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Estimation of Heat Tolerance Ability of Saanen, Local and Jamnapari × Local Goats and a Suitable Temperature-Humidity Index

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ABSTRACT. *The changes in four physiological parameters (rectal temperature, skin temperature, respiration rate and pulse rate) to the fluctuating ambient temperature and relative humidity, were compared among three Jamnapari × local (J×L) cross-bred goats, three Saanens and three local goats, to ascertain the most heat tolerant type and to establish a suitable temperature-humidity index for this species. These ambient and physiological parameters were measured simultaneously at hourly intervals from 0700 hrs to 1700 hrs on ten different sunny days (Experiment I). On another ten different sunny days (Experiment II), 27 females belonging to these three types, were exposed to direct sunlight for one hour during the midday, and the physiological parameters were recorded before and after exposure.*

The mean ambient temperature and the relative humidity during the experimental period were found to be 27.2 ± 2.23°C and 56.9 ± 9.51% RH, respectively (n=110). All the physiological parameters showed significant positive correlations with changes in the ambient temperature but were found to be negatively correlated with relative humidity. The changes in the physiological parameters, with the exception of the skin temperature, were significantly higher ($P<0.01$) in the Saanen. The Saanen also showed the highest increase in all physiological parameters when exposed to direct sunlight, suggesting that it is the least heat tolerant breed. The J×L cross had the lowest initial values and the lowest increases in rectal temperature and respiration rate during the period of study suggesting that J×L cross is the most adapted type to the Sri Lankan mid-country conditions.

The best temperature-humidity index that explains variations in rectal temperature and skin temperature in goats was found to be (0.70 × Dry bulb temperature) + (0.30 × Wet bulb temperature). The relationship of

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temperature-humidity indices with pulse rate and respiration rate suggested the existence of additional influential factors than ambient temperature and relative humidity, on these parameters.

INTRODUCTION

Ambient temperature and relative humidity, are the two most important environmental factors that affect animal production in the tropics (Yousef, 1982). Animals maintain a relatively stable body temperature under a fluctuating thermal environment, and their ability to tolerate heat can be assessed by monitoring the physiological responses such as respiration rate, pulse rate, and body temperature. Measurement of these physiological responses would help to select the most suitable breed to be used for milk or meat production. In addition, the heat tolerance ability of animals have been related to various combinations of temperature and humidity (Bianca, 1965). However, no satisfactory heat tolerance index has yet been devised exclusively for goats.

Hence, the objectives of the present study were:

i) to ascertain the most heat tolerant breed, by comparing the physiological responses among the Saanens, Locals and Jamnapari × Local crosses, to changes in ambient temperature and relative humidity and,

ii) to determine the most appropriate temperature-humidity index for goats.

MATERIALS AND METHODS

A two stage experiment was conducted at the University Livestock farm at Uda Peradeniya from December 1995 to May 1996. All animals used in the experiments were in good health and received identical care. They were housed in brick walled pens and were given an adaptation period of 14 days before commencing the experiment. During this period the physiological measurements such as the rectal temperature, skin temperature, respiration rate and pulse rate were taken at regular intervals to accustom them to the experimental procedures.

Experiment I

Nine non-pregnant lactating does, comprising of three pure-bred Saanens, three locals (indigenous breed) and three 50% Jamnapari x 50% local (J×L) cross bred goats at 20-28 months of age, were used. The mean body weights of Saanen, local and J×L were 59.3 ± 2.52, 43.0 ± 2.65 and 66.3 ± 2.08 kg, respectively. Following the adaptation period, the environmental and physiological parameters as given below were measured simultaneously at hourly intervals from 0700 hours to 1700 hours on ten different sunny days.

Experiment II

Nine lactating does from each type (n=27) were exposed to direct sunlight in a paddock for a period of one hour between 1200 and 1400 hrs. Measurements on physiological and environmental parameters were obtained just before and after the exposure to determine the heat tolerance indices of goats.

Measurements

(a) Environmental parameters

A wet and dry bulb thermometer placed inside the pen at a height of 4 ft. was used to measure the ambient temperature (AT). Using the wet and dry bulb temperature readings and the chart, relative humidity (RH) was estimated.

(b) Physiological parameters

The rectal temperature (RT) was measured by inserting a clinical thermometer into the rectum for one minute. The skin temperature (ST) of the dorsal flank region of the goat was measured using a flat thermistor probe attached to a telethermometer. The respiration rate (RR) was determined visually, by counting the number of flank movements per minute and the pulse rate (PR) was measured by placing the finger tips on the femoral artery, ensuring minimal disturbance to the animal.

Analysis of data

Mean hourly values for all the above parameters were estimated for the three types separately. Correlation and Regression coefficients were computed and regression lines were superimposed to quantify the relationships between changes in environmental variables and physiological variables. The physiological measurements of the three types, to the changes in ambient conditions were compared using analysis of variance.

Heat tolerance capacity of each type was computed separately, based on the differences observed in each physiological parameter, after exposure to direct sunlight using the following formula.

$$Percentage\ increase = \left[\frac{Post\ exposure\ value - Pre\ exposure\ value}{Pre\ exposure\ value}\right] \times 100$$

$$Heat\ Tolerance \propto \frac{1}{Percentage\ increase}$$

To determine the best temperature-humidity index (THI) which describes the combined effects of thermal and environmental factors on different physiological parameters of goats, different weightage (percentage values) combinations (*e.g.*: 60:40, 65:35, 70:30) were given to dry and wet bulb temperatures and the resultant THI values were correlated with changes in physiological parameters.

RESULTS AND DISCUSSION

(i) Experiment I

(a) Environmental parameters

The mean AT and RH during the experimental period fluctuated in opposite directions (Figure: 1a) and assumed mean values of 27.2 ± 2.23°C and 56.9 ± 9.51%, respectively (n=110).

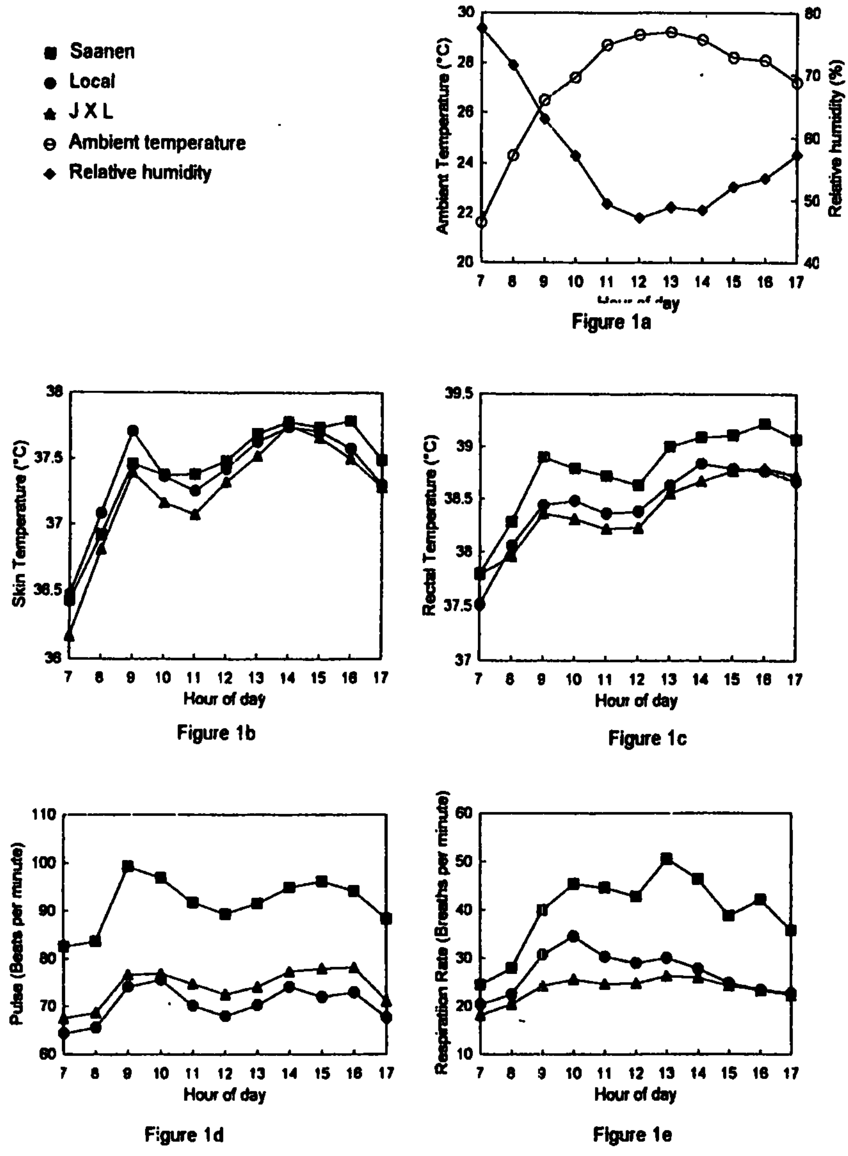

Figure 1. **Hourly mean values of environmental and physiological parameters.**

(b) Hourly fluctuations in physiological parameters

The hourly changes in ST, RT and PR of all three types were paralleled to one another, with two peak values in the morning and afternoon (Figures: 1b, 1c, 1d). The reason for the morning rise could be partly explained by the orientation of the goat pen. The long, half-walled side of the pen was facing the eastern direction and thus the sun rays fell directly into the pen for about an hour from 0830 to 0930 hours. The afternoon increase in RT has also been reported by other workers (Kumar *et al.*, 1993; Ghosh and Pan, 1994; Kaushish *et al.*, 1987). A similar two peak pattern was also observed for the RR (Figure: 1e).

The lowest fluctuations in the mean hourly RR (7.8 breaths/minute), PR (10.4 beats/min) and RT (1°C) were found in J×L goats, while Saanen exhibited the highest fluctuations in these parameters (26.1 breaths/minute, 16.8 beats/min. and 1.42°C, respectively). Highly significant differences ($P < 0.001$) in the above physiological changes were observed between the Saanen and the other two types of goats. These fluctuations in the physiological parameters reflect the responses of the different types of goats to the changes in the ambient conditions.

(c) Physiological responses to changes in ambient parameters

The variations in the physiological parameters to the changes in the AT are given in Figures: 2, 3, 4 and 5. Significant positive correlations were observed between AT and all the physiological parameters (Table 1).

The responses of RR, PR and RT in the Saanen breed to increasing AT was significantly higher ($P < 0.01$) than in the other two types (Figures: 3, 4, 5). However, no significant differences were observed in the response of the ST, between the Saanen and Local breeds. In contrast, J×L cross showed the lowest ST, RR and RT in response to increasing AT. The ST and RR responses in the J×L cross were found to be significantly different ($P < 0.01$) when compared with the Saanen and Local breeds. However, no such differences were seen between the J×L crosses and the Local breeds.

The ST reflects the balance between heat gained from and heat lost to the environment. Heat-gain depends on the hair and skin characteristics of the animal (Acharya *et al.*, 1995), while the heat loss depends mainly on the amount of blood flow to the skin and on its insulatory properties. Differences

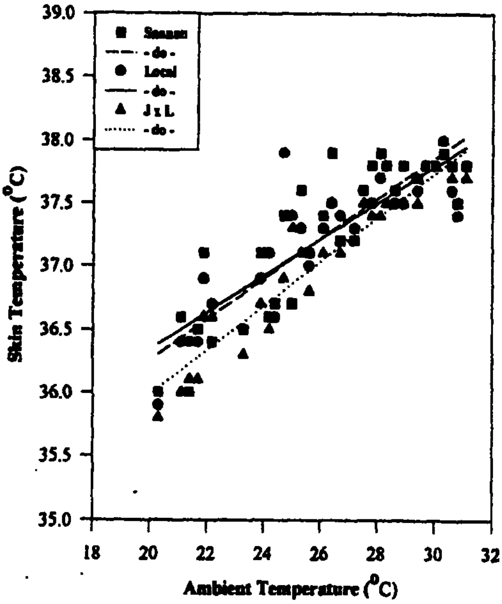

Figure 2. Comparison of skin temperatures with changes in the ambient temperature.

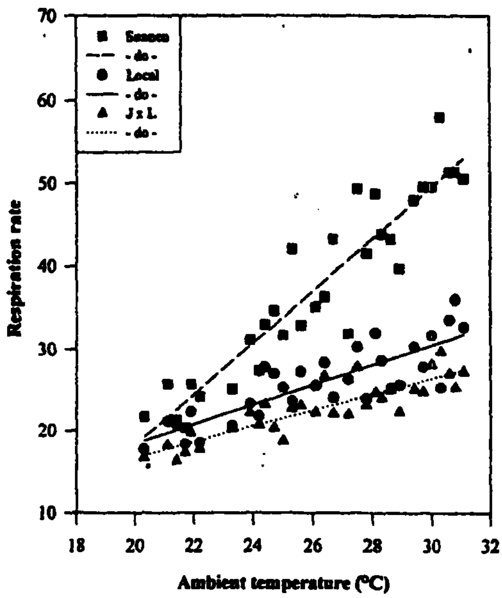

Figure 3. Comparison of respiration rates with changes in the ambient temperature.

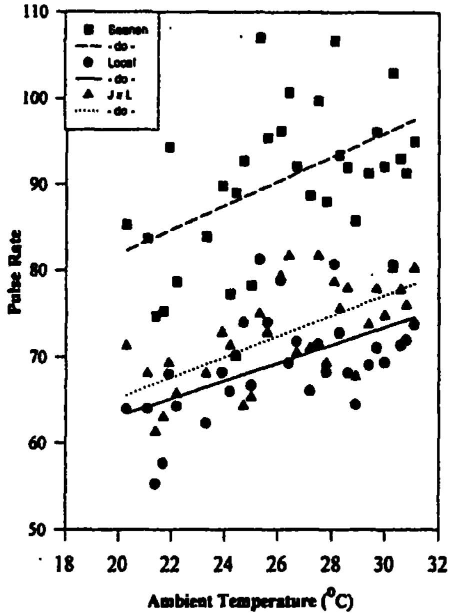

Figure 4. Comparison of pulse rates with changes in the ambient temperature.

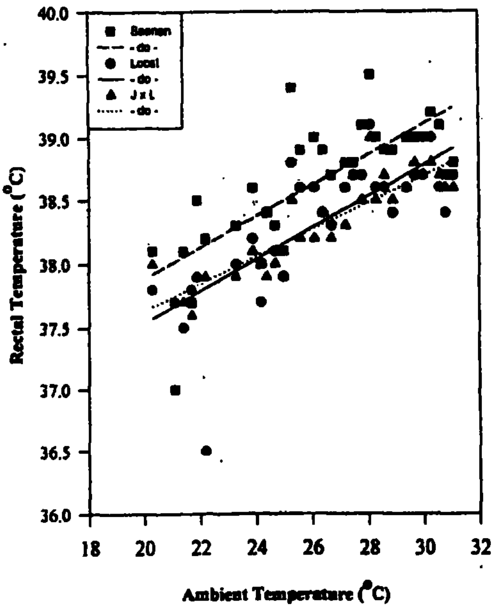

Figure 5. Comparison of rectal temperatures with changes in the ambient temperature.

Table 1. Regression equations and correlation coefficients between physiological parameters and environmental variables.

Parameter	Goat	Relationship to AT (°C)	Relationship to RH (%)
RT	Saanen	y = 0.122 x + 35.436 (r = 0.7422)**	y = -0.013 x + 39.483 (r = 0.7102)**
	Local	y = 0.124 x + 35.058 (r = 0.7524)**	y = -0.013 x + 39.126 (r = 0.7772)**
	JxL	y = 0.106 x + 35.506 (r = 0.8897)**	y = -0.012 x + 39.133 (r = 0.9035)**
ST	Saanen	y = 0.160 x + 33.048 (r = 0.8681)**	y = -0.013 x + 39.483 (r = 0.7102)**
	Local	y = 0.145 x + 33.449 (r = 0.8631)**	y = -0.012 x + 38.090 (r = 0.7079)**
	JxL	y = 0.175 x + 32.472 (r = 0.9441)**	y = -0.019 x + 38.334 (r = 0.9224)**
RR	Saanen	y = 3.128 x - 44.326 (r = 0.9352)**	y = -0.283 x + 55.502 (r = 0.8769)**
	Local	y = 1.212 x - 5.873 (r = 0.8369)**	y = -0.010 x + 25.271 (r = 0.0624)
	JxL	y = 0.974 x - 2.811 (r = 0.8771)**	y = -0.070 x + 27.215 (r = 0.7006)**
PR	Saanen	y = 1.410 x + 53.693 (r = 0.5383)**	y = -0.037 x + 93.779 (r = 0.1782)
	Local	y = 1.040 x + 42.277 (r = 0.5478)**	y = 0.036 x + 68.202 (r = 0.2410)
	JxL	y = 1.197 x + 41.305 (r = 0.6740)**	y = -0.110 x + 80.858 (r = 05794)*

** $P < 0.01$ * $P < 0.05$

in the above characteristics among the three types of goats may have been responsible for the variations in the ST.

Respiratory evaporation serves as an important method of heat dissipation at high temperatures when the thermal gradient between the skin and environment is reduced. The fact that the goat is no exception to this rule is evidenced by the RR response to AT.

The PR also increases with a rise in AT, as the heart rate increases to improve the peripheral circulation in order to dissipate excess body heat. The results of the present experiment confirm the existence of this mechanism in goats. The differences in the physiological responses of the three types to changes in AT (as given by regression equations in Table 1) imply that Saanen is the most responsive and the least heat tolerant breed and, that J×L is the least responsive and the most heat tolerant type, under the above experimental conditions.

Correlation coefficients between RH and RT/ST were found to be significantly negative (Table 1). Due to the strong inverse relationship between the AT and RH (Figure: 1a), it was difficult to determine the direct effect of humidity on the physiological parameters.

(ii) Experiment II

After exposure to direct sunlight for one hour all the three types exhibited an increase in all the physiological parameters. The estimated heat tolerance indices based on these changes are given in Table 2. The RR showed the highest increase while the RT showed the lowest, confirming that the goat is a predominantly panting species as suggested by Hafez (1968).

Upon exposure to direct sunlight, Saanen demonstrated the highest pre-exposure and post-exposure values, as well as the highest percentage increase in all the physiological parameters measured while J×L cross breed showed the lowest pre-exposure, post-exposure and percentage increase values of ST, RR and RT (Table 2). Heat tolerance is negatively correlated with percentage increase. The estimated heat tolerance indices were lowest for Saanen in all four parameters reiterating Saanen as the least heat tolerant breed. The results also suggest J×L as the most heat tolerant.

Temperature-humidity index (THI)

It is apparent from these results that an appropriate index to assess the thermal status of the environment should include at least AT and RH. The importance of each ambient factor depends on the relative dependency of the animal on the different routes of heat dissipation. For example, the wet bulb temperature (T_{WB}) which gives an assessment of relative ambient humidity becomes less important with diminishing sweating capacity. Animals that rely more on sweating for dissipation of heat are more sensitive to increasing ambient vapour pressure at high temperatures than others.

In the present study, an attempt was made to identify the most suitable combination of the dry bulb and wet bulb temperatures (T_{DB} and T_{WB}) to explain variations in physiological parameters of goats. In order to accomplish this correlation coefficients were estimated between different percentage combinations (60:40, 65:35, 70:30) of dry and wet bulb temperatures at a given time with values of each physiological parameter at that time. The most correlated combinations was considered as the most suitable THI. The formula for each physiological parameter was obtained by computing the regression equation for the most suitable combination.

Table 2. **Changes in the physiological parameters, after exposure of animals to direct sunlight for one hour.**

	Parameter	Saanen	Local	JxL
ST	Initial value	36.5±0.85	36.0±0.69	36.1±0.93
	Final value	39.4±1.30	38.0±0.63	37.9±1.23
	Increase	2.89	1.94	1.8
	% increase	7.91	5.38	4.98
	HT Index	12.64%	18.59%	20.08%
RR	Initial value	58.4±23.91	36.4±16.52	30.1±9.95
	Final value	111.2±20.63	69.2±15.34	53.8±14.06
	Increase	52.8	32.8	23.7
	% increase	90.4	90.1	78.7
	HT Index	1.11%	1.11%	1.27%
PR	Initial value	88.4±6.16	70.0±11.47	76.7±9.48
	Final value	101.2±16.36	77.6±18.69	85.6±7.64
	Increase	12.8	7.6	8.9
	% increase	14.5	10.9	11.6
	HT Index	6.90%	9.17%	8.62%
RT	Initial value	39.1±0.11	38.8±0.21	38.7±0.33
	Final value	40.1±0.44	39.8±0.35	39.7±0.30
	Increase	1.07	1.04	1.02
	% increase	2.74	2.68	2.64
	HT Index	36.50%	37.31%	37.88%

For each value, n = 30

The respective temperature humidity indices which explain variations in RT are given below:

$THI_{RT\text{-}Saanen}$: $0.70 \times T_{DB} + 0.30 \times T_{WB}$ $\qquad$ $RT_{Saanen} = 0.15\ THI + 34.98\ (r=0.45)$ *

$THI_{RT\text{-}Local}$: $0.85 \times T_{DB} + 0.15 \times T_{WB}$ $\qquad$ $RT_{Local} = 0.12\ THI + 35.21\ (r=0.42)$ *

$THI_{RT\text{-}J\times L}$: $0.70 \times T_{DB} + 0.30 \times T_{WB}$ $RT_{J\times L} = 0.14\ THI + 34.82\ (r=0.58)$ *

$THI_{ST\text{-}Saanen}$: $0.70 \times T_{DB} + 0.30 \times T_{WB}$ $ST_{Saanen} = 0.21\ THI + 32.22\ (r=0.68)$ *

* = ($P<0.01$) n = 330

Accordingly, the $0.70 \times T_{DB} + 0.30 \times T_{WB}$ combination was the most suitable temperature-humidity index to explain variations observed in ST and RT.

The higher weightage given to dry bulb temperature in these indices implies that the ST and RT of goats are affected more by changes in AT than humidity.

With regard to RR and PR, $0.65 \times T_{DB} + 0.35 \times T_{WB}$ combination was found to be better suited, suggesting greater relative dependency of these two parameters on RH. The inconsistency of the temperature-humidity indices computed for RR and PR may be due to the fact that these parameters are influenced by additional factors than AT and RH.

CONCLUSIONS

The present study has utilized 330 observations for each physiological parameter and corresponding values of ambient parameters to derive the above indices for each type of goat. The following conclusions can be made based on the results of this study.

Saanen can be rated as the least heat tolerant and J×L cross as the most heat tolerant, among the three types tested. However, Saanen breed did not appear to be too much stressed, possibly because the maximum temperature in the present study did not exceed 31.1°C. The results also suggest J×L as the most adapted type to the environmental conditions prevailing in the mid country of Sri Lanka.

The estimation of temperature-humidity indices, which combine the effects of both AT and RH revealed the $0.70 \times T_{DB} + 0.30 \times T_{WB}$ to be the best index to explain the thermoregulatory responses of ST and RT while the $0.65 \times T_{DB} + 0.35 \times T_{WB}$ combination was the best to explain variations in RR and PR of goats.

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