Morphostructural variability in the Pastoreña goat in different regions of the Mixteca of México: A phenotypic study to establish the racial profile

Variabilidad morfoestructural en la cabra Pastoreña en diferentes regiones de la Mixteca de México: Un estudio fenotípico para establecer el perfil racial

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Abstract

In the present study, we evaluated the morphostructural variability of the Pastoreña goat (PG) in Mixteca region of Oaxaca, Mexico. This study was carried out to evaluate five qualitative ranges and thirteen morphometric characteristics of 249 animals (185 females and 64 males) from 2 to 5 years old. Descriptive statistics analysis was performed on the qualitative (QV) morphometric (MV) variables, and variance analysis and Tukey test by sex. The Pearson correlations were calculated for MV, determining the morphostructural harmonic model. The canonical discriminant analysis and analysis of principal coordinates were made for QV and principal component analysis for MV. The results of QV indicated some features in the racial profile of the PG. MV showed sexual dimorphism ($p<0.05$). The coefficient of variation indicated morphostructural homogeneity. The correlations in MV suggest harmonic-morphostructural and harmonic-median models for females and males, respectively. The multivariate analysis showed similarities in the sampled localities. In conclusion, the qualitative and quantitative variables demonstrated in the PG characterize as a unique goat breed in the Mixteca of México and justify further conservation efforts.

Keywords
native goat • transhumance •pastoralism

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Resumen

En el presente estudio, evaluamos la variabilidad morfoestructural de la cabra Pastoreña (CP), en la región de la Mixteca, Oaxaca, México. El estudio se realizó para evaluar cinco rangos cualitativos y trece características morfológicas de 249 animales (185 hembras y 64 machos) de 2 a 5 años de edad. Se realizó un análisis estadístico descriptivo de las variables cualitativas (VQ) y morfométricas (VM), análisis de varianza y la prueba de Tukey por sexo. Las correlaciones de Pearson se calcularon para VM, determinando el modelo armónico morfoestructural. El análisis canónico discriminante y el análisis de las coordenadas principales se realizaron para QV y análisis de componentes principales para VM. Los resultados de las VQ indicaron algunas características en el perfil racial de la CP y las VM mostraron dimorfismo sexual ($p < 0,05$). El coeficiente de variación indicó homogeneidad morfoestructural. Las correlaciones en VM sugieren modelos armónicos-morfoestructurales y armónicos-medianos para las hembras y machos, respectivamente. El análisis multivariado mostró similitudes en las localidades muestreadas. Como conclusión, las variables cualitativas y cuantitativas demostradas en la CP se caracterizan como una raza única de cabra en la Mixteca de México y justifican mayores esfuerzos de conservación.

Palabras clave
cabra nativa • trashumancia • pastoralismo

Introduction

The data bank for animal genetic resources (AnGR) of FAO (2007) is an essential source of information necessary for maintaining appropriate conservation programs and provides a framework for the management of livestock biodiversity. In this context, FAO has provided support since 1960 to countries to characterize and conserve native livestock breeds. They have committed to establish the Domestic Animal Diversity Information System (DAD-IS) as a mechanism to exchange information about native races to facilitate the management of the AnGR. The system creates access to a database that facilitates the efficient distribution of guidelines and documents worldwide.

México has a population of native goats known in Spanish as "Pastoreña goat (PG)" that are bred by shepherds who inhabit the Mixteca region in the states of Puebla and Oaxaca. Historical data indicate that the breeding of these goats' dates from around 1560, subsequently establishing three groups of herds known as stratum: *señorios*, *nobles*, and *macules*. In the 17th-century, livestock husbandry intensified with goat herds being raised on communal lands abundant in shrubs or trees. From 1585 to 1595, the production of sheep and goats was approximately 150,000 animals, remaining stable throughout the 19th century up to the agricultural livestock census of 1970 (7).

The research in the Mixteca goats are few, a study conducted by Ramirez *et al.* (2014) indicates the presence of 2 production systems, the first is the transhumant, with herds formed by more than 800 animals, predominantly

the white phenotype and feeding only with continuous grazing given in large regions. The second is a system. The second system is heterogeneous; the phenotypes of goats are brown, black, white and their combinations. The herds are fed with grazing and agricultural supplements, and there is the nocturnal confinement in pens. Particularly in the Mixteca of Oaxaca, the research by our research group focused on the first system, predominantly pastoral goats with individual herds from 900 to 1500 animals. The study was conducted in flocks with around 1000 PG with uniform phenotypic characteristics in the transhumance system.

The phenotypic characterization of animals in a specific region identifies the attributes of a race in the production system environment (25, 31), but there is only one study describing the breed limitedly (26). Therefore, it is necessary to demonstrate that the study population can be categorized as a homogeneous group (5). In this context, it is essential to define a set of qualitative and morphometric variables that characterize the phenotype of the AnGR population under study to establish standards that distinguish it from other races (30, 32). While molecular genetic characterization provides a better definition of race, phenotypic variables are also important (17). Therefore, multivariate analysis that includes the discriminant method, analysis of principal coordinates, main components, cluster analysis and correlations could provide data to establish identity traits of a race (16, 20, 22, 24), both as a descriptive tool and to form models of AnGR (1, 31) essential for conservation programs of a breed.

The study was motivated under the hypothesis that the phenotypic values of PG may be unique, giving a total adaptation of breeding in the adverse environmental conditions of the Mexican Mixteca. The shepherds preserve them as a race free of crosses with exotic breeds. Therefore, the objective of this study was to document the variability that occurs in the Mixteca regions on the qualitative and quantitative traits of PG.

Material and methods

Animals and Location

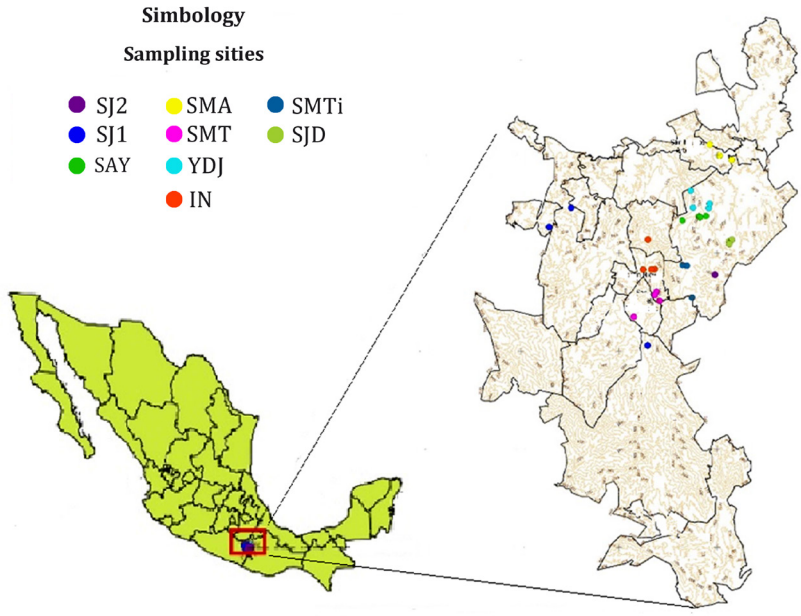
México has a population of 8,754,204 goats (6), with 1,251,734 found in state of Oaxaca, concentrated mainly in the Mixteca region, where there are herds of PG that are mostly of a specific lineage, characterized by white or cream color, robust physique, thin limbs and capable of grazing in rocky, inaccessible terrain (figure 1, page 363). Individual herds include 100 to 1500 animals. All graze on communal lands, but the large herds are raised in a transhumance system, while the small herds are taken out to feed during the day and at night confined to pens. Their primary zootechnical function is meat production; the adult males and old females are commercialized from July to October to be prepared in a native dish known as *Chito* and *Mole de Cadera*. Milk production is not the main activity, but occasionally the shepherds who care for and are living with herds in the transhumance system, drink milk and make cheese for self-consumption.

The study was conducted during the summer of 2017, in the Mixteca of Oaxaca, México and included 9 places in 3 regional districts (figure 2, page 363) with the following characteristics:

Region 1: Huajuapan de León is at coordinates 17°48'00" N 97°46'00" W. Region 2: Silacayoapan is at coordinates 17°30'00" N 98°08'00" W.

Region 3: Santiago Juxtlahuaca is at coordinates 17°43'00" N 97 ° 19'00" W.

Figure 1. A flock of goat pastoreña in the Mixteca of Oaxaca, México.
Figura 1. Rebaño de la cabra pastoreña en la Mixteca de Oaxaca, México.



SJ1 = Santiago Juxtlahuaca 1, SJ2 = Santiago Juxtlahuaca 2, SAY = San Andrés Yutatío, SMA = San Marcos Arteaga, SMT = San Miguel Tlacotepec, YDJ = Yucuñuti de Juárez, IN = Ixpantepec Nieves, SMTi = Santa María Tindú, SJD = San Juan Diquiyú.

Figure 2. Geographical map of the sampling places in the Mixteca of Oaxaca, México.
Figura 2. Mapa geográfico de los lugares de muestreo en la Mixteca de Oaxaca, México.

The area varied between 1200-2730 meters above sea level and included different microclimates from semi-warm sub-humid to semi-dry semi-warm. The maximum temperature in the summer is 22°C and the minimum in the winter of -3°C (13).

Sample calculation

Two hundred and forty-nine animals (185 females and 64 males) of 2-5 years (measured by dentition) were selected using non-probability sampling methods, which was purposive sampling and snowball sampling. The sample size was calculated equally in each of the 3 regions, using the following formula:

$$n=(Z^2_{\alpha/2}*p*q)/i^2$$

where:

$Z^2_{\alpha/2}$ = the value of the percent confidence level (95%)

i = the margin of error in decimals (0.1)

p = the estimated value for the proportion of the sample that will respond a given way to an expected value (0.90)

q i= equal to $1-p$ (0.1) (5).

Qualitative variables

In the study, the qualitative variables (QV) suggested by the FAO (2007) were evaluated (table 1, page 365).

Quantitative Variables - Morphometric

Thirteen quantitative - morphometric variables (MV) were recorded in centimeters (cm) according to the FAO (2012): Head length (HL), head width (HW), face length (FL), height at withers (HAW), body length (BL), height at rump (HAR), rump length (RL), rump width (RW), chest girth (CG), chest depth (CD), chest width (CW), shoulder point width (SPW), shin circumference (SC), and live weight (LW) in kilograms (kg).

Statistical analysis

The numerical codes (table 1, page 365) obtained from the QV were processed and analyzed, as recommended by Jordana *et al.* (1993). Descriptive statistics analysis was performed on the qualitative (QV) and morphometric (MV) variables. The morphometric indexes (MI) were calculated with MV of each sex, and these data were analyzed using the following fixed effect model:

$$Y_{\beta i} = \mu + S_i + e_{\beta i}$$

where:

$Y_{\beta i}$= individual data

μ = fixed overall mean

S_i = effect of sex (i = male, female)

$e_{\beta i}$= experimental error, assumed to be independently, normally distributed, with zero-mean and constant variance.

Differences between means were accessed using Tukey's Test by sex, and the Pearson´s coefficients of correlation were calculated for MV and MI to determine the morphostructural harmonic model. Data were generated from the correlation matrix; Kaiser-Meyer-Olkin measures of sampling and Barlett´s test of sphericity were computed to validate the analysis factor of the data sets. Stepwise discriminant procedure was used to identify morphological characters with high discriminatory power using the sex factor as the separating variable. The canonical discriminant analysis (CAN) and principal coordinates (PCoA) were made in QV; CAN and principal component analysis (PCA) in MV were obtained (8). All analysis was carried out using the InfoStat software (2).

Table 1. Numeric code for each variant within the qualitative variables to generate the qualitative matrix.

Tabla 1. Código numérico para cada variante dentro de las variables cualitativas para generar la matriz cualitativa.

Trait	Code		
	0	1	2
Coat			
Color	White	Cream	Black
Type	Glossy	Dull	
Texture	Soft	Rough	
Pattern	Straight	Wavy	Curly
Length	Short	Medium	Long
Hair Cover *			
Shorts	Present	Absent	
Bun	Present	Absent	
Raspail	Present	Absent	
Pelisse	Present	Absent	
Tassels	Present	Absent	
Beard	Present	Absent	
Pigmentation			
Skin	Present	Absent	
Mucous	Present	Absent	
Hoof	Present	Absent	
Horns	Present	Absent	
Shape	Arched	Spiral	Straight
Orientation	Spiral up	Spiral back	Lateral
Ears			
Size	Small	Medium	Big
Orientation	Erect	Semi-pendulous	Pendulous
Facial profile	Concave	Straight	Convex

* Shorts = long hair growth in hindquarters, Bun = long hair growth around neck, Raspail = long hair growth on dorsal region, Pelisse = long hair growth on shoulder point width.

Calzón=Crecimiento de pelo largo en cuartos traseros, Arropo=crecimiento de pelo largo alrededor del cuello, Raspil=Crecimiento de pelo largo en la región dorsal, Pelliza=crecimiento de pelo largo en el pecho.

Results and discussion

Qualitative variables

Table 2 (page 366) shows the relative frequencies (%) of QV in the PG population. The variables evaluated in most of the population showed homogeneity, demonstrating typical characteristics of PG contrary to other studies carried out in some Mixteca regions (10, 26) and in America where Creole goats exhibited variable characteristics (8, 9, 28).

The color white was the main feature that identified the PG, predominating as afeature of breeding selection (15).

Table 2. Frequencies (%) of qualitative variables by sex in the Pastoreña goat population.
Tabla 2. Frecuencias (%) de variables cualitativas por sexo en la población de cabra Pastoreña.

Females			Males		sig.	Females			Males		sig.
Trait	**AF**	**RF**	**AF**	**RF**	**sex**	**Trait**	**AF**	**RF**	**AF**	**RF**	**sex**
Coat Color						Beard					***
					**	Present	118	63.8	64	100	
White	130	70.30	59	92.19		Absent	67	36.2	0	0	
Cream	55	29.71	5	7.81		Pigmentation					
Type					ns	Skin					ns
Glossy	142	76.80	50	78.13		Present	85	45.90	28	43.80	
Dull	43	23.20	14	21.88		Absent	100	54.10	36	56.30	
Texture					ns	Mucous					ns
Soft	142	76.80	50	78.13		Present	119	64.31	46	71.88	
Rough	43	23.20	14	21.88		Absent	66	35.70	18	28.13	
Pattern					*	Hoof					ns
Straight	171	92.41	53	82.81		Present	3	1.62	4	6.25	
Wavy	12	6.49	9	14.06		Absent	182	98.40	60	93.80	
Curly	2	1.08	2	3.13		Horns					ns
Length					***	Present	177	95.70	60	93.80	
Short	47	25.41	8	12.50		Absent	8	4.32	4	6.25	
Medium	138	74.60	45	70.31		Shape					***
Long	0	0	11	17.19		Arched	172	97.18	4	6.67	
Hair cover Short						Spiral	4	2.26	56	93.30	
					*	Straight	1	0.56	0	0	
Present	2	1.08	4	6.25		Orientation					ns
Absent	183	98.91	60	93.80		Spiral up	71	40.11	28	46.70	
Bun					*	Spiral back	61	34.50	28	46.70	
Present	0	0	2	3.13		Lateral	45	25.40	4	6.67	
Absent	185	100	62	96.90		Ears					
Raspail					***	Size					ns
Present	0	0	6	9.38		Small	0	0	1	1.56	
Absent	185	100	58	90.60		Medium	184	99.50	61	95.31	
Pelisse					***	Big	1	0.54	2	3.13	
Present	0	0	6	9.38		Orientation					ns
Absent	185	100	58	90.61		Erects	165	89.19	59	92.19	
Tassels					ns	Semi-pendulous	19	10.27	4	6.25	
Present	15	8.11	10	15.63		Pendulous	1	0.54	1	1.56	
Absent	170	91.89	54	84.40		Facial profile					ns
						Straight	185	100	64	100	

ns = No significance (P > 0.05). *P < 0.05. **P < 0.001. ***P < 0.0001. AF=Absolute frequency. RF=Relative frequency. Sig.=Significance.

ns = no significativo (P > 0,05), *P < 0,05, **P < 0,001. ***P < 0,0001. AF=Frecuencia absoluta. RF = Frecuencia Relativa. Sig.=Significancia.

Shepherds of the PG habitually prefer young with white fur, with the white-creamy color as the second most popular option because they empirically associate light coats with greater vigor, as well as being able to identify animals in dark places with excess foliage quickly.

Sexual dimorphism in QV occurred <10% in PG populations. Males had a distinct hair phenotype consisting of short hair with buns, raspail, and pelisse. Among females, 97% had aegagrus horns, and 93% had prisca-type horns. Other studies showed that Cuban goats had 94% of female-type horns and 87% of male-type prisca horns (16). In our study, the presence of a beard was 100% and 63% for males and females, respectively. The tassels, pigmentation in skin, mucous and hooves, the orientation of horns, size and orientation of ears, and straight facial profile showed homogeneity between each sex ($p>0.05$), and there was statistical interaction in the sex-locality variable. The females were different ($p<0.05$) in appearance and texture of hair, beard, pigmentation, horns, and orientation of ears. The males demonstrated differences between localities in appearance, texture, and length of hair, horns, pigmentation of the skin, mucous membranes, hooves and the shape-orientation of ears. These differences may be due to the continuous exchange of males between small herds to be used as breeding stock bucks. Meanwhile, the larger herds associated with a transhumance system are isolated, and the trade or exchange of the bucks is not frequent; also, the environmental conditions influence the phenotype of the races (8, 29).

The quantitative variables – morphometric

The descriptive statistics of the MV are shown in table 3 (page 368), demonstrating sexual dimorphism among PG ($p<0.05$); previously, this parameter has been reported in similar studies in PG of the Mixteca (26), in the Creole goats of Veracruz (18) and Guerrero (19), México. The variation in phenotypic expression is mostly attributed to genetics, sexual selection, and natural selection. The causes may be due to the size of the herds associated with the ecological management of the regions, the climate and feeding strategies (23, 27). The values in the MV were higher in the PG when compared with other studies of Creole goats in México (3, 10), Patagonia, Argentina (15), Lara Venezuela (21), Granma, Cuba (6) and the White Celtiberian goats in Almeria, Spain (12). Live weight also showed a significant difference between sex ($P> 0.05$); however, it was not taken in the analysis of additional data since the period in our study was carried out between the dry and rainy seasons. The coefficient of variation (CV) is used to evaluate morphostructural homogeneity in the same population. CV in the HAW, BL, CD, CG, and HAR define the profile of a race (31), where the PG had a CV = 5%, indicating that the study population had morphostructural homogeneity in these MVs. The CV was less than 10%, indicating a median morphostructural identity in the PG population. Rodero *et al.* (2015) cited a similar CV for the population of females in the Florida and Payoya breeds, except for the CV for BCD (11.95%) and HL (11.31%) in the Payoya goats. Herrera and Luque (2007), and Revidatti *et al.* (2013) cited similar values for the Blanca Andaluza and Celtiberian breeds in Spain, and the Formosa creole goat in Argentina, respectively. Other studies report a CV higher than 10% (20, 34), and according to Herrera (2007), when there is a CV <10%, it is a good indicator of natural selection.

Table 3. Means, standard deviations and coefficients of variation for the population and sex of the Pastoreña goat.

Tabla 3. Medias, desvíos estándar y coeficientes de variación para la población y sexo de la cabra Pastoreña.

MV (cm)	Population		Females		Males		
	n = 221		n = 170		n = 51		Sig.
	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)	Sex
HAW	71.06±5.8	8.16	68.68±3.5	5.1	79.02±4.76	6.02	***
BL	73.9±6.61	8.95	71.32±4.78	6.7	82.49±4.18	5.06	***
HL	26.03±2.06	7.92	25.17±1.26	5.02	28.9±1.54	5.33	***
FL	20.65±1.81	8.74	19.94±1.27	6.39	23±1.23	5.36	***
HW	9.71±1.19	12.3	9.31±0.94	10.09	11.04±0.98	8.87	***
SPW	20.08±2.7	13.43	18.94±1.7	9	23.9±1.68	7.01	**
CW	23.09±2.45	10.62	22.68±2.46	10.86	24.45±1.86	7.6	***
CD	33.66±3.42	10.16	32.22±2.21	6.85	38.47±2.09	5.44	***
CG	89.83±8.51	9.47	86.44±5.9	6.82	101.14±5.63	5.56	***
HAR	71.37±5.15	7.21	69.46±3.59	5.16	77.75±4.38	5.64	***
RW	16.76±1.63	9.72	16.33±1.4	8.6	18.22±1.49	8.17	***
RL	23.35±2.6	11.12	22.35±1.89	8.45	26.67±1.73	6.48	***
SC	11.04±1.38	12.49	10.52±0.99	9.44	12.78±1.01	7.87	***
LW (kg)	49.71±12.7	25.54	44.59±8.49	19.04	67.38±8.1	12.03	***

CV = Coefficient of variation. Sig. = Significance. **P < 0.001. ***P < 0.0001. HL = head length. HW = head width. FL = face length. HAW = height at withers. BL = body length. HAR = height at rump. RL = rump length. RW = Rump Width. CG = Chest Girth. CD = Chest Depth. CW = Chest Width. SPW = Shoulder Point Width. SC = Shin Circumference. LW = Live Weight.

CV = Coeficiente de Variación. Sig. = Significancia. **P < 0,001. ***P < 0,0001.
HL = Longitud de la Cabeza. HW = Ancho de la Cabeza. FL=longitud de la cara.
HAW = Altura a la Cruz. BL = Distancia Longitudinal. HAR=Altura a la Grupa. RL = Longitud de la Grupa.
RW = Ancho de la Grupa. CG = Perímetro Torácico. CD = Distancia Dorsoesternal. CW = Distancia Bicostal.
SPW = Distancia Entreencuentros. SC = Perímetro de Caña. LW = Peso Vivo.

However, genetic diversity is the main factor in the adaptability of organisms to the change of environmental conditions; the results of this study showed that Patoreña goats have high genetic diversity at the regions studied, and there is adaptation to the environment over the time. The CV results in the PG indicated that the environment influences morphostructural homogeneity. Simultaneously, the shepherds have influenced the CV with their management scheme compared to the CV >10% reported in the northern region of the Mixteca (26).

The correlations of the MV are shown in table 4 (page 369). This data defines the morphostructural harmonic model in the population (33). Therefore, the increase in the number of significant correlations improves the morphostructural harmonic model in a population. The correlations of our study show a harmonic model in females (97.8%) and males (79.1%) in the MV.

Table 4. Correlation of the morphometric variables and the probabilities for females (upper diagonal) and males (lower diagonal) of Pastoreña goat population.

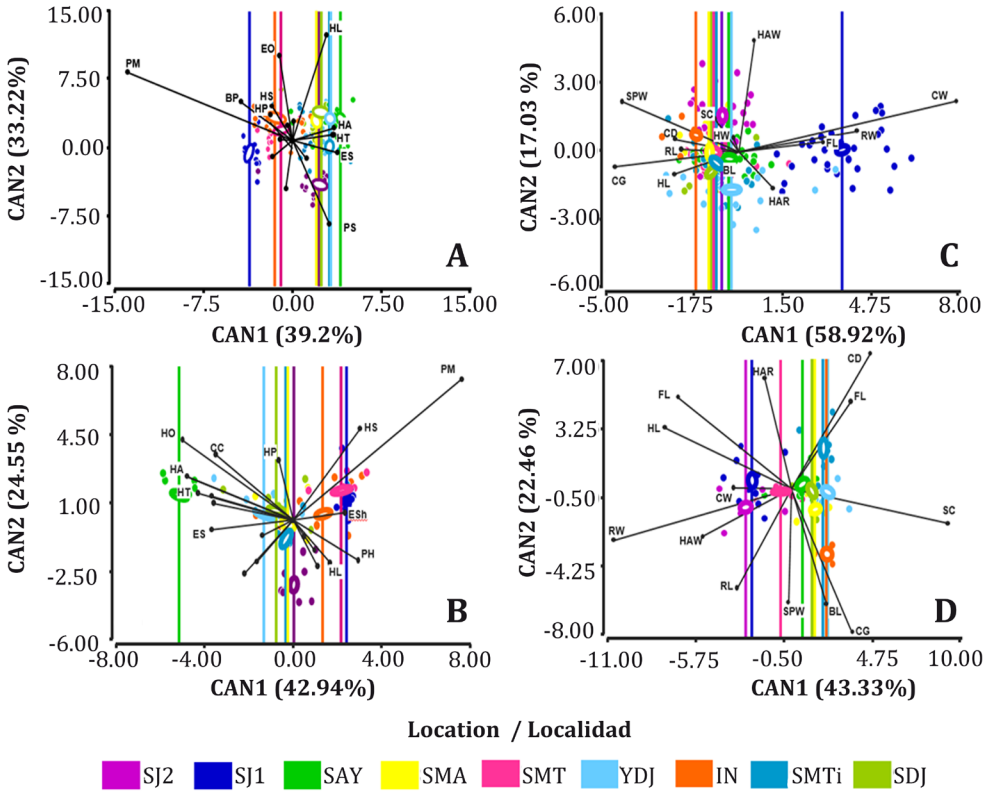
Tabla 4. Correlación de las variables morfométricas y las probabilidades para las hembras (diagonal superior) y los machos (diagonal inferior) de la población de cabra Pastoreña.

MV	HAW	BL	HL	FL	HW	SPW	CW	CD	CG	HAR	RW	RL	SC	LW
HAW	1	0.57*	0.46***	0.34***	0.28**	0.4***	0.28**	0.55*	0.52*	0.75*	0.35***	0.41***	0.4***	0.49***
BL	0.48**	1	0.54*	0.52*	0.53*	0.57*	0.4***	0.72*	0.69*	0.48***	0.51***	0.58*	0.53*	0.72*
HL	0.51**	0.47**	1	0.69*	0.45***	0.53*	0.35***	0.67*	0.6*	0.46***	0.51*	0.42***	0.44***	0.65*
FL	0.39*	0.1ns	0.57***	1	0.41***	0.47***	0.37***	0.62*	0.52*	0.37***	0.54*	0.34***	0.37***	0.61*
HW	0.11ns	0.21ns	0.39*	0.28ns	1	0.4***	0.42***	0.54*	0.52*	0.34***	0.46***	0.5***	0.28**	0.65*
SPW	0.31*	0.5**	0.51***	0.33*	0.47**	1	0.33***	0.67*	0.67*	0.35***	0.47***	0.42***	0.53*	0.66*
CW	0.2ns	0.32*	0.42*	0.17ns	0.32*	0.43*	1	0.36***	0.39***	0.21ns	0.56*	0.31***	0.06ns	0.47***
CD	0.46**	0.63***	0.63***	0.22ns	0.27ns	0.63***	0.47**	1	0.83*	0.52*	0.58*	0.56*	0.55*	0.85*
CG	0.43*	0.41*	0.55***	0.23ns	0.47**	0.6***	0.67***	0.71***	1	0.45***	0.52*	0.57*	0.59*	0.82*
HAR	0.57***	0.41*	0.34*	0.36*	0.26ns	0.42*	0.5ns	0.48**	0.37*	1	0.38***	0.41***	0.37***	0.5***
RW	0.35*	0.4*	0.62***	0.41*	0.41*	0.73***	0.35*	0.62***	0.53***	0.36*	1	0.38***	0.22*	0.67*
RL	0.18ns	0.53***	0.49**	0.25ns	0.49**	0.43*	0.19ns	0.6***	0.46**	0.51**	0.31*	1	0.43***	0.57*
SC	0.4*	0.45**	0.39*	0.23ns	0.17ns	0.5**	0.23ns	0.47**	0.44*	0.38*	0.22ns	0.39*	1	0.5*
LW	0.42*	0.65***	0.68***	0.24ns	0.46*	0.73***	0.52**	0.76***	0.71***	0.53**	0.7***	0.66***	0.5**	1

ns = no significant difference, *P<0.05, **P<0.001, ***P<0.0001. HL = Head length, HW = Head width, FL = Face length, HAW = Height at withers, BL = Body length, HAR = Height at rump, RL = Rump length, RW = Rump width, CG = Chest girth, CD = Chest depth, CW = Chest width, SPW = Shoulder point width, SC = Shin circumference.

ns=no significativo, *P<0,05, **P<0,001, ***P<0,0001, HL= Longitud de la cabeza, HW Ancho de la cabeza, FL=Longitud de la cara, HAW=Altura a la cruz, BL=Distancia longitudinal, HAR=Altura a la grupa, RL=Longitud de la grupa, RW=Ancho de la grupa, CG=Perímetro torácico, CD=Distancia dorsoesternal, CW=Distancia bicostal, SPW=Distancia entreencuentros, SC=Perímetro de caña, LW=Peso vivo.

The PG had a better harmonic morphostructural model than the Spanish goats such as the Cabra Blanca Serrana Andaluza (correlations of 65 and 20% for females and males, respectively), and a model similar to the White Celtiberian goat (76.47 and 50.73% for females and males, respectively) (12). Therefore, the results obtained in the PG indicated that it is a native breed. Figure 3 (page 370), shows the canonical discriminant analysis (CAN). The variations in the groups for QV in the females (figure 3a, page 370) and males (figure 3b, page 370) were 72.4% and 75.95%, respectively, corresponding to 1) appearance, texture and length of the coat, skin and pigmented mucosa, 2) size and orientation of the ears, 3) presence and shape of the horns. The population of female goats SJ1 and SJ2 and males SJ2 and SAY were discriminated by the population. The MV for females (figure 3c, page 370) 75.95% of the population variation was given with the variables: 1) Face length, 2) raised on the cross, 3) width of the chest distance, 4) dorsoesternal distance, 5) width of the rump and perimeter of the cane. The SJ1 locality was discriminated.



CC = Coat color, PM = Pigmented mucous, PS = Pigmented skin, PH = Pigmented hoof, HP = Horn presence, HO = Horns orientation, HS = Horns shape, HL = Hair length, HA = Hair appearance, HT = Hair texture, HP = Hair pattern, EO = Ears orientation, ES = Ears sizes, ESh= Ears shape, BP = Beard presence.

HL = Head length, HW = Head width, FL = Face length, HAW = Height at withers, BL = Body length, HAR = Height at rump, RL = Rump length, RW = Rump width, CG = Chest girth. CD = Chest depth, CW = Chest width, SPW = Shoulder point width, SC = Shin circumference.

CC = Color de la capa, PM = Mucosa pigmentada, PS = Piel pigmentada, PH = Pezuñas pigmentadas, HP = Presencia de cuernos, HO = Orientación de los cuernos, HS = Forma de los cuernos, HL = Longitud del pelo, HA = Apariencia del pelo, HT = Textura del pelo, HP = Patrón de nodulación del pelo, EO = Orientación de las orejas, ES = Tamaño de las orejas, ESh= Forma de las orejas, BP = Presencia de barba.

HL = Longitud de la cabeza, HW = Ancho de la cabeza, FL = Longitud de la cara, HAW = Altura de la cruz, BL = Distancia longitudinal, HAR = Altura a la grupa, RL = Longitud de la grupa, RW = Ancho de la grupa, CG = Perímetro torácico, CD = Distancia dorsoesternal, CW = Distancia bicostal, SPW = Distancia entre encuentros, SC = Perímetro de caña.

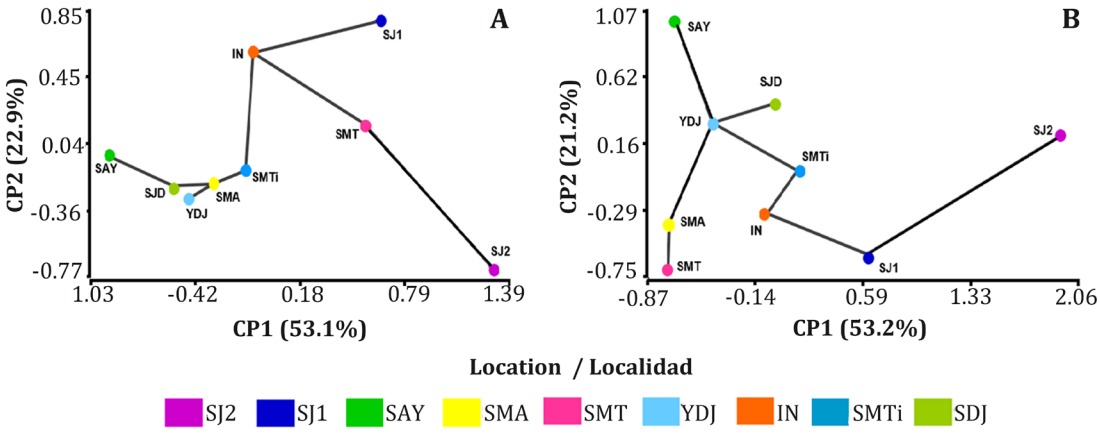
Figure 3. Graphical representation of the discriminant variables, the centroid of each location, dispersion of the population of Pastoreña goats for qualitative variables a) females, b) males; quantitative variables c) females, d) males.

Figura 3. Representación gráfica de las variables discriminantes, el centroide de cada localidad y dispersión de la población de la cabra Pastoreña para las variables cualitativas a) hembras, b) machos; variables cuantitativas c) hembras, d) machos.

The MV in the males (figure 3d, page 370) was 65.79% of the population variation, given the variables: 1) raised to the cross, 2) length of the face, 3) dorsoesternal distance and 4) perimeter of the thorax and cane, where SJ1, SJ2 and IN are slightly discriminated from the rest of the population. The results of the CAN in PG coincided with other studies (8, 28).

The QV transformed into a numerical matrix and consequently classical multi-dimensional scaling (PCoA) was applied to the variables (figure 4). The PCoA indicates the similarities (distances) of the qualitative variables of the population in the PG by locality, therefore, the values were 76% and 74.4% for females and males, respectively. Figure 4 also indicates the differences between the populations of the PG by location in Euclidean distances; the greatest differences between the similarities of the females (figure 4a) occurred in the SJ2 locality *versus* IN (1.93), SJD (1.95) and SAY (2.37). Most of the similarities were in YDJ *vs.* SMA (0.48) and SJD (0.49), and SJD *vs.* SMA (0.48). In males (figure 4b), the differences were in SMT vs. SJ2 (2.85), SMA (2.78) and SAY (2.83). The minor differences were between SMTi and IN (0.67), YDJ *vs.* SDJ (0.91) and SMTi (1.01); these results suggest a relationship of similarities between geographical space and localities (14, 15).

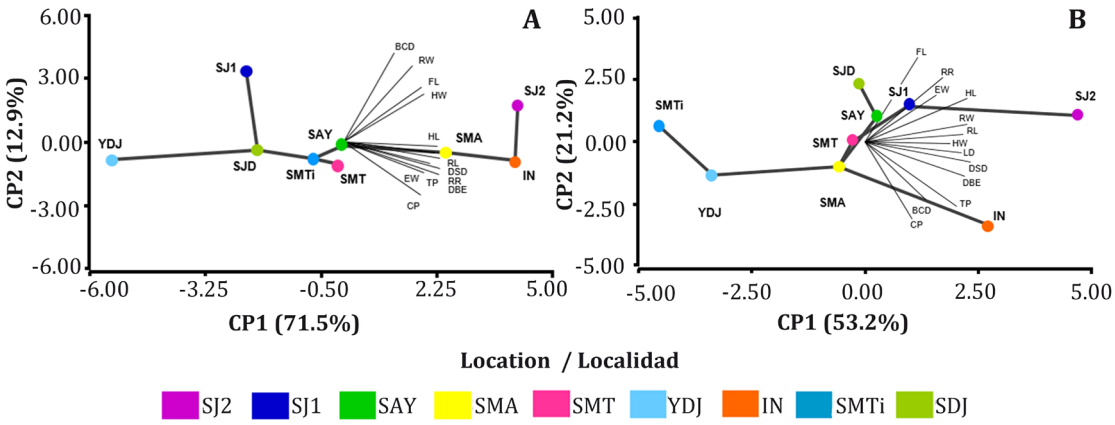
Figure 5 (page 372), shows the results of PCA for MV. The population of females (figure 5a, page 372) shows the morphostructural variables, the CP1 axis shows 71.5% of the total variability observed, corresponding: 1) BL, 2) SPW, 3) CD and 4) CG. The CP2 axis shows 12.9% of the total variability observed, corresponding to 1) FL, 2) HAW, 3) CW and RW. There was a close relationship between the towns of SJD, SMTi, SMT and SAY.



a) females, b) males. / a) hembras, b) machos.

Figure 4. Principal coordinates graphics for qualitative variables of Pastoreña goat population, expressed in Euclidian distances between locations.

Figura 4. Gráfica de coordenadas principales para las variables cualitativas de la población de la cabra Pastoreña, expresadas en distancia Euclidiana entre localidad.



HL = Head length, HW = Head width, FL = Face length, HAW = Height at withers, BL = Body length, HAR = Height at rump, RL = Rump length, RW = Rump width, CG = Chest girth, CD = Chest depth, CW = Chest width, SPW = Shoulder point width, SC = Shin circumference.

HL = Longitud de la cabeza, HW = Ancho de la cabeza, FL = Longitud de la cara, HAW = Altura de la cruz, BL = Distancia longitudinal, HAR = Altura de la grupa, RL = Longitud de la grupa, RW = Ancho de la grupa, CG = Perímetro torácico, CD = Distancia dorsoesternal, CW = Distancia bicostal, SPW = Distancia entre encuentros, SC = Perímetro de caña.

Figure 5. Graphical representation of principal components of Pastoreña goat population by locations with quantitative variables: a) females and b) males.

Figura 5. Representación gráfica de componentes principales en la población de la cabra Pastoreña por localidad con las variables cuantitativas: a) hembras y b) machos.

The biggest difference was in SJ2 and IN *vs.* SJ1 and YDJ, with a cophenetic correlation coefficient of 0.990. The population of males (figure 5b) in MV had the total variation in the CP1 axis of 55.9%, the highest proportion corresponded to 1) BL, 2) HL, 3) SPW, 4) CD, 5) RW and RL. The axis CP2 had a total variation of 18.9%, corresponding to 1) HAW, 2) HL and 3) HAR and RW. The closest variabilities were between SMA, SMT, SAY and SJD, and the most remote between SJ2 and IN *vs.* SMTi and YDJ, with a coefficient of cophenetic correlation of 0.958. In both cases, the figures showed a relationship between the location of the goat population. On the other hand, the PCA shows a well-defined selection criteria and/or environmental selection, since the variation is explained by all the variables of CP1 in the MVs of the PCA; Similar responses have been published in Blanca Celtiberica goats (28) and different in Cuban Creole goats (16). These last authors found negative correlations in the first CP and at the same time, the PCA biplots agglomerated the population of goats by location with different Euclidean indices.

Conclusion

The results of the descriptive statistics, correlations, CAN, PCoA, PCA in the population of the PG showed uniformity within the population, even though there was a wide geographical distribution and few selection criteria in the males. The PCoA and PCA values showed variations between the locations, mainly attributed to the selection criteria and environmental variations. The characterization of qualitative and quantitative variables in the PG offers basis for its conservation, as long as the selection criteria are applied properly to improve the racial profile. The PG should be recognized as a Standardized breed as defined by FAO and be registered by the government livestock organisms of the Mixteca Oaxaca, México. Consequently, it is vital to carry out genetic studies with molecular markers to guarantee the phenotype of this goat.

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Conflict of interest

The authors do not have any conflict of interest to declare.

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