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Small Ruminant Research 74 (2008) 107–112

Small Ruminant Research

www.elsevier.com/locate/smallrumres

Genetic parameters for fleece quality assessed by an ancient Tzotzil indigenous evaluation system in Mexico

Hilda Castro-Gámez [a], Raúl Perezgrovas [b], Gabriel Campos-Montes [a], Reyes López-Ordaz [a], Héctor Castillo-Juárez [c,*]

[a] *Departamento de Genética y Bioestadística, Facultad de Medicina Veterinaria y Zootecnia, Universidad Nacional Autónoma de México, Circuito Exterior, Ciudad Universitaria, Coyoacán, D.F., C.P. 04510, México*

[b] *Instituto de Estudios Indígenas, Universidad Autónoma de Chiapas, Centro Universitario, Campus III, San Cristóbal de las Casas, Chiapas. C.P. 29264, México*

[c] *Departamento de Producción Agrícola y Animal, Universidad Autónoma Metropolitana, Unidad Xochimilco, Calzada del Hueso 1100, Coyoacán, D.F., C.P. 04960, México*

Received 27 February 2007; received in revised form 27 March 2007; accepted 2 April 2007
Available online 15 May 2007

Abstract

The University of Chiapas established in 1991 a flock of local criollo sheep from the Highlands of Chiapas to serve as an open nucleus for a genetic selection program. Its objective is to provide selected rams and ewes to the indigenous Tzotzil villages. From the perspective of the Tzotzil women, wool quality (TWQ) refers to a mix of diverse fleece characteristics. In this study, 2472 production records from the three varieties of Chiapas wool sheep were utilized, from the 1997–2004 period. Sheep are kept at the Centro Ovino Teopisca in Chiapas, Mexico. Individual TWQ is the mean of four fleece quality grades granted by Tzotzil shepherdesses prior to shearing within groups of contemporary animals in a truncated scale. Genetic parameters for TWQ, greasy fleece weight (FW) and staple length (SL) were estimated by using an animal model. TWQ had a mean (S.D.) of 3.12 (0.67), and h^2 (S.E.) was 0.39 (0.05), while Re (S.E.) had a value of 0.48 (0.02). FW had a mean (S.D.) of 426 g (164), and h^2 (S.E.) was 0.31 (0.05), while Re (S.E.) had a value of 0.51 (0.02). SL had a mean (S.D.) of 10.3 cm (2.45), and h^2 (S.E.) was 0.43 (0.06), while Re (S.E.) had a value of 0.55 (0.02). Genetic correlation (S.E.) between TWQ and FW was 0.63 (0.04), between TWQ and SL was 0.98 (0.01), while between FW and SL was 0.47 (0.04). TWQ showed an important additive genetic component. Hence, its inclusion as selection criterion in a breeding program will prove useful. Repeatability for TWQ had a high value and it can be utilized as a criterion to keep animals within the nucleus flock.

Keywords: Chiapas sheep; Criollo sheep; Wool quality; Genetic parameters; Tzotzil

1. Introduction

Chiapas sheep breed derives from crosses among Churra, Lacha and Manchega breeds that were brought to Mexico by the Spaniard conquers since the beginning of the 16th century. Nowadays this breed can be found in the southeast mountain region of Mexico named Los Altos (Highlands) in the state of Chiapas. Chiapas breed

* Corresponding author. Tel.: +52 55 5617 4126; fax: +52 55 5617 4126.
E-mail address: hcjuarez@correo.xoc.uam.mx (H. Castillo-Juárez).

0921-4488/$ – see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.smallrumres.2007.04.002

is a medium size sheep (27 kg) with a double-coated fleece consisting of an outer coat of long and thick fibers, and an inner coat of short and thin fibers. Three different varieties of this breed have been identified: *Chamula* has black skin and fleece, with white spots in the frontal region of the head and the tip of the tail; *Chiapas* is white with black spots around the eyes, muzzle and ears; and *Café* sheep has creamy-white fleece with three different skin colors: brown, black and gold.

Chiapas sheep are raised mainly by indigenous shepherdesses of the Tzotzil ethnic group. They have very specific production objectives and use an ancient and traditional husbandry system based on empirical practices that have been passed on from generation to generation (Perezgrovas et al., 2002). A large amount of the Tzotzil's annual family income (36%) comes from manufacturing wool products that are worn on a daily basis and in ceremonies. There are thousands of Tzotzil families living in indigenous villages scattered over the mountains of Chiapas. Wool garments and handicrafts are manufactured in an artesian way based on native techniques like the manual spinning of combed wool with a wooden spindle (*malacate*), the weaving of clothes utilizing the ancient back-strap loom, as well as the use of natural pigments to dye the wool (Perezgrovas and Castro, 2000a).

The manufacturing process to make wool garments is a strong cultural issue in these indigenous communities. That is why the Tzotzil criteria to determine wool quality are different from those of Western systems. Understanding these differences implies a challenge in the design and implementation of animal breeding programs for this sheep breed (Perezgrovas and Castro, 2000a). From the Tzotzil perspective, wool quality (TWQ) means the balancing of several fleece traits at a time (Perezgrovas and Castro, 2000b). Through observation and direct interviews with Tzotzil shepherdesses while they were undertaking their animal evaluations, it was possible to determine that TWQ is mainly associated with the length of the staple and the proportion of long fibers within it, followed by the fleece texture and the color uniformity. TWQ is then subjectively determined by these women. In the US evaluation system, fleece grades are based on spinning count, but they are also subjectively determined according to grade standards (Pohle, 1963). In 1992, the University of Chiapas funded an open nucleus flock of these sheep in Los Altos region, Chiapas. Selection objectives are based on fleece quality and wool quantity in order to provide improved sheep to the Tzotzil communities. The participation of Tzotzil shepherdesses and artisans to establish and to define selection objectives has been crucial to obtain the kind of animals desired by these indigenous communities.

Having a quantitative measure for TWQ, allows the quantitative evaluation of its variance genetic components and hence to estimate its heritability and repeatability values to be considered in their breeding and selection programs. Hence, the aim of this study was to estimate the heritability and repeatability for TWQ as well as its genetic correlation with two common wool traits utilized in Western systems: greasy fleece weight at shearing and staple length.

2. Materials and methods

2.1. Data

A total of 2472 production records from 708 sheep of the three different varieties of Chiapas breed, obtained from 1997 to 2004, were used. Animals are located at the Centro Ovino Teopisca, in the Highlands of Chiapas, Mexico, raised under an extensive grazing system based on native grasses (rainy season, June–November) and with food supplement based on milled maize fodder (dry season, December–May).

Mating is controlled by assigning one ram for each group of 25–30 ewes, with a breeding system within color variety and avoiding inbreeding.

Shearing is made every 6 months (during April and October) just after TWQ is empirically evaluated by Tzotzil shepherdesses. Prior to shearing, wool samples are taken from the mid-lateral region to determine the staple length (SL) and the composition of fibers of the fleece. SL was defined as the distance between the tip and base of the staple as it lies relaxed, without the removal of crimp.

To obtain TWQ in every animal and fulfill the normality distribution assumption of this trait required for the analysis performed, the mean of the assessment made by groups of four Tzotzil shepherdesses before shearing was used. These groups worked in the presence of one or two researchers and one translator to assist with language and cultural issues. In their grade level, scale 1 is bad, 2 is regular, 3 is good and 4 is excellent. Because of this TWQ scale, analysis showed a truncated asymmetric distribution, anyway. The criteria used for this quality scale are shown in Table 1. Every evaluation was based on contemporary groups. The groups of shepherdesses and those of the animals to be evaluated were conformed randomly.

All the sheep 12 months old or younger were distributed in groups of around 20 animals each, regardless of their wool color and sex. Sheep from 13 to 24 months of age were kept apart in groups of around 20 animals of the same sex, regardless of their wool color. These groups were kept in stables where animals had around 400 m^2 to move freely.

Tzotzil shepherdesses evaluate the quality of the fleece by using empirical visual and tactile techniques (Table 1). After this, these indigenous women interchange points of view regarding the conditions of the fleece, the staple and its fibers,

Table 1
Tzotzil wool quality criteria and its scale

Staple length based on hand measures		Name		Grade level	
Tzotzil	English	Tzotzil	English		
Bej kom	One finger width	Chopol, Socom, Chaval yok	Useless, short, without fine fibers	1	
Chin kom	Two fingers width				
Ox kom	Three fingers width	Ja ta buk, Scanto ta slak, Chopol ta	For the weft, not ready for the blade, bad (in corporal region)	2	
Chanim kom	Four fingers width	Ja ta buk, Olol buk, Jutuc buk, Olol teom, Purc teom Lek ik Lek sak	For the weft, half is used for the weft, small part is used for the weft, half is used for the wrap, all for the wrap, good black color, good white color	3	
Kej lej	Distance between the tip of the first and the end of the first phalange of the second finger when they form a 90° angle				
Chutum, Chix	Distance between the tips of the first and the second (chutum) or third (chix) fingers when they form a 90° angle	Toj lek buk, Mero lek buk, Lek buk, Lok xa, Lek ik, Lek sak	Excellent for the weft, very good for the weft, good for the weft, ready for the blade, good black color, good white color	4	

with respect to its aptitude to be used in the several parts of the wool transformation process in to typical and traditional garments.

During the evaluation process, technicians wrote down the information for every animal, including the indigenous names used to classify the wool quality (Table 1). All the subjective elements that were being discussed by the Tzotzil women while evaluating the wool quality were translated in situ for the technicians using the mentioned scale to assess the fleece quality.

A fleece sample was taken from the right mid-lateral area of every sheep. The longer fibers from each sample were taken apart and measured to estimate SL. Once the TWQ and SL were measured, the shorn sheep and its greasy fleece at shearing (FW) were weighed.

2.2. *Statistical and genetic analysis*

Variance components, heritability, repeatability and genetic correlations for the studied fleece traits were calculated using mixed model methodology with bivariate animal models, and by restricted maximum likelihood (REML) methods using ASREML software (Gilmour et al., 2002). The model included significant fixed effects of sex, year-season of shearing, wool color and shearing number ($P < 0.05$) as well as the animal additive genetic effect, permanent environment effect and residual as random effects for TWQ, FW and SL traits. No interaction between fixed effects were found significant ($P > 0.20$). In matrix notation, the model used was:

$$\mathbf{Y} = \mathbf{X\beta} + \mathbf{Zu} + \mathbf{Wp} + \mathbf{e},$$

where $\mathbf{X}$ is a known incidence matrix accounting for the fixed effects, $\boldsymbol{\beta}$ the unknown vector of fixed effects, $\mathbf{Z}$ a known incidence matrix associating animal effects to the vector of observations $\mathbf{Y}$, $\mathbf{u}$ the vector of unknown random animal effects, $\mathbf{W}$ a known incidence matrix associating permanent environment effects to the vector of observations $\mathbf{Y}$, $\mathbf{p}$ the vector of unknown permanent environment effects and $\mathbf{e}$ is the vector of residual random effects. Assuming normality we have:

$$\begin{pmatrix} \mathbf{Y} \\ \mathbf{u} \\ \mathbf{p} \\ \mathbf{e} \end{pmatrix} \sim N\left(\begin{pmatrix} \mathbf{X\beta} \\ 0 \\ 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \mathbf{V} & \mathbf{ZG} & \mathbf{WQ} & \mathbf{R} \\ \mathbf{GZ'} & \mathbf{G} & 0 & 0 \\ \mathbf{QW'} & 0 & \mathbf{Q} & 0 \\ \mathbf{R} & 0 & 0 & \mathbf{R} \end{pmatrix}\right),$$

with $\mathbf{V} = \text{var}(\mathbf{Y}) = \mathbf{ZGZ'} + \mathbf{WQW'} + \mathbf{R}$, $\mathbf{G} = \mathbf{gA} = \text{var}(\mathbf{u})$, the genetic (co)variance matrix ($\mathbf{gA} = \sigma^2_{\mathbf{u}}\mathbf{A}$), where **g** represents the additive genetic variance and **A** is the additive relationship matrix among all the sheep in the pedigree file. $\mathbf{Q} = \text{var}(\mathbf{p})$, the permanent environment (co)variance matrix ($\sigma^2_{\mathbf{p}}\mathbf{I}$) and $\mathbf{R} = \text{var}(\mathbf{e})$, the residual effects (co)variance matrix ($\sigma^2_{\mathbf{e}}\mathbf{I}$).

If we define **Go** as the symmetric matrix containing variances of ($\sigma^2_{u_{ii}}$) and covariances ($\sigma_{u_{ij}}$) among the animal effects for the two traits, then

$$\text{Var}\begin{pmatrix} \mathbf{u}_1 \\ \mathbf{u}_2 \end{pmatrix} = \begin{pmatrix} \sigma^2_{u_{11}} & \sigma_{u_{12}} \\ \text{Symm} & \sigma^2_{u_{12}} \end{pmatrix} \otimes \mathbf{A} = \mathbf{Go} \otimes \mathbf{A} = \mathbf{G},$$

where $\mathbf{u}_j$ is the vector of animal effects for the *j*th trait, while $\otimes$ stands for the Kronecker product.

The matrix **A** contains the relationships among sheep, sires of sheep and dams of sheep. There were 2472 sheep records from 708 animals present in the data set, but the number of animal effects (the size of **A**) included in this pedigree file was 931.

The analyses were performed by obtaining univariate estimates for genetic and residual (co)variances to use them as starting values in the bivariate analysis.

Heritability for the *i*th trait was estimated as

$$\hat{h}^2_i = \frac{\hat{\sigma}^2_{u_i}}{(\hat{\sigma}^2_{u_i} + \hat{\sigma}^2_{e_i})},$$

and its repeatability as

$$\text{Re}_i = \frac{\hat{\sigma}^2_{u_i} + \hat{\sigma}^2_{p_i}}{(\hat{\sigma}^2_{u_i} + \hat{\sigma}^2_{p_i} + \hat{\sigma}^2_{e_i})},$$

where $\hat{\sigma}^2_{u_i}$ is the animal additive genetic variance for the *i*th trait, $\hat{\sigma}^2_{p_i}$ the permanent environment variance for the *i*th trait and $\hat{\sigma}^2_{e_i}$ is the residual variance for the *i*th trait.

With genetic variance $\hat{\sigma}^2_{u_i}$ and genetic covariance $\hat{\sigma}_{u_{ij}}$, genetic correlation between the *i*th and *j*th traits was estimated as

$$\hat{r}_{g_{ij}} = \frac{\hat{\sigma}_{u_{ij}}}{(\hat{\sigma}_{u_{ii}}\hat{\sigma}_{u_{jj}})}.$$

3. Results

Descriptive statistics for the studied traits is shown in Table 2. Heritabilities, repeatabilities, genetic and phenotypic correlations for the studied traits are shown in Table 3.

Table 2
Number of records (*N*), mean, standard deviation (S.D.), for Tzotzil wool quality (TWQ), staple length (SL) and greasy fleece weight (FW)

Trait	*N*	Mean	S.D.
TWQ	2471	3.12	0.67
SL (cm)	2249	10.32	2.45
FW (g)	2564	425.68	164.10

Table 3
Heritability, repeatability (Re) and genetic correlations for Tzotzil wool quality (TWQ), staple length (SL) and greasy fleece weight (FW)

Trait	TWQ	SL	FW	Repeatability
TWQ	**0.39 (0.05)**	0.98 (0.02)	0.63 (0.04)	0.48 (0.02)
SL	0.69 (0.01)	**0.43 (0.06)**	0.47 (0.04)	0.55 (0.02)
FW	0.43 (0.02)	0.38 (0.02)	**0.31 (0.05)**	0.51 (0.02)

Heritabilities in diagonal (bold), genetic correlations above diagonal and phenotypic correlations below diagonal. Standard errors in parenthesis.

4. Discussion

4.1. Heritabilities

Heritability for greasy fleece weight (0.31), although within the range of the studies published for this trait, was smaller than most of these estimates. A review from Fogarty (1995) estimated the average heritability for this trait across several wool breeds as 0.35, while the weighed mean estimate in a review by Safari et al. (2005) based on 20 independent studies was 0.37. It is worthy to note that these latter authors also found this mean to be 0.31 when maternal heritability was included in the used models. Heritability of staple length (0.43) was also similar to the weighed mean heritability (0.46) found for this trait in the review by Safari et al. (2005) for wool breeds. In any case, the lowest estimate found for this trait (0.08) was estimated by Ozcan et al. (2005) in first shearing Turkish Merino sheep.

Heritability for TWQ (0.39) was similar to those estimates published for Western fleece grade measures. Hanford et al. (2002) estimated the heritability for fleece grade as 0.41 in Columbia sheep. The review by Safari et al. (2005) estimated the weighed mean heritability for crimp frequency, a measure associated to wool quality, as 0.41 too. Bromley et al. (2000) based on visual spinning count USDA grade system, found the heritability for fleece grade in Columbia, Polypay, Rambouillet and Targhee sheep ranging from 0.26 to 0.50, while in another study with these same wool breeds and using univariate models, Bromley et al. (2001) estimated it as 0.41. Consistently, using data from Targhee sheep, Hanford et al. (2003) estimated the fleece grade heritability as 0.41, while based on the U.S. spinning count system for fleece grade, Hanford et al. (2006) estimated it as 0.36 in Polypay sheep. When quality was measured with a subjective visual appraisal of fiber diameter based on the English Worsted Yarn Count System, Okut et al. (1999) estimated fleece grade heritability in Columbia, Polypay, Rambouillet and Targhee sheep, averaging 0.42, 0.40 and 0.37 at young, middle and older ages, respectively. On the other hand, some studies have found rather low heritability estimates for the fleece grade. For example, Hanford et al. (2005) using Rambouillet sheep data estimated it as 0.16. Other authors have used other wool quality criteria and have found the heritability for these measures to be rather high too. For example, Notter et al. (2007) using Targhee sheep data and based on optical fiber diameter assessment system quality criteria (OFDA) estimated heritabilities for micron average of the fiber, micron standard deviation of the fiber, spinning fineness, comfort factor and average curvature as 0.62, 0.49, 0.64, 0.38 and 0.50, respectively. Accordingly, using Merino sheep data, Snyman et al. (1998) estimated the heritability for mean fiber diameter as 0.63. Finally, the review by Safari et al. (2005) estimated the weighed mean for staple strength, another measure of wool quality, as 0.34, which is a little bit lower than the one found for TWQ in our study.

4.2. Repeatabilities

The repeatabilities for FW (0.51) were within the range of those found in literature for Western wool breeds (Fogarty, 1995; Safari et al., 2005). The review by Fogarty (1995) found repeatability for FW ranging from 0.34 to 0.84 with a mean of 0.58. More recently, Lee et al. (2000) estimated repeatability for FW as 0.64 in Rambouillet sheep. Repeatability of SL (0.55) was in the range of published studies too. Bromley et al. (2001) estimated it as 0.56 in Targhee sheep, Behrendt et al. (2004) as 0.61 from wool obtained from the midside of the sheep and as 0.39 from wool obtained from the pin bone in Australia, while Hanford et al. (2003) as 0.74 in Targhee sheep and Nakagwa et al. (2005) as 0.39 in Suffolk sheep in Japan. The repeatability found for TWQ (0.48) suggests that shearing measures evaluated across time are rather similar. The repeatability found for TWQ shows that this ancient trait can be used as criterion to keep animals in the flock.

4.3. Genetic and phenotypic correlations

Genetic correlation between TWQ and SL was very high and positive (0.98) as expected since TWQ criteria favor long fibers. Its phenotypic correlation (0.69) also showed that there is a positive association between these traits. Genetic correlation between TWQ and FW was also positive and high (0.63) and the phenotypic correlation for these two traits was positive and medium size (0.43). Selecting for TWQ hence causes an important expected correlated response to selection in SL and FW, meaning that the Tzotzil breeding program based on TWQ will increase the SL and FW.

The genetic correlation between SL and FW (0.47) was slightly above the published estimates for Western wool breeds. Safari et al. (2005) estimated a 95% confidence interval for this estimate in published literature from 0.18 to 0.45 with a weighed mean of 0.32.

4.4. Selection for TWQ

Based on Tzotzil criteria, improving TWQ mean would result in animals with fleeces having longer staples and with a higher proportion of long and thick fibers that are preferred for the traditional textile process, while there will be an increase in the FW. Regardless of the truncated scale for TWQ, expected changes in SL and in TWQ itself due to selection will force to extend up this Tzotzil scale, unless an optimum staple length and fiber proportions criteria were established in the near future. From the point of view of the Western textile industry, high quality fleeces are those constituted by white, short and thin fibers. These criteria are different to those considered by Tzotzil women. Under these considerations, direct participation of the shepherdesses in the sheep breeding program implies that the animals bred in the nucleus flock that will be introduced later in the community flocks will provide the desired wool quality required for the laborious Tzotzil textile process. The fleece of these TWQ selected sheep and their descendants will facilitate the elaboration of wool garments worn on a daily basis and during ceremonial events by these indigenous communities living in Southern Mexico. It is worthy to emphasize that these wool garments are meant to distinguish the members of this ethnical group. In any case, based on cultural issues, the actual breeding program requires the direct participation of groups of Tzotzil shepherdesses. Their quality assessment includes a subjective evaluation of fleece texture and color uniformity that might require to be objectively measured in the near future. Hence, disentangle the components of TWQ to build a selection index will constitute a challenge for improving the Tzotzil breeding program.

5. Conclusions

TWQ showed an important additive genetic component and was positively associated with FW and SL. Hence, its inclusion as selection criterion in the Tzotzil indigenous sheep breeding program would have a significant impact in the Chiapas sheep. The design of a modern Tzotzil breeding program needs to address the challenge of having a truncated scale for TWQ and the nature of its subjective component. Improving the quality of the fleece based on their own criteria will contribute to improve the family income of these indigenous communities living mostly in extreme isolation and poverty.

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