Archiv Tierzucht 56 (2013) 42, 430-442

Original study

Association between body and udder morphological traits and dairy performance in Spanish Assaf sheep

M. Ángeles Pérez-Cabal[1], Emilio Legaz[2], Isabel Cervantes[1], Luis Fernando de la Fuente[3], Raúl Martínez[4], Félix Goyache[5] and Juan Pablo Gutiérrez[1]

[1]Dpto. de Producción Animal, Facultad de Veterinaria, Universidad Complutense de Madrid, Madrid, Spain, [2]Castellana de Ganaderos Sociedad Cooperativa, Madrid, Spain, [3]Dep. Producción Animal, Universidad de León, León, Spain, [4]Asociación Nacional de criadores de ganado ovino de la Raza Assaf, Zamora, Spain, [5]SERIDA-Somió, Gijón, Spain

Abstract

The relationship between 17 body and 8 udder measurements and phenotypic dairy performance were studied using information from 280 Spanish Assaf ewes from 2 to 4 years old belonging to 18 flocks. The influence of the environmental area on the dairy traits was assessed by fitting a fixed model including the flock effect and the age effect. A factor analysis was also carried out to determine the lowest number of independent factors that account for most of the variation in the traits. The flock was statistically significant for performance trait and predicted breeding value (PBV) while the age was only significant in 150 days standardized milk yield (MY150) and daily milk yield (DMY). In general, not much association was found between morphological and dairy performance traits. Few body traits showed significant phenotypic correlations; mainly those related to height, diameters, ears and tail, with the latter being the most correlated but unfavourable for DMY and PBV. Among udder conformation, udder depth and length were the most correlated traits to milk production, while deep udders and short teats were related to lower somatic cell counts. The different traits were classified for analyses into six factors relating mainly to: live weight; production and udder traits; cheese production; stature; teats and udder health; and udder dimensions. Trade of animals was concluded to be unreasonably based on morphological or even on performance traits. The participation of breeders in an appropriate breeding scheme based on accurate genetic evaluations is encouraged.

Keywords: Assaf, conformation, production, udder

Archiv Tierzucht 56 (2013) 42, 430-442
doi: 10.7482/0003-9438-56-042

Received: 29 October 2012
Accepted: 23 January 2013
Online: 22 March 2013

Corresponding author:
Juan Pablo Gutiérrez; email: gutgar@vet.ucm.es
Departamento de Producción Animal, Facultad de Veterinaria, Universidad Complutense de Madrid, Avda. Puerta de Hierro s/n, 28040 Madrid, Spain

Abbreviations: ACW: anterior croup width, BD: bicoastal diameter, CH: cross height, CIH: cistern height, CL: croup length, CP: cane perimeter, CRH: croup height, CV: coefficient of variation, CW: chest width, DD: dorsoesternal diameter, DMY: daily milk yield, EL: ear length, EW: ear width, EY150: dry extract, FY150: fat yield, HL: head length, HW: head width, LDL: longitudinal diameter, LW: live weight, MSA: measure of sampling adequacy, MY150: total milk yield standardized to 150 days, PBV: milk yield breeding value, PCW: posterior croup width, PDV: predicted breeding value, PY150: protein yield, SD: standard deviation, TA: teat angle, TAW: tail width, TL: teat length, TP: teat placement, TW: teat width, TXP: thorax perimeter, UD: udder depth, UL: udder length, UW: udder width

Introduction

The Spanish Assaf sheep breed is one of the recently imported sheep populations, which has become well-established in Spain because of its high performance level (Gutiérrez *et al.* 2007). The breed in Spain is increasing with 700 000 heads in 2001 (Ugarte *et al.* 2001). The Assaf sheep breed was created in Israel by cross-breeding the East Friesian (Milchschaf) with the Awassi breed (Goot 1986). The breed was introduced in Spain mainly by the male-mediated absorption of Spanish native dairy sheep breeds mainly the Castellana, Churra, Manchega and also Latxa (Ugarte *et al.* 2002, Legaz *et al.* 2008). This absorption process was clarified at the genomic DNA level (Legaz *et al.* 2008) and at the mitochondrial DNA level (Pedrosa *et al.* 2007). It has also been demonstrated that today this breed can be considered as a unique compact and sufficiently homogenized population (Legaz *et al.* 2011). In fact, the farmers have organized themselves and gathered all the previously well-developed dairy recording schemes (Jiménez & Jurado 2005, Gutiérrez *et al.* 2007) into a single breeding organization officially recognized by the Spanish Government with approximately 200 000 Spanish Assaf heads owned by roughly 300 farmers that are currently registered in the official flock book (http://www.assafe.es).

Given the high dairy performance, Spanish Assaf individuals are on high demand in other countries such as Greece, but information on the population is still scarce and is still being gathered (Gutiérrez *et al.* 2007, Legaz *et al.* 2008, Legaz *et al.* 2011). Contributions to the characterization of local domestic animal populations are of major importance, given that the breed is the operation unit for the assessment of livestock diversity all over the world (Simon 1999, Duchev *et al.* 2006).

Characterization of local genetic resources falls firstly on the knowledge of the morphological trait variation (Azor *et al.* 2008, Delgado *et al.* 2001). Multifactorial analyses of morphological traits can discriminate amongst different population types when all the measured morphological variables are considered simultaneously (Traoré *et al.* 2008). These kinds of studies are rarely reported in sheep (Riva *et al.* 2004, Carneiro *et al.* 2010), but have been conducted in the Spanish Assaf sheep breed (Legaz *et al.* 2011).

Relationships between the dairy performance of ewes and some morphological traits, particularly if these are udder traits, are often considered when selling animals, but this relationship has never been measured in the Spanish Assaf breed, although it was studied briefly in this breed in Israel (Sagi & Morag 1974) and rarely in other sheep populations (Labussière *et al.* 1981, Labussière 1988, Dzidic *et al.* 2004, Ayadi *et al.* 2011, de la Fuente *et al.* 2011). The aim of this study was to analyse the relationship between 17 body measurements in 280 ewes ranging from 2 to 4 years of age in addition to 8 udder scores collected during the period of maximum levels of lactation with the dairy predicted breeding value and phenotypic dairy performance.

Material and methods

Data

A total of 280 ewes from 2 to 4 years of age belonging to 18 flocks were scored for 17 body measurements and 8 udder traits (Legaz *et al.* 2011). The zoometric variables measured were live weight (LW), head width (HW), chest width (CW), anterior croup width (ACW), posterior croup width (PCW), croup length (CL), thorax perimeter (TXP), cane perimeter (CP), head length (HL), cross height (CH), croup height (CRH), longitudinal diameter (LD), dorsoesternal diameter (DD), bicoastal diameter (BD), tail width (TAW), ear length (EL) and ear width (EW). This last trait was considered for registration after the study was started and consequently there is a fewer number of records for it.

The methodology used for measuring udder traits were those described by Labussiere *et al.* (1981) and used in ovine breeds from the Mediterranean basin. The morphological udder traits measured were udder length (UL), udder depth (UD), udder width (UW), cistern height (CIH), teat placement (TP), teat length (TL), teat width (TW) and teat angle (TA). The LW was determined with scales and measurements were carried out using a Lydthin stick, tape measure and Vernier calliper. The TP was subjectively scored in lateral view meaning 1=turned backwards, 2=vertical, 3=a little forward, 4=forward and 5=much forward. Animals were put on a flat floor and held down by the respective owners while a single technician carried out the measurement. Females were measured during the period of maximum levels of lactation.

A total of 228 out of the 280 ewes also presented information from the 2009 official milking recording system. Monthly test day records were used to obtain total milk yield standardized to 150 days (MY150) following Fleischman's method (Barillet 1985). Accordingly, fat (FY150), protein (PY150) and dry extract (EY150) contents per lactation were obtained as percentage. To do this, daily amounts of fat, protein and extract in kg were estimated from the scored percentage at each test day and the total amounts were then obtained following Fleischman's method (Barillet 1985). Afterwards, they were transformed again to percentages to establish a global unique value for the lactation. Total milk yield obtained from lactations with a missing intermediate test day record were removed from the analyses but the components were kept since they were not considered to be affected in any relevant manner. The daily milk yield (DMY) corresponding to the date when morphological measures were taken was estimated by interpolation of the previous and posterior test day milk yields. Monthly somatic cell count records were averaged to obtain a lactation mean and then transformed to somatic cell score (SCS150) using a base 2 logarithmic function (Ali & Shook 1980). Given that dairy performances are strongly affected by systematic effects and searching for an approximation to the natural relationship between production and morphology traits being less dependent on those effects, the information from the official genetic evaluation was added to this analysis. Therefore, the predicted breeding value (PBV) for MY150 was also available for 194 ewes from the 2010 official genetic evaluation (Jiménez & Jurado 2010). To carry out this genetic evaluation, only genealogical information from artificial insemination and paternity tests were used, ensuring a good connectedness among the 98 active participant herds in 2009. In this year, 282 579 lactations belonging to 120 537 animals were used (Jiménez & Jurado 2010). The genetic evaluation is implemented yearly using BLUP methodology. An animal model with repeated measurements included the flock-year-month of lambing, the type of lambing, number of lambing and interval between lambing and first milking test as fixed affects. The random effects were genetic additive effects and permanent environmental effects. Genetic groups were considered for those individuals with lack of genealogical information. The reason for including the PBV in this analysis was to give some information related to genetic correlation between performance and morphological traits. However, note that the PBV is finally a fine adjustment of MY150 that accounts for the main systematic effects and also for the information from relatives. Therefore, it is closer to the true breeding value than the rough phenotype but it can be still far from the true breeding value. The raw means, standard deviations, coefficient of variation and the number of records for performance traits and PBV are summarized in Table 1 as well as the summary for body and udder traits (Legaz *et al.* 2011). The wide variability of the Spanish Assaf breed (Legaz *et al.* 2011) is well-known, including its dramatic improvement in recent years. Thus, it is interesting to note the high standard deviation of MY150 with a coefficient of variation around 30 %. Also, the mean value of MY150 was relevantly higher than other means previously referred to for this breed (de la Fuente *et al.* 2006, Gutiérrez *et al.* 2007, Jiménez & Jurado 2010, Milan *et al.* 2011).

Table 1
Raw means, standard deviation, coefficient of variation in percentage and the number of records for the 6 dairy performance traits, the milk yield breeding value and the 17 measured morphological traits

Traits	Number	Mean	SD	CV
MY150, L	202	425.46	126.24	29.67
FY150, %	224	5.39	1.19	22.08
PY150, %	224	4.03	0.44	10.92
EY150, %	224	16.15	1.37	8.48
SCS150	224	4.70	1.70	36.17
Daily milk yield, cL	228	2 729.35	1 056.35	38.70
Milk yield breeding value, L	194	21.49	26.31	122.43
Live weight, kg	280	75.74	11.23	14.82
Head width, cm	280	13.01	0.53	4.11
Chest width, cm	280	22.86	1.42	6.23
Anterior croup width, cm	280	20.43	1.14	5.57
Posterior croup width, cm	280	17.18	1.00	5.81
Croup length, cm	280	22.25	1.23	5.53
Thorax perimeter, cm	280	105.68	6.67	6.31
Cane perimeter, cm	280	8.95	0.49	5.51
Head length, cm	280	26.60	1.09	4.08
Cistern height, cm	280	74.10	3.35	4.52
Croup height, cm	280	75.94	3.27	4.31
Longitudinal diameter, cm	280	73.09	3.53	4.83
Dorsoesternal diameter, cm	280	34.65	1.97	5.70
Bicoastal diameter, cm	280	25.51	2.53	9.93
Ear length, cm	280	18.19	1.69	9.28
Ear width, cm	107	10.12	0.81	8.00
Tail width, cm	280	12.35	1.85	15.00
Udder length, cm	280	11.26	1.55	13.73
Udder depth, cm	280	19.53	3.18	16.30
Udder width, cm	280	9.81	1.34	13.67
Cistern height, cm	280	4.67	1.48	31.68
Teat placement, cm	280	2.78	0.61	21.96
Teat length, cm	280	3.06	0.72	23.43
Teat width, cm	280	1.75	0.32	18.55
Teat angle, grades	280	63.25	10.66	16.85

Statistical analyses

Statistical analyses were carried out using the SAS/STAT package v8.2 (SAS Institute Inc., Cary, NC, USA). Basic statistics for the body measurements and qualitative traits were obtained using the PROC UNIVARIATE. The procedure PROC CORR was also used to compute the Pearson correlations between traits. Standard errors of correlations were also computed (Zar 1999). The influence of the environmental area (Northern Central Spain vs. Madrid and surrounding provinces) on the body traits already reported by Legaz *et al.* (2011) was assessed here for dairy performance traits and PBV using the PROC GLM by fitting a model including the flock effect with 18 levels and the age effect with 3 levels beginning in the second year. Additionally, a factor analysis was carried out using PROC FACTOR to determine the number of independent traits that account for most of the variation in the traits (Vukasinovic *et al.* 1997, Roughsedge *et al.* 2000). This analysis was computed from the standardized variables (mean zero and variance one). The data appropriateness was tested using the Kaiser-Meyer-Olkin measure of sampling adequacy (MSA). Traits with low MSA were removed from factorial analysis if its communality was lower than 0.60. To facilitate interpretation, the VARIMAX orthogonal factor rotation was used. Only factors accounting for more variation than any individual trait (eigenvalue greater than 1) were retained. The number of factors extracted depended on a required minimum proportion of common variance of 0.60.

Results

Table 2 shows the significance of the age of the animal and flock effects on the performance and PBV traits. The flock was a determinant ($P<0.05$) for all variables. However, the age of the ewes showed only weak significance in the two traits involving milk performance, *i.e.* MY150 and DMY, while it was not statistically significant for composition traits (SCS150 and PBV). The significance level of these effects on the morphological traits were somehow lower than for production, especially for the flock effect and were reported by Legaz *et al.* (2011). Given that the connectedness among animals is ensured by artificial insemination and that the flock effect was included in the genetic evaluation model, its significant influence on PBV would provide information on the probable genetic differences of animals between different flocks.

Table 2
Significance level of flock and age effect for each performance trait and milk yield breeding value

Traits	Flock	Age
MY150	***	**
FY150	***	ns
PY150	***	ns
EY150	***	ns
SCS150	*	ns
Daily milk yield	***	*
Milk yield breeding value	**	ns

*$P<0.05$, **$P<0.01$, ***$P<0.001$, ns: not significant

Statistically significant correlations among performance and PBV traits are shown in Table 3. Traits measuring milk amount (MY150 and DMY) showed negative correlations with traits measuring composition (from −0.20 to −0.35), except for PY150, with correlations that were not statistically significant. The correlation between MY150 and DMY was 0.71, showing that both traits are highly linked. The correlation between MY150 and the PBV was 0.48. The correlation between PBV and DMY was slightly lower (0.46) as a consequence of being a highly related but different phenotypic trait of MY150 that was the trait used to compute PBV. However, looking at their standard error those correlations were not statistically significant. The SCS150 was positively correlated with FY150 and presented negative phenotypic correlations with MY150 and DMY. However, the genetic correlation between SCS150 and PBV was not statistically significant (−0.05).

Table 3
Phenotypic correlations among performance and milk breeding value traits

	FY150	PY150	EY150	SCS150	DMY	PBV
MY150	−0.34***	0.01	−0.27***	−0.31***	0.71***	0.48***
	(0.06)	(0.07)	(0.06)	(0.06)	(0.05)	(0.07)
FY150		0.40***	0.95***	0.17*	−0.33***	−0.16*
		(0.06)	(0.02)	(0.06)	(0.06)	(0.07)
PY150			0.62***	0.05	−0.08	−0.09
			(0.05)	(0.06)	(0.06)	(0.07)
EY150				0.11	−0.30***	−0.16*
				(0.06)	(0.06)	(0.07)
SCS150					−0.24***	−0.06
					(0.06)	(0.07)
Daily milk yield						0.46***
						(0.06)

*P<0.05, **P<0.01, ***P<0.001, standard errors in brackets

Phenotypic correlations between all morphological traits and performance and PBV traits are shown in Table 4. In general, not much association was found between body traits and dairy performance traits. Few body traits showed significant correlations, mainly those related to height and diameters, that is overall size, ears and tail traits. Correlations ranged from −0.31 to 0.21 with TAW as the most antagonistic trait with performance. The size traits (height and diameters) showed positive but weak phenotypic correlations with MY150 and DMY. Milk components were not associated with any of the body traits, except for PY150, which showed a negative correlation with BD. Udder health (by SCS150) was associated with ears and tail, while PBV only showed significant correlation with TAW.

It is worth remarking the correlations between ears and tail with dairy performance traits. Ear length showed a low correlation with variables regarding the amount of milk and SCS150, while EW was not correlated to any performance trait. Surprisingly, TAW was the most correlated trait among all the morphological traits with MY150, FY150, SCS150, DMY and PBV (from −0.31 to 0.15).

The relationship between udder traits and dairy performance was strong, again with the traits related to milk amount being the most correlated with udder conformation. The highest correlation in this group (0.47) was found between UD and MY150. Both UD and UL had similar correlations with daily production, although UL was the most correlated with DMY. Regarding the association between udder traits and the rough approach used here to

Table 4
Phenotypic correlations between all morphological traits and performance and PBV traits.

Traits	MY150	FY150	PY150	EY150	SCS150	DMY	PBV
Body traits							
Live weight	0.10 (0.07)	0.06 (0.06)	−0.00 (0.06)	0.04 (0.06)	−0.00 (0.06)	−0.01 (0.06)	−0.08 (0.07)
Head width	0.05 (0.07)	−0.02 (0.06)	−0.01 (0.06)	−0.04 (0.06)	−0.01 (0.06)	**0.17** (0.06)	−0.04 (0.07)
Chest width	0.10 (0.07)	−0.03 (0.06)	0.03 (0.06)	−0.02 (0.06)	0.04 (0.06)	0.02 (0.06)	−0.10 (0.07)
Anterior croup width	−0.03 (0.07)	0.09 (0.06)	−0.05 (0.06)	0.05 (0.06)	0.10 (0.06)	−0.01 (0.06)	−0.10 (0.07)
Posterior croup width	0.00 (0.07)	−0.04 (0.06)	−0.04 (0.06)	−0.06 (0.06)	−0.02 (0.06)	0.03 (0.06)	−0.06 (0.07)
Croup length	0.00 (0.07)	−0.09 (0.06)	0.09 (0.06)	−0.05 (0.06)	0.03 (0.06)	0.01 (0.06)	−0.10 (0.07)
Thorax perimeter	0.05 (0.07)	0.07 (0.06)	−0.06 (0.06)	0.03 (0.06)	0.03 (0.06)	−0.03 (0.06)	−0.13 (0.07)
Cane perimeter	0.04 (0.07)	0.04 (0.06)	−0.01 (0.06)	0.02 (0.06)	0.07 (0.06)	0.01 (0.06)	−0.13 (0.07)
Head length	0.11 (0.07)	0.03 (0.06)	0.10 (0.06)	0.04 (0.06)	−0.01 (0.06)	**0.13** (0.06)	0.12 (0.07)
Cistern height	**0.14** (0.07)	−0.09 (0.06)	−0.07 (0.06)	−0.11 (0.06)	0.03 (0.06)	**0.21** (0.06)	0.09 (0.07)
Cross height	**0.13** (0.07)	−0.08 (0.06)	−0.11 (0.06)	−0.11 (0.06)	0.00 (0.06)	**0.20** (0.06)	0.08 (0.07)
Longitudinal diameter	0.06 (0.07)	0.05 (0.06)	0.05 (0.06)	0.05 (0.06)	0.06 (0.06)	0.09 (0.06)	−0.04 (0.07)
Dorsoesternal diameter	**0.18** (0.06)	−0.03 (0.06)	−0.11 (0.06)	−0.08 (0.06)	0.02 (0.06)	**0.17** (0.06)	−0.04 (0.07)
Bicoastal diameter	0.03 (0.06)	0.03 (0.06)	**−0.13** (0.06)	−0.03 (0.06)	0.03 (0.06)	0.08 (0.06)	−0.13 (0.07)
Ear length	**0.19** (0.07)	−0.08 (0.06)	0.11 (0.06)	−0.03 (0.06)	**−0.17** (0.06)	**0.17** (0.06)	0.03 (0.07)
Ear width	0.07 (0.10)	0.03 (0.09)	0.09 (0.09)	0.04 (0.09)	−0.05 (0.09)	0.05 (0.09)	−0.13 (0.10)
Tail width	**−0.24** (0.07)	**0.13** (0.06)	−0.08 (0.06)	0.09 (0.06)	**0.15** (0.06)	**−0.31** (0.06)	**−0.31** (0.06)
Udder traits							
Udder length	**0.25** (0.06)	**−0.21** (0.06)	**−0.13** (0.06)	**−0.22** (0.06)	**−0.15** (0.06)	**0.39** (0.06)	0.10 (0.07)
Udder depth	**0.47** (0.06)	−0.01 (0.06)	0.10 (0.06)	−0.01 (0.06)	0.10 (0.06)	**0.36** (0.06)	**0.33** (0.06)
Udder width	−0.02 (0.07)	−0.03 (0.06)	**−0.18** (0.06)	−0.08 (0.06)	−0.02 (0.06)	**0.24** (0.06)	0.00 (0.07)
Cistern height	**0.29** (0.06)	0.04 (0.06)	0.13 (0.06)	0.07 (0.06)	−0.03 (0.06)	**0.17** (0.06)	0.13 (0.07)
Teat placement	−0.03 (0.07)	−0.03 (0.06)	**−0.14** (0.06)	−0.04 (0.06)	−0.04 (0.06)	−0.03 (0.06)	0.00 (0.07)
Teat length	0.07 (0.07)	−0.09 (0.06)	−0.07 (0.06)	−0.12 (0.06)	**0.17** (0.06)	0.12 (0.06)	0.13 (0.07)
Teat width	0.09 (0.07)	**−0.15** (0.06)	−0.12 (0.06)	**−0.19** (0.06)	**0.16** (0.06)	0.12 (0.06)	0.13 (0.07)
Teat angle	0.10 (0.07)	0.09 (0.06)	0.10 (0.06)	0.10 (0.06)	−0.05 (0.06)	0.04 (0.06)	0.04 (0.07)

Values with $P<0.05$ are in bold, standard errors in brackets the genetic ability to milking in global lactations, that is PBV, only UD (0.33) seemed to have some statistical importance. Udder health measured by SCS150 was positively associated with teats for both length and width measurements. However, there was no statistically significant relationship between SCS150 and UD.

Partial correlations of traits included in the factor analysis between morphological traits and performance are shown in Table 5. Ear width and TP were not considered for the factorial analysis because they did not fit the MSA requirements. Therefore, 165 records were finally considered in the factor analysis. Basically, most of the coefficients were close to zero or low, except for SCS150, MY150, DMY and PBV with some udder traits. The total Kaiser-Meyer-Olkin measure of sampling adequacy was 0.74, leading us to conclude that the data were appropriate for the factor analysis.

Table 5
Partial correlations between morphological traits and performance and PBV traits

Traits	MY150	FY150	PY150	EY150	SCS150	DMY	PBV
Body traits							
Live weigth	0.18	0.15	0.13	−0.13	**−0.21**	−0.03	0.03
Head width	−0.12	0.03	0.02	−0.02	−0.17	0.18	0.00
Chest width	−0.02	−0.12	−0.04	0.10	0.06	0.04	−0.01
Anterior croup width	−0.03	0.08	0.02	−0.07	0.11	0.03	0.00
Posterior croup width	−0.12	0.02	0.00	−0.04	−0.08	0.01	0.04
Croup length	−0.09	−0.13	0.05	0.08	0.10	−0.04	−0.06
Thorax perimeter	−0.01	−0.15	−0.12	0.14	0.10	−0.13	0.03
Cane perimeter	0.12	0.01	−0.03	0.00	0.10	−0.04	−0.13
Head length	−0.04	0.06	0.07	−0.03	−0.06	0.01	0.17
Cistern height	−0.10	−0.03	−0.04	0.02	0.05	0.05	0.04
Cross height	−0.01	−0.05	−0.04	0.05	−0.04	−0.02	0.04
Longitudinal diameter	−0.01	−0.03	−0.05	0.05	0.11	0.13	0.00
Dorsoesternal diameter	0.16	0.07	0.02	−0.06	0.00	−0.03	**−0.23**
Bicoastal diameter	−0.12	0.16	0.05	−0.15	−0.07	0.18	0.01
Ear length	0.05	−0.07	0.00	0.05	−0.04	−0.01	−0.09
Tail width	0.02	−0.05	−0.11	0.06	0.10	**−0.25**	−0.17
Udder traits							
Udder length	−0.06	0.08	0.07	−0.10	**−0.20**	**0.28**	0.07
Udder depth	**0.22**	0.16	0.16	−0.15	0.14	0.06	0.10
Udder width	−0.08	0.03	−0.06	−0.01	0.05	**0.30**	−0.03
Cistern height	0.03	−0.02	−0.03	0.04	−0.10	0.10	−0.02
Teat length	0.03	−0.02	0.01	0.02	0.10	−0.04	−0.04
Teat width	−0.10	−0.04	−0.07	0.03	0.02	0.06	0.07
Teat angle	−0.07	−0.05	−0.04	0.05	0.03	0.00	0.01

Values greater or equal than 0.20 are written in bold.

The results of the factor analysis are shown in Table 6, where the correlation between the traits and common factors with eigenvalue greater than 1, which explained individually at least the 5 % of the total variance, are presented. A detailed view of the associations among variables found in each factor, when the minimum correlation between the trait and the factor is 0.40, shows the following: three factors were mainly related to animal morphology and weight, two factors mainly related udder conformation to milk performance and one factor was related to milk components. The six first factors explained 61 % of the total variance.

Table 6
Results from the factorial analysis: correlations between the traits and the factors with eigenvalue greater than 1

Factor	1	2	3	4	5	6
Body traits						
Live weight	**0.90**	0.12	0.13	0.08	0.00	0.06
Head width	0.37	0.05	−0.15	0.12	−0.02	0.04
Chest width	**0.83**	0.07	−0.04	−0.05	0.00	−0.14
Anterior croup width	**0.71**	0.00	0.06	0.23	0.07	0.07
Posterior croup width	**0.51**	−0.06	−0.19	0.34	0.02	−0.11
Croup length	**0.48**	−0.08	−0.11	0.12	0.17	−0.33
Thorax perimeter	**0.86**	0.06	0.10	0.19	−0.03	0.21
Cane perimeter	**0.56**	−0.08	−0.11	0.09	0.00	−0.14
Head length	0.29	0.20	0.24	0.35	0.05	−0.18
Cistern height	0.19	0.11	−0.11	**0.88**	0.04	0.10
Croup height	0.28	0.13	−0.08	**0.85**	0.06	0.10
Longitudinal diameter	**0.49**	0.00	0.08	0.30	0.02	−0.24
Dorsoesternal diameter	**0.55**	0.17	−0.01	**0.56**	−0.01	0.25
Bicoastal diameter	**0.75**	0.01	0.03	0.08	0.00	0.30
Ear length	0.04	0.24	−0.23	0.22	−0.10	−0.28
Tail width	**0.67**	−0.33	0.20	−0.12	−0.01	0.22
Udder traits						
Udder length	0.23	0.26	−0.22	0.10	0.06	**0.52**
Udder depth	0.07	**0.64**	0.17	0.28	0.22	−0.26
Udder width	0.08	0.02	−0.04	0.21	0.05	**0.74**
Cistern height	0.21	**0.43**	0.21	0.19	−0.27	**−0.49**
Teat length	0.09	0.13	−0.07	0.09	**0.86**	0.12
Teat width	0.13	0.17	−0.12	0.00	**0.88**	0.03
Teat angle	0.13	0.24	0.18	0.17	**−0.48**	−0.40
Performance traits						
MY150	0.06	**0.84**	−0.19	−0.01	−0.09	0.01
FY150	0.05	−0.22	**0.90**	0.01	−0.06	0.06
PY150	−0.09	0.05	**0.60**	−0.11	−0.04	−0.36
EY150	0.02	−0.16	**0.93**	−0.03	−0.10	−0.06
SCS150	−0.12	−0.36	0.19	0.12	**0.47**	−0.11
Daily milk yield	−0.01	**0.76**	−0.28	0.15	0.00	0.20
Milk yield breeding value	−0.19	**0.66**	−0.03	0.05	0.12	0.03
Eigenvalue	5.63	3.01	2.65	2.60	2.19	2.09
Variance explained	0.22	0.13	0.10	0.07	0.05	0.05
Cumulated	0.22	0.35	0.44	0.51	0.56	0.61

Values greater or equal than 0.40 are written in bold.

The first factor, which explained 22% of the total variance, included 11 out of 16 body traits with a correlation greater than or equal to 0.40. It related to the body weight with the intake capacity (body size). The second most important factor grouped milk production (MY150, PBV and DMY) and udder capacity (UD and CIH). Factor 3 was associated with milk components. Factor 4 was mainly related to stature (height). Factor 5 grouped teat traits and SC150, showing the relationship between udder health and teats. Finally, last factor grouped udder morphology traits. This partition can provide us with tools to select some animals according to a particular main desired objective such as size (factor 1), production (factor 2), milk components (factor 3) and udder health (factor 5).

Discussion

The negative correlations between traits measuring milk amount (MY150 and DMY) and traits measuring composition agree with those found for the Lacaune breed (Barillet *et al.* 2001) except for PY150, because they estimated a strong genetic correlation with milk production. It is important to mention this surprising result, given that it seems that a highly productive ewe in terms of milk yield will not necessarily be accompanied by a lower protein percentage, even when milk yield and milk composition have been shown to be usually negatively correlated (Barillet & Boichard 1987, Fuertes *et al.* 1998). Correlation between MY150 and PBV is particularly interesting given that PBV is computed from MY150 by adjusting some important systematic effects and adding information from known relatives. Therefore, under a trait with moderate heritability (0.209, Jiménez & Jurado 2010), the PBV are expected to be close to MY150 in this breed with a short history (Gutiérrez *et al.* 2007, Legaz *et al.* 2008, Legaz *et al.* 2011) but differing mainly due to the adjustment for systematic effects in PBV. This value was 0.48, which shows how important the influence of such systematic effects is on performance and the value of carrying out a genetic evaluation to select animals instead of using performances as Spanish farmers tended to do. The SCS150 was positively correlated with FY150 and presented negative phenotypic correlations with MY150 and DMY, higher than those observed in the Churra breed (Baro *et al.* 1994), although our results agreed with the estimated correlation between SCS150 and PBV. Contradictory results can be found in the literature for genetic relationships mainly depending on the breed, the parity and on the model used. Negative genetic relationships were found in the Churra breed (El Saied *et al.* 1999) and in the Latxa breed (Legarra & Ugarte 2005), while in the Lacaune breed Rupp *et al.* (2003) estimated positive genetic correlations from 0.09 to 0.19.

Regarding production and conformation, animals that produced more milk tended to be larger as in dairy cows (Hansen 2000, Pérez-Cabal *et al.* 2003) because of the need to increase food intake to solve the higher energy requirements for milk production. Ears and tail, which are usually considered to be important in the breed definition, showed little relationship with performance. Therefore, the interest in selecting highly productive animals has frequently been accompanied by selecting animals with long ears and fat tails. Some breeders, in search for a particular breed standard, believed that long ears and fat tails were indicators of productivity. This could explain the light relationship found between these morphological traits and performance traits. In addition, the partial correlations showed that the relationship between ears and performance were negligible, once the effect of other variables was eliminated. Given the correlations obtained for TAW and EW (with PBV), if animals with wide tails were selected, the correlated response might be a decrease in production. Moreover, some peripheral traits such as ear and tail size were shown in the literature to have a low or null relationship with other morphological traits (Legaz *et al.* 2011). Therefore, farmers are best advised not to use these traits as selection criteria since correlated response in milk performance might be undesirable.

The relationship between udder traits and dairy performance was strong and both UD and UL had similar correlations with DMY. However, UL was the most partially correlated with DMY while UD did it with MY150, leading us to think that depth is more associated with the total milk produced per lactation and length is related to the daily yield. Different studies with Mediterranean dairy sheep breeds showed strong positive genetic correlations between udder volume and total milk yield mainly due to the correlations with UD (Legarra & Ugarte 2005, Iñiguez *et al.* 2009). Milk components were mainly related to UL such that the shorter the udder the larger the content of fat and protein.

The factorial analysis extracted 6 factors that explained 61 % of total variance. When only correlations equal or greater than 0.40 are of concern, morphological traits were clearly separated in factors. Factor 1 relates to live weight and gathered body size traits (width, perimeters and diameters) and TAW, while factor 2 was related to the amount of milk production and udder capacity. Legaz *et al.* (2011) already reported that udder traits were an independent group of morphological traits but in their study TAW was represented closer to udder traits than to body traits. There was no high association between body size and production as expected because the intake capacity provides production energy requirements. The amount of milk was mainly related to udder conformation instead to the physical need to hold the whole milk volume. Milk components gathered in factor 3 related to cheese production, according to phenotypic correlations obtained, such that selection for milk production and cheese should be considered as different goals. Regarding udder health, only teat morphology appeared to be associated with SCS150, although partial correlations showed mainly a relationship with UL. Therefore, short and narrow teats with small angles seemed to lead to more healthy udders. Here also some influence of UD and CIH on udder health can be seen. In dairy cows, relationships between udder health and conformation showed that long teats and lower udders, which are closer to the ground, are more prone to infections (Seykora & McDaniel 1986, Lund *et al.* 1994). Finally, some factors could not be clearly explained (i.e. factors 4 and 6). It could be due to the small data set used (only 165 out of 218). Further analyses should be done in the future if more information is available.

The association of morphological and udder traits with dairy performance and milk predicted breeding value was studied in the Spanish Assaf breed. Morphological traits related to animal size (height and diameters) including ear length showed weak or negligent correlations to amount of milk production, while the tail width was the most unfavourable correlated trait with production and the PBV among all conformation traits. Therefore, fat tail should not be considered as a main criterion when selecting animals for production. Udder depth is more associated with the total milk production per lactation, while length is related to the daily yield. From the factor analysis of the different factors it can be concluded that the genetics of milk production depended mainly on udder morphology and its ability to physically hold a high level of milk but it is independent of the animal size.

Relationships between the dairy performance of ewes and some morphological traits (including udder traits) were studied in the Spanish Assaf breed to assess if morphological traits can partially indicate the dairy performance of ewes. Such relationships have been established and could be used to evaluate animals without any information. Nevertheless, these relationships have shown to be too weak both in the phenotypic view and in the rough approximation to the genetic view assessed here via PBV. Furthermore, genetic correlations between morphological and performance traits are missing because the required information on morphological traits to carry out a reliable estimation of genetic parameters under a multitrait model is and will be missing for a long time in this breed. In such scenario, the trade of animals based only on morphological traits remains unjustified.

Other issues such as longevity or milk performances should be taken into account. Even dairy performances are not useful for trade purposes because they are highly influenced by systematic effects. Therefore, the best advice would be to encourage farmers to participate in an official performance record collection programme in order to have accurate data of the animals that can be used then as the only good way to assess their genetic background.

Acknowledgements

Authors are indebted to the farmers from the ASSAF.E association who collaborated in this study.

References

Ali AKA, Shook GE (1980) An Optimum Transformation for Somatic Cell Concentration in Milk. J Dairy Sci 63, 487-490

Ayadi M, Such X, Ezzehizi N, Zouari M, Najar T, Ben M' Rad M, Casals R (2011) Relationship between mammary morphology traits and milk yield of Sicilo-Sarde dairy sheep in Tunisia. Small Rumin Res 96, 41-15

Azor PJ, Goyache F, Gutiérrez JP (2008) [Statistical methods and genetic differentiation between populations]. In: de Andalucía j (ed) La ganadería andaluza en el siglo XXI. Patrimonio Ganadero Andaluz. Vol III, Sevilla, Spain, 169-184 [in Spanish]

Barillet F (1985) [Genetic improvement of sheep milk composition. The example of the Lacaune breed]. Ph.D. Thesis, L'institute National Agronomique, Paris-Grignon, France [in French]

Barillet F, Boichard D (1987) Studies on dairy production of milking ewes. I. – Estimates of genetic parameters for total milk composition and yield. Génét Sél Evol 19, 459-474

Barillet F, Rupp R, Mignon-Grasteau S, Astruc JM, Jacquin M (2001) Genetic analysis for mastitis resistance and milk somatic cell score in French Lacaune dairy sheep. Genet Sel Evol 33, 397-415

Baro JA, Carriedo JA, San Primitivo F (1994) Genetic Parameters of Test Day Measures for Somatic Cell Count, Milk Yield, and Protein Percentage of Milking Ewes. J Dairy Sci 77, 2658-2662

Carneiro H, Louvandini H, Paiva SR, Macedo F, Mernies B, McManus C (2010) Morphological characterization of sheep breeds in Brazil, Uruguay and Colombia. Small Rumin Res 94, 58-65

De la Fuente LF, Gabiña D, Carolino N, Ugarte E (2006) The Awassi and Assaf breeds in Spain and Portugal. In: European Association for Animal Production (EAAP) 57th Annual Meeting. Antalya, Turkey

De la Fuente LF, Gonzalo C, Sánchez JP, Rodríguez R, Carriedo JA, San Primitivo F (2011) Genetic parameters of the linear body conformation traits and genetic correlations with udder traits, milk yield and composition, and somatic cell count in dairy ewes. Can J Anim Sci 91, 585-591

Delgado JV, Barba C, Camacho ME, Sereno FTPS, Martínez A, Vega-Pla JL (2001) [Characterization of domestic animals in Spain]. Anim Gen Res Inf 29, 7-18 [in Spanish]

Duchev Z, Distl O, Groeneveld E (2006) Early warning system for loss of diversity in European livestock breeds. Arch Tierz 49, 521-531

Dzidic A, Kaps M, Bruckmaier RM (2004) Machine milking of Istrian dairy crossbreed ewes: udder morphology and milking characteristics. Small Rumin Res 55, 183-189

El-Saied UM, Carriedo JA, de la Fuente LF, San Primitivo F (1999) Genetic Parameters of Lactation Cell Counts and Milk Protein Yields in Dairy Ewes. J Dairy Sci 82, 639-644

Fuertes JA, Gonzalo C, Carriedo JA, San Primitivo F (1998) Parameters of Test Day Milk Yield and Milk Components for Dairy Ewes. J Dairy Sci 81, 1300-1307

Goot H (1986) Development of Assaf, a synthetic breed of dairy sheep in Israel. In: Proceedings of the 37th Annual Meeting of the European Association for Animal Production, Budapest, Hungary, 1-29

Gutiérrez JP, Legaz E, Goyache F (2007) Genetic parameters affecting 180-days standardised milk yield, test-day milk yield and lactation length in Spanish Assaf (Assaf.E) dairy sheep. Small Rumin Res 70, 233-238

Hansen LB (2000) Consequences of Selection for Milk Yield from a Geneticist's Viewpoint. J Dairy Sci 83, 1145-1150

Iñiguez L, Hilali M, Thomas DL, Jesry G (2009) Udder measurements and milk production in two Awassi sheep genotypes and their crosses. J Dairy Sci 92, 4613-4620

Jiménez MA, Jurado JJ (2005) [Scheme in the Assaf breed in Leon]. ITEA 26, 99-101 [in Spanish]

Jiménez MA, Jurado JJ (2010) [National program for genetic selection of Spanish Assaf sheep breed]. In: XV Reunión Nacional de Mejora Genética Animal. Vigo, Spain [in Spanish]

Labussière J (1988) Review of physiological and anatomical factors influencing the milking ability of ewes and the organization of milking. Livest Prod Sci 18, 253-274

Labussière J, Dotchewski D, Combaud JF (1981) [Morphological characteristics of the udder of Lacaune ewes and relationships with milkability. Methodology used for collection of data]. Ann Zootech 30, 115-136 [in French]

Legaz E, Álvarez I, Royo LJ, Fernández I, Gutiérrez JP, Goyache F (2008) Genetic relationships between Spanish Assaf (Assaf.E) and Spanish native dairy sheep breeds. Small Rumin Res 80, 39-44

Legaz E, Cervantes I, Pérez-Cabal MA, de la Fuente LF, Mártinez R, Goyache F, Gutiérrez JP (2011) Multivariate characterisation of morphological traits in Assaf (Assaf.E) sheep. Small Rumin Res 100, 122-130

Legarra A, Ugarte E (2005) Genetic Parameters of Udder Traits, Somatic Cell Score, and Milk Yield in Latxa Sheep. J Dairy Sci 88, 2238-2245

Lund T, Miglior F, Dekkers JCM, Burnside EB (1994) Genetic relationships between clinical mastitis, somatic cell count, and udder conformation in Danish Holsteins. Livest Prod Sci 39, 243-251

Milán MJ, Caja G, González-González R, Fernández-Pérez AM, Such X (2011) Structure and performance of Awassi and Assaf dairy sheep farms in northwestern Spain. J Dairy Sci 94, 771-784

Pedrosa S, Arranz JJ, Brito N, Molina A, San Primitivo F, Bayón Y (2007) Mitochondrial diversity and the origin of Iberian sheep. Gen Sel Evol 39, 91-103

Pérez-Cabal MA, Alenda R (2003) Lifetime Profit as an Individual Trait and Prediction of its Breeding Values in Spanish Holstein Cows. J Dairy Sci 86, 4115-4122

Riva J, Rizzi R, Marelli S, Cavalchini LG (2004) Body measurements in Bergamasca sheep. Small Rumin Res 55, 221-227

Roughsedge T, Brotherstone S, Visscher PM (2000) Effects of cow families on type traits in dairy cattle. Anim Sci 70, 391-398

Rupp R, Lagriffoul G, Astruc JM, Barillet F (2003) Genetic Parameters for Milk Somatic Cell Scores and Relationships with Production Traits in French Lacaune Dairy Sheep. J Dairy Sci 86, 1476-1481

Sagi R, Morag M (1974) Udder conformation, milk yield and milk fractionation in the dairy ewe. Ann Zootech 23, 185-192

Seykora AJ, McDaniel BT (1986) Genetics Statistics and Relationships of Teat and Udder Traits, Somatic Cell Counts, and Milk Production. J Dairy Sci 69, 2395-2407

Simon DL (1999) European approaches to conservation of farm animal genetic resources. Anim Gen Res Inf 25, 77-97

Traoré A, Tamboura HH, Kabore A, Royo LJ, Fernández I, Álvarez I, Sangare M, Bouchel D, Poivey JP, Francois D, Sawadogo L, Goyache F (2008) Multivariate analyses on morphological traits in goats in Burkina Faso. Arch Tierz 51, 588-600

Ugarte E, Ruiz R, Gabiña D, Beltrán de Heredia I (2001) Impact of high-yielding foreign breeds on the Spanish dairy sheep industry. Livest Prod Sci 71, 3-10

Ugarte E, Serrano M, de la Fuente LF, Pérez-Guzmán MD, Alfonso L, Gutiérrez JP (2002) [Current status of genetic improvement programs in sheep milk]. ITEA 98, 102-117 [in Spanish]

Vukasinovic N, Moll J, Künzi N (1997) Factor analysis for evaluating relationships between herd life and type traits in Swiss Brown cattle. Livest Prod Sci 49, 227-234

Zar JH (1999) Biostatistical Analysis. 4th ed. Prentice Hall, Upper Saddle River, NJ, USA