of mineral. All the prophylactic measures against sheep diseases were taken and followed regularly as instructed by the institute health division to get the healthy animal for the experiment.

Observations and measurements

The body weight of each animal was taken at the start of the experiment and average daily weight gain (ADG) was calculated. Each day feed and water intake was recorded by subtracting the residual feed and water from the previous day offered to feed and water, respectively. The thermoregulatory behavior includes; respiration rate (RR), pulse rate (PR), rectal temperature (RT), and skin temperature (ST) were recorded in the morning (0700h) and afternoon (1400h) in each week. The RR was observed through the inward and outward movement of the flank region per minute. The PR was recorded by palpating the beats in the femoral artery in a minute. The RT was recorded by inserting a clinical digital thermometer in the rectum. The ST was measured by a laser thermometer at the shaved post-scapular region. The behavior of the individual animals was recorded for two days in each week from morning 0800 h to evening 1700 h. The behavior was recorded at 10 minutes intervals in scanned sampling by a trained veterinarian without disturbing the animals. The feeding, rumination, panting, idle standing and idle lying behaviors were recorded (Table 1). The blood samples were collected at 1400 h of the day on weekly basis from the jugular vein in heparinised tubes. From the collected blood samples, the plasma samples were separated through centrifugation at 1500g and kept in storage in different aliquots at -20° C for further endocrine level estimation. The hormone-like thyroxine (T4), triiodothyronine (T3), cortisol, growth hormone (GH) and insulin-like growth factor-1 (IGF-1) was estimated in RIA gamma counter (PC-RIA MAS; Stretche, Germany) using RIA kits supplied by Immunotech; Marseille Codex, France.

Table 1
Behavioral observations during the study period

Behavior	Observations ¹
Feeding	Lamb remained near the feed trough for eating, chewing, and swallowing in standing condition
Ruminating	Lamb chewed ruminal content
Panting	Lamb display rapid and short respiration and with severe abdominal movement
Idle standing	Lamb remained in standing condition without performing any other behavior (neither eating nor ruminating) or activities
Idle lying	Lamb remained in lying without performing any other behavior (neither eating nor ruminating)
¹ All the behaviors were recorded from 08:00 h morning to evening to evening 17:00 h	

Statistical analysis

The experimental data were analyzed in GLM procedure using SPSS software, version 14.0. The fixed factor was temperature exposure and dependent variables were the parameters estimated in the study. The statistical significance was fixed in ($P < 0.05$) and data are presented in mean $\pm$ SE.

Results

Feed intake, water intake and average daily weight gain

The dry matter intake, water intake and ADG are described in Table 2. The dry matter intake was comparable ($P > 0.05$) among C and T groups. However, the water intake was higher ($P < 0.05$) in T group lambs. The ADG did not differ ($P > 0.05$) between the groups.

Table 2
Effect of summer on feed intake, water intake and body weight changes of growing lamb

Group	DMI (g) ³	WI (L/Kg DMI) ⁴	Initial weight (Kg)	End weight (Kg)	ADG ⁵
C ¹	511.9	3.4	16.3	19.0	134.3
T ²	518.0	4.4	16.4	18.8	121.4
SE	9.2	0.1	0.6	0.07	13.5
P value	0.6	<0.01	0.97	0.832	0.513
¹ C, control group; ² T, simulated summer exposed group; ³ DMI, dry matter intake; ⁴ WI, water intake; ⁵ ADG, average daily gain					

Thermoregulatory behavior

The thermoregulatory behavior of lambs during heat exposure is depicted in Table 3. The RR in morning and afternoon was higher ($P<0.01$) in T group lambs as compared to C. The PR in the afternoon increased ($P<0.05$) in the T group in comparison with C. The RT in the morning was higher ($P<0.05$) in C group lambs; whereas, it was higher ($P<0.05$) in the afternoon in the T group. The ST in the afternoon was higher ($P<0.05$) in the T group.

Table 3
Effect of summer on thermoregulatory behaviour of growing lamb

	Morning				Afternoon			
	RR ³	PR ⁴	RT ⁵ (°C)	ST ⁶ (°C)	RR	PR	RT (°C)	ST (°C)
C ¹	29.3	73.8	39.8	35.4	55.2	81.1	39.8	35.4
T ²	52.4	73.9	39.6	35.9	94.8	88.8	40.0	36.2
SE	2.4	1.7	0.0	0.5	2.4	1.9	0.0	0.2
P value	0.001	0.961	0.038	0.437	0.001	0.006	0.024	0.013
¹ C, control group; ² T, simulated summer exposed group; ³ RR, respiration rate; ⁴ PR, pulse rate; ⁵ RT, rectal temperature; ⁶ ST, skin temperature								
The morning recording was taken at 0700 h and after record were taken at 1400 h								

Behavioral Response

The behavioral response of lambs during heat exposure is depicted in Table 4. The feeding time was lower ($P<0.01$) in the T group lamb during the heat exposure period. The rumination time decreased ($P<0.01$) in heat-exposed lambs (T) in comparison with C. The heat exposure increased ($P<0.01$) the panting time of T group lambs. However, the idle standing and lying time not varied ($P>0.05$) between the C and T groups.

Table 4
Effect of summer on behavior of growing lamb

	Feeding time (min)	Rumination (min)	Panting (min)	Idle standing (min)	Idle lying (min)
C ¹	177.0	174.0	1.9	41.9	107.0
T ²	95.0	129.0	161.0	24.4	99.0
SE	8.3	10.3	14.9	7.0	14.2
P value	0.001	0.005	0.001	0.089	0.667
¹ C, control group; ² T, simulated summer exposed group					
The behavior of the individual animals was recorded for two days in each week from morning 0800 h to evening 1700 h					

Endocrine profile

The effect of heat exposure on the endocrine profile of lamb is depicted in Table 5. The GH and IGF-1 did not differ ($P>0.05$) between C and T groups. The plasma T4 level was higher ($P<0.05$) in T group lambs. The T3 level also showed a similar trend although it was not significant ($P>0.05$). The plasma cortisol level has also remained similar ($P>0.05$) in both C and T groups.

Table 5
Effect of summer on endocrine profile of growing lamb

	GH ³ (mU/L)	IGF1 ⁴ (ng/ml)	T4 ⁵ (nMol/L)	T3 ⁶ (nMol/L)	Cortisol (nMol/L)
C ¹	0.15	111.0	52.57	3.28	43.05
T ²	0.13	122.0	58.89	3.88	42.24
SE	0.06	5.1	3.1	0.26	3.29
P value	0.825	0.126	0.161	0.092	0.861
¹ C, control group; ² T, simulated summer exposed group; ³ GH, growth hormone; ⁴ IGF1, insulin like growth factor 1; ⁵ T4, thyroxine; ⁶ T3, tri-iodo-thyronine					

Discussion

Exposure to heat is a common phenomenon for all creatures in the hot semi-arid region. The lambs of the T group were in heat exposed as clearly indicated by higher temperatures inside the climate chamber.

Exposure to simulated summer increases the water intake of lambs. The higher water intake in T group lambs might be due to higher water requirements for the evaporative cooling mechanism through the

respiratory tract and skin surface to cope with the high-temperature exposure (De et al., 2017a). However, comparable dry matter intake and ADG of both the groups reflected the adaptability of Malpura lambs to the summer environment of the semi-arid region.

The RR and PR indicate the animals' thermal comfort and adaptability of the animal to harsh conditions (Dias e Silva et al., 2016). The higher respiration rate is a thermolysis response to maintain the homeothermy in exposure to higher environmental temperature (McManus et al., 2009). The increase in RR in T group lamb was a natural response to cope with higher temperatures during summer through evaporative heat dissipation (De, Sharma, Kumawat, Kumar, & Sahoo, 2020). The metabolic status and homeostasis in circulation are reflected through PR (De et al., 2014). The increase in PR in the T group plausibly increases blood flow to the surface from the core to elevate the heat loss from the body (Mohapatra et al., 2019). A similar increase in PR was also reported by (Indu et al., 2015) in sheep in heat exposure. The higher RT value of lambs in the T group indicated exposure of lambs to a higher temperature and in such conditions, the respiratory evaporative cooling mechanism for thermolysis was not sufficient to maintain their body temperature (De et al., 2017a). In concordance with our findings (Fadare et al., 2012) also reported an increase in RT to occur when the physiological activities fail to nullify the excess heat load. However, the ability to conserve the body heat within normal range and improvement of comparable bodyweight with C group reflected the adaptability of the lambs to harsh summer of semi-arid environment. The higher ST in the lambs of the T group plausibly ascribed to vasodilation to redistribute the heat load in the skin capillary through increase blood flow for heat dissipation from the skin surface (Alhaidary, 1560; De et al., 2019). Along with that, the higher environmental temperature around the lambs may transfer heat to the animal is a normal thermodynamic process that can contribute to the higher ST in T group lambs.

The behavioral alteration in animals is used to evaluate the welfare of the animals (Pascual-Alonso et al., 2015). However, heat stress may alter the behavior, welfare and production of sheep (Bernabucci et al., 2010). Sheep alter their behavioral responses in higher environmental temperatures (De et al., 2017b). Behavioral response is an indicator of farm animal welfare (Piccione et al., 2011). Higher temperature reduces the appetite (Polsky and von Keyserlingk, 2017) to reduce the heat production (Sevi et al., 2001) of the animal. However, in the present study, the lambs of the T group did not reduce their feed intake although their feeding time reduced significantly. This might be due to their most of the intake in the cooler part of the day i.e. in the evening hours so that they can generate heat as per their body requirement to adjust with the microclimatic heat load. Their voluntary feed intake gets depressed during day time as an adaptive strategy, to produce less metabolic heat in the day time when the microclimatic temperature was high. In the conference of our study, (Spiers et al., 2004) reported reduced feed intake in higher temperature in dairy cattle and (Alvarez et al., 2013) in goat. Furthermore, van Wettere et al., 2021) also reported grazing time decreased in sheep during summer.

In the present study, the rumination time reduced in T as compared to C, which might be an effort of T group lamb to produce less metabolic heat (Rashid et al., 2013) during the day time to support the reduced heat load in high-temperature exposure which helped the animal to maintain body temperature

(Soriani et al., 2013). In accordance with our observations; researchers also reported reduced rumination in ruminants under heat stress (Hirayama et al., 2004; Moallem et al., 2010). Rumination generally generates heat through bacterial fermentation (Piccione et al., 2014) and it is a good indicator of animal welfare (Gregorini et al., 2012).

Panting is a counter mechanism of animals in response to higher environment temperature (Ghassemi Nejad and Sung, 2017) and therefore panting is used to assess the heat stress of sheep (De et al., 2020). When the environmental temperature is higher than the core temperature, then the dissipation of body heat through convection and radiation is not sufficient to maintain the heat load; at that situation, sheep compelled to start panting for immediate evaporative heat loss (De, Kumar, Saxena, et al., 2017a) which might be the plausible reason of higher panting in the exposure of higher environmental temperature.

The lying behavior generally imparts rest to the animal and enhances animal welfare (Leme et al., 2013). In adult crossbreed sheep we found lower idle lying and higher idle standing time under higher ambient temperature (De et al., 2017b). Other previous studies also support the higher standing and lower-lying time in sheep (Dikmen et al., 2011; Kanjanapruthipong et al., 2015; Legrand et al., 2011). However, in the present study, the comparable changes of the idle lying and standing time indicated efficiency of adaptability of local Malpura lambs to the summer of the hot semi-arid region without affecting their comfort much with only modification of the physiological responses and feeding behavior.

Commonly the endocrine profile alters under heat stress in sheep and is involved with thermal adaptation and can be an indicator for assessment of heat stress (Joy et al., 2020). The GH and IGF-1 are involved in the growth and peripheral tissue development of lambs (Matteri et al., 2000). However, diversion of energy expenditure for respiratory and evaporative cooling reduces the energy available for growth that might ultimately lead to lower GH and IGF-1 (De et al., 2017c). A similar finding was reported by (Aggarwal and Upadhyay, 2013) in lambs during the summer months. Furthermore, high temperatures suppress the thyroid hormone gland activity and reduce the thyroid hormone (Al-Dawood, 2017; Ross et al., 1985). Cortisol, a stress hormone increased during heat stress in sheep reported in early studies (Ghassemi Nejad et al., 2014). However, the similar endocrine level of T and C group lambs reflects the metabolic and endocrine adaptability of native lambs to the high temperature of the semi-arid region. The similar growth showed that their growth did not affect high temperature, which might manifest energy sufficiency as the C group might explain the unchanged GH and IGF-1. The comparable level of T3, T4 and cortisol express the metabolic adaptability of the lambs to cope up with the summer temperature of the hot semi-arid region.

Conclusion

The current experiment exhibited that the native Malpura lambs of the hot semi-arid region can negate the high summer temperature with modification of their physiological responses and behavioral adjustment for a limited period. Although further study is required as high-temperature persist for a longer

period in semi-arid tropics and always remained associated with walking stress for long-distance grazing and exposure to solar radiation.

Declarations

Acknowledgments

The authors acknowledge the Director, Central Sheep and Wool Research Institute, Avikanagar, Rajasthan, India for providing facilities to carry out the research.

Funding

The authors thankfully acknowledge the National Initiative on Climate Resilient Agriculture (NICRA), Government of India for providing financial assistance.

Conflict of Interest

The authors of the manuscript declare that there was no competing interest.

Ethics approval and consent to participate

The experiment was carried out with the prior approval of institute animal ethics committee.

Consent for publication

Not applicable

Availability of data and material

All the data and materials used are incorporated and mentioned in the manuscript.

Code availability

Not applicable.

Authors' contributions

KD and DK designed the experiment. PKK and SS carried out laboratory analysis. TKJ carried out animal experimentation. DK performed the statistical analysis. KD and AM drafted the manuscript. AS overall supervise the experiment.

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Figures

Figure 1

Temperature and humidity inside the shed