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INFLUENCE OF THE TEMPERATURE-HUMIDITY INDEX ON SOME PHYSIOLOGICAL PARAMETERS IN DAIRY GOATS

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Abstract

The aim of this paper is to study the microclimate in a dairy goat farm during the warmest (July and August) and coldest months of the year (January and February) and evaluate its impact on animal welfare and health. Temperature, relative humidity and illuminance were monitored. The severity of temperature stress was determined by calculating the temperature-humidity index (THI). The average value of THI for the month of August exceeded that for the month of July by 1.5 and it also remained above the threshold accepted for extremely high heat stress (28.6). During the cold days of the year (January and February), when the goats were mainly in the barn, THI did not exceed 17, varying between 5 and 16.8. The average relative humidity and illuminance remained within their permissible values. As a physiological adaptive response during the hot months, animals responded with an increase in rectal and skin temperature, pulse rate and respiratory movements while rumen contractions decreased.

Key words*: goats, temperature stress, temperature-humidity index, physiological parameters*

INTRODUCTION

The welfare and good health condition of goats are of utmost significance for unleashing their genetic potential in terms of milk production. The temperature, humidity, air movement, illuminance, etc. are extremely important environmental factors. (Aleena et al., 2018; Archana et al., 2018; Pragna et al., 2018).
Aleena et al. (2018) and others specify goats as animals with a large adaptation potential with reference to the changing environmental conditions. Nevertheless, upon non-observance of fundamental requirements towards the rearing conditions, problems related to the growth (Pragna et al., 2018), productivity (Archana et al., 2018), as well as the immunity (Dangi et al., 2015) are observed.
Regardless of the growing climate changes, goats are considered to be drought-tolerant animals (Serradilla et al., 2018; Stone et al., 2020), which are capable of surviving (Chebli et al., 2020) and fighting multiple disease agents (Pal & Chakravarty, 2020). In this respect, their breeding is considered to be more cost-effective than that of cattle. Goats use relatively low-quality feeds to create valuable high-quality food products (Peacock & Sherman, 2010). According to Darcan & Silanikove (2018), they also do not require expensive buildings.
The high-producing dairy goats, however, require optimal conditions on the pastures and in the barns so as to be safeguarded against stressful situations (Amamou et al., 2019). To this regard, Ribeiro et al. (2018) are of the opinion that it is necessary the zoo-hygienic parameters to be analysed and evaluated due to the fact that each breed has different adaptability characteristics and welfare problems (Gelasakis et al., 2017). Upon heat stress, there is redistribution of the available resources of the body, which affects the growth, reproduction, productivity and health. Consequently, the ambient temperature dictates the intensity of the metabolic processes, the heart and respiratory rate et al. (Fonseca et al., 2016).
In Bulgaria, the high summer temperatures of not only the external environment but also in the barns prove critical as they considerably exceed 28ºC, which is the optimum limit for goats. On that account, we set ourselves the task to examine the microclimate in a dairy goat farm during the warmest (July and August) and coldest months of the year (January and February) and evaluate its impact on the animals' welfare and health.

MATERIALS AND METHODS

The farm we studied keeps 170 goats of the Bulgarian White Dairy breed and is situated in South Bulgaria. The construction and technological characteristics of the building are displayed in Table 1:

Table 1. Construction and technological characteristics of the building

Element of the building	Characteristics
Length, m	38
Width, m	8
Height, m	3.2
Roof Structure	Wooden
Roof	Tiles
Walls	Bricks + adobe, without external or internal mortar
Floor	Rammed clay
Doors:	Wooden
Windows	Wooden
Building orientation	East-west
Method of breeding	free range
Cleaning	Manual
Sewerage	No
Feeding	Manual
Watering	Metal troughs in the building
Milking	Mechanically in a churn
Ventilation	Natural
Area per 1 animal: From the building (304 m²) From the yard (760 m²)	 1.74 m 4.34 m

The building is a typical brick-adobe masonry with walls width of 0.24 m and has no internal and external insulation. There is a tile roof mounted on the wooden roof construction. The goats are bred freely on a floor of rammed earth and straw bedding. Each animal is ensured 1.74 m^2 in the building and 4.34 m^2 in the yard. The building has southern exposure and 'east-west' orientation. The ventilation is natural and the cleaning of the manure- manual.

During most of the year (190-240 days), the goats are grazing with the exception of the days when the weather conditions are inappropriate. In the winter, the feeding and watering are performed in the building, and in the summer- in the yard. During the lactation period the goats are given 600 g concentrated feed extra.

The control over the temperature (ºC) and relative humidity (%) in and outside the building was exercised by measuring them with the Assman psychrometer and the Six's maximum and minimum thermometer at 9:00, 13:00, 17:00 and 21:00 in January, February, July and August. The illuminance level was determined with a lux meter PU 150 Praha. The temperature humidity index was determined using the equation reported by Marai et al. (2007):

$$THI = T - [(0.31 - 0.0031\ RH)\ (T - 14.4)],$$

where T is the dry bulb thermometer temperature (ºC), and RH is the relative humidity (RH %/100). Upon THI values of < 22.2, the animals are outside the heat stress zone; from 22.2 to < 23.3 there is a moderate heat stress; from 23.3 to < 25.6 there is a severe heat stress, and upon THI of 25.6 and more, the animals are subjected to extremely severe heat stress.

The physiological parameters of one and the same animals were reported during all months. The following recordings were made three times at 11:00, 13:00, 15:00 and 17:00 each month during the period of the study:

Rectal temperature (ºC) - with an electronic thermometer "Kebl", model 2130.

Arterial pulse rate (beats/min)- with a chronometer on the femoral artery, on the inside of the rear leg.

Respiratory movements (n/per minute)- with a chronometer by tracking the chest and the flanks movements of the animal.

Skin temperature (ºC) - with a Compact infrared thermometer 105518 with a range from -50 to + 550ºC and a resolution of 0.1ºC. The values are the mean of the temperature measured at the forehead, back and the stomach of the animals.

Rumen contractions (n/5 min)- by means of a moderate pressure on the inside of the left flank for 5 minutes. The data obtained was processed in compliance with the statistical methods and the margin of fluctuation, the arithmetic mean and the maximum limits are displayed.

The THI effect on the physiological parameters studied was reported by means of a one-way analysis:

$$Y_{ij} = \mu + THI_i + e_{ij},$$

where: Y_{ij} – is the dependent variable (each of the physiological parameters studied), μ is a mean effect, THI_i – the effect of the average THI for the month and e_{ij} is the random residual effect.

RESULTS AND DISCUSSIONS

The goats are reared in a standard brick-adobe building which provides both sufficient barn and yard space for each animal (Table 1).

Table 2 displays data about the microclimatic parameters inside and outside the building.

The microclimate in the dairy goat farms is of key importance for the health of the animals and the production of milk. The stocking density, the feeding and watering front, the cleaning and ventilation systems are all of significance for the microclimate's keeping within the permissible limits. Marciniak (2014) further adds that the design and the structure of the buildings are also important. According to the set norms in our country (Ordinance No. 44, 2006), the optimal temperature range related to goats is between 10 and 17ºC, and temperatures above 35ºC are considered critical. Upon ventilation malfunction, it is possible that the goats are overcooled or overheated.

We consider that the transient minimum temperatures of –2ºC which we registered in the winter months were not perilous for the goats. Bøe & Ehrlenbruch (2013) also take a similar stand by stating that this is due to the goats ability to adapt quickly (for approximately 2 days) to the low ambient temperature. However, the summer temperatures which exceed the optimal limits are critical. Having analysed the average temperatures inside and outside the barn (Table 2), we can assume that there are conditions for heat stress. The highest outdoor temperature was recorded in August (37.6ºC). High temperatures were also registered inside the barn in both summer months (36ºC). The average relative humidity inside the barn was within the maximum limits only during the summer months and exceeded them significantly during the others. The luminance intensity, with a few exceptions, was within the set norms.

Table 2. Temperature, relative humidity and luminous intensity mean values inside and outside the building during the different months

Parameters	Margin of fluctuation		Mean		Maximum limit
	inside	outside	Inside	outside	
Temperature, ºC					
January	-6 - 18.4	0 – 20.2	5.7 ± 1.8	10.5 ± 2.1	
February	-10 - 17.4	-2 - 21	12.3 ± 2.3	9.8 ± 1.7	
July	16 - 36.4	25 - 36	26.5 ± 1.4	30.5 ± 1.9	6-20-28
August	20.7 - 37.6	27 - 36	29.2 ± 1.1	31.2 ± 2.2	
Relative humidity, %					
January	38 - 90	58 - 100	64.5 ± 2.1	93 ± 4.1	
February	35 - 92	43 - 100	63.7 ± 2.7	95 ± 4.5	
July	42.8 - 47.4	58 - 77	45 ± 0.8	67.5 ± 2.2	50-80
August	36 - 43	45 - 72	39.5 ± 1.8	58.5 ± 1.8	
Luminous intensity, lux					
January	21 - 2120	3 - 160	1720	104	
February	30 - 1960	11 - 175	1605	111	
July	25 - 235000	12 - 688	107500	189	50-150
August	32 - 241000	13 - 705	120500	204	
Temperature-humidity index,THI					
January	0 - 16.8	3.5 - 19.2	5.1	12.5	
February	0 - 15.6	2.1 - 18.1	3.8	11.2	
July	16.1 - 32.8	15.7 - 35	24.5	32.8	22.2
August	17 - 33.3	15.8 - 36.9	25.2	33.3	

Summarizing the results of the examinations carried out, we may consider that the building studied has low to average temperature resistance both during the coldest winter (-15ºC) and the warmest summer days (above +35ºC).

We used the temperature-humidity index to assess the barn environment factors and the extent to which they form its comfort or discomfort (Marai et al., 2007) (Figure 1). Upon index values of < 22.2 - there is no heat stress, from 22.2 to < 23.3 there is a moderate heat stress, from 23.3 to < 25.6 there is a severe heat stress, and upon values of 25.6 and more, the stress is extremely severe. The data analysis indicates that both the temperatures in the barn (25º - 36ºC) and in the region (35º - 42.1ºC) form THI values which exceed the threshold for not only moderate but also extremely severe heat stress (28.6).

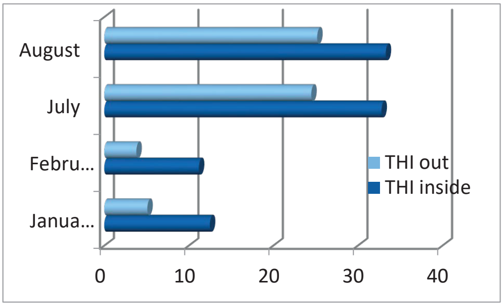

Figure 1. THI mean values inside and outside of the goat building

In the literature it is indicated that the small ruminants deal with the heat stress better than the cattle. The comparisons are made on the basis of THI values between dairy goats and dairy cows and prove the more flexible adaptability capacity of the goats (Silanikove, 2000). However, in this case the THI effect during grazing is not considered as it is in our country for example, where the small ruminants are mostly pasture-raised.
According to Kapgate et al. (2016), the type of building where the goats are kept during the summer does not have a significant effect on their physiological parameters.
Another study proves that goats in fact react to the changes in the microclimate by displaying changes in their physiological parameters, and the building characteristics also have an effect on them (Wadhwani et al., 2016). Bhatta et al. (2005) also ascertain a positive correlation between the THI and the physiological values of the goats.
Figure 2 displays the mean values of the physiological parameters examined by months. In our study, the internal body temperature varies within the reference parameters for the type, with the values being around the upper limits in July and August. Marai et al. (2007) also report an increase in the rectal temperature, pulse rate and respiration. According to (Al-Haidary, 2000), the high THI values are the reason for the lack of appetite, thermoregulation processes activation (da Silva & Rocha, 2020; Alyamani & Koluman, 2020), changes in the hormonal background, which affect the productivity and the fertility of the goats, and decrease in the production effectiveness (Souza et al., 2012). Therefore, controlling the physiological status of the animals is of important diagnostic significance for the assessment of the degree of the heat stress. Lucena et al., 2013; Ribeiro et al., 2016, 2018; Ribeiro et al., 2018a also consider that they are suitable for studying the adaptability of the small ruminants.
The maintenance of constant body temperature depends on the synchronicity between a range of complex physiological processes. Due to the fact that the sweat glands secretion in goats is poor, the acceleration of the shallow breathing and the increased ventilation of the upper respiratory passages are of great importance for the heat loss upon high ambient temperature. When the physiological cooling mechanisms of the body fail to dissipate the excess heat, the organism unlocks supplementary morpho-logical, blood and biochemical processes.

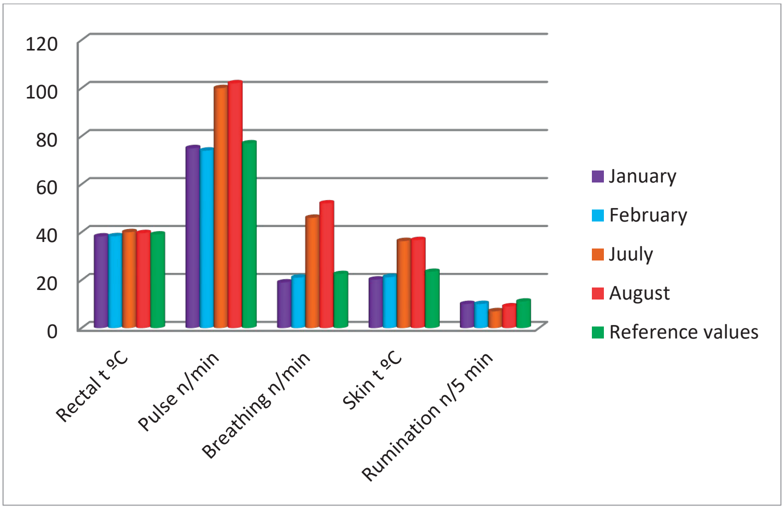

Figure 2. Mean values of the physiological parameters examined by months

We ascertained that upon increase in the THI values, the skin temperature also increases ($p<0.001$) (Table 3).

Table 3. THI influence on the physiological parameters examined and degree of reliability.

Physiological indicator	X[1]	SE[2]	F[3] p[4]
Rectal t ºC	39.02	0.15	33.9***
Pulse n/min	87.88	1.19	163.3***
Breathing n/min	34.5	1.28	178.4***
Skin t ºC	28.6	0.53	297.4***
Rumination n/5 min	9.7	0.54	6.01**

[1]X - Average
[2]SE - standard error,
[3]F - Fischer's criteria,
[4]p - Degree of reliability
***- Significance upon p<0.001,
** - Significance upon p<0.01

When the animals are bred under an optimal temperature-humidity regime, this temperature remains lower than the rectal by 5-6ºC. Upon high THI values, however, it is capable of reaching the rectal temperature (Campbell, 2011). The reason for this, according to Ligeiro et al. (2006), is the small size of their body which means that goats are forced to expose to the sun radiation surface which is larger when compared with their weight. During the day, there is a normal variation in rectal temperature from 0.3°C to 1.9ºC (Piccione & Refinetti, 2003).

The seasons change and the microclimate parameters related to it affect the body and skin temperature of the goats. In order to maintain these parameters within the norm, the animals try to dissipate the heat by accelerating their respiration (Yamani & Koluman, 2020).

The increased respiration rate upon high THI values is a temporary mechanism, which the animal uses to maintain its temperature homeostasis (Ribeiro et al., 2018a). During our study, we ascertained a change in not only the rate but also the depth of the respiratory movements. We consider that the reason for the abovementioned is the high activity of the animals in grazing conditions.

The pulse rate elevation is a reason for an increased blood flow towards the peripheral vessels. In this way a loss of heat is performed through release, transmission, convection or evaporation (Marai et al., 2007). The temperature increase over 31.6ºC according to Lucena et al. (2013) leads to heart rate elevation to 121 beats per minute which is also an indicator for thermal discomfort in goats.

The conditions in which the goats are reared, the feed content and the state of the digestive system determine the rumen movements. The higher summer values of the THI lead to slowing down of the rumen contractions ($p<0.01$). Similar results are reported by Alam et al. (2011), who also record slowing down of the ruminations when the THI values are high. In the course of time, the animals adapt and the number of the rumen contractions comes close to the reference values for the breed.

CONCLUSIONS

The accurate analysis of the factors which have effect on the health, behaviour and productivity of the goats is of importance for the production effectiveness. In conclusion, we can summarise that the high THI values reported during the summer months in South Bulgaria (24.5-25.2ºC outside, and 32.8-33.3ºC in the building) significantly affect the rectal and skin temperature ($p<0.001$), the pulse rate and the respiration ($p<0.001$) and have less effect on the rumen movements ($p<0.01$).

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