Morphological differentiation between two Moroccan goat breeds

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Abstract The objective of this study was to identify morphological measurements that best distinguish Moroccan Barcha and Atlas goat breeds. Ten measurements (body weight - BW, body length - BL, heart girth - HG, withers height - WH, rump height - WH, back length - BAL, neck length - NL, head length - HL, ear length - EL, and ear width - EW) of 876 adult animals of both sexes (547 Barcha and 329 Atlas) were studied. Average BW, HG and WH of Barcha goats were 37.4±11.1 kg, 75.0±5.26 cm and 71.8±3.41 cm, respectively. The corresponding values for Atlas goats were 38.8±8.92 kg, 76.2±5.56 cm and 72.3±4.11 cm, respectively. Most correlations were positive and significant, BW with BL (0.87) and BW with HG (0.91) being the highest for Barcha and Atlas breeds, respectively. The multivariate analysis of variance revealed significant ($P<0.001$) differences in the morphological traits of Barcha and Atlas breeds. Variance components analysis showed that between-breed variability explained 11.26% of total variance. The factor analysis extracted two factors with a total variance of 66.9%. The first factor had high loadings for BW (0.93), BL (0.88), HG (0.87) and WH (0.90), whilst the second factor had high association with EW (0.80) and EL (0.79). Results of the stepwise discriminant analysis showed that out of 10 variables considered, six were found to be the most discriminant characters. The Mahalanobis distance of the morphological traits between Barcha and Atlas was 3.832 ($P<0.001$). The developed discriminant function clearly discriminated and classified the Barcha and the Atlas goats into their breeds of origin, thus yielding after a cross-validation 87.2% and 78.1% correctly assigned to their source genetic group. It was concluded that there was a clear separation between Barcha and Atlas goats.

Keywords: goats, Barcha breed, Atlas breed, morphological trait, discriminant analysis

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Introduction

Goats form the second largest of livestock species in Morocco with about 5601500 animals in 2012. They are an important livestock species in the socio-economic lives of Moroccan farmers. Local goats are mainly raised for meat production, but some high milking does are also milked for self consumption, with this regard goats are considered as the cows of poor farmers. Little work has been done on Moroccan goats. Until recently, goats were marginalized compared to sheep. Even the ANOC (National Association for Sheep and Goats), which is supposed to be equally interested in sheep and goats, has ignored the latter species for many years. It is only recently that the ANOC became interested in this species. Moreover, only three major populations were identified in Morocco. They were mainly named according to their geographic location or production system: Black population, Northern population and Draa population. These populations have ability to tolerate harsh climates, suitability to poor systems because of their small size, ability to thrive on poor quality diets, low water turnover and thus good resistance to water stress (Hossaini-Hilali and Benlamlih, 1995). During the last few years, some populations have been officially recognized within the Black population. These are Atlas, Barcha and Ghazalia populations, which have some phenotypic similarities but also some differences. Goat populations in Morocco have not been characterized and are still genetically unimproved. There is therefore an urgent need to characterize these goat populations and to quantify differences between them in order to provide information for successful breeding improvement programs.

Information on morphological characteristics is a prerequisite to sustainable breed improvement, utilization and conservation (FAO, 2012). Multivariate analyses of morphological traits have been proved to be suitable in assessing the variation within a population and can discriminate different population types when all measured morphological variables are considered simultaneously. These kinds of studies were commonly reported in goats (Jordana et al., 1993; Herrera et al., 1996; Capote et al., 1998; Dossa et al., 2007; Zaitoun et al., 2005).

The objectives of this study were to morphologically characterize the Bacha and the Atlas goat breeds. Results obtained from this study would provide information useful to contribute to the establishment of breed standards and to be utilized as criteria for describing breeds and differentiating between them.

Material and methods

Data collection

The study was carried out on 876 goats of Barcha (547 animals) and Atlas (329 animals) local breeds. Both sexes were included in the study (94.9% females and 5.1% males). Animals were of adult age since all of them have 4, 6 or 8 permanent incisors. The goats originated from different flocks and were reared under the traditional extensive system. Data were collected from January to March 2009 at Moulay Bouazza region (Middle Atlas) in 23 flocks. Eight breeders raised Barcha goats only, nine breeders raised Atlas goats only and six breeders had a mixture of both breeds with different proportions.

Studied traits

Morphological measures taken on each animal were body weight (BW), body length (BL, distance from the point of the shoulder to the pin bone), heart girth (HG, perimeter of the chest just behind the front legs and withers), withers height (WH, height from the withers to the ground), rump height (WH, height from the rump to the ground), back length (BAL, distance between withers and rump), neck length (NL, distance from the base of the skull to the point of connection with the trunk), head length (HL, frontal distance from poll to the lower lip), ear length (EL, distance from the base to the tip of the ear along the dorsal surface) and ear width (EW, maximum distance at the middle of the ear) (Yakubu et al., 2010; Ebegbulem et al., 2011; Okpeku et al., 2011). All measurements were taken using flexible tape (with records taken to the nearest cm), except for withers height and rump height that were taken by graduated measuring stick and calibrated wooden calliper, and body weight that was measured using a dynamometric scale of 100 kg capacity. When measured, animals were put on a flat floor with the head held up, while restricting the animal by holding. Morphological measurements were taken from the right side of the animal. All measurements were taken early in the morning before grazing or receiving feed in order to avoid undesirable variations due to weight and rumen volume change.

Statistical analyses

The statistical analyses were carried out using the SAS/STAT package (2002). Data were first analyzed using MEAN and FREQ procedures to obtain descriptive statistics for morphological traits studied and frequency distribution of data. The PROC CORR was used to compute the Pearson correlations between traits. The effect of breed on body measurements was assessed using GLM procedure through the multivariate 4-way analysis of variance, fitting a mixed model that included the fixed effects of breed (Barcha and Atlas), age (4, 6 and 8 permanent incisors), sex (female and male) and the random effect of flock. All interactions were assumed to be unimportant, and therefore excluded from analysis. Difference between breeds was assessed using linear contrasts. The VARCOMP procedure was used to assess the proportion of the between-breed variability by fitting the same model as previously, but breed effect was considered as random. The FACTOR procedure was used to perform factor analysis, which is a data reduction technique that combines measurements into uncorrelated components. The stepwise discriminant analysis was applied using PROC STEPDISC to identify the morphological traits that have more discriminant power than others in separating the breeds. The significance level applied for retaining or adding a variable was 0.05. The CANDISC procedure was used to perform canonical discriminant analysis for deriving canonical functions, which are linear combinations of body measurements that summarize variation between breeds, and for calculating the squared Mahalanobis distance necessary for the differentiation between breeds. The DISCRIM procedure was applied to perform discriminant analysis to estimate the proportion of animals that were properly classified into their original breed. The percentage of misclassified animals indicates the degree of admixture between the breeds. Predictor variables introduced into the canonical discriminant and discriminant analyses were those body measurements retained following the stepwise discriminant analysis. The PROC GPLOT was used to plot the animals into the canonical variables.

Results

Arithmetic means for morphological traits of goats by breed and sex are shown in Table 1. Body measurements suggest that both breeds are of medium size. Their measurements were similar, with a slight advantage for Atlas breed, except for ear length and ear width that were larger for Barcha breed. Coefficients of variation were small and less than 10% for all traits of both breeds, except for body weight of Barcha breed. They varied from 1.33% for ear width to 11.1% for body weight in Barcha goats, and from 2.06% for ear length to 8.92% for body weight for Atlas breed. Differences exist between males and females for body measurements, except in ear traits. Overall, the sexual dimorphism (M/F) averaged 1.08 in both breeds. Barcha and Atlas males were 28% and 23% heavier than females, respectively. Based on results of MANOVA analysis for body measurements, Barcha and Atlas breeds were morphologically significantly different (P<0.001). Variance components analysis showed that the overall between-breed variability explained 11.3% of total variance, varying from 0 for rump height and back length to 45.5% for ear width.

Pearson's coefficients of correlation among morphological measurements of the two breeds are shown in Table 2. Out of 45 correlations, 28 and 32 were significant (P<0.001) in Barcha and Atlas breeds, respectively. All correlations were positive and medium to high, except those that included ear length and ear width that were weak and sometimes negative. For Barcha goats, correlation coefficients varied from -0.03 between heart girth and ear length to 0.87 between body weight and body length, whereas for Atlas goats, they ranged from -0.04 between back length and ear width to 0.91 between body weight and heart girth.

The Kaiser's Measure of Sampling Adequacy (MSA) value was 0.86. It varied from 0.48 (ear length) to 0.92 (neck length). Two factors with eigenvalues greater than 1 were extracted. The factors 1 and 2 accounted for 53.5% and 13.4%, respectively, making 66.9% of the total variance, while subsequent factors contributed with less than 9% each (Table 3). The factor 1 assigned positive coefficients to all body measurements, except EL and EW for which it gave negative values. The factor 2 assigned positive coefficients to all morphological traits except BW, HG, WH and BAL for which it gave negative coefficients. The highest relative contributions to factor 1 were BW, BL, HG and WH, and those highly contributing to factor 2 were EW and EL (Figure 1). Thus, the factor 1 axis gave a major relevance to the variables related to heavier body weight and greater size of goats, while the factor 2 could be linked to their ear length and ear width. Variables' communality, which represents the proportion of variance of each of the 10 variables shared by all remaining body measurements, was medium to high, and ranged from 0.26 for HL to 0.87 for BW.

Based on the stepwise discriminant analysis, six of the ten body measurements were the most discriminant traits between Barcha and Atlas goats; EW, EL, BW, BAL, BL and NL. Their partial R^2 values were 0.31, 0.19, 0.03, 0.01, 0.01 and 0.01, respectively. Therefore, only these variables were retained for subsequent analyses.

The Mahalanobis distance between Barcha and Atlas breeds was 3.832 (P<0.001). Only one statistically significant (P<0.001) canonical variable was identified through the canonical discriminant analysis. The canonical correlation was equal to 0.688. The resulting R^2 values were 0.032, 0.027, 0.002, 0.001, 0.270 and 0.307 for BW, BL, BAL, NL, EL and EW, respectively. The canonical function differentiating between Barcha and Atlas goats was as follows:

CAN1= -0.0697BW-0.1976BL+0.2045BAL+ 0.2477 NL+ 1.5927EL+ 3.7506 EW

The canonical means of Barcha and Atlas goats were 0.735 and -1.222, respectively. These values indicated that Barcha breed could best discriminated by CAN1, and differed markedly in body measurements from Atlas breed. Figure 2 shows that the CAN1 separated clearly between Barcha and Atlas breeds. It also shows that the Barcha individuals were the most homogeneous, and clustered together on the right hand of the CAN1; the Atlas animals were mainly distributed on the negative values of the CAN1.

The discriminant analysis showed that 83.7% of animals were correctly classified, leaving a 16.3% rate of error. Further, 88.7% of Barcha animals were correctly classified, but Atlas breed does more with a 21.3% misclassified animals. The use of cross-validation option provided a better assessment of classification accuracy. Thus, every data point was reclassified as if it were a new unknown observation; this provided a more conservative accuracy assessment (Table 4). The examination of misclassified animals may be carried out to determine why they did not classify as expected.

Discussion

Body measurements of Barcha and Atlas goats were

Table 1. Arithmetic means and coefficients of variation (%) for morphological traits of females and males of Barcha and Atlas goats

Trait[a]	Barcha					Atlas				
	F	M	Total	CV	M/F	F	M	Total	CV	M/F
BW (kg)	36.9	47.2	37.4	11.1	1.28	38.3	47.3	38.8	8.92	1.23
BL (cm)	98.7	102.5	98.9	2.67	1.04	99.5	103.6	99.8	2.32	1.04
HG (cm)	74.7	81.9	75.0	5.26	1.10	75.6	84.9	76.2	5.56	1.12
WH (cm)	71.4	79.8	71.8	3.41	1.12	71.6	82.0	72.3	4.11	1.14
RH (cm)	71.0	79.5	71.4	3.85	1.12	70.8	81.2	71.4	4.60	1.15
BAL (cm)	60.7	63.5	60.8	3.36	1.05	60.9	63.0	61.0	3.60	1.03
NL (cm)	31.8	33.6	31.9	2.60	1.06	31.8	33.3	31.9	2.74	1.05
HL (cm)	24.0	25.7	24.1	2.17	1.07	24.0	25.7	24.1	2.79	1.07
EL (cm)	21.0	21.0	21.0	1.69	1.00	20.5	20.5	20.5	2.06	1.00
EW (cm)	8.80	8.80	8.80	1.33	1.00	8.54	8.62	8.54	3.13	1.01

[a] BW: body weight, BL: body length, HG: heart girth, WH: withers height, RH: rump height, BAL: back length, NL: neck length, HL: head length, EL: ear length, EW: ear width.
F: female, M: male, Total: both sexes, M/F: sexual dimorphism.

Table 2. Correlation coefficients among body measurements of Barcha (below diagonal) and Atlas (above diagonal) goats

Trait[a]	BW	BL	HG	WH	RH	BAL	NL	HL	EL	EW
BW		0.83***	0.91***	0.85***	0.70***	0.70***	0.63***	0.43***	0.03NS	0.06NS
BL	0.87***		0.80***	0.71***	0.57***	0.82***	0.66***	0.37***	0.02NS	0.04*
HG	0.77***	0.71***		0.78***	0.64***	0.70***	0.60***	0.36***	0.03NS	0.04*
WH	0.82***	0.67***	0.71***		0.86***	0.56***	0.59***	0.55***	0.03NS	0.06NS
RH	0.72***	0.60***	0.62***	0.87***		0.46***	0.51***	0.53***	0.06NS	0.07*
BAL	0.76***	0.86***	0.70***	0.65***	0.59***		0.49***	0.22***	0.03NS	-0.04*
NL	0.65***	0.68***	0.59***	0.64***	0.5***	0.57***		0.33***	0.04NS	0.03NS
HL	0.37***	0.20***	0.25***	0.48***	0.43***	0.19***	0.34***		0.01NS	0.08NS
EL	0.02NS	0.02NS	-0.03NS	-0.01NS	-0.01NS	0.0NS	0.02NS	0.00NS		0.05NS
EW	0.08NS	0.10NS	0.09NS	0.0NS	0.09NS	0.11NS	0.06NS	0.03NS	0.04NS	

[a] BW: body weight; BL: body length; HG: heart girth; WH: withers height; RH: rump height; BAL: back length; NL: neck length; HL: head length; EL: ear length; EW: ear width
NS: P>0.05, * P<0.05, ***P<0.001

Table 3. Factor pattern and communality of the body measurements with factors 1 and 2 in Moroccan goats

Trait	Factor pattern		Communality
	Factor 1	Factor 2	
Body weight	0.93	-0.07	0.87
Body length	0.88	-0.10	0.79
Heart girth	0.87	-0.07	0.76
Withers height	0.90	0.05	0.82
Rump height	0.82	0.14	0.68
Back length	0.81	-0.04	0.66
Neck length	0.76	0.06	0.58
Head length	0.49	0.15	0.26
Ear length	-0.05	0.79	0.63
Ear width	-0.01	0.80	0.65
Eigenvalues	5.35	1.34	
Percentage of total variance	53.5	13.4	

medium. Values found in this study were higher than those reported by Ibnelbachyr et al. (2015) for the same breeds and other Moroccan goat breeds. These differences may be explained by the period within which the measurements were realized. In the current study, measurements were taken during a rainy year and season characterized by the grass availability on pastures. Using the morphological measurements, some zoometric

Table 4. Actual and cross-validated numbers and percentages of Moroccan goats classified into breed

		Breed	Barcha	Atlas	Total
Actual	Number	Barcha	485	62	547
	%		88.7	11.3	
	Number	Atlas	70	259	329
	%		21.3	78.7	
Cross-validated	Number	Barcha	477	70	547
	%		87.2	12.8	
	Number	Atlas	72	257	329
	%		21.9	78.1	

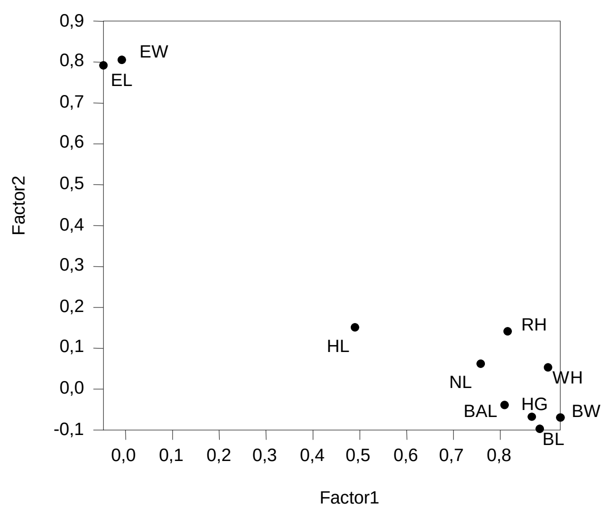

Figure 1. Association among morphological variables of Moroccan goats assessed by factor analysis

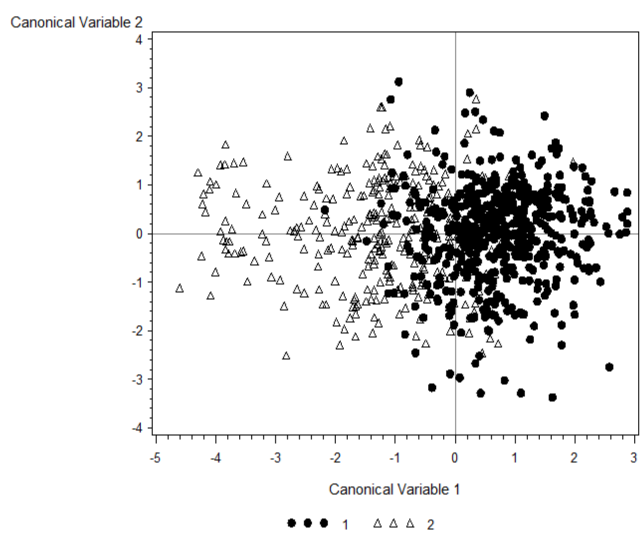

Figure 2. Canonical representation of the local Moroccan goats breeds using the morphological variables (1: Bracha, 2: Atlas)

indices were computed. The body index (Body length / Heart girth) of these two breeds was higher than 0.90 indicating that animals are longiline. The height index (Withers height / Body length) was lower than 1 suggesting that these breeds can be classified as ectomorphic since the body length is greater than the withers height. The height slope (Withers height - Rump height) revealed that the back of animals is straight, with a slight descending rump for Atlas goats.

The body measurements of both breeds presented coefficients of variation lower than 10%, except for body weight of Barcha breed. The coefficient of variation for the variables was similar to those found by Dossa et al. (2007) in the study of goat populations in Western Africa (6.3% for height at withers, 10.5% for ear length, and 11.1% for thorax depth).

The overall sexual dimorphism (M/F) averaged 1.08 in both breeds, indicating low sexual dimorphism. This means that differences in skeletal size and body mass between males and females of the current study were not so important. Okpeku et al. (2011) stated that the influence of sex on the body weight and morphometric traits are likely connected with the usual between-sex hormonal action which leads to differential growth rates.

Through MANOVA, significant morphological differences were observed between population means of Barcha and Atlas breeds, with a small advantage for the latter one. These differences were not expected since both breeds presented some highly similar phenotypic characteristics and were considered for a long time as belonging to the same Black population. Pirez et al. (2013) concluded that the rejection of hypothesis that the population mean vectors are equal justifies the use of other multivariate techniques aimed at size reduction or the discarding of variables.

The between-breed variability explained 11.3% of total variance suggesting that most variability between Barcha and Atlas breeds was due to within-breed differences. The between-breed variability varying from 0.0 to 45.5% indicated that some measurements were similar for both breeds, but some others, which differentiate between the two breeds, were different. Aziz and Al-Hur (2013) estimated the between-breed variability of three Saudi goat types to 27%. They explained that the residual variance may be attributed to random, environmental or ontogenetic factors.

All correlations were positive and medium to high, except those that included ear length and ear width that were weak and sometimes negative. Moreover, 28 and 32 correlations in Barcha and Atlas breeds, respectively out of 45 correlations were significant ($P<0.001$). The high number of significant positive correlations among body measurements confirmed the high degree of harmony in the morphology model of Barcha and Atlas goats. Furthermore, as it is frequently reported in growth studies (Yakubu, 2009; Okpeku et al., 2011; Ibnelbachyr et al., 2015; Pares Casanova, 2015), strong correlations between body weight and morphometric traits were observed. This indicates that traits such as BL, HG, WH and RH may be effective in predicting body weight, and their selection can lead to the improvement of body weight. The present correlation estimates are in the range of values recorded for goats in earlier studies (Yakubu, 2009; Okpeku et al., 2011; Ibnelbachyr et al., 2015; Pares Casanova, 2015). Additionally, the high correlations among body measurements in the current study are precondition for the application of principal component analysis.

The factor analysis extracted two factors that accounted for 66.9% of the total variance. The factor 1 gave a major relevance to the variables related to heavier body weight and greater size of goats, whereas the factor 2 could be linked to their ear length and ear width. Okpeku et al. (2011) extracted two factors for each sex of West African Dwarf and Red Sokoto goats accounting for 94.15% and 97.65% of the total variance for females and males, respectively of West African Dwarf and 79.89% and 86.38% of the generalized variance of females and males, respectively of Red Sokoto. They termed the first factor as "body size factor" and the second factor as "neck factor". Pares Casanova (2015) showed that the first two factors explained more than 90% of the total variance of eleven goat breeds of different origin (10 Spanish and 1 African).

Based on the stepwise discriminant analysis, six body measurements (EW, EL, BW, BAL, BL and NL) were the most discriminant traits between Barcha and Atlas goats. This indicates that taking these measurements was more important than acquiring numerous additional measurements. Ear width and ear length were the most discriminant traits between the two breeds. In fact, the ear size was different between the two breeds. Ears of Barcha were larger and more pendulous than those of Atlas goats. Ibnelbachyr et al. (2015) reported that the most discriminating traits between the Moroccan goat populations were body length, heart girth, hair length, horn length, ear length and live body weight. Zaitoun et al. (2005) indicated that nose shape was the most discriminating variable among different native goat breeds of Jordan, followed by withers height then body weight and ear type. Yakubu et al. (2010) revealed that rump height, body length, horn length, face length, chest girth, neck circumference and head width were the most important morphometric traits permitting discrimination between West African Dwarf and Red Sokoto goats in Nigeria. Jimcy et al. (2011), working on goat populations from India, found that the most discriminant variables selected by stepwise procedure were head width, height at withers, chest depth, rump length, rump width, shin circumference and body length. Aziz and Al-Hur (2013) reported that ear length and canon circumference were the most discriminative variables among the three Saudi goat breeds, namely Ardi, Line1 and Line2. From the canonical discriminant analysis, Ebegbulem et al. (2011) extracted six variables as strong discriminant variables: rump height was the best discriminant variable, followed by body weight, heart girth, body length, and foreleg length in that order.

The Mahalanobis distance between Barcha and Atlas breeds was 3.832 (P<0.001) suggesting that the two breeds were morphologically different. Yakubu et al. (2011) reported Mahalanobis distance of 72.28 between West African Dwarf and Red Sokoto goat breeds, indicating that there is considerable genetic variation between them. Aziz and Al-Hur (2013) reported that the distance between Line1 and Line2 was the closest (0.55), i.e. they were poorly differentiated from each other, while distances between Ardi and each of Line1 and Line2 were larger, accounting for 25.03 and 21.44 between Arid and each of Line1 and Line2, respectively.

Only one statistically significant (P<0.001) canonical variable was identified through the canonical discriminant analysis. Zaitoun et al. (2005) reported that CAN1 accounted for 82.4% of the total variation, followed by CAN2 which represented 10.7% of the total variation. Nose shape in addition to withers height, foreleg height and rump height dominated CAN1, while shin circumference showed the largest influence on CAN2 (Zaitoun et al., 2005).

Overall, 17.3% of the animals of both breeds were misclassified. The high percentage of accurate classification of the individual goats into their respective breeds indicates that the discriminant function accurately classified the individual goats into their respective breeds, and hence may help in selective breeding in future breeding programmes. Traore et al. (2008) correctly allocated 79.3% of Sudan and 82.7% of Sudan-Sahel goat populations of Burkina Faso into their source population. Likewise, Dossa et al. (2007) correctly classified more than 70% of goats from Benin into their different populations. Hirbo et al. (2006) concluded that the low assignment rates may indicate either high gene flow or low power to assign because of too few variables used in analysis.

Conclusions

Based on morphometric traits, there was clear separation between Barcha and Atlas goat breeds. The BW, BL, BAL, NL, EL and EW were the most discriminanting characters in separating the breeds. However, the low Mahalanobis distance between Barcha and Atlas at the morphological level could be due to the genetic exchange that has taken place between these breeds. These results may be valuable for genetic improvement and may help in preserving the local goat breeds. However, the genetic characterization using genetic markers is needed to consolidate information arising from morphological differentiation.

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