RESEARCH ARTICLE

Seasonal Variation in Physio-Biochemical Responses in Osmanabadi Goat Kids: Growth Assessment by Alkaline Phosphatase as a Biomarker

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Abstract

The present study was planned to assess the impact of different seasons and temperature humidity index (THI) on physiology, metabolism, and growth performance in Osmanabadi kids. For the study, 6 kids (0-3 months) were reared under a semi-intensive system and exposed to three different seasons, viz., summer (April-May), monsoon (July-August) and winter (December-January). Physiological and meteorological variables were recorded at weekly intervals, while for biochemical estimations, blood was collected, at a 15-day interval. Body temperature and respiration rates were higher in summer and winter, while the heart rate was highest during summer ($p<0.05$). Maximum body weight was seen in summer ($p<0.05$), followed by monsoon and winters, respectively. Serum protein, albumin, globulin, and phosphorus (P) didn't vary, but alkaline phosphatase (ALP) and calcium (Ca) levels were significantly ($p<0.05$) higher in summer and monsoon. It can be concluded that, despite high THI ranges (81-82), during summer and monsoon seasons which resulted in physio-biochemical alterations, the Osmanabadi goat kids were able to maintain a steady growth rate, due to higher thermotolerance and better adapted to regional climatic conditions. We also observed a notable positive correlation between ALP, calcium and growth and that serum ALP concentrations can be used as a biomarker for measuring growth in Osmanabadi goat kids.

Key words: Alkaline phosphatase, Growth biomarker, Osmanabadi goat kid, Temperature humidity index, Thermotolerance

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Introduction

Small ruminants like goats, played a crucial role in human evolution, survival, and growth, and since ages have provided us with meat, milk, wool, fiber and dung. Small body size and mass, its ability to alter metabolism, sustain on unconventional feeds, tolerate toxic plant compounds, better feed conversion efficiency, low water requirement and high heat tolerance make goats an ideal livestock in arid and tropical regions. These characteristics give the goat its ability to colonize in diverse geographical climatic zones, around the world (Banerjee *et al.,* 2014) and today more than 80% are distributed in tropical Asiatic and African regions (Silanikove *et al.,* 2010).

Despite its evolutionary thermotolerance, it is also negatively affected by chronic heat stress or multi-stressors, which reduce growth and performance (Sejian *et al.,* 2010). The ideal rearing temperatures for goats are between, 13-27˚C and beyond this range the balance between heat loss and gain is compromised, resulting in heat stress (Jyotiranjan *et al.,* 2017). In heat-stressed animals, reduction in feed intake, increased water consumption, alterations in body temperature, respiration rate, heart rates and metabolism, negatively affect the growth, production, and reproduction (Popoola *et al.,* 2014; Yamani and Koluman, 2020; Singh *et al.,* 2023). In the advent of climate change, global warming and increasing demand for animal-origin food, heat stress remains a major constraint resulting in huge economic losses (Wankar *et al.,* 2021).

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India ranks 1st in goat population globally, with over 148.88 million heads, and a steady growth rate of over 10.14% (Kochewad *et al.,* 2023). Here goats are mostly reared extensively or semi-intensively which exposes them to adverse climatic conditions and aggravates the heat stress impact (Sejian *et al.,* 2010; Mondal *et al.,* 2020).

Osmanabadi goat breed is a native from the Marathwada region of Maharashtra and is also, reared extensively in Andhra Pradesh, Telangana, and Karnataka states. The breed is well known for its lean meat, prolific fecundity, optimum growth rates and high thermotolerance (Kochewad *et al.,* 2023). Although it is relatively well adapted to high ambient temperatures, prolonged exposure decreases its performance and production (Pragna *et al.,* 2018; Mane *et al.,* 2022). Keeping in mind the above facts the present study was undertaken to evaluate the seasonal variation in physio-biochemical responses in Osmanabadi goat kids (0-3 months) and their growth assessment by alkaline phosphatase as a biomarker.

Materials and Methods

Experimental Animals and Management

Six healthy Osmanabadi kids (0-3 months; mean body weight 6.97 kg) were selected for the study, from the livestock farm complex, College of Veterinary and Animal Sciences, Parbhani, MAFSU, Maharashtra, India. All the animals were reared semi-intensively and were fed according to ICAR (2013) standards. The experimental procedure was approved by the institutional animal ethical committee and was strictly followed. The animals were studied for two months consecutively during each of the three seasons, *viz.,* summer (April-May), monsoon (July-August) and winter (December-January), 2022-23.

Sampling and Analyses

The physiological variables, *viz*, body temperature (BT, °F, digital thermometer), respiration rate (RR, breaths/min, by flank movement) and heart rate (HR, beats/min, by direct heart auscultation) were recorded weekly at 0900 h, of all the animals. The body weight (b.wt , kg) was recorded at 1000 h at weekly intervals on a digital weighing balance.

Meteorological variables during the experimental period were recorded exactly at the same place, near the goat shed at 1400 h. Dry bulb temperature (DB, °C) and wet bulb temperature (WB, °C) were measured by a digital temperature recorder (Testo make). Similarly, solar intensity (LUX) and wind speed (WS, M/sec) were recorded on digital lux meter and digital anemometer (Testo make). While, the temperature humidity index (THI) was calculated by the following formula (NRC, 1971),

$$THI = 0.72\ (Wb + Db) + 40.6$$

Where, Wb=wet bulb temperature and Db=dry bulb temperature

Blood (5 mL) was collected at 0930 h on every 15th day by jugular venipuncture in sterile glass tubes. Serum was harvested after 45 min by centrifuging the sample at 3500 g for 20 min, and two aliquots were made and stored at -20°C till further analyses. One was used for biochemical analyses and the other for enzyme estimation. In all the sera samples, albumin, total protein, globulin, alkaline phosphatase (ALP), calcium and phosphorus were analyzed on an automatic biochemical analyzer (UNICORN, 120, VECTOR) by commercial kits, following the manufacturer's instructions.

Statistical analysis

Physiological, biochemical, and meteorological variables were analyzed on GLM software (SPSS, 22.0) by one-way ANOVA and indicated by their *p* values. All values were represented as ±SEM and significance were reported at $p<0.05$. Differences among treatments were determined by Tukey's test and indicated by superscripts $^{a, b, c}$. Correlations between variables were estimated by Pearson's correlation and indicated by the *r* value.

Results and Discussion

The results for physiological parameters and body weight are presented in Table 1, while changes in BT, RR and HR with THI are shown in Figure 1. No significant variation was observed in body temperature (BT) during the winter and summer seasons, but in monsoon it was lower ($p<0.05$). Body temperature was also positively correlated to respiration rates (r=0.357; Table 4). The respiration rates (RR) were also significantly higher ($p<0.05$) during winter and summer, as compared to monsoon (Table 1). The highest RR of 27.48 breaths/min was recorded in winter and a negative correlation was found between RR and body weight (r=-0.199) and WS (r=-0.447), respectively (Table 4). Heart rate (HR) increased significantly ($p<0.05$) in summer than in monsoon and winter and it was positively correlated with wet bulb temperature (r=0.454). Body weight didn't vary during monsoon and winter, but it increased significantly ($p<0.05$) in the summer (Table 1).

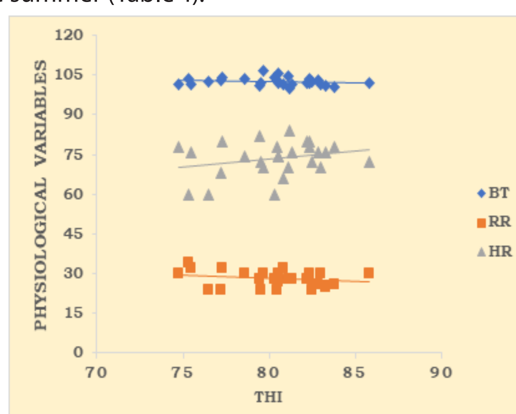

Fig. 1: Seasonal variations in body temperature (°F), respiration rate (breaths/min), and heart rate (beats/min) with respect to THI in Osmanabadi goat kids

Thermogenesis in response to cold environments or high ambient temperatures and heat stress commonly results in elevated body temperature and respiration rates, making them very good indicators to confirm stress in small ruminants (Alam *et al.,* 2011). The body temperature of goats and sheep was significantly higher during summer than in

Table 1: Physiological variables during different seasons in Osmanabadi goat kids

Variable	Winter	Summer	Monsoon	SEM	*P*
Body temperature (BT, °F)	102.40^{b}	102.39^{b}	101.32^{a}	0.086	0.001
Respiration rate (RR, breaths/min)	27.48^{c}	25.95^{b}	22.22^{a}	0.275	0.001
Heart rate (HR, beats/min)	76.29^{a}	79.76^{b}	75.95^{a}	0.440	0.001
Body weight (BW, kg)	7.00^{a}	8.42^{b}	7.65^{a}	0.131	0.001

Values with different superscripts (^{a,b,c}) within a row indicate significance at p<0.05 for the variable

thermoneutral conditions (Popoola *et al.,* 2014; Rathwa *et al.,* 2017; Younis, 2020). A recent study in Mahabubnagar local goats also recorded higher rectal temperature (p<0.05) in the hot season (Mane *et al.,* 2022) which corroborates our findings. Similar to BT, the RR was also higher during winter and summer as compared to monsoon. The respiratory frequency alters and increases in response to variation in metabolism, thermogenesis or as an effective heat dissipation mechanism, hence RR is considered to be the most simple and reliable indicator of heat stress in goats (Okoruwa, 2014). We recorded the highest RR in the goat kids during the winter season (27.48 breaths/min), which reflects cold-induced thermogenesis and increased metabolism. However, the increase in RR during summer (25.95 breaths/min) was an evaporative cooling mechanism adopted by the goats. Our results are in agreement with other workers, who reported increased RR in goats during summer stress (Al-Samawi *et al.,* 2014; Panda *et al.,* 2016; Jyotiranjan *et al.,* 2017; Younis, 2020; Yamani and Koluman, 2020; Mane *et al.,* 2022).

The heart rate didn't vary during winter and monsoon but was elevated during summer, which indicates adjustments in cardiovascular functions, increased peripheral vasodilatation, and higher muscular activity (increased RR) for heat dissipation mechanisms (Al-Dawood, 2017). Similarly, increases in the heart rate during summer seasons have been recorded in sheep and goats (Alam *et al.,* 2011; Al-Samawi *et al.,* 2014; Okoruwa, 2014; Rathwa *et al.,* 2017; Yamani and Koluman, 2020). Also, Shaji *et al.* (2016) reported increased pulse rate in adult Osmanabadi goats, exposed to thermal stress, which further corroborates our findings.

Higher body weight during the summer season and a positive relation with solar intensity (r=0.491) is an interesting finding of the present study as reduction in feed intake and higher water consumption are the first manifestations of heat stress (Salama *et al.,* 2014). A decrease in dry matter intake results in poor weight gain, performance, and weight loss as the animal enters a negative energy balance (Okoruwa, 2014; Wankar *et al.,* 2017; Pragna *et al.,* 2018). The higher weight gain of Osmanabadi kids during the summer season in this study might be due to better adaptability and thermotolerance of the breed to hot environments (Banerjee *et al.,* 2014). Few studies have earlier reported a positive impact of heat stress on feed digestibility in ruminants (Wankar *et al.,* 2019). The higher feed digestibility was attributed to slower ingesta passage rates or reduced circulating thyroid hormone resulting in low gut motility and an increase in feed retention times (Wankar *et al.,* 2019), resulting in better nutrient absorption and utilization. In this study none of these variables were recorded, but might be the reason for better feed utilization, resulting in higher weight gains in Osmanabadi goat kids, during summers.

Table 2: Biochemical components in Osmanabadi goat kids during different seasons

Biochemical Component	Winter	Summer	Monsoon	SEM	*P*
Albumin (gm/dL)	2.27	2.58	2.37	0.055	0.068
Total protein (gm/dL)	6.02	6.91	6.02	0.181	0.065
Globulin (gm/dL)	3.74	4.33	3.64	0.136	0.082
Alkaline phosphatase (ALP, U/L)	91.58^{a}	214.94^{b}	185.83^{b}	15.300	0.002
Phosphorus (mg/dL)	6.75	7.99	7.89	0.264	0.103
Calcium (mg/dL)	8.48^{a}	9.58^{b}	8.94^{ab}	0.173	0.033

Values with different superscripts (^{a,b,c}) within a row indicate significance at p<0.05 for the variable

The variations in the biochemical components and meteorological variables are presented in Tables 2 and 3, while, the correlations between alkaline phosphatase (ALP), serum calcium and phosphorus and correlations between physiological, biochemical, and meteorological variables are shown in Figure 2 and Table 4, respectively. There was no notable difference for serum albumin, total protein, globulin, and phosphorus during different seasons, but ALP and calcium were significantly higher (p<0.05) in summer and monsoon as compared to the winter season (Table 2). Serum albumin was positively correlated with ALP (r=0.378), phosphorus (r=0.623) and calcium (r=0.886). Similarly, total protein was also positively correlated with other biochemical variables (r=0.243 to 0.904, Table 4). Alkaline phosphatase was correlated with calcium (r=0.359) and WS (r=-0.474), and so was phosphorus associated with serum calcium (r=0.535). While serum calcium was negatively correlated with WS (r=-0.381, Table 4).

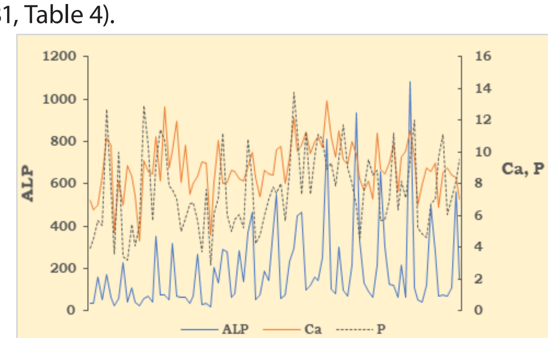

Fig. 2: Correlations between ALP (U/L), Ca (mg/dl) and P (mg/dl) in Osmanabadi goat kids

Dry bulb temperature (DB) was highest in summer (p<0.05), and wet bulb temperature (WB) was in monsoon season, while solar intensity was maximum during winter and summer

($p<0.05$). Wind speed (WS) didn't vary and temperature humidity index (THI) was significantly higher ($p<0.05$) in summer and monsoon than winter season (Table 3).

No significant variation was seen for total protein, albumin, and globulin levels, which might be due to optimum hepatic functions during different seasons. However, a significant decrease was seen for total protein, albumin, and globulin, in heat-stressed goats which the researchers attributed mainly to decreased liver functions or protein catabolism for energy production (Dangi *et al.*, 2012). Similarly, no variation was reported for protein, albumin, and globulins concentrations in heat-stressed Malpura ewes and black Bengal goats (Perveen *et al.*, 2019). The positive correlation of the serum total protein, albumin and globulin with ALP, calcium and phosphorus also reflects their involvement in enzyme and mineral metabolism, transport, and regulation.

Table 3: Environmental variables during different seasons

Variable	Winter	Summer	Monsoon	SEM	*P*
Dry bulb temperature (DB, °C)	31.52^a	34.11^b	31.37^a	0.465	0.016
Wet bulb temperature (WB, °C)	20.08^a	22.45^b	26.01^c	0.583	0.001
Solar intensity (LUX)	57652.22^a	54953.40^a	31474.37^b	4572.226	0.039
Wind speed (WS, M/sec)	3.25	2.80	3.20	0.188	0.560
Temperature humidity index (THI)	77.75^a	81.32^b	81.92^b	0.538	0.001

Values with different superscripts (^{a,b,c}) within a row indicate significance at $p<0.05$ for the variable

Alkaline phosphatase is a tissue non-specific enzyme, extensively produced in the liver, kidneys, and bones. Its primary functions are bone metabolism, mineralization and phosphorus turnover, and the levels are quite high in growing animals and decrease by puberty (Narisawa *et al.*, 2013). The ALP levels are known to be high as the environmental temperature increases (Kour *et al.*, 2015). In this study also, maximum ALP activity was recorded, during summer and monsoon seasons, which are corroborated by other researchers and coincide with the highest growth and calcium turnover in Osmanabadi goat kids (Kour *et al.*, 2015).

We found no variation for serum phosphorus, which indicates optimum turnover and similar results were reported during heat stress versus normal conditions in Baladi and Shami goats (Younis, 2020). On the contrary, in other studies, heat stress has also been shown to significantly reduce the phosphorus and calcium levels in sheep, owing to negative turnover for the minerals (Ramana *et al.*, 2013). Serum calcium levels were significantly highest ($p<0.05$) in summer, followed by monsoon and winter. Also, we found a positive correlation between ALP and calcium, which confirms the role of ALP in bone metabolism, mineralization, and growth. Contradictorily, others have reported a significant decrease in calcium concentration during heat stress in goats (Okoruwa, 2014; Rathwa *et al.*, 2017).

Table 4: Interaction and correlations among different physiological, biochemical, and environmental variables

Correlation	THI	DB	WB	LUX	WS	BT	RR	HR	BW	Albumin	Protein	Globulin	ALP	Phosphorus	Calcium
THI	1	0.625**	0.783**	-0.083	-0.216	-0.174	-0.264	0.262	0.061	0.227	0.259	0.254	0.174	0.203	0.184
DB		1	0.003	0.334	-0.168	0.184	-0.087	-0.148	0.139	0.114	0.018	-0.016	0.082	0.323	-0.054
WB			1	-0.373	-0.143	-0.370	-0.269	0.454*	-0.038	0.200	0.317	0.338	0.158	0.003	0.279
LUX				1	0.070	0.491**	-0.051	-0.215	.153	-0.187	-0.234	-0.237	0.038	0.009	-0.233
WS					1	0.142	-0.447*	-0.158	-0.278	-0.238	-0.296	-0.298	-0.474*	-0.267	-0.381*
BT						1	0.357**	-0.015	-0.008	-0.037	-0.082	-0.095	-0.042	0.046	-0.127
RR							1	-0.068	-0.199*	-0.047	-0.119	-0.139	-0.127	-0.158	-0.140
HR								1	0.135	-0.156	-0.085	-0.049	0.141	0.014	-0.057
BW									1	-0.025	0.043	0.072	-0.046	-0.005	0.064
Albumin										1	0.871**	0.754**	0.378**	0.623**	0.886**
Protein											1	0.980**	0.297**	0.541**	0.904**
Globulin												1	0.243*	0.468**	0.846**
ALP													1	0.159	0.359**
Phosphorus														1	0.535**
Calcium															1

*Correlation is significant at the 0.05 level, **Correlation is significant at the 0.01 level

Conclusions

From the study, it can be concluded that in arid, tropics and subtropics, high environmental temperatures, and THI, remain major constraints for animal welfare, performance, and production in goats. However, due to better adaptability and thermotolerance in Osmanabadi breed, different seasons had no significant impact on the growth patterns, although there were notable physiological and metabolic variations. If the management, feeding, and housing are optimum, the Osmanabadi goat breed can sustain and perform, even under unfavourable climatic conditions and THI ranges of 81-82. Also, alkaline phosphatase can be used as a potential biomarker to assess growth in Osmanabadi goats".

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References

Alam, M.M., Hashem, M.A., Rahman, M.M., Hossain, M.M., Haque, M.R., & Sobhan, Z. (2011). Effect of heat stress on behaviour, physiological and blood parameters of goat. *Progressive Agriculture, 22,* 37-45.

Al-Dawood, A. (2017). Towards heat stress management in small ruminants – A review. *Annals of Animal Science, 17*(1), 59-88.

Al-Samawi, K.A., Al-Hassan, M.J., & Swelum, A.A. (2014). Thermoregulation of female Aardi goats exposed to environmental heat stress in Saudi Arabia. *Indian Journal Animal Research, 48*(4), 344-349.

Banerjee, D., Upadhyay, R.C., Chaudhary, U.B., Kumar, R., Singh, S., & Ashutosh, G.J.M. (2014). Seasonal variation in expression pattern of genes under HSP70 family in heatand cold-adapted goats (Capra hircus). *Cell Stress Chaperon*,*19*,401-408.

Dangi, S.S., Gupta, M., Maurya, D., Yadav, V.P., Panda, R.P., & Singh, G. (2012). Expression profile of HSP genes during different seasons in goats (Capra hircus). *Tropical Animal Health and Production*, *44*,1905-1912.

ICAR. (2013). Nutrient requirement of goat. Indian Council of Agricultural Research, New Delhi

Jyotiranjan, T., Mohapatra, S., Mishra, C., Dalai, N., & Kumar Kundu, A. (2017). Heat tolerance in goat-A genetic update. *The Pharma Innovation Journal*, *6*(9),237-245.

Kochewad, S.A., Chavan, S.B., Neeraj Kumar, Tayade, A.S., Dhumal, N., Jadhavar, P., & Sammi Reddy, K. (2023). Self-sustaining goat farming model for livelihood improvement of small and marginal farmers. Technical Bulletin No.40. ICAR-National Institute of Abiotic Stress Management, Baramati, Pune, Maharashtra, India, Pp 25.

Kour, S., Devi, J., Kour, K., Chakraborty, D., Ganai, A.W., & Khajuria, P. (2015). Effect of Thermal Stress on Haematological parameters and Enzymatic Activities in two breeds of goat after Thermal Stress. *Journal of Animal Research*, *5*(4),855-862.

Mane, D.U., Kishan Kumar, M., Sarat Chandra, A., Nagalakshmi, D., Sakaram, D., Venkataramana, K., & Rathod, S. (2022). Physiological, haematological and serum biochemical parameters of Mahabubnagar local goats under different systems of rearing. *The Pharma Innovation Journal*, *SP-11*(10),1263-1271.

Mondal, T., Avishek, P., Dangi, S.S., Bag, S., Sarkar, M., & Das, B.C. (2020). Expression kinetics of heat-induced genes and possible crosstalk between them in black Bengal goat. *Biological Rhythm Research*, *51*(8),1243-1258.

Narisawa, S., Yadav, M.C., & Millán, J.L. (2013). In vivo overexpression of tissue-nonspecific alkaline phosphatase increases skeletal mineralization and affects the phosphorylation status of osteopontin. *Journal of Bone and Mineral Research*, *28*(7),1587-98. https://doi.org/ 10.1002/jbmr.1901. PMID: 23427088; PMCID: PMC3688694

NRC. (1971). National Research Council. A guide to environmental research on animal. National Academy of Sciences, Washington, DC, Pp 374.

Okoruwa, M.I. (2014). Effect of heat stress on thermoregulatory, live bodyweight and physiological responses of dwarf goats in southern Nigeria. *European Scientific Journal, 10*(27),255-264.

Panda, R., Ghorpade, P.P., Chopade, S.S., Kodape, A.H., Palampalle, H.Y., & Dagli, N.R. (2016). Effect of heat stress on behaviour and physiological parameters of Osmanabadi goats under katcha housing system in Mumbai. *Journal of Livestock Sciences*, *7*,196-199.

Perveen, S., Kumar Das, P., Ranjan Ghosh, P., Banerjee, D., Mukherjee, J., & Naskar, S. (2019). Alterations in haematobiochemical profile and blood metabolites during different periods of prepubertal growth in black Bengal goat (Capra hircus): effect of sex and season. *Biological Rhythm Research*, *50*(4),626-636.

Popoola, M.A., Bolarinwa, M.O., Yahaya, M.O., Adebisi, G.L., & Saka, A.A. (2014). Thermal comfort effects on physiological adaptations and growth performance of west African dwarf goats raised in Nigeria. *European Scientific Journal (Special Edition)*, *3*,275-280.

Pragna, P., Sejian, V., Bagath, M., Krishnan, G., Archana, P.R., Soren, N.M.,Beena, V., & Bhatta, R. (2018). Comparative assessment of growth performance of three different indigenous goat breeds exposed to summer heat stress. *Journal of Animal Physiology and Nutrition*, *102*, 825-836.

Ramana, D.B.V., Pankaj, P.K., Nikhila, M., Rani, R., & Sudheer, D. (2013). Productivity & physiological responses of sheep exposed to heat stress. *Journal of Agrometeorology*, *15*, 71-76.

Rathwa, S.D., Vasava, A.A., Pathan, M.M., Madhira, S.P., Patel, Y.G., & Pande, A.M. (2017). Effect of season on physiological, biochemical, hormonal, and oxidative stress parameters of indigenous sheep. *Veterinary World*,*10*(6),650- 654.

Salama, A.A.K., Caja, G., Hamzaoui, S., Badaoui, B., Castro Costa, A., & Facanha, D.A.E. (2014). Different levels of response to heat stress in dairy goats. *Small Ruminant Research*, *121*,73-79.

Sejian, V., Maurya, V.P., & Naqvi, S.M. (2010). Adaptability and growth of malpura ewes subjected to thermal and nutritional stress. *Tropical Animal Health and Production*, *42,* 1763–1770.

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

Silanikove, N., Leitner, G., Merin, U., & Prosser, C.G. (2010). Recent advances in exploiting goat's milk: quality, safety, and production aspects. *Small Ruminant Research*, *89*,110-124.

Singh, S.V., Misra, A.K., Gaurav Kumar, & Ukey, A. (2023). Thermal imaging and physiological responses of crossbred goats under different housing system during hot humid season. *Indian Journal of Dairy Science*, *76*(3), 304-307.

Wankar, A.K., Rindhe, S.N., & Doijad, N.S. (2021). Review- Heat stress in dairy animals and current milk production trends, economics, and future perspectives: The global scenario. *Tropical Animal Health and Production, 53,* 70. DOI:10.1007/s11250-020-02541-x

Wankar, A.K., Singh, G. & Yadav, B. (2017). Biochemical profile and methane emission during controlled thermal stress in buffaloes (*Bubalus Bubalis*). *Buffalo Bulletin, 36*(1), 15-22

Wankar, A.K., Singh, G., & Yadav, B. (2019). Effect of temperature X THI on acclimatization in buffaloes subjected to simulated heat stress: Physio-metabolic profile, methane emission and nutrient digestibility. *Biological Rhythm Research,*Pp 1-15. https://doi.org/10.1080/09291016.2019.1673652.

Yamani, H.M.M., & Koluman, N. (2020). Impact various seasons on expression patterns HSP60 and physiological parameters. *Journal of Dairy, Veterinary & Animal Research, 9*(1), 1-4.

Younis, F.E. (2020). Impact of heat stress on physiological, haematological, biochemical, electrolytic, immunologic and antioxidant parameters in Baladi and Shami goats of Egypt. *Animal Science Reporter (e-edition), 13*(1), 21-39.