Small Ruminant Research 121 (2014) 207–214

Contents lists available at ScienceDirect

Small Ruminant Research

journal homepage: www.elsevier.com/locate/smallrumres

Genetic variability for heat stress sensitivity in Merino de Grazalema sheep

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ARTICLE INFO

Article history:
Received 21 July 2013
Received in revised form 5 June 2014
Accepted 21 June 2014
Available online 2 July 2014

Keywords:
Double purpose sheep
Heat stress
Reaction norm models
Genetic parameters
Cheese

ABSTRACT

Different fixed linear models and reaction norm genetic models were used to estimate heat stress effects, which were measured by a combined index of average temperature and relative humidity known as THI, registered on the same test day (TD). A total of 17,602 TD with the results of daily milk yield (MY), daily fat plus protein yield (FP) and daily dry matter yield (DM) were available. These data are from 2622 Merino Grazalema sheep: daughters of 77 bucks and 870 ewes kidding between 2006 and 2011 in a total of 27 dairy units in Andalusia, Spain. During the period of the study, the productive characteristic increased slightly, whereas the climatic variables and the THI index increased substantially. The analyses shows the presence of a comfort zone (THI < 47) where the heat stress had no effect, but at THI ≥ 48 a depressive heat stress thermal zone started to take effect and MY decreased at a rate of −17 g of milk/day for each THI point, which consequently affected the FP and DM daily yield. In genetic terms, it was found that the (co)variance components were heterogeneous throughout the trajectory of the THI scales. Hence, the best animals selected in the comfort zone are not the best in a stress zone. The estimates of heritability (h^2) within the comfort zone were h^2 = 0.161 for MY, h^2 = 0.151 for FP and h^2 = 0.157 for DM, but at THI ≥ 48 decreased to h^2 = 0.081; h^2 = 0.094 and h^2 = 0.105 for the same dependent variables. The principal components analysis of the genetic correlations matrices shows that the first eigenvalue accounts for between 71% and 82% of the total genetic variance, whereas the second eigenvalue accounts for around 17%, which indicates the presence of possible changes in the form of response throughout the THI scale. The use of a reaction norm model is highly recommended in the breeding program of this sheep breed, since it shows an important genetic variability in the sensitivity of the animals to heat stress and to identify robust animals with respect to the changes along the trajectory of THI.

1. Introduction

The Merino de Grazalema is a double purpose (meat–milk) Spanish breed of sheep, originating from old crossings of Merina and Churra breeds. This breed is reared under extensive or semi-extensive grazing low input systems due to its good adaptation to a special microclimate of certain mountainous areas in South West Andalusia in Spain: natural parks with high ecological value, such as Sierra de Grazalema and Serranía de El Bosque, with an average rainfall of 1500 mm from autumn to spring and dry and hot summers (Molina et al., 2005). It also plays an important role in the sustainable rural development of this area, contributing to the conservation zones

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http://dx.doi.org/10.1016/j.smallrumres.2014.06.007
0921-4488/

of high ecological value: Grazalema Natural Park, Park of the Cork Oak Groves and Park of Mountainous Area of Ronda.

Traditionally, the breed was mainly reared for meat production, but it is no longer competitive as a meat breed (Molina et al., 2005) and as a consequence is in danger of extinction (DAD-IS, 2013). Due to its origin, and having been selected for its dairy traits only during the last decade, it has lower milk yields than other Spanish dairy ewes (Ugarte et al., 2001). However, its milk has high dry matter content (Molina et al., 2005) and very good technological properties (Castro et al., 2009), with a high yield of good quality cheese, which has won international recognition (five awards at "2012 World Cheese Awards" in Birmingham, United Kingdom; http://worldcheeseawards.com/).

The milk recording scheme and the breeding program of the breed are managed by the Merino de Grazalema Breeders Society (GBS). The breeding goal is to increase cheese yield, therefore the main selection criterion is based on the breeding values for milk yield and milk contents of fat and protein. Milk yields and fat and protein contents are registered monthly in the official milk recording scheme of the breed. No estimates of the genetic parameters for these traits in this breed have been previously published. Estimates of the genetic parameters for another two Spanish dairy sheep breeds (Latxa and Manchega), were reported by Serrano et al. (2001), which are within the range of those presented in the review by Carta et al. (2009).

There is evidence that climate change is affecting Andalusia in greater measures than most European regions (IPCC, 1997; Martinez Linares, 2009). Increases of up to 3 °C for maximum temperatures are predicted in the inland regions of Andalusia, and even higher in the mountainous areas where the Merino de Grazalema has its habitat. This temperature increase can negatively affect the physiology and performances of this breed in a similar manner to that which has been reported to affect other dairy animals (West, 2003). The economic consequence of heat stress has already been identified for Murciano-Granadina and Payoya goats in Spain (Menéndez-Buxadera et al., 2012) and similar effects were also reported for milk yield in Valle del Belice dairy sheep in Palermo, Italy (Finocchiaro et al., 2005). Moreover, both groups of authors found important genetic variation in response to heat stress.

A combination of test day records of milk yield and milk components contents with climate daily records from weather stations near the farms were used to analyze the variability of these traits across a scale of values of an index combining temperature and humidity (THI). This made it possible to quantify the reaction norm or plasticity of each trait – an old biological concept recently reviewed by de Jong and Bijma (2002). Random regression models were used for these analyses in dairy cattle (Bohmanova et al., 2005, 2008; Aguilar et al., 2009; Brugemann et al., 2011; Bernabucci et al., 2014; Hammami et al., 2013), dairy sheep (Finocchiaro et al., 2005) and dairy goats (Menéndez-Buxadera et al., 2012). The application of the random regression models to solve different types of problems in animal breeding was reviewed by Schaeffer (2004).

The objective of this work was to quantify the effect of temperature and humidity (combined in an index called THI) on milk yield and composition and to estimate the genetic parameters of the response of the animals of Merino de Grazalema breed to heat stress. Reaction norm models (RNM) were used that are similar to the random regression model originally applied to dairy cattle by Schaeffer and Dekkers (1994). This genetic variation can be used in breeding programs to select animals that are robust for climatic changes.

Table 1
Least squares means, standard deviation (within parenthesis) and coefficient of variation (CV%) of the traits and climatic variables studied.

	Means	CV%
Milk (kg/day)	0.683 (0.311)	45.5
Fat (kg/day)	0.052 (0.021)	40.4
Protein (kg/day)	0.042 (0.016)	38.1
Dry matter (kg/day)	0.133 (0.053)	39.8
Fat (%)	8.07 (1.79)	22.2
Protein (%)	6.27 (0.70)	11.2
Dry matter (%)	19.85 (2.11)	10.6
Relative humidity (%)	64.42 (13.43)	21.0
Temperature (°C)	11.15 (3.90)	34.9
THI	48.55 (10.07)	22.2

2. Materials and methods

Data were recorded between 2006 and 2011, and consisted of 25,968 monthly individual test day records (TD) of daily milk, fat plus protein (FP) and dry matter (DM) yields. Data outside the range of ±3.3 standard deviations around the mean, and TD recorded under 10 and over 240 days post kidding and those belonging to flocks with below 20 TD were excluded. After this editing process, the remaining data was comprised of: 17,602 TD records from 2622 animals, daughters of 77 bucks (of which 17 were used to connect the 27 existing flocks) and 870 ewes (of which 340 had production records). The combinations of herd-test day were grouped in 192 contemporaneous groups (CG) with at least 20 records each (85% of which had over 30 observations).

The climatic variables were the average daily temperature (T in °C) and relative humidity (RH in %) as recorded by the Spanish Meteorological Agency, on the same day as the milking record, at weather stations located less than 15 km away from the farm (http://datosclima.es/estaciones.php). Temperature and humidity were combined in an index, THI, with the equation described in NRC (1971) and used by Bohmanova et al. (2008):

$$\mathrm{THI} = [(1.8 \times T + 32) - (0.55 - (.0055 \times \mathrm{HR}) \times (1.8 \times T - 26))]$$

The evolution through the years under study of the climate variables and the THI is shown in Supplementary Fig. 1.

Supplementary Fig. 1 related to this article can be found, in the online version, at http://dx.doi.org/10.1016/j.smallrumres.2014.06.007.

Two models were used to study this data. The first model was a general linear fixed model that includes the following fixed factors: flock ($n = 27$), year ($n = 6$) and month of kidding ($n = 12$), combined as $\boldsymbol{FYM_i}$ with 142 levels; age of the ewe at lambing in years ($\boldsymbol{EK_j}$) with 11 levels; litter size ($\boldsymbol{LS_k}$) with 3 levels, the $\boldsymbol{THI_l}$ values classified in 40 levels, and days of lactation modeled as linear, quadratic and cubic fixed co-variables. The results of this fixed model were used to show the pattern of response of each trait through the different levels of THI (Fig. 1) and to estimate the LS mean of all traits and climatic variables for all years (Table 1). The second model, used for the genetic analysis, is a Reaction Norm Model (RNM), solved with ASReml 3 software (Gilmour et al., 2009):

$$\mathbf{y_{ijklmno}} = \mathbf{fixed_i} + \mathbf{EK_j} + \mathbf{LS_k} + \sum_{\mathbf{r=0}}^{2} \Phi_{\mathbf{r}} \mathbf{b_{lr}} + \sum_{\mathbf{r=0}}^{1} \Phi_{\mathbf{r}} \mathbf{a_{mr}} + \mathbf{P_n} + \mathbf{e_{ijklmno}}$$

where $\boldsymbol{y}$ is a set of TD records of dependent variables (milk, FP and DM); the flock-date of recording (very similar to $\boldsymbol{FYM_i}$) and days in milk are included in $\boldsymbol{fixed_i}$, with 192 levels; $\boldsymbol{EK_j}$ and $\boldsymbol{LS_k}$ are as in the previously described general fixed linear model. A fixed co-variable ($\mathbf{b_l}$) modeled