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Genetic variation for tolerance to heat stress in dairy small ruminants: Results obtained in Spain

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Abstract. Research has been carried out to study the genetic response to heat stress of Payoya and Murciano-Granadina goats and Merino de Grazalema sheep. Test day records of milk, fat and protein yield and pedigree records and values of an index (THI) combining average temperature and relative humidity, registered on test day in weather stations located at less than 20 km of the farms, were analysed with norm of reaction models. Heritability of dairy traits at and genetic correlations between different points of the trajectory of THI values were estimated, showing a heterogeneity of the genetic (co)variance components through this trajectory. Breeding values were also estimated (EBV) for all animals for different THI values. Two types of animals were identified: Those showing a large variation of their EBV through the THI trajectory (sensitive) and those showing an almost constant EBV (tolerant). This allows for the selection of animals showing a higher tolerance to heat stress with practically no further expense added to the present cost of the breeding programs.

Keywords. Goats – Sheep – Dairy traits – Heat stress – Genetic response.

Variation génétique pour la tolérance au stress thermique dans les petits ruminants laitières. Résultats obtenus en Espagne

Résumé. *La réponse génétique au stress thermique chez les chèvres de la race Murciano-Granadina et de la race Payoya et des brebis laitières de la race Merino Grazalema a été étudié. Le rendement laitier, en matière grasse et en protéines, le pedigree des animaux, enregistrés dans les régimes nationaux de contrôle laitier, ainsi que les valeurs de l'indice de température et l'humidité relative (THI) enregistré le jour de contrôle laitier dans les stations météorologiques situées à moins de 20 km des fermes, ont été analysés avec les modèles de norm de reaction. L'héritabilité des caractères laitiers et ainsi que les corrélations génétiques entre et à différents points de la trajectoire des valeurs THI, ont montré une hétérogénéité des composantes de la (co)variance génétique pour cette trajectoire. Les valeurs génétiques (EBV) ont été également estimées pour tous les animaux à différentes valeurs du THI. De cette étude, deux groupes d'animaux sont identifiés : un premier groupe avec une grande variation des valeurs EBV le long de la trajectoire THI (animaux sensibles) et un deuxième groupe d'animaux avec les valeurs EBV constantes (animaux tolérants). Ça permet de sélectionner les animaux tolérant au stress thermique sans pratiquement aucun coût supplémentaire aux programmes de sélection.*

Mots-clés. *Chèvres – Brebis – Characters laitières – Stress thermique – Response génétique.*

I – Introduction

Drastic climatic changes have been predicted for the Southern regions of Spain (Andalusia an Murcia) within the next 30 years, including up to 6°C rising of maximum temperatures and up to 8°C of minimum temperatures in the inland mountainous areas (de Castro *et al*., 2005). It is precisely in these areas where the largest part of the goats and an important part of sheep are raised, often under extensive or semi-extensive type of managing linked to the very fragile *dehesa* system. In order to cope with these climatic changes, animals more robust to extreme conditions will be needed. Menéndez Buxadera *et al*. (2012) found an important genetic variation for the response to heat stress in two breeds of goats in the south of Spain. Finocchiaro *et al.* (2005) observed similar variation in dairy sheep in Valle de Belice in Palermo, Italy.

The aim of this work is to present and compare the main results on the genetic (co)variance components of tolerance to heat stress, obtained with reaction norm models, in three studies carried out on two local breeds of dairy goats and one local breed of dairy sheep in Andalusia, one of the hottest regions of Spain.

II – Material and methods

1. Dairy performance and climatic data

Dairy performance data and pedigree records were registered in the official dairy recording schemes of Murciano-Granadina (MG) and Payoya (PY) goats and Merino de Grazalema (MDG) sheep. They were handed over by the respective breeders associations. They were edited to assure that each herd would be represented at least with 25 monthly test day records (TD) and each animal with at least 3 TD in the data base and that all values would be within the range of 3.3 standard deviations around the mean. Herds were connected through artificial insemination bucks, in the case of goats and through the exchange of rams and, sometimes, of ewes in the case of sheep. Climatic data were registered in weather stations located at less than 20 km from the farms. A THI index, combining maximum temperature (°C) and average relative humidity (%), according to the formula used by Finocchiaro *et al.* (2005) THI = [T-(0.55 × (1-RH)) × (T-14.4)], was used.

Table 1 shows the main descriptive figures of the data of each breed used for the statistical analyses.

Table 1. Data of each of the breeds used for the heat stress studies

	Murciano-Granadina	Payoya	Merino de Grazalema
Years	200-2006	2002-2007	2004-2012
No. of records	63640	81625	17602
No. of animals in pedigree	6037	9917	2744
No. of herds	20	18	27
Average daily milk yield (kg)	2.06 ± 0.93	1.89 ± 0.83	0.671 ± 0.28

2. Statistical methods and models

Daily milk yield (DMY) and daily fat plus protein yield (DFPY) were independently analysed using Asreml 3 (Gilmour *et al*., 2009) with a norm of reaction model (NRM) to estimate the genetic (co)variance components. This model assumes that the additive genetic components of the traits are given by a general effect (intercept) and a specific effect (slope), both correlated with the response to THI values. The phenotypic value of each trait in each animal is thus given by:

$$Y_{ijklmn:thi} = FTD_i + FE_j + f(\Phi thi{:}q)_k + r(a;\ \Phi thi{:}q)_l + r(p)_m + e_{ijklmn}$$

Being, $Y_{ijklmn:thi}$ the observation of the dependent variable in the n^{th} point of the THI scale; FTD_i the fixed effect of the combination herd-test day (240, 474 and 192 levels for MG, PY and MDG, respectively); FE_j are the following fixed effects: litter size (4 levels for each goat breed and 3 levels for the sheep breed), interaction between week of lactation (45 levels for MG and 40 levels for PY) and lactation number (4 levels in both breeds) and age of the ewes at kidding (from 1 to 11 or more years); $f(\Phi thi:q)_k$ is a fixed function of the covariable of THI values modelled with a second order (q = 2) Legendre polynomial coefficient (Φ); $r(a; \Phi thi:q)_l$ is a vector representing the additive genetic function of the l^{th} animal with data and their parents without data, being Φthi:q the THI covariable modelled with a first order (q = 1) Legendre polynomial; r(p)m is a random function of permanent environmental effects of the m^{th} animal with data; e_{ijklmn} is the residual random term with homogeneous variance. The expected components of variance are:

$$V(y) = \Phi \begin{bmatrix} A\sigma^2_{a_o} & A\sigma_{a_{so}} \\ A\sigma_{a_{os}} & A\sigma^2_{a_s} \end{bmatrix} \Phi' + I_p \sigma^2_p + e$$

The (co)variance matrix contains elements related to a function of the intercept ($\sigma^2_{a_o}$), the slope ($\sigma^2_{a_s}$) and their covariance $\sigma^2_{a_{so}}$. *A* is the relationship matrix between all animals and the term I_p is the identity matrix for the permanent environmental effects and their σ^2_p variance. With this model it is possible to estimate the heritability (h^2), the genetic correlations (r_g) and the environmental permanent correlations (r_{pe}) for each trait at all points of the trajectory of the environmental scale using the elements of for the corresponding level of THI, following the procedure of Jamrozik and Schaeffer (1997). Estimates of breeding values for any animal can be obtained at any point of the trajectory of THI from $EBV^i_{thi} = \sum_{p=0}^{1} \Phi_{thi} \quad a_i'$,

where vector a_i contains the solutions for the additive genetic random regression coefficients corresponding to each animal and vector Φ_{thi} contains the first-order Legendre polynomial coefficients evaluated at THI.

III – Results and discussion

1. Phenotypic response

Figure 1 shows the phenotypic response of DMY (in kg in left Y-axis) and DFPY (in g in right Y-axis) to THI values for MG and PY goats (A) and for MDG ewes (B).

Fig. 1. Graph of daily milk yield DMY (kg) and daily fat plus protein yield DFPY (g) as a function of THI values for Murciano-Granadina and Payoya goats (A) and for Merino de Grazalema ewes (B).

As opposed to what has been reported for dairy cattle (Bohmanova *et al.*, 2007), in this case there is a climatic effect before reaching the threshold value from which yields start decreasing. What we see in former figures is a first increase of production from the lowest to middle THI values (which can be considered a zone of comfort) and a decrease of production from middle to high THI values (which can be considered a stress zone). Therefore, models like that proposed by Misztal (1999), frequently used in the studies of heat stress in dairy cattle, which assume that there is not effect below a threshold THI value, are not valid for the breeds under study. The different pattern of response shown by the two breeds of goats, smoother in the case of MG, could be explained on the bases of their different production systems. Payoya goats are raised under an extensive system, as opposed to the intensive system prevailing in the case of MG and, therefore, they are more exposed to the fluctuations of weather conditions. It is also worth to notice that the ranges of THI values are different for both species because the different distribution of parturitions.

2. Genetic response

Heritabilities estimated with the NRM for the comfort and stress zones and the genetic correlations among the responses of both zones are given in Table 2. The heritability of both traits is slightly larger in the comfort zone for all breeds, except PY goats. Genetic correlations between the production responses in both zones are very similar for all breeds, with the exception of DMY in MDG ewes. These correlations are high but different from one. Actually, the traits studied can not be treated as the same trait over the whole THI trajectory. The same is true for the EBV, as can be seen in Fig. 2, which show the EBV of the best 200 animals for DFPY (selected for their EBV at the comfort zone) estimated at each point of the THI trajectory. Three types of responses are clearly shown: (i) “Tolerant” animals with better EBV at high THI values, (ii) “Robust” animals with EBV independent of the THI values, and (iii) “Sensitive” animals with better EBV at low THI values. For MDG sheep, however, only robust and sensitive animals were found.

Table 2. Range of heritability (h^2) values of daily milk yield (DMY) and daily fat plus protein yield (DFPY) in the comfort and stress thermic zones and genetic correlation (r_g) between the production responses in both zones for the three breeds under study

	h^2 comfort	r_g (between zones)	h^2 stress
Murciano-Granadina goats			
DMY	0.27 – 0.30	0.69 – 0.85	0.22 – 0.28
DFPY	0.21 – 0.23	0.71 – 0.85	0.20 – 0.22
Payoya goats			
DMY	0.21 – 0.22	0.71 – 0.90	0.22 – 0.24
DFPY	0.19 – 0.20	0.72 – 0.91	0.20 – 0.21
Merino de Grazalema sheep			
DMY	0.24 – 0.38	0.85 – 0.95	0.11 – 0.23
DFPY	0.17 – 0.22	0.56 – 0.90	0.13 – 0.15

IV – Conclusions

Three types of responses to THI were observed: sensitive, with estimated breeding values (EBV) decreasing as THI increase; robust, with EBV independent of THI, and tolerant, with EBV increasing as THI increase. This genetic variability for the response to climatic conditions can be used to select the most adequate animals (tolerant or robust) to cope with future climate changes.

Fig. 2. **Estimated breeding values (EBV) of the best 200 (selected for their BV at the comfort zone) Murciano-Granadina goats (A) Merino de Grazalema sheep (B) estimated at each point of the THI trajectory.**

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