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Effect of supplementation of *Terminalia arjuna* on physiological responses of lactating goats to natural summer stress

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Abstract
The increasing demand for small ruminants' products owing to urbanization, growing human populations and developing economies, paralleled by frequent hot climate are serious threats for the agriculture sector. The adverse effects of heat stress increases morbidity and mortality rates, affects the performance of animals, and results in great economic losses. The present study explored the effect of increase in temperature humidity index on physiological response of beetle goats under summer stress and evaluated the therapeutic effect of *Terminalia arjuna* supplementation in its alleviation. Goats were exposed to two different levels of temperature humidity index. Rectal temperature and respiration rate were significantly greater at higher THI than at low THI but no significant effect was observed in heart rate of goats. However, with the supplementation of *Terminalia arjuna* there was reduction in rectal temperature in summer stressed goats from 39.02 ± 0.11to 38.67 ± 0.08, respiration rate from 29.91 ± 1.09 to 27.95 ± 0.72 and heart rate from to 88.54 ± 1.13 to 86.95 ± 0.84. The results suggest *Termialia arjuna* is supplementation as cardio-protective agent and may play a role in alleviation of adverse effects of summer stress on physiological response.

Keywords: Temperature humidity index, rectal temperature, respiration rate, heart rate, *Termialia arjuna*

Introduction
Goats play a predominant role in the sustenance of the livelihoods of impoverished families, especially in rural areas with significant contribution in the agricultural revolution and advancement of human civilization (Zeder 2008) [30]. The climate change is the most serious long-term challenge faced by small ruminants' owners of the world, as it impacts animals' production and health (Silanikove and Koluman 2015) [22]. Animals undergo various kinds of stressors which may be physical, nutritional and chemical or heat stress. Heat stress is the physiological strain associated with an exposure to an extreme and hot environment (Gupta *et al* 2013) [9]. High ambient temperature accompanied by high relative humidity cause activation of physiological mechanisms including endocrine, neuroendocrine and behavioral responses. Activation of the neuroendocrine system affects the secretion of hormones and neurotransmitters that allow them to adapt to stress.

Mechanisms which allow animals to adapt to heat stress and to achieve thermo-tolerance include physical and physiological changes like reduced feed intake and metabolic heat production, increased surface area of skin to dissipate heat, increased blood flow to take heat from the body core to the skin and extremities to dissipate the heat, increased numbers and activity of sweat glands, panting and increased water intake (Sarangi 2018) [19]. A variety of strategies are adapted by small ruminant farmers to overcome the adverse effects of elevated temperature/ heat stress which may include use of shades, feeding schedules and grazing times, providing adequate fresh and cool drinking water, the use of fans and evaporative cooling (Bucklin *et al* 1991) [4]. However, use of shades, fans or evaporative cooling is not possible in semi-intensive systems as goats are grazed in the open during most of the day, and this necessitates other strategies including therapeutic intervention to counter the adverse effects of heat stress.

Terminalia arjuna, a deciduous tree of the combretaceae family is abundantly available throughout India and the therapeutic properties of the bark have been used by ancient Indian people as medicine to treat different disease conditions due to its high antioxidant activity and health protective effects (Sinha *et al* 2008) [25]. *Terminalia arjuna* bark contains many active

constituents such as tannis, triterpenoid, saponins (arjunic acid, arejunolic acid, arjungenin and arjunglycosides), flavonoids, ellagic acid, gallic acid, oligomericproanthocyanidins, phytosterol, calcium, magnesium, zinc, copper, and coenzyme-Q (Doorika and Ananthi 2012) [7]. The objective of this study aims to evaluate the impact of thermal stress and ameliorative potential of *Terminaliaarjuna* on physiological traits of beetle goats under natural summer stress.

Material & Methods

Animals and Management

The study was conducted on twelve apparently healthy beetal goats with normal reproductive history and sexual behavior, in the age group of 3-5 years which were randomly divided into 2 groups viz: Control group: (n=6) during pre-summer (April –May) and summer (June- August) seasons.(no supplementation with *Terminalia arjuna* bark powder) and Treatment group : supplemented with *Terminalia arjuna* bark powder @42mg/kg. b.w./day (n=6) daily for 30 days during summer (June- August) seasons. The animals were maintained at the Goat Research Farm of Guru Angad Dev Veterinary and Animal Sciences University (GADVASU), Ludhiana. The goats were kept under semi loose housing system kept in pens, each enclosing an open area of 50 x 30 sq feet and a closed area of 17 x 30 sqfeet. All the experimental protocols using animals in this study have been conducted after getting the approval of the Institutional Animal Ethical Committee (IAEC) of the Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana (Punjab), India and were carried out according to the guidelines of the IAEC vide CPSCA approval of research protocol vide F.No.25/19/2018-CPCSEA.

Metrological data and physiological responses

Ambient temperature and relative humidity

Ambient temperature and relative humidity were recorded inside the shed with the help of thermo hygrometer (Lakhani *et al* 2016) [14] and Temperature humidity index (THI) of the animal shed was calculated using the formula:

$$THI = (0.81 \times Ta) + \{(RH \div 100) \times (Ta - 14.4)\} + 46.6$$

(Where, Ta = Average ambient temperature in ^{0}C and RH = Average relative humidity)

Respiration rate

The rate of respiratory movements in different animals was recorded by the 'flank method' by standing at the back of the animal and making the observations on the rise and fall of the abdominal flank.

Rectal temperature

The rectal temperature of all the goats was recorded with the help of digital rectal thermometer with a metallic probe. The probe of the thermometer was lubricated with liquid paraffin. Care was taken that the probe of the thermometer remained in contact with the rectal mucous membrane. The thermometer was kept inside till the digital display scale showed constant reading.

Heart rate

Heart rate was recorded with the help of stethoscope by auscultation between 4/5 intercostal space.

Statistical analysis

The data subjected to one-way analysis of variance (ANOVA) for comparison of means in different groups and the significant –differences were detected by the Fisher's least - significant- difference test. All analysis were performed with the statistics package Version 9.3, SPSS software.

Results and Discussion

Effect of Temperature humidity index (THI)

Temperature-humidity index (THI) is considered as sensitive indicator for the stressfull climatic condition (Silanikove 2000a) [23]. Increased air temperature and temperature humidity index value above the critical thresholds level lead to disturbance in physiology of animal and milk yield as in hot climatic conditions the nutrient intake of animal declines (West 2003). Armstrong (1994) [28, 3] classified THI as 72 indicating absence of heat stress, 73 to 78indicatingmild heat stress, 73 to 88 indicating moderate heat stress, 89-98 indicating severe heat stress and more than 98 indicating danger for animal.

In the present study the goats of pre summer showed THI value ranging from 73 to 77 which falls in mild/moderate heat stress. In the summer control THI was in the range of 86 and 92 respectively indicating severe heat stress (Table 1). Shinde *et al* (1990) [21] reported that production performance of cows is negatively correlated with temperature-humidity index. When the environmental temperature rises from the upper critical limit, the detrimental effects of heat stress on animals in terms of reduction in production of milk, changes in composition of milk and reduced reproductive performances are observed in livestock.

Table 1: Temperature, relative humidity and temperature humidity index of beetle goats on days of sampling in pre summer and summer

Season	Pre summer			Summer			
Day	**0**	**15**	**30**	**0**	**15**	**30**	**45**
Temp	29.2	31.3	32.4	38.1	40.4	43.9	39.6
RH%	25	31	28	40	36	38	47
T.H.I	73.66	76.88	77.56	86.56	88.28	92.93	90.12

Effect on rectal temperature

The Rectal temperature (Mean ± SE) of goats in pre summer, summer control and *Terminalia arjuna* supplemented group is presented in table 2, figure 1a & 1b.The overall mean rectal temperature was 38.54 ± 0.04, 39.02 ± 0.11 and 38.67 ± 0.08 in in pre summer, summer control and *Terminalia arjuna* supplemented group respectively.

Table 2: Rectal temperature (Mean ± S.E) of beetle goats supplemented with *Terminalia arjuna* @ 42 mg/kg. b.w. / day

Rectal Temperature (ºC)			
Pre summer (THI <80)		**Summer (THI > 80)**	
Day / Group		**Control**	**TA supplemented**
0	38.43 ± 0.07^{a}	38.96 ± 0.25^{ab}	38.48 ± 0.08^{a}
15	38.55 ± 0.08^{a}	38.48 ± 0.07^{b}	38.76 ± 0.19^{a}
30	38.65 ± 0.05^{a}	39.38 ± 0.14^{a}	38.78 ± 0.19^{a}
45	-	39.26 ± 0.20^{a}	38.66 ± 0.22^{a}
Mean	38.54 ± 0.04^{b}	39.02 ± 0.11^{a}	38.67 ± 0.08^{b}

[ab]The value with different superscripts differ significantly between the groups ($p \leq 0.05$).

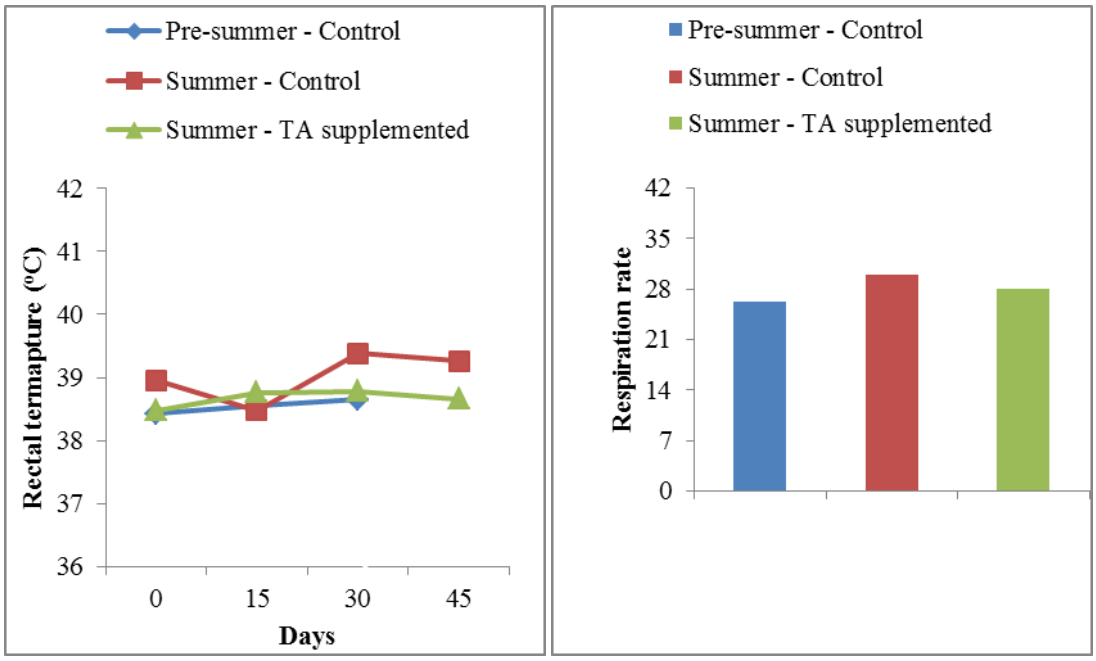

Fig. 1(a): Progressive changes in the level (Mean±SE)
1(b): Overall mean of rectal temperature (º C) of beetal goats supplemented with *Terminalia arjuna* (42 mg/kg b.w./day)

The body temperature is a good measure of heat tolerance in animals. Its variation above or below normal is measure of the animal ability to resist stress factor of the environment (Srikandakumar *et al* 2003) [26]. The value of rectal temperature in goats of summer group was significantly higher from goats of pre summer group. A rise in rectal temperature of 1°C or less is enough to reduce performance in most livestock species was documented by Shebaita and El-Banna (1982) [20]. Marked increase in rectal temperature from 37 °C to 41 °C during heat stress has also been reported previously in kids by Al-Tamimi (2007) [2].

However, with the supplementation of *Terminalia arjuna* there was reduction in rectal temperature from 39.02 ± 0.11to 38.67 ± 0.08. This indicates alleviation of heat stress by supplementation of *Terminalia arjuna.* Similar decrease in rectal temperature of goats by antioxidant supplementation was reported under heat stress conditions (Kumar *et al*, 2012) [13].

Effect on respiration rate

The (Mean ± SE) of respiration rate of goats in pre summer, summer control and *Terminalia arjuna* supplemented group is presented in table 3, figure 2a & 2b. The overall mean respiration rate was 26.22 ± 0.75, 29.91 ± 1.09 and 27.95 ± 0.72 in pre summer, summer control and *Terminalia arjuna* supplemented group respectively.

Table 3: Respiration rate (Mean ± S.E) of beetle goats supplemented with *Terminalia arjuna* @ 42 mg/kg. b.w. / day

Respiration Rate (breaths / min)			
	Pre summer (THI <80)		Summer (THI > 80)
Day/ Group		Control	TA supplemented
0	25.33 ± 1.25^{a}	28.00 ± 2.17^{bc}	27.16 ± 0.54^{a}
15	28.00 ± 1.52^{a}	25.00 ± 1.39^{c}	29.66 ± 1.11^{a}
30	25.33 ± 0.98^{a}	32.00 ± 1.87^{ab}	26.16 ± 1.95^{a}
45	-	34.66 ± 1.05^{a}	28.83 ± 1.70^{a}

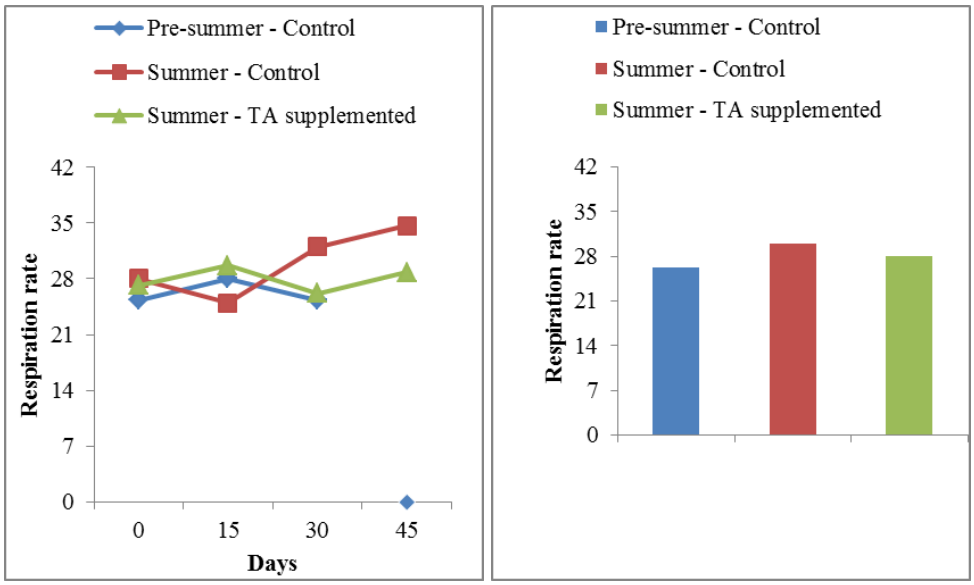

Fig. 2(a): Progressive changes in the level (Mean±SE)
2(b): Overall mean of respiration rate (beats/minute) of beetal goats supplemented with *Terminalia arjuna* (42 mg/kg b.w./day)

Respiration rate is a practical and reliable measure of heat load and an indicator of heat stress (Alam *et al*, 2011; Okoruwa *et al*, 2013) [1, 15]. The respiration rate (breaths/min) can change frequently and it is indirectly influenced by the animal's activities (metabolism and muscle activity) (Devendra, 1987) [6], and environmental conditions (Silanikove, 2000b) [24]. The basal reference respiration rate is 16–30 breaths/min in sheep (Zaytsev *et al.* 1971) [29], and 15–30 breaths/min in goats (Robertshaw and Dmi'el, 1983) [18]. The value of respiration rate in goats of summer group was significantly higher from goats of pre summer group. The increased respiration rate is probably indicating an effort of animals to maintain their normal body temperature by increasing their heat dissipation through increasing respiratory evaporation (Hamzaoui *et al*, 2013) [11].

The present results showed that supplementation of *Terminalia arjuna* was able to reduce respiration rate in summer stressed goats from 29.91 ± 1.09 to 27.95 ± 0.72. Similar decrease in respiration rate of heat stressed goats after supplementation of amla powder has been reported (Randhawa *et al.* 2015) [17]. This decrease in respiration rate in heat stressed supplemented goats indicated that *Terminalia arjuna* may reduce some effects of heat stress in goats.

Effect on heart rate

The (Mean ± SE) of heart rate of goats in pre summer, summer control and *Terminalia arjuna* supplemented group is presented in table 4, figure 3a &3b. The overall mean heart rate was 88.05 ± 0.96, 88.54 ± 1.13 and 86.95 ± 0.84 in pre summer, summer control and *terminaliaarjuna* supplemented group respectively.

Table 4: Heart rate (Mean ± S.E) of beetle goats supplemented with *Terminalia arjuna* @ 42 mg/kg. b.w. / day

Heart rate (beats / min)			
	Pre summer (THI <80)		Summer (THI > 80)
Day/ Group		Control	TA supplemented
0	86.33 ± 1.85[a]	91.16 ± 1.95[a]	89.16 ± 1.70[a]
15	90.16 ± 1.77[a]	83.16 ± 1.01[b]	85.83 ± 1.37[a]
30	87.66 ± 1.20[a]	88.33 ± 2.26[a]	85.16 ± 1.92[a]
45	-	91.50 ± 2.17[a]	87.66 ± 1.66[a]
Mean	88.05 ± 0.96[a]	88.54 ± 1.13[a]	86.95 ± 0.84[a]

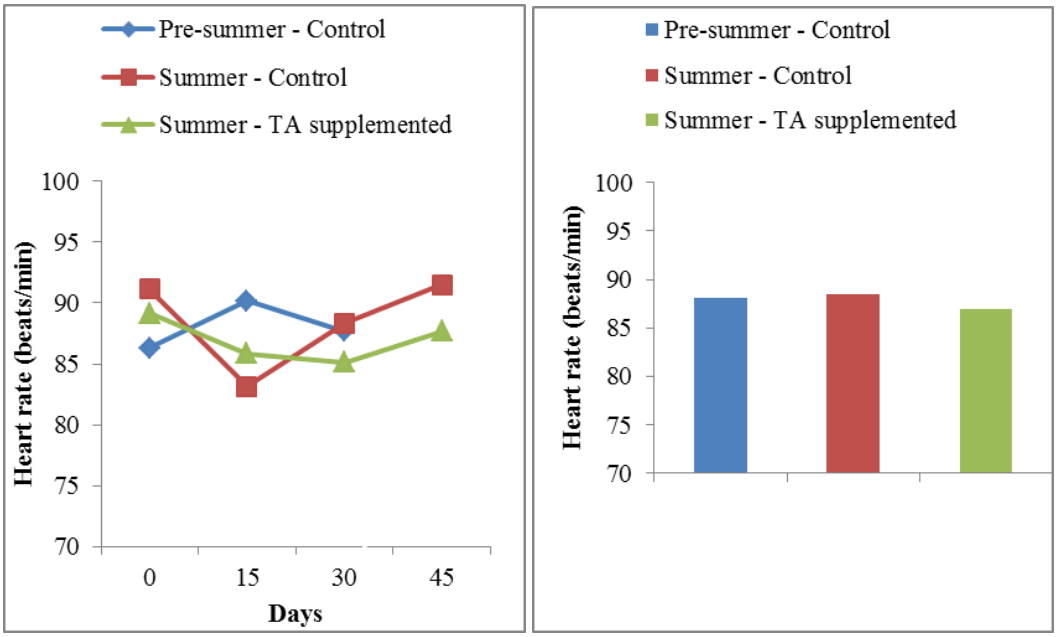

Fig. 3(a): Progressive changes in the level (Mean±SE)
3(b): Overall mean of heart rate (beats/minute) of beetal goats supplemented with *Terminalia arjuna* (42 mg/kg b.w./day)

Heart rate (expressed through beats/min) can be rapidly altered due to animal biological activities or by external factors such as temperature. Normal heart rates range from 90 to 95 beats/min (Heath and Olusanya 1985) [12] for goats, and from 70 to 80 beats/min for sheep (Zaytsev *et al.* 1971) [29]. There was no significant changein value of heart rate in goats of summer group and of presummer group in the present study. Sunagawa *et al.* (2002) [27] did not detect any significant changes in heart rate when sheep were exposed to heat stress. However Alam *et al.* (2011) [1] and Okoruwa (2014) [16] showed a higher heart rate in goats (74 to 91 beats/min) on heat exposure.

The present results showed that supplementation of *Terminalia arjuna* was able to decrease heart rate in summer stressed goats from to 88.54 ± 1.13 to 86.95 ± 0.84. *Termialiaarjuna* is one of the best cardio-protector agent. Improvement of cardiac muscle function and subsequent improved pumping activity of the heart seems to be the primary benefit of *Terminalia arjuna*. Saponin glycosides might be responsible for the inotropic effect of while the flavonoids provide free radical antioxidant activity and vascular strengthening. A dose-dependent decrease in heart rate and blood pressure was noted in dogs given terminalia intravenously (Choudhary *et al.* 2011) [5].

Conclusion

Climate change has negative impacts on livestock health and performance (El-Tarabany and El-bayoumi 2015) [8]. High ambient temperature has adverse effects that result in oxidative stress /enzymatic dysfunction and aberration of physiological/ reproductive functions (Hall *et al.* 2001) [10]. The physiological traits of animal's is sensitive to changes in the environmental temperature and help to assess responses to the stressing agent (Okoruwa, 2014) [16]. Numerous nutritional interventions/supplementations in diet are needed to minimize the negative effect of summer stress in goats. The present study explored the effect of increase in Temperature humidity index on physiological response of beetle goats under normal

summer stress and evaluated the therapeutic effect of *Terminalia arjuna* supplementation in its alleviation. It may be concluded that the varying degree of heat stress in pre summer and summer season was related with increasing Temperature humidity index (THI) affecting physiological response of goats viz: respiration rate, heart rate and rectal temperature in goats. However oral supplementation of TA @ 42mg/Kg B.W for 30 days significantly improved physiological response of beetal goats in summer and alleviated partially the adverse effects of summer stress.

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