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ORIGINAL ARTICLE

Physiological Responses, Growth Rate and Blood Metabolites Under Feed Restriction and Thermal Exposure in Kids

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The study was carried out to study the cumulative effect of thermal stress and feed restriction in kids. Twelve kids of Alpine x Beetle cross were divided into two groups. Group 1 served as control and group 2 was put on restricted feeding and exposed at 40, 42 and 44°C. Body weights of both groups were similar before thermal exposure and feed restriction. Body weight of group 1 increased significantly and were higher than group 2 throughout the experiment. Body weight gain, average daily gain and feed conversion efficiency were comparable in both groups after removal of thermal stress and switching over to ad libitum feeding (42-63 days). Body weights of group 2 remained lower than group 1, the losses in body weights of group 2 could not be compensated and there was approximately 25% loss in body weight at the end of experiment. Physiological responses of group 2 were significantly lower before exposure to high temperature but increased significantly after exposure at temperature 40, 42 and 44°C and the increase was in commensurate with the increase in exposure temperature. Blood glucose, total protein, albumin and serum enzymes decreased significantly on exposure at higher temperature and differences were higher in feed restricted group. T_3, T_4 and cortisol concentration were similar in both groups before feed restriction and thermal stress. T_3, T_4 concentration decreased while cortisol concentration increased significantly after exposure to high temperature. Variations in plasma enzymes, acid phosphatase, alkaline phosphatase, SGOT and SGPT were not significant before feed restriction and thermal stress. The activities of acid phosphatase and alkaline phosphatase decreased whereas that of SGOT and SGPT increased significantly on exposure at temperature 40°C and subsequent changes at temperature 42 and 44°C were not significant. The study indicated that animals of group 2 experienced more stress as observed by significant alteration in body weights, physiological responses, serum enzymes, electrolytes, plasma hormones and blood metabolites and the losses occurred in body weights of group 2 could not be compensated after removal of thermal stress and switching over to ad libitum feeding.

Key words: Feed restriction, thermal stress, enzymes, physiological responses, blood parameter, kids

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Key words: Feed restriction, thermal stress, enzymes, physiological responses, blood parameter, kids

Goats are considered highly suitable living species for the hot and arid regions of the world. Heat stress is one of the major constraints on animal production in tropics (Marai *et al.*, 2007,

Nardone *et al*., 2010). Physiological changes occur when goats are subjected to different stresses but paramount and fundamental are loss of weight, loss of performance and sometimes even loss of life. Browsing of goats to open fields during most of the day hours make them susceptible to heat stress despite of heat resistant characteristics (Al Tamini, 2007). There is evidence for deleterious effects on goat productivity when goats had been exposed over temperatures 34-36°C. Goats reared in arid and semi-arid environments are subjected to multiple stresses simultaneously. Hence apart from heat stress and physical strain of grazing activity, the sheep and goats are subjected to feed shortage (Hooda and Naqvi, 1990). Animals respond to adverse environment conditions in various ways in order to maintain homeostasis. There is clear evidence that animals subjected to prolonged periods of heat stress significantly reduce their dry matter intake (Abdel-Samee and Diel, 1998, Beatty *et al*., 2006). When exposed to hot environment domestic animals are found to show increased respiratory frequency and rectal temperature (Avendono- Reyes *et al*., 2011, Spiers *et al*., 2004), body surface temperature (Spain and Spiers, 1998, Martello *et al*., 2009), heart rate (Zahner *et al*., 2004) to maintain body temperature. The levels of blood parameters reflect the metabolic activities during stress. Concentrations of serum total protein and albumin have been used as indices for nutritional status. Serum total protein and albumin concentration decrease during thermal stress in goats (Dangi *et al*., 2012, Helal *et al*., 2010, Sejian *et al*., 2010b). Serum glutamic oxalo-acetate transaminase (SGOT) and serum glutamic pyruvic transaminase (SGPT), indicators of tissue damage, are involved in amino acid metabolism. Serum SGPT levels increase during heat stress in goats (Sharma and Kataria, 2011) while no change was observed in SGOT concentration in heat stressed goats (Ocak *et al*., 2009, Sharma and Kataria, 2011). Alkaline phosphatase indicator of alkalosis and stress is involved in energy metabolism, its concentration decreased in goats during thermal stress (Helal *et al*., 2010). Blood glucose show greater differences in hot conditions and its levels increased significantly during heat stress in sheep (Al-Haidary *et al*., 2012). During stress various endocrine responses are involved to improve the fitness of the animals. One among such responses is the activation of hypothalamo-pituitary adrenal axis and secretion of cortisol is a classic endocrine response to stress (Kannon *et al*., 2000). The decrease in blood circulating T_3 and T_4 levels determine lower metabolic and thermogenic rates (McManus *et al*., 2009). Sivakumar *et al*. (2010) observed significant fall in T_3 and T_4 concentration in goats exposed to thermal stress. In arid and semi-arid regions feed shortage occurring in summer is associated with heat stress. Low levels of feeding which decreases the metabolic heat production reduce rectal temperature and respiration rate (Mohamad and Abdelatif, 2010). The review indicates that earlier studies have been carried out with a single stress at a time and information on multiple stresses are lacking. Since goats are subjected to multiple stresses, the aim of this study was to investigate the responses of Alpine x Beetle kids to induced feed restriction and heat stress for growth rate, physiological reactions and blood metabolites.

MATERIALS AND METHODS

Twelve male kids of Alpine x Beetle cross of approximately four months of age were used for this study. The kids were randomly divided into two groups based on their body weights so that the

initial average body weight of each group was almost equal. Both the groups were kept on preliminary feeding for two weeks and offered berseem ad libitum. Feed intake was recorded daily for both groups. Then the study was carried out in three phases of 21 days each (total 63 days). In the first 21 days the kids of group 1 and group 2 were kept in the goat pens. The environmental temperature in the pens varied between 19-22°C and relative humidity 40-45%. Group 1 was given ad libitum feeding whereas group 2 was put on restricted feeding and offered berseem 50% of their initial recorded intake. Further the quantity of feed offered to group 2 (restricted feeding) was adjusted weekly in such a way that their body weight remain almost stagnant. In the second phase (21 days), the kids of group 2 were continued restricted feeding and subjected to thermal stress in a climatic chamber for two hours daily for a period of 6 days at each exposure temperature of 40, 42 and 44°C with one day gap at each exposure temperature. At the end of thermal exposure period (second phase, 21 days), the animals of group 2 were shifted in goat pens with group 1 and switched over to ad libitum feeding and offered berseem ad libitum and concentrate @ 400 g per animal per day for the next 21 days (third phase). The kids of group 1 were given berseem ad libitum and concentrate @ 400 g per animal per day throughout the experimental period of 63 days (three phases). Water was made available freely to both groups. Concentrate mixture consisted of maize grain 32, mustard cake 11, ground nut cake 22, wheat bran 20, de-oiled rice 12 mineral mixture 2 and common salt 1% having 20% crude protein and 70% TDN. Physiological responses, respiration rate (RR), pulse rate (PR), rectal temperature (RT) and surface temperature (ST) were recorded in the morning at 7.00 AM and at the end of thermal exposure on alternate day during the period between 21-42 days of experiment. Feed intake was recorded daily. Body weights of kids were taken at weekly interval. RR was recorded by flank movement, PR by palpation of femoral artery, RT by digital thermometer and ST at the middle of flank by using a non-contact thermometer (Raytak R, Model Rayngen STRL) by keeping the instrument 3 inches away from the surface and directed towards the site of measurement. Blood samples were collected from jugular vein of each animal before thermal exposure and at the end of exposure at temperature 40, 42, 44°C in sterile heparin coated vacutainer tube to obtain plasma and in non-heparin tube to obtain serum. After collection the blood samples were transported to the laboratory in an ice bucket. Plasma was separated immediately by centrifuging the blood samples at 3000 rpm for 20 minutes and used for analysis of enzymes. Second non heparin tube containing blood allowed to clot at room temperature for few hours and serum was separated by centrifugation at 3000 rpm for 20 minutes. Total protein, albumin, chloride and glucose were estimated by using kits supplied by Span Diagnostics Pvt. Ltd. (Surat India). Globulin was determined by subtracting the albumin values from total protein for each sample. Sodium and potassium were determined by a flame photometric method. Plasma enzymes SGPT, SGOT, alkaline phosphatase and acid phosphatase were estimated by kits provided by Span Diagnostic Pvt. Ltd. (Surat, India). Plasma cortisol was estimated by cortisol EIA kit (Caymon Chemical Company, 1180 East Ellsworth road Ann. Arbour M 48108, USA). T3 and T4 were estimated by RIA assay kit provided by Beckman Coulter. The data was analyzed and

subjected to test of significance by Sigma Plot 11.0 software package (Systat software Inc., USA)

RESULTS

Body weights of group 1 and group 2 were similar at the beginning of experiment. It increased significantly in group 1 throughout the experimental period, little changed in group 2 during the period of restricted feeding and heat exposure (0-42 days) and increased significantly thereafter when switched over to ad libitum feeding (43-63 days). Changes observed in dry matter intake, weight gain, average daily gain and feed conversion efficiency of group 2 during the period of restricted feeding and heat exposure were less. On switching over to ad libitum feeding, weight gain and average daily gain was comparable in group 1 and group 2 (43-63 days), however, the average body weight of group 2 was 25% lower than group 1 (Table 1). Investigations into the effects of environmental temperature on average daily gain and feed efficiency identified a clear link between live weight gain, feed conversion ratio and environmental temperature. A decrease of body weights and growth rate at elevated temperature has been observed in sheep (Marai *et al*., 2007) and at a temperature greater than 30°C in lamb (Dixon *et al*., 1999). Animals fed with restricted diet exhibited compensatory growth during re-alimentation period as a result of increase in dry matter intake and increase in efficiency of feed utilization. Compensatory growth has also been recorded in ewe lambs (Villeneuve *et al*., 2010) and Malpura sheep (Maurya *et al*., 2004) with compensatory indices of 94 and 90 % respectively. In present study body weight gain, average daily gain, and feed conversion efficiency were comparable in group 1 and group 2 during the period 42-63 days and body weight loss of group 2 could not be compensated and there was approximately 25% loss in body weight at the end of experiment. The observed differences could be due to deteriorating quality of berseem fodder fed during this period (April- May). This fact is further authenticated as there was lower body weight gain, average daily gain and feed conversion efficiency between period 43-63 days compared to period 21-42 days in group 1 (ad libitum fed).

Physiological responses, respiration rate (RR), pulse rate (PR) and rectal temperature (RT) have been presented in table 2. RR, PR and RT of group 1 and group 2 were similar before the animals were put on restricted feeding but these responses were significantly lower in group 2 (feed restricted) before exposure to thermal stress. On exposure to high temperature at 40, 42 and 44°C, RR, PR and RT of group 2 increased significantly. The proportion of increase in RR became higher with the increase in exposure temperature and RR reached up to 98.28 breaths per minute at 44°C. PR also increased with increase in exposure temperature but the deviations in PR from the pre exposure values were less than RR at 40, 42 and 44°C. RT increased significantly at temperature 40°C but further increase at 42 and 44°C was non significant. Rectal temperature of goats found to be elevated with high environmental temperature in earlier studies (Marai *et al*., 2007, Phulia *et al*., 2010, Manish *et al*., 2010). Increased RR is an attempt to increase heat loss by evaporative cooling. An increased RR in response to heat stress have been reported in goats (Manish *et al*., 2010, Sivakumar *et al*., 2010), sheep (Stochman, 2006) and dairy cows (Martello *et al*., 2009, Titto *et al*., 2013). Increase in pulse rate increases blood flow to the surface and facilitate heat loss by sensible means (Marai *et al*., 2007). The findings of increased pulse rate in the present

study are in agreement with previous studies in goats (Manish *et al*., 2010, Sivakumar *et al*., 2010). The lower values of RR, PR and RT in group 2 animals during feed restriction in the present study may be an adaptation response and attributed to their lower metabolic rate during energy deficiency. Mohamad and Abdelatif (2010) reported that low levels of feeding which decreases the metabolic heat production reduce rectal temperature and respiration rate. The surface temperature of group 1 and group 2 were observed to be similar before the animals were subjected to feed restriction and exposed to elevated temperature. It increased significantly in group 2 at temperature 40, 42 and 44°C and the variations were significantly higher and different from group 1 (Table 2). The observed increase in surface temperature in this study may be attributed to exposure to heat stress, which has been reported to cause vasodilatation of skin capillaries bed and consequently increase the blood flow to the skin surface to enhance heat loss (Mc Manus *et al*., 2009, Al-Haidary *et al*., 2012).

Blood glucose level was 57.25± 1.24 and 56.83± 1.26 mg/dl before the kids were subjected to heat stress. Its concentration decreased significantly at temperature 40, 42 and 44°C. Plasma glucose levels showed greater differences in group 2 (feed restriction) and its levels decreased consistently with feed restriction (Table 3). The findings of this study are in agreement with earlier findings reported in sheep (Hooda and Naqvi, 1990, Ocak and Guey, 2010, Sejian and Srivastava, 2010). The changes in the nutritional status of goats and thermal environment may influence the composition of blood. The decrease in blood glucose could be related to decrease in availability of nutrients and lower rate of production of propionate (Mohamad, 2012) or due to increase in plasma glucose utilization to provide energy for muscular expenditure required for high muscular activity associated with increased respiration rate (Sejian and Srivastava, 2010).

Serum total protein, albumin and globulin concentration of group 1 and group 2 were similar before the kids were subjected to feed restriction and thermal exposure. Total protein and albumin concentration of group 2 decreased significantly on exposure at 40°C and subsequent decrease at temperature 42 and 44°C was non-significant compare to concentration at 40°C. Total protein and albumin concentration of group 2 were significantly lower than group 1 throughout the experiment but there was no difference in globulin concentration of group 1 and group 2. Earlier studies in goats (Dangi *et al*., 2012, Helal *et al*., 2010, Sejian *et al*., 2010b) have also reported significant decrease in total protein, albumin and globulin concentration under heat stress. The decrease in plasma protein could be due to decrease in protein synthesis as a result of decrease in anabolic hormone secretion (El-Masry and Habeeb, 1989) or due to protein catabolism to divert amino acids towards gluconeogenesis (Sejian *et al*., 2010b). The synthesis of plasma protein is markedly impaired when the supply of amino acids from the digestive process is not adequate. Mohamad (2012) observed significantly lower total protein and albumin in desert rams consuming low amount of Lucerne hay. Similar results were recorded in goats fed low level of Lucerne (Kheir & Ahmad, 2008). The lower level response could also be associated with an increase in water consumption and development of hemodilution (Bernabucci *et al*., 2010).

The serum concentration of electrolytes (Sodium, Potassium and Chloride) in group 1 and

group 2 were similar before the kids were subjected to feed restriction and heat stress. Serum electrolytes concentration decreased significantly in group 2 at temperature 40°C but subsequent decrease in electrolytes concentration at temperature 42 and 44°C was non-significant. Na, K and Cl concentration of group 1 and group 2 were significantly different with lower values in group 2 throughout the experiment (Table 3). The serum electrolytes concentration in this study were within normal reference values established in goats (Ikhimioya & Imasuen, 2007, Ayo *et al*., 2009). Heat stress posed a significant threat to the homeostatic mechanism of goats. The decrease in electrolytes concentration in this study is supported by earlier findings reported in cattle (Beatty *et al*., 2006, Srikandakumar *et al*., 2003) and buffalo heifers (Singh *et al*., 2012). Heat stressed animals lost more potassium and chloride in sweat than non heat stressed animals (Mallone *et al*., 1985, Singh *et al*., 2012). The decrease in electrolytes concentration observed in this study may also be due to expanded blood volume where water is transported in the circulatory system for evaporative cooling as suggested by Al-Haidary (2004).

Thyroxine (T_4), triidothyronine (T_3) and cortisol concentration were similar in group 1 and group 2 before feed restriction and thermal exposure. T_4 & T_3 concentration decreased and cortisol concentration increased significantly in group 2 at 40°C but subsequent decrease in T_3 and T_4 concentration and increase in cortisol concentration at 42 and 44°C was non-significant. T_3 & T_4 concentration were lower while cortisol was higher in group 2 compared to group 1 throughout the experiment (Table 4). The findings of this study coincided with the earlier findings. (Sivakumar *et al*., 2010, Sejian *et al*., 2010 a, Helal *et al*., 2010) who reported significant decline in thyroid hormone concentration in goats. Mader *et al*. (2009) opined that animals activate coping mechanisms when challenged by environmental stressors and heat stress in general is associated with significant depression of thyroid gland activity, resulting in lowering of thyroid hormone levels. In addition, blood thyroid hormones are considered to be good indicator of nutritional status of an animal. The decrease in T_3 and T_4 concentration in this study could be a response to negative energy balance and heat stress might have extended the duration of negative energy balance and low levels of thyroid hormones as suggested by Mohebbi-Fani *et al*. (2009) and Todini (2007) in small ruminants. Hence the feed restriction and thermal stress could have elicited reduction in thyroid hormone concentration and might be an adaptive effort of kids to avoid additional heat load due to metabolic activity. The rise in plasma cortisol is due to activation of the adrenocorticotropin (ACTH) releasing mechanism in the hypothalamus by thermo-receptors of the skin (Minton, 1994). The increased cortisol level in heat stressed goat is well documented and our results coincided with earlier work (Kaushik *et al*., 1997, Sivakumar *et al*., 2010, Sejian *et al*., 2010a). Cortisol works as vasodilators to facilitate heat loss and have stimulatory effects on proteolysis and lipolysis, hence, providing energy to the animal to help to offset the reduction of feed intake (Cunningham and Klein, 2007). Respiratory evaporative cooling was more energy expensive, however, in this study there was very high rise in respiratory rate of feed restricted kids indicating that this group experienced more stress. The significant increase in cortisol levels might have facilitated to meet the energy requirement by diverting proteolysis derived amino acid towards

gluconeogenesis (Sejian *et al*., 2010a).

Variations in plasma enzymes activities of acid phosphatase, alkaline phosphatase, SGOT and SGPT of group 1 and group 2 were statistically non significant before feed restriction and thermal exposure. Acid phosphatase and alkaline phosphatase activities decreased whereas SGOT and SGPT activities increased significantly at exposure temperature 40°C but subsequent change in the activities of these enzymes at temperature 42 and 44°C were non-significant. Activities of acid phosphatase and alkaline phosphatase of group 2 was significantly lower whereas that of SGOT and SGPT were higher than group 1 throughout the experiment (Table 4). Decrease in acid phosphatase and alkaline phosphatase in this study is in agreement with earlier studies on goats (Helal *et al*., 2010), sheep (Sejian *et al*., 2010b, Abdel-Samee *et al*., 2008) and in buffalo heifers (Singh *et al*., 2012). Alkaline phosphatase and acid phosphatase are involved in energy generation in animal body. Decrease in the activities of these enzymes might be due to reduction in thyroid hormone concentration and reduced metabolic activity that occurred during feed restriction and heat stress in the kids. The observations of Brown-Brandal *et al*. (2003) that a metabolic shift occurred in heat stressed cows due to drop in maintenance requirement as a result of reduced feed intake also support this view. Serum level of SGOT and SGPT is helpful in diagnosis of welfare of animals. Sharma and Kataria (2011) also found increased plasma SGPT concentration while no change was observed in SGOT concentration of heat stressed goats (Ocak *et al*., 2009, Sharma and Kataria, 2011). SGOT appeared to be the best indicator for the assessment of thermal stress in animals. Singh *et al*. (2012) observed that hyperthermia resulted in significantly increased SGOT concentration in stressed susceptible buffalo heifers when exposed to elevated temperature in a climatic chamber.

Table 1 Body weight gain, DMI and feed conversion efficiency of kids subjected to feed restriction and thermal stress

Parameters	Group	Period of experiment (Days)			Overall
		Restricted feeding		Ad libitum	
		0-20	21-42	43-63	0-63
Body Weight (Kg)	1	15.00 ± 0.50^{Aa}	16.56 ± 0.31^{Ab}	18.66 ± 0.43^{Ac}	20.28 ± 0.46^{A}
	2	14.50 ± 0.36^{Aa}	14.86 ± 0.22^{Ba}	15.45 ± 0.25^{Ba}	16.14 ± 0.31^{B}
DMI/animal/day (g)	1	0.694 ± 0.92^{Aa}	0.805 ± 0.92^{Ab}	0.617 ± 0.8^{Ac}	0.706 ± 0.9^{A}
	2	0.222 ± 0.6^{Ba}	0.278 ± 0.73^{Ba}	0.581 ± 0.9^{Ab}	0.360 ± 0.70^{B}
Body weight gain (Kg)	1	2.08 ± 0.08^{Aa}	2.41 ± 0.27^{Ab}	1.25 ± 0.17^{Ac}	1.91 ± 0.17^{A}
	2	0.41 ± 0.15^{Ba}	0.50 ± 0.22^{Ba}	1.25 ± 0.21^{Bb}	0.72 ± 0.14^{B}
Average daily gain (g)	1	99.00 ± 4.00^{Aa}	114.90 ± 9.84^{Ab}	59.00 ± 8.20^{Ac}	91.00 ± 11.32^{A}
	2	19.33 ± 7.20^{Ba}	23.50 ± 10.51^{Ba}	59.30 ± 10.19^{Ab}	34.04 ± 9.68^{B}
Body weight gain/ Kg feed intake (g)	1	134.96 ± 4.64^{Aa}	146.76 ± 8.55^{Ab}	80.75 ± 14.67^{Ac}	120.92 ± 16.25^{A}
	2	39.03 ± 22.43^{Ba}	44.86 ± 26.28^{Ba}	93.43 ± 15.28^{Ab}	59.10 ± 21.56^{B}

Superscript a,b,c,d differ significantly in a row for individual parameter
Superscript A, B, differ significantly between groups for individual parameter

Table 2 Physiological reactions of kids subjected to feed restriction and thermal stress

Parameters	Group	Before feed restriction	Before thermal exposure	Exposure temperature (°C)		
				40	42	44
Respiration rate/minute	1	14.5^{Aa} ±0.18	14.74^{Aa} ±0.21	19.50^{Ab} ±0.23	19.94^{Ab} ±0.26	20.44^{Ab} ±0.28
	2	14.10^{Aa} ±0.17	12.74^{Bb} ±0.19	53.89^{Bc} ±0.80	75.39^{Bd} ±0.88	98.28^{Be} ±2.26
Pulse rate/minute	1	55.8^{Aa} ±0.31	56.18^{Aa} ±0.27	57.39^{Ab} ±0.26	59.06^{Ac} ±0.26	60.05^{Ac} ±0.26
	2	55.2^{Aa} ±0.29	53.46^{Bb} ±0.29	58.28^{Bc} ±0.10	61.11^{Bd} ±0.29	64.00^{Be} ±0.31
Rectal temperature (°F)	1	101.2^{Aa} ±0.12	101.36^{Aa} ±0.11	101.40^{Aa} ±0.18	101.40^{Aa} ±0.17	101.40^{Aa} ±0.20
	2	101.0^{Aa} ±0.11	100.60^{Bb} ±0.16	103.00^{Bc} ±0.14	103.00^{Bc} ±0.19	103.2^{Bc} ±0.15
Surface temperature (°C)	1	29.5^{Aa} ±0.31	30.52^{Aa} ±0.27	30.48^{Aa} ±0.15	32.97^{Ab} ±0.15	33.14^{Ab} ±0.23
	2	30.2^{Aa} ±0.32	30.75^{Aa} ±0.28	38.94^{Bb} ±0.13	40.89^{Bc} ±0.19	41.44^{Bc} ±0.35

Superscript a,b,c,d,e differ significantly in a row for individual parameter
Superscript A, B, differ significantly between groups for individual parameter

Table 3 Blood biochemical of kids subjected to feed restriction and thermal stress

Parameter	Group	Before exposure	Exposure temperature (°C)			Overall mean
			40	42	44	
Sodium (m eq./l)	1	143.08^{Aa} ±1.04	143.17^{Aa} ±0.75	143.17^{Aa} ±0.99	143.08^{Aa} ±0.87	143.12^{A} ±0.99
	2	143.50^{Aa} ±0.75	132.25^{Bb} ±1.28	131.67^{Bb} ±1.36	132.83^{Bb} ±0.61	135.06^{B} ±1.40
Potassium (m eq./l)	1	4.83^{Aa} ±0.21	5.00^{Aa} ±0.18	5.00^{Aa} ±0.18	4.92^{Aa} ±0.15	4.94^{Aa} ±0.22
	2	5.17^{Aa} ±0.33	3.58^{Bb} ±0.15	3.75^{Bb} ±0.21	3.58^{Bb} ±0.24	4.02^{Bb} ±0.31
Chloride (m eq./l)	1	102.92^{Aa} ±1.07	103.00^{Aa} ±0.53	103.33^{Aa} ±0.69	103.08^{Aa} ±0.65	103.80^{Aa} ±0.74
	2	102.67^{Aa} ±0.67	97.92^{Bb} ±0.71	98.00^{Bb} ±0.53	97.75^{Bb} ±0.92	99.08^{Bb} ±1.05
Glucose (mg/dl)	1	57.25^{Aa} ±1.24	56.33^{Aa} ±0.95	56.58^{Aa} ±0.99	56.83^{Aa} ±1.42	56.75^{A} ±1.15
	2	56.83^{Aa} ±1.26	46.75^{Bb} ±1.04	44.08^{Bc} ±1.33	43.75^{Bc} ±0.87	47.35^{B} ±1.63
Total protein (g/dl)	1	6.02^{Aa} ±0.15	5.92^{Aa} ±0.09	5.90^{Aa} ±0.07	5.83^{Aa} ±0.15	5.92^{A} ±0.12
	2	5.93^{Aa} ±0.13	5.68^{Bb} ±0.15	5.40^{Bb} ±0.14	5.32^{Bb} ±0.08	5.51^{B} ±0.18
Albumin (g/dl)	1	3.05^{Aa} ±0.09	3.08^{Aa} ±0.07	3.15^{Aa} ±0.11	3.15^{Aa} ±0.09	3.07^{Aa} ±0.10
	2	3.07^{Aa} ±0.10	2.75^{Bb} ±0.08	2.70^{Bb} ±0.10	2.62^{Bb} ±0.09	2.80^{B} ±0.11
Globulin (g/dl)	1	2.97^{Aa} ±0.08	2.84^{Aa} ±0.10	2.75^{Aa} ±0.09	2.72^{Aa} ±0.10	2.85^{A} ±0.12
	2	2.86^{Aa} ±0.08	2.83^{Aa} ±0.09	2.60^{Ab} ±0.08	2.50^{Bb} ±0.10	2.71^{B} ±0.09

Superscript a,b,c differ significantly in a row for individual parameter
Superscript A, B, differ significantly between groups for individual parameter

Table 4 Plasma enzymes and hormone concentration of kids subjected to feed restriction and thermal stress

Parameter	Group	Before exposure	Exposure temperature (°C)			Overall mean
			40	42	44	
Acid phosphatase (KA units)	1	2.28^{Aa} ±0.10	2.37^{Aa} ±0.05	2.30^{Aa} ±0.14	2.27^{Aa} ±0.09	2.30^{A} ±0.08
	2	2.28^{Aa} ±0.09	1.77^{Bb} ±0.07	1.67^{Bb} ±0.03	1.65^{Bb} ±0.04	1.84^{B} ±0.12
Alkaline phosphatase (KA units)	1	17.40^{Aa} ±1.23	17.17^{Aa} ±0.87	17.50^{Aa} ±1.18	17.00^{Aa} ±1.18	17.27^{A} ±1.55
	2	18.42^{Aa} ±1.42	13.63^{Bb} ±1.02	13.98^{Bb} ±1.04	13.83^{Bb} ±0.63	14.97^{B} ±1.09
SGOT (IU/l)	1	73.58^{Aa} ±1.18	74.42^{Aa} ±1.10	72.83^{Aa} ±0.90	71.92^{Aa} ±0.83	73.19^{A} ±1.15
	2	72.00^{Aa} ±1.19	79.58^{Bb} ±1.48	80.00^{Bb} ±1.10	79.77^{Bb} ±1.31	77.84^{B} ±1.63
SGPT (IU/l)	1	27.33^{Aa} ±1.55	28.92^{Aa} ±0.65	27.25^{Aa} ±1.26	26.33^{Aa} ±1.40	27.46^{A} ±1.25
	2	27.33^{Aa} ±1.26	31.08^{Bb} ±1.05	30.33^{Bb} ±1.08	30.95^{Bb} ±1.48	29.93^{B} ±1.76
Triidothyronine (p mol/l)	1	5.42^{Aa} ±0.40	5.33^{Aa} ±0.40	5.42^{Aa} ±0.37	5.58^{Aa} ±0.55	5.44^{A} ±0.36
	2	5.17^{Aa} ±0.33	2.72^{Bb} ±0.28	2.65^{Bb} ±0.17	2.53^{Bb} ±0.16	3.27^{B} ±0.50
Thyroxine (p mol/l)	1	25.83^{Aa} ±1.18	25.25^{Aa} ±1.30	24.97^{Aa} ±1.23	23.42^{Aa} ±0.92	24.87^{A} ±1.10
	2	25.58^{Aa} ±1.33	16.58^{Bb} ±0.92	16.08^{Bb} ±0.90	15.58^{Bb} ±0.95	18.46^{B} ±1.56
Cortisol (n mol/l)	1	22.13^{Aa} ±1.17	22.66^{Aa} ±1.64	21.67^{Aa} ±1.61	22.92^{Aa} ±1.71	22.34^{A} ±1.80
	2	22.58^{Aa} ±1.30	43.92^{Bb} ±3.08	44.58^{Bb} ±1.43	42.17^{Bb} ±2.05	38.31^{B} ±2.10

Superscript a,b differ significantly in a row for individual parameter
Superscript A, B, differ significantly between groups for individual parameter

CONCLUSION

The study indicated that feed restriction and thermal stress had severe impact on kids as revealed by changes in physiological reactions, mineral balances, enzymes activities, hormone secretion and blood metabolites. The feed restricted and thermal exposed group experienced more stress and the losses incurred in body weights in this group could not be compensated during post stress period.

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REFERENCES

Abdel-Samee, A.M. and Diel, J. (1998) Shearing and fat supplementation effects on growth traits of Suffolk lambs under moderate and severe heat stress condition. *First Int. Conf. Anim. Prod. Heal. in Semi Arid Areas*, Sues Canal University, Egypt, September 1-3, 1999, 251-259.

Abdel-Samee, A.M., Abd-Alla, O.A. and El-Adawy, S.A.I. (2008) Nutritional treatment for alleviation of heat stress in Awassi sheep using acacia and olive pulp in sub-tropics. *Egypt. J. Comp. Pathol. and Clin. Pathol.* **21,** 466-467.

Al-Haidary, A.A. (2004). Physiological responses of Naimy sheep to heat stress challenge under semi-arid environment. *Int. J. Agri. Biol.* **2,** 307-309.

Al-Haidary, A.A., Aljumaah, R. S., Alshaikh, M.A., Abdoun, K.A., Samara, E.M., Okab, A.B. and Alfuraiji, M.M. (2012) Thermoregulatory and physiological responses of Nazdi sheep exposed to environmental heat load prevailing in Saudi Arabia. *Pak. Vet. J.* **32,** 515-519.

Al-Tamini, H.J. (2007) Thermo regulatory response of goat kids subjected to heat stress. *Small Rum. Res.* **7,** 280-285.

Ames, D.R. and Brink, D.R. (1977) Effect of temperature on lamb performance and protein efficiency ratio. *J. Anim. Sci.* **44,** 136-144.

Avendono-Reyes, L., Hernandez-Rivera, J.A., Alvaraze-Valenzuela, F.D., Macias-Cruz, U., Diaz-Molinar, R., Correa-Calderon, A., Robinson, P.H. and Fadel, J.G. (2011) Physiological and productive responses of multiparous lactating Holstein cows exposed to short term cooling during severe summer conditions in an arid region of Mexico. *Int. J. Biomet.* doi: 1007/s00484-011-0510-x.

Ayo, J.O., Minka, N.S., Sackey, A.K.B. and Adelaiye, A.B. (2009) Responses of serum electrolytes of goats to twelve hours of road transportation during the hot dry season in Nigeria and effect of pre-treatment with ascorbic acid. *Onder. J. Vet. Res.* **76,** 409-418.

Beatty, D.T., Barnes, A., Taylor, E., Pethick, E., McCarthy, M. and Maloney. S.K. (2006) Physiological responses of Bos taurus and Bos indicus cattle to prolonged, continuous heat and humidity. *J. Anim. Sci.* **84,** 972-985.

Bernabucci, U., Lacetera, N., Baumgard, L.H., Rhoads, R.P., Ronchi, B. and Nardone, A. (2010) Metabolic and hormonal acclimation to heat stress in domesticated ruminants. *Animal* **4,** 1167-1183.

Brown-Brandal, T.M., Nienaber, J.A., Eigenberg, R.A., Hahn, G.L. and Freetly, H. (2003) Thermo-regulatory responses of feeder cattle. *J. Therm. Biol.* **28,** 149-157.

Cunningham, J.G. and Klein, B.G. (2007) Veterinary Physiology (4th Edition) Saunders Elsevier. Missouri.

Dangi, S.S., Gupta, M., Maurya, D., Yadav, V.P., Panda, R.P., Singh, G., Mohan, N.H., Bhure, S.K., Das, B.C., Bag, S., Mahapatra, R.K. and Sarkar, M. (2012) Expression profile of HSP genes during different seasons in goats (Capra hircus). *Trop. Anim. Health and Prod.* **44,** 1905-1912.

Dixon, R.M., Thomas, R., and Holmes, J.H.G. (1999) Interaction between heat stress and nutrition in sheep fed roughage diet. *J. Agri. Sci.* **132,** 351-59.

El-Masary, K.A. and Habeeb, A. A. (1989). Thyroid Function in lactating Friesian cows and water buffaloes under winter and summer. *Proc. 3rd Egypt. Brit. conf. anim. fish and poult. Prod*. **2**, 613-620.

Helal, A., Hashem, A.L.S., Abdel-Fattah, M.S. and El-Shaer, M. (2010) Effect of heat stress on coat characteristics and physiological responses of Balady and Damascus goat in Sinai Egypt. *Am. Eurasi. J. Agri. Envir. Sic.* **7,** 60-69.

Hooda, O.K and Naqvi, S.M.K. (1990) Effect of thermal load and feed restriction on relative adaptability of Malpura and Avikalin sheep in semi-arid region. *Ind. J. Anim. Sci.* **60**: 608-611.

Ikhimioya, I. and Imasuen, J.A. (2007) Blood profile of West African Dwarf goat fed Panicum maximum supplemented with Afzelia Africana and Newbuodia laevis. *Pak. J. Nut.* **6**: 79-84.

Kannon, G., Terril, T.H., Kouakou, B., Gazal, O.S., Gelaye, S., Amoah, E.A. and Samake, S. (2000) Transportation of goats: effect on physiological stress responses and live weight loss. *J. Anim. Sci.* **78:** 1450-57.

Kaushik, S.K., Sengupta, B.P. and Georie, G.C. (1997) Effects of thermal stress and water restriction on cortisol levels of Beetle and Black Bengal goats. *Ind. J. Anim. Sci.* **72**: 1891-1898.

Kheir, M.I. and Ahmad, M.M.M. (2008) Effect of water and feed restriction on some physiological and Hematological parameters and blood constituents of Sudanese Desert goats fed high and low quality forages under semi-arid conditions. *Ind. J. Anim. Res.* **42**: 93-95.

Mader, T.L., Gaughan, J.B., Johnson, L.J. and Hahn, G.L. (2009) Tympanic temperature in confined beef cattle exposed to excessive heat load. *Int. J. Biometeorol.* doi 10:1007/s00484-009-0229-0.

Mallone, P.G., Beede, D.K., Collier, R.J. and Wilcox, J. (1985) Production and physiological responses of dairy cows to varying dietary potassium during heat stress. J. *Dairy Sci.* **68**: 1479- 85.

Manish, K., Jindal, R., Nayyar, S. and Singla, M. (2010) Physiological and biochemical responses in Beetle goats during summer season. *Ind. J. Small Rum.* **16**: 255-57.

Marai, I.F.M., El-Darawany, A.A., Fadiel, A. and Abdel-Hafez, M.A.M. (2007) Physiological traits as affected by heat stress in sheep: a review. *Small Rum. Res.* **71**: 1-12.

Martello, L.S., Savastano, H. Jr., Silva, S.L. and Balieiro, J.C.C. (2009) Alternative body sites for heat stress measurement in milking cows under tropical conditions and their relationship to thermal discomfort of animals. *Int. J. Biomet.* **54**: 647-652.

Maurya, V.P., Naqvi, S.M.K. and Mittal, J.P. (2004) Effect of dietary energy level on physiological responses and reproductive performance of Malpura sheep in hot semi-arid regions of India. *Small Rum. Res.* **55**: 117-122.

Mc Manus, C., Paluda, G.R., Louvandini, H., Gugel, R. Sasaki, L.C.B. and Paiva, S.R. (2009) Heat tolerance in Brazilian sheep: physiological and blood parameters. *Trop. Anim. Heal. Prod.* **41**: 95-101.

Minton, J.E. (1994) Function of hypothalamic pituitary adrenal axis and sympathetic nervous system in models of acute stress in domestic farm animals. *J. Anim. Sci.* **72**: 1891-1898.

Mohamad, S.S. (2012) Effect of level of feeding and season on rectal temperature and blood metabolites in desert rams. *Acad. J. Nut.* **1**: 14-18.

Mohamad, S.S. and Abdelatif, (2010) Effect of feeding and season on thermo-regulation and semen characteristics in desert rams. *Global Vet.* **4**: 207-215.

Mohebbi-Fani, M., Nazifi, S., Rowghani, E., Baharam, S. and Jamshid, O. (2009) Thyroid hormones and their relationships with serum glucose, beta hydroxyl butyrate, non-esterified

fatty acids, cholesterol and lipoproteins of high yielding dairy cows at different stages of lactation. *Com. Clin. Pathol.* **18**: 211-216.

Nardone, A., Ronchi, B., Lacetera, N., Ranieri, M.S. and Bernabucci, U. (2010) Effects of climate change on animal production and Sustainability of livestock system. *Lives. Sci.* **130**: 57-69.

Ocak, S., Darcon, N., Ankaya, S. and Cinal, T. (2009) Physiological and biochemical responses in German fawn kids subjected to cooling treatment under Mediterranean climate conditions. *Turk. J. Vet. Anim. Sci.* **33**: 455-61.

Ocak, S. and Guey, O. (2010) Physiological responses and some blood parameters of bucks under Mediterranean climate condition. *Ana. J. Agri. Sci.* **25**: 113-119.

Phulia, S.K., Upadhyay, R.C., Jindal, S.K. and Misra, R.P. (2010) Alteration in surface body temperature and physical responses in Sirohi goats during day time in summer season. *Ind. J. Anim. Sci.* **80**: 340-342.

Sejian, V., Maurya, V.P. and Naqvi, S.M.K. (2010a). Adaptability and growth of Malpura ewes subjected to thermal and nutritional stress. *Trop. Anim. Heal. Prod.* **42:** 1763-1770.

Sejian, V. and Srivastava. R.S. (2010) Effect of melatonin on adrenal cortical functions of Indian goats under thermal stress. *Vet. Med. Int.* doi: 10.4061/2010/348919.

Sejian, V., Srivastava, R.S. and Varshney, V.P. (2010 b) Effect of short term thermal stress on biochemical profile in Marwari goats. *Ind. Vet. J.* **87**: 503-505.

Singh, S.P., Hooda, O.K., Kundu, S. S. and Singh, S.V. (2012) Biochemical changes in heat exposed buffalo heifers supplemented with yeast. *Trop. Anim. Heal. Prod.* **44**: 1383-1387.

Sharma, A.K. and Kataria, N. (2011) Effects of extreme hot climate on liver and serum enzymes in Marwari goats. *Indian J. Anim. Sci.* **81**: 293-295.

Sivakumar, A.V.N., Singh, G. and Varshney, V.P. (2010) Antioxidant supplementation on acid base balance during heat stress in goats. *Asian Aust. J. Anim. Sci.* **23**: 1462-68.

Spain, J.N. and Spiers, D.E. (1998) Effect of fan cooling on thermo-regulatory responses of lactating dairy cows to moderate heat stress. Proc. 4th Int. Dairy Housing conf. ASAE, St Joseph, MI, pp 232-238.

Spiers, D. E., Spain, J.N., Sampson, J.D. and Rhoads, R.P. (2004) Use of physiological parameters to predict milk yield and feed intake in heat stressed dairy cows. *J. Therm. Biol.* **29**: 759-764.

Srikandakumar, A., Johnson, E. H. and Mahgoub, O. (2003) Effect of heat stress on respiratory rate, rectal temperature and blood chemistry in Omani and Australian Merino sheep. *Small Rum. Res.* **49**: 193-198.

Stochman, C.A. (2006) The physiological and behavioral responses of sheep exposed to heat load within intensive sheep industries. Ph. D. thesis School of Veterinary and Biomedical Sciences, Murdoch University, Australia

Titto, C.G., Negrao, J.A., Titto, E.A.L., Canaes, T. de Souza, Titto, R.M. and Pereira, A.M.F. (2013) Effects of an evaporative cooling system on plasma cortisol, IGF-1 and milk production in dairy cows in a tropical environment. *Int. J. Biomet.* **57**: 299-306.

Todini, I. (2007) Thyroid hormone in small ruminants: effects of endogenous, environmental and nutritional factors. *Animal*

1: 997-1008.

Villeneuve, L., Cinq-Mars, D. and Lacasse, P. (2010) Effect of restricted feeding of pre pubertal ewe lambs on growth performance and mammary gland development. *Animal* **4**: 994-950.

Zahner, M., Schrader, L., Hauser, R., Keck, M., Langhans, W. and Wechsler, B. (2004) The influence of climatic conditions on physiological and behavioral parameters in dairy cows kept in open stables. *Anim. Sci.* **78**: 139-147.