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Characterisation of Tunisian local goats' response to heat stress in arid region

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Abstract - Characterisation of the response in the traits of economic interest to high heat loads is the first step to evaluate the need to introduce adaptation to extreme weather in breeding programmes. The main objective of our study was to evaluate the effect of temperature and humidity on the weightof kids from a Tunisian local goat breed. Growth recording from 2010to 2019 were merged with temperature and humidity data provided by the state meteorological agency. A total of 4,173 body weights in the caprine herd of the Arid Areas Institute of Médenine were used. Different models including alternatively the effects of heat load as a temperature-humidity index (THI), the average temperature (Tavg) and the maximum temperature (Tmax) on weight were used. Heat load on the day of recording or the average heat load of the 7 days previous to the day of weighing (THI7, Tavg7, Tmax7) were tried. Heat load was modelled either as a class effect (c) or through quadratic (quad) or cubic (cub) Legendre polynomials. Overall, 18 models were used. All models included effects of age and weight of dam, the interaction sex*type of birth and year of recording, plus random animal effects. Models using cTHI and cTavg7 provided the best goodness of fit, with Tmax models showing the worst performance. Heat tolerance thresholds were estimated at 21/20, 25/28, 68/66 for Tavg/Tavg7, Tmax/Tmax7, THI/THI7, respectively, from the cubic polynomial fit. Slopes of decay in expected weight after the threshold were around 300 g/degree of Tavg or THI above the threshold. According to these results, heat stress is limiting the growth of kids in this local breed of goats. Tavg and THI seemed to provide a better way of measuring heat load compared with Tmax. Average of heat loads in the period previous to recording of weights showed better results than heat load on the same date, but not for all the studied variables.

Keywords: Goats, Heat tolerance, weight, arid area.

1. Introduction

Goat meat production is a widely extended activity in the more arid areas of Tunisia. Local breeds are normally used because of their adaptation to produce under the harsh conditions of this region. Local goat breeds are famous for their walking ability, resistance to hydricrestrictions and high temperatures and good fertility. However, these breeds are also
characterised by a very small size and low productivity (Najari, 2005). This makes farmers tend to resort to using foreign selected breeds, which lack adaptation to harsh conditions.

Therefore, improvement of growth characteristics of local breeds is important to increase farm benefits (Zhang et al., 2008) and ensure the sustainability of genetic resources and goat farming in these areas (Atoui et al., 2019).

In livestock productivity, the increase of temperature have significant and adverse implications in all production traits since it affects the ability of the animals to thermoregulate (DeShazer et al., 2009). To measure heat stress, different indices have been used, the temperature humidity index (THI), Black Globe-Humidity Index (Buffington et al., 1981), Heat Load Index and the Respiratory Rate Predictor (Silva et al., 2007). The THI has proven a useful tool to gauge livestock productivity response as a function of climate.

Although, the Tunisian local goat breed has been extensively studied to describe growth curves and phenotypic performances (Najari, 2005), no studies have been carried out to examine the THI values for environmental conditions in the Tunisian arid regions and relating them to potential heat stress conditions for animals.

In this context, the study aims to evaluate the effect of temperature and humidity on growth traits of Tunisian breed kids, in the perspective of developing improvement plans for the sector appropriate to the arid environment, the pastoral farming system, and also, to the adaptive and productive potentials.

2. Material and methods

2.1. Data

All studied animals belong to the goat experimental herd of the Arid Areas Institute of Médenine Tunisia (33°30' N and 10° 40' E), which is located in southeastern Tunisia, between the mountains of Matmata and the Mediterranean Sea. This region is characterized by an arid continental Mediterranean climate; with irregular precipitations with an average annual rainfall of about 200mm. The summer is normally the hottest and driest season with a maximum temperature of 47°C (Ouni et al., 2007).

Weights of kids that are regularly recorded along the preweaning period recorded from 2010 to 2019 were merged with temperature and humidity data provided by the state meteorological agency. After merging with the meteorological data and edits to eliminate records with missing critical information or with abnormal values for the weights or for other variables entering the analyses, 4,173 weights from 443 kids in a range of ages from 1 to 171 days were used in the analyses. The average weight of kids increased from 2.5 kg at birth to 12.9 kg at 150 days of age.

Data on daily average (Tavg), maximum (Tmax) and minimum temperatures and average relative humidity were provided by the official meteorological agency of the region. Combining daily average temperature (T in ºC) and relative humidity (RH in %), a temperature-humidity index (THI) was obtained following the NRC (1971) formula, which has been extensively used to gauge heat load (HL) in livestock studies,

$$THI = (1.8\times T+32) - (0.55 - 0.0055\times RH) \times (1.8\times T - 26)$$

Figure 1 shows the change of the average of Tavg, Tmax and THI along the days of the year. Kidding season begins in October and continues until February, with a concentration during November and December, with months of weight recording ranging from January through June. Despite that data from the hottest months of the year are not available, temperatures reached values that have been considered above the comfort region in goats. Maximum and average temperatures and average THI reached values around 35, 26 and 72, respectively, in the hottest days of data collection.

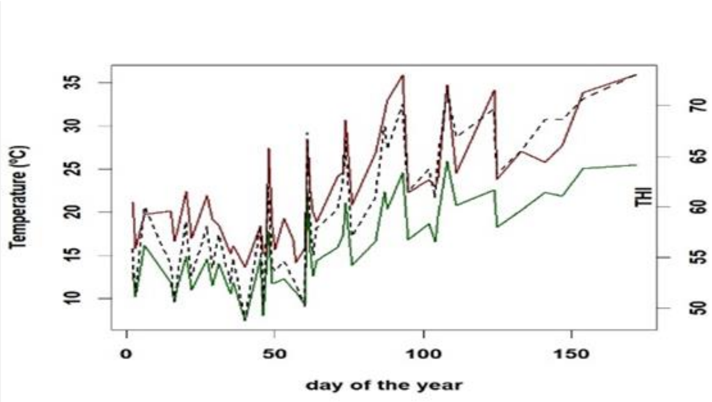

Figure 1. Average of daily maximum and average temperatures and THI along the days of the year when weights were recorded

2.2. Statistical Analyses

Three models were used to analyse the data in order to characterise the response in weight to increasing HL. The statistical model in its general form was:

$$y_{ijklmno} = YM_l + AD_m + WD_n + ST_o + \sum_{r=1}^{2} \beta_{ro}\phi_r(t_{ij}) + f(HL_k) + a_i + e_{ijklmno}$$

, where $y_{ijklmno}$ is the j^th^ record from i^th^ animal at age t_{ij} under a HL k, YM_l is the year×month effect (l =1,…13), AD_m is the age of dam at kidding effect (m=1,…13), WD_n is the weight of dam at kidding effect (n=1,…3), ST_o is the sex×type of birth effect (o=1,…6), β_{ro} are the fixed regression coefficients nested to the sex×type of birth to fit the fixed mean growth of population for each sex-type of birth combination, ϕ_r (t_{ij}) is the mth Legendre polynomial term evaluated at the standarised age, $f(HL_k)$ was our target effect, the function to characterize the effect of increasing heat load on weight, a_i is the random

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animal effect ($Var(a)=I\sigma_a^2$) and $e_{ijklmno}$ is the residual term ($Var(e)= I\sigma_e^2$). Heat load was modelled either as a class effect (c) or through quadratic (quad) or cubic (cub) Legendre polynomials. In addition to meteorological data on the day of weighing (Tavg0, Tmax0, THI0), the average of temperatures and THI in the 7 days before the day of weighing (Tavg7, Tmax7, THI7) were also used as measures for the heat load on animals to account for lag effects. Overall, 18 models were analysed with the combination of HL function and HL variables.
Models were solved using the remlf90 package of the blupf90 family of programmes (Misztal et al., 2002). The software provides estimates for the effects of the model as well as for the variances together with statistics useful for model comparison such as -2log likelihood (2logL) and the Akaike information criterion (AIC).
Change point techniques were used to identify changes of slope in the trajectory fitted through the regression functions to establish comfort thresholds and subsequent rate of decay in weight in the heat stress region. The segmented package of R (Muggeo, 2008) was used for this purpose.

3. Results and discussion

Values of the AIC for all the combinations of HL variable, time of measure of HL and type of function used to estimate the HL effect on weights are shown in Table 1.

Table 1. Akaike's information criterion for models that differed in the heat load variable, on the day when the heat load is taken and on the type of function used to describe the heat load (HL) effect.

HL function[1]	Tavg0[2]	Tavg7[2]	Tmax0[2]	Tmax7[2]	THI0[2]	THI7[2]
Class	10353	10212	10554	10359	10047	10196
Quad pol.	10760	10632	10844	10712	10734	10582
Cub pol.	10749	10635	10838	10716	10681	10585

[1] HL effect was modelled as a class effect or through quadratic (quad) or cubic (cub) Legendre polynomials ; [2]Tavg/Tmax=daily average/maximum temperature, THI=average daily temperature and humidity index ; 0 refers to the day of weighing and 7 to average of the seven days previous to the weight recording

Models considering the HL as a class effect showed better goodness of fit than polynomials, but showed a quite unsmooth behaviour (see Figure 2), not expected in biological processes. For the continuous polynomial functions, cubic polynomials showed a better goodness of fit than quadratic polynomials for HL taken on the day of recording. As for HL measure, Tmax showed worse results than Tavg or THI. Models based on average values in the previous 7 days tended to be superior to the models using the HL on the day of weighing within the same type of model and type of variable.
Figure 2 shows results of fitting alternatives models on a given meteorological value for the models with best goodness of fit. Raw means of weights by degree of thermal load are highly influenced by the confounding between age and heat load due to the concentration of kiddings during the winter period. Solutions for the HL effect as a classification factor showed a non smooth behaviour but a clear trend to show a decrease in expected weight for the highest HL. The two polynomial fits were quite similar and also showed the decrease in weight under heat stress.

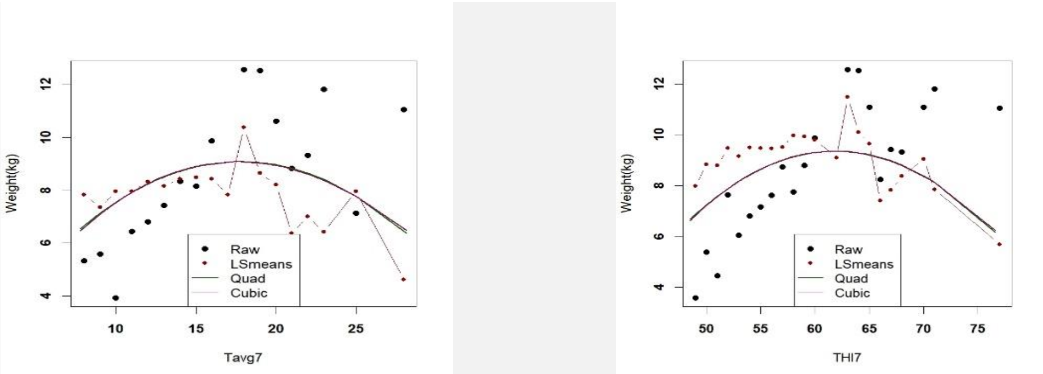

Figure 2. Raw means of weights, solutions of the class effect of heat load, quadratic and cubic Legendre polynomials fitted to weights and mean of daily average temperatures (Tavg7) or temperature and humidity index (THI7) in the 7 days previous to recording the weights

Estimated thresholds and slopes obtained from the changepoint analyses applied to the polynomial fits are shown in Table 3.

Table 3. Estimated thresholds and rate of change in expected weight with heat load increase.

	Tavg0[1]	Tmax0[1]	THI0[1]	Tavg7[1]	Tmax7[1]	THI7[1]
Threshold	21.4	24.9	68.4	20.2	27.7	65.6
Slope (kg/º)	-0.232	-0.034	-0.312	-0.300	-0.289	-0.269

Heat tolerance thresholds were estimated at 21/20, 25/28, 68/66 for Tavg0/Tavg7, Tmax0/Tmax7, THI0/THI7, respectively, from the cubic polynomial fit. Slopes of decay in expected weight after the threshold were around 300 g/degree of Tavg or THI above the threshold. These results indicate that for higher typical summer temperatures in the region, which could be well over 5 degrees above the threshold, the expected loss of weight of a kid might be 1.5 kg, which is well over a 10% of the weights at the end of the studied period

Conclusion

Heat stress affects negatively the potential growth of kids in this local breed of goats. Tavg and THI seemed to provide a better way of measuring heat load compared with Tmax. Average of heat loads in the period previous to recording of weights are preferred over using the HL on the day of recording.

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