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Abstract. A total of 49,918 and 1,176,670 test-day records belonging to 8,231 lactating goats and 177,605 lactating ewes, respectively, were used to study the response of Spanish dairy goats (Florida breed) and sheep (Manchega breed) to heat stress. The productive traits which were controlled include daily milk, fat and protein yields. The tolerance threshold and the slope of the response of these traits to thermal stress have been calculated. Test day records from each herd were merged with maximum and average daily temperature and a temperature-humidity index (THI) registered in weather stations the day of milk recording. Two sets of data were analysed: data from high milk yielding animals and data from low milk yielding animals. Two thresholds were found, one for low temperatures and the other for high temperatures. Climatic effects on yields were less marked in ewes compared to goats. Small differences were found between high and low productive animals in respect to thresholds and slopes, except for the reduction of fat and protein yields due to heat stress.

Keywords. Manchega sheep – Florida goats – Milk – Protein – Fat – Yields – Heat stress.

Effets de la température et de l'humidité sur les performances des brebis et des chèvres à hautes et à faibles rendements laitières

Résumé. *Un total de 49.918 et 1.176.670 test-jour des enregistrements réalisés sur, respectivement, 8.231 chèvres et 177.605 brebis en lactation ont été utilisées pour étudier le stress thermique dans des chèvres espagnoles de race Florida et des brebis espagnoles de race Manchega. Les paramètres étudiés sont la production journalière de lait, de matière grasse et de matière protéique. Le seuil de tolérance et de pente de la réponse de ces paramètres au stress thermique ont été calculés. Les enregistrements quotidiens de chaque troupeau ont été combinés avec la température quotidienne maximale et moyenne et un index de température-humidité (THI), enregistrés dans les stations météorologiques le jour même du contrôle laitier. Deux ensembles de données ont été analysés: données parvenant des animaux à haute production laitière et données issus des animaux à faible production laitière. Deux seuils ont été trouvés, un pour les basses températures et l'autre pour des températures élevées. Les effets du climat sur les rendements étaient moins marqués dans le cas des brebis. Pas de différences importantes ont été trouvées entre les animaux les plus et les moins productifs en ce qui concerne les seuils et les pentes, à l'exception de la décroissance des rendements de la matière grasse et de la matière protéique induite par le stress thermique.*

Mots-clés. *Brebis Manchega – Chèvre Florida – Lait – Matière protéique – Matière grasse – Productions – Stress thermique.*

I – Introduction

Sheep and goats are thought to cope with extreme climatic conditions, especially high temperatures (Sevi and Caroprese, 2012). However, Finocchiaro *et al*. (2005) observed an effect of high temperature-humidity index (THI) values in dairy sheep in Italy. Menendez-Buxadera *et al*. (2012) stated an effect of heat stress on milk production and fat and protein contents in sheep (Merina de Grazalema) and goat (Murciano-granadina and Payoya) native Spanish breeds. Moreover, Carabaño *et al.* (2013) used THI, maximum and average temperature to study the effects of climatic conditions on dairy traits in Manchega sheep and Florida goats and they reported that average and maximum temperature were the climatic variables better explaining these effects. One of the approaches to study the response of animals to heat stress is based on the analysis of the relationship between bioclimatic indexes (like THI) and the production and reproduction traits registered in milk recording schemes. The first model, proposed by Misztal (1999) and applied to dairy cattle, was a random regression model of test day milk yield on THI, assuming a thermo-neutral range of THI values and a zone of lineal decrease of yields from a given threshold. This and other similar models have been posteriorly applied to the study of heat stress on sheep and goats (Finochiaro *et al.*, 2005; Menendez-Buxadera *et al.*, 2012 and 2014). The aims of this work are to define climatic thresholds and slopes of milk, fat and protein yields for Manchega breed of sheep and Florida breed of goats and to test the hypothesis of the inverse relationship between yield levels and heat effects.

II – Materials and methods

Test day milk records collected by the official milk recording schemes of Manchega sheep and Florida goats, registered from 2000 to 2010 and from 2006 to 2012, respectively, and breeding values (BV) were provided by de corresponding breeders associations (AGRAMA and ACRIFLOR). Climatic data, registered at weather stations close (<20 km) to the farms, were provided by the Spanish Meteorological Agency. An index combining maximum temperature and average relative humidity $[THI = T - (0.55 x \frac{1 - HR}{100} x (T - 14.4)]$ was calculated following Finocchiaro *et al*. (2005). Data from each breed were organised in two sets containing: (1) data from high yielding animals (above the average BV plus one standard deviation) and (2) data from low yielding animals (below the average BV minus one standard deviation). Number of records and summary statistics are given in Table 1.

Data analyses were performed in two steps:

1) The following mixed models were used with SAS software (SAS 9.2 Inst. Inc., Cary NC, USA) to test the significance of fixed factors considered to affect milk traits:

$$y_{ijklmno} = HY_i + PADIM_j + NL_k + MT_i + CLI_m + animal_n + e_{ijklmno} \quad \text{(for Manchega data)}$$

$$y_{ijklmn} = HYS_i + PADIM_j + MF_k + CLI_m + animal_m + e_{ijklmn} \quad \text{(for Florida data)}$$

Where, *y* is the value of the milk trait being analysed (daily milk, protein or fat yield), *HY* is the herd and year of parturition, *HYS* is the combination of herd, year and season of parturition, *PADIM* is the combination of number of parturition, age of the animal and days in milk, *NL* is the number of lambs born (1-3), MT is the milking shift (morning or evening), *MF* is the number of daily milking (1-2), *CLI* is the climatic variable (average and maximal temperatures and THI categorised and considered as fixed factor), *animal* and *e* are the random effects of the ewe or the goat and *e* the residual term.

2) Least square means for the climatic factor (CLI) were obtained with former models and then used to calculate the thresholds and slopes of the regressions between the traits and the climatic variables using a break point regression method which is implemented in the R package "segmented" (Vito and Muggeo, 2008).

Table 1. Number of records and descriptive statistics of milk traits for all, high† yielding and low† yielding Manchega ewes and Florida goats used in the analyses

	Manchega ewes			Florida goats††		
	All ewes	High yielding	Low yielding	All goats	High yielding	Low yielding
Test day records	1,176,670	247,362	102,265	49,918	6,757	7,427
Animals	177,605	36,536	16,507	8,231	1,150	1,159
Herds	175	162	160	20	20	20
Weather stations	60	58	57	15	15	15
Milk (g/day)	1,103 ± 538	1,349.7 ± 572.3	868.4 ± 454.4	2,350 ± 1,088	3,102 ± 1,238	1,703 ± 874
Protein (g/day)	62.84 ± 28.60	75.34 ± 29.53	50.76 ± 25.19	72.28 ± 37.79	92.73 ± 44.74	53.43 ± 30.08
Fat (g/day)	76.07 ± 36.13	92.06 ± 37.85	59.83 ± 30.40	106.49 ± 56.25	132.45 ± 64.92	80.11 ± 46.64

† High (and low) yielding animals are those with estimated breeding values one standard deviation over (and below) the average.

†† Only data from the first three lactations have been considered.

III – Results and discussion

Threshold values and slopes obtained for each trait, climatic variable and production level by breed are given in Table 2. Goats showed wider comfort regions than sheep. Comfort thresholds for daily average temperature were around 8/11ºC and 22/20ºC in goats/sheep for cold and heat, respectively. Production loss beyond the comfort region varied across traits and thermal region. For all traits and both breeds, significant production losses were observed. However, for the hot temperatures, significant losses were only observed for fat and protein yields. High yielding animals showed more losses associated to thermal load than low yielding animals, particularly in the case of goats.

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Table 2. Estimates (mean ± standard error) of thresholds and slopes[†] for each production trait and climate variable[††]. Slopes of decay are expressed per unit of increase of climatic variable (ºC for T, Tmax and unit for THI)

		Manchega sheep				Florida goat			
		High-yielding[†††]		Low-Yielding[†††]		High-yielding[†††]		Low-Yielding[†††]	
Trait	**Parameter**	**T (°C)**	**THI**	**T (°C)**	**THI**	**T (°C)**	**THI**	**T (°C)**	**THI**
Milk	Thrcold	10.7 ± 0.2	11.6 ± 0.2	11.5 ± 0.2	9.9 ± 0.9	8.4 ± 0.2	10.5 ± 0.2	7.9 ± 0.3	8.3 ± 0.1
(g/day/ºC)	Thrhot	20.5 ± 0.2	19.5 ± 0.3	18.6 ± 0.3	17.6 ± 0.8	22.4 ± 0.3	20.5 ± 0.3	21.6 ± 1.6	23.9 ± 0.6
	b(Thrcold)	9.55 ± 0.62	12.79 ± 0.65	7.76 ± 0.72	9.95 ± 1.17	74.42 ± 21.52	59.74 ± 21.13	85.61 ± 16.79	93.76 ± 26.54
	b(Thrhot)	0.32 ± 0.78	2.78 ± 0.47	-0.42 ± 0.84	-0.51 ± 1.35	9.95 ± 6.86	-19.94 ± 11.44	2.15 ± 2.16	-1.37 ± 2.50
Fat	Thrcold	11.7 ± 0.2	11.5 ± 0.6	11.4 ± 0.2	10.2 ± 1.0	8.7 ± 0.1	9.5 ± 0.2	6.7 ± 0.2	8.3 ± 0.2
(g/day/ºC)	Thrhot	20.4 ± 0.2	18.3 ± 0.6	17.5 ± 0.2	17.7 ± 0.9	20.1 ± 1.2	20.4 ± 0.3	24.6 ± 0.5	21.0 ± 1.7
	b(Thrcold)	0.36 ± 0.04	0.38 ± 0.05	0.26 ± 0.05	0.39 ± 0.09	2.78 ± 1.08	1.76 ± 0.89	2.23 ± 0.62	3.44 ± 1.54
	b(Thrhot)	-0.30 ± 0.05	-0.53 ± 0.07	-0.14 ± 0.05	-0.29 ± 0.09	-0.69 ± 0.24	-2.76 ± 0.48	-1.18 ± 0.44	-1.14 ± 0.57
Protein	Thrcold	10.7 ± 0.4	12.1 ± 0.3	10.4 ± 0.3	9.4 ± 0.2	8.8 ± 0.1	10.7 ± 0.2	6.5 ± 0.1	11.5 ± 1.0
(g/day/ºC)	Thrhot	18.7 ± 0.2	18.7 ± 0.5	17.67 ± 0.3	17.41 ± 0.2	20.7 ± 0.8	20.5 ± 0.2	23.7 ± 0.6	23.6 ± 0.4
	b(Thrcold)	0.36 ± 0.03	0.53 ± 0.03	0.34 ± 0.05	0.35 ± 0.08	2.92 ± 0.64	1.40 ± 0.62	4.40 ± 1.75	2.39 ± 0.42
	b(Thrhot)	-0.33 ± 0.03	-0.42 ± 0.06	-0.09 ± 0.04	-0.17 ± 0.07	-0.35 ± 0.16	-1.11 ± 0.35	-0.52 ± 0.23	-0.62 ± 0.37

[†] Thrcold: cold threshold; Thrhot: hot threshold; b(Thrcold): slope below the cold threshold; b(Thrhot): slope above the hot threshold.

[††] T (daily average temperature); Tmax (daily maximum temperature); THI (daily temperature-humidity index).

[†††] Ewes/Goats with an EBV for 120 (for ewes)/240(for goats) days milk yield above/below mean ± standard deviation.