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Phenotypic diversity of local goats in northern Mexico

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Abstract
The study documented phenotypic diversity of local goats from Comarca Lagunera in northern Mexico. Two hundred and five goats were chosen from 2980 local animals. Morpho-structural and phenotypic traits, age, live weight, body condition, and 33 zoometric characteristics were recorded. Principal components analysis (PCA), factor, and cluster analyses were performed to describe the phenotypic composition of the goats. A dominant phenotype was found without wattles; bearded; backward slanting, erect horns; short hair; hanging tail and ears; straight head profile, with pigmentation in the skin, hooves, mucous membranes, and udder with a patchy coat pattern; where two-colour coated animals were predominant (61%). Height at withers, chest circumference, and lumbosacral height had low variation (<10%). Twenty-two variables had a moderate variation (10–20%). Age, live weight, ear, and horn length, leg width, udder, teats, and length and distance between teats had the greatest variation (>20%). Three components accounted for 34.4% of the total variability observed. The first principal component represented 17.0% of the total variation, while PC2 accounted for 9.9%. The cluster analysis generated four clusters (Clu). Clu1 grouped variables of the trunk, neck, and head; Clu2, the trunk and head; Clu3 limb variables; and Clu4 adaptation to heat and harsh environments. A moderate intrapopulation variability was sufficient to differentiate phenotypically diverse groups in the local goat population of the Comarca Lagunera region. The population has developed diverse mechanisms of adaptation to the environment which can be used to establish genetic improvement schemes in the local goat population of northern Mexico.

Keywords: Genetic variability, morphostructure, small ruminants, zoometric measures
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Introduction
In most developing countries, goat farming is carried out in subsistence production systems, located in rural and peri-urban areas with low productivity, where mainly local breeds (also known as creole,

indigenous, or native) animals are used. In these places, goat production is essential for the survival of rural communities, since they are animals with unique adaptation characteristics and low maintenance requirements (Abarca-Vargas *et al*., 2020; Torres-Hernández *et al*., 2021).

Local goats are a genetic resource with potential to be used as a basis in the development of genetic improvement programs, where animals with the ability to adapt to particular environmental conditions are produced (Batubara *et al*., 2011). They constitute an important reservoir of genetic diversity that justifies the development of appropriate management systems aimed at improving productive performance, without loss of genomic diversity (Sevane *et al*., 2018). Before considering genetic–productive improvement schemes, it is essential to know the type of genetic resource that one has (Peña *et al*., 2017). Processes such as crossing, acclimatization, adaptation, and isolation can generate a specific population due to slight changes in the genome, which can be detected by differences in observable and measurable body characteristics, which, together, make up the phenotype of individuals (Alawiansyah *et al*., 2020). Furthermore, the lack of information on the characteristics of a population or breed can lead to the underutilization and loss of these resources (Bedada *et al*., 2019). In this regard, zoometric studies make it possible to identify these characteristics within a population, especially in those that are protected and/or threatened as a result of the decrease in the number of individuals due to the hybridization process (Arredondo-Ruiz *et al*., 2013).

For this reason, interest has increased in the study of indigenous livestock breeds adapted to low-income production systems, especially concerning biometric characteristics of shape and size, since the variation between individuals is the result of the interaction of genotypes with the environment (Adenaike *et al*., 2020; Hossain *et al*., 2020). The aforementioned suggests that differences within a population can be attributed to the development of unique characteristics in a given genotype adapted to a specific environment (Peña *et al*., 2017). This is essential in developing an appropriate breeding and improvement program adapted to each ecosystem (Belkhadem *et al*., 2019), as long as we consider that understanding the genetic changes behind phenotypic variation can facilitate efforts to carry out effective genetic improvement (Li *et al*., 2020).

In Mexico, there are approximately 8 830 720 goats distributed throughout the country (FAOSTAT, 2020), concentrating mainly in arid and semi-arid regions, where small producers manage them extensively (Echavarría-Chairez *et al*., 2006). The FAO recognizes that in Mexico there are specimens of various genetic groups (Alpine, Boer, Guadalupe Island goat, Creole, Granada, La Mancha, Lagunero Mosaic, Mixtec Mosaic, Central Mosaic, Nubia, Saanen, and Toggenburg; FAOSTAT, 2021). However, the information on the morphological characteristics of most of these populations is unknown, which limits their use, conservation, and genetic improvement and places the native or local populations at severe risk of disappearance (FAO-DAD-IS, 2019). Regarding this, Mexico has increased efforts in recent years to characterize the phenotype of local or native goat populations (Sánchez-Gutiérrez *et al*., 2018; Silva-Jarquín *et al*., 2019; Valencia-Franco *et al*., 2019; Villarreal-Arellano *et al*., 2019; Abarca-Vargas *et al*., 2020). Notwithstanding, in the northern region, specifically in Comarca Lagunera, which is the main goat milk-producing region under extensive grazing (Maldonado-Jáquez *et al*., 2018), information in this regard is limited. Therefore, the approach was to document the phenotypic diversity of the local goats from Comarca Lagunera as part of the efforts to characterize the population and identify ecotypes or racial types, which will lay the foundations for genetic improvement programs to focus on taking advantage of the adaptation characteristics that these animals have to the arid environment of northern Mexico.

Materials and Methods

The animals used were treated according to the standards of ethics, care, and animal welfare of the Federation of Animal Sciences Societies (FASS, 2010), National Academy of Medicine (NAM, 2011), and the Mexican Institution by Instituto Nacional de Investigaciones Forestales, Agricolas y Pecuarias (INIFAP), and the fund destined to promote the development of science and technology in the state of Coahuila (FONCYT) of the Consejo Estatal de Ciencia y Tecnología del Estado de Coahuila, México (COECYT), with the approval and follow-up of the project "Typification of goat producers and differentiation of ecotypes in local goats in Comarca Lagunera, Coahuila."

The study was carried out in four locations (Francisco I. Madero, San Pedro de las Colonias, Viesca, and Torreon) in the region known as Comarca Lagunera in the state of Coahuila, Mexico (Figure 1). The region is located between coordinates 24° 22' N and 102° 22' W, with an average height of 1139 m.a.s.l. The climate is dry or desert, semi-warm with a cool winter, and annual rainfall and temperatures of 240 mm and 25 °C, respectively (García, 2004). The vegetation of the area is that of a dessert grassland, with species like *Larrea tridentata*, *Flourensia cernua, Agave lechuguilla, Atriplex canescens, Prosopis spp., Acacia farnesiana, Salsola kali, Amaranthus hybridus, and Solanum eleagnofolium.* The most abundant grasses are *Bouteloua spp., Muhlembergia repens, Sporobolus spp,* *Cenchrus ciliaris, Cynodon dactylon, and Echinocloa colona* (Maldonado-Jáquez *et al*., 2017)*;* and the soil texture is mainly sandy loam (sand 81%, silt 14%, and 5% clay) (Sariñana-Navarrete *et al.,* 2021).

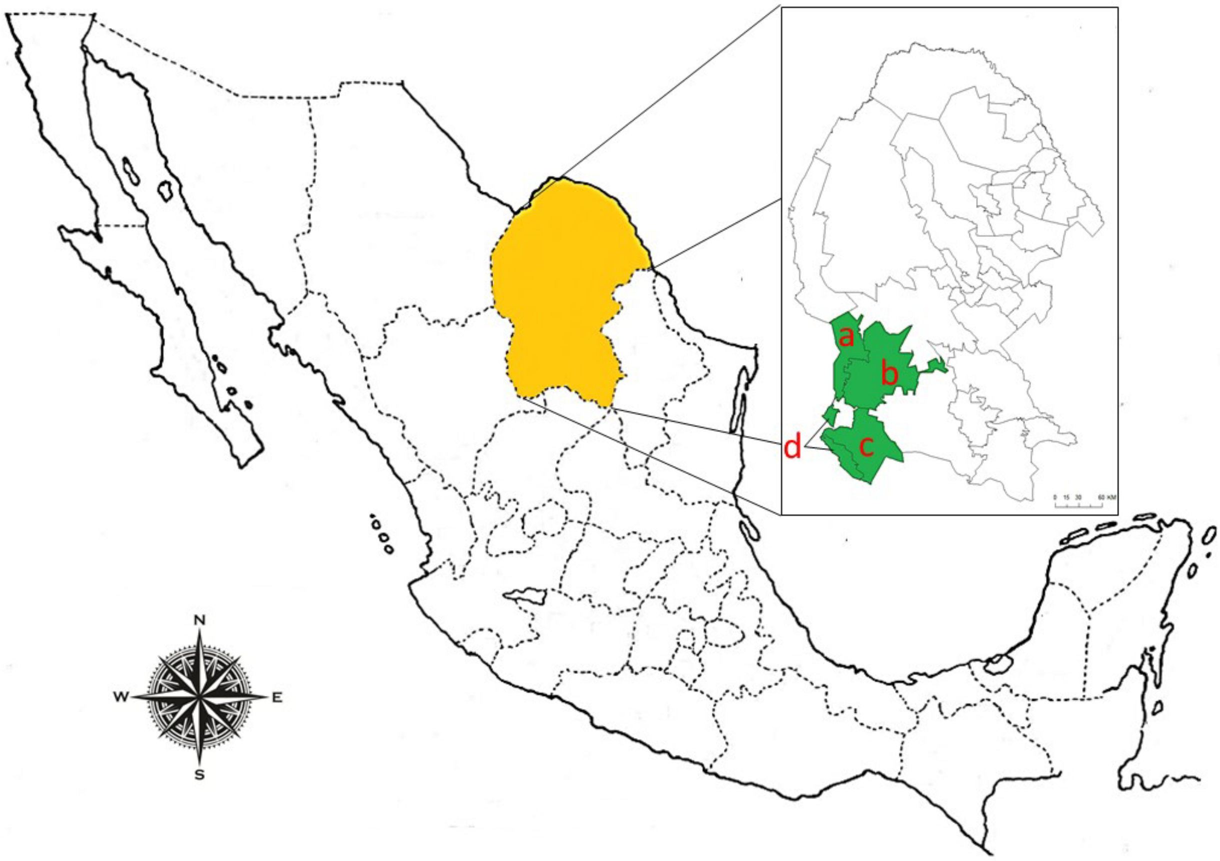

Figure 1 Geographical location of the sampled localities in the Comarca Lagunera in the state of Coahuila, Mexico. a) Francisco I. Madero; b) San Pedro de las Colonias; c) Viesca; d) Torreón

A total of 205 local adult does (> two kiddings) were randomly chosen from a nucleus of 2980 animals from 26 production units located in the municipalities of San Pedro de las Colonias (n = 38), Francisco I. Madero (n = 34), Torreón (n = 66), and Viesca (n = 67). The sample size from each municipality was not uniform due to the characteristics of the herds chosen in each place.

Goat management was typical of an extensive system (day grazing and night confinement), without supplementation, where sanitary management was traditionally limited to vaccination against Brucellosis and management against external parasites. Feeding was carried out with native plant species of the region, grasses such as *Sporobolus spp.* and *Muhlenbergia spp*., shrubs (*Acacia spp*. and *Prosopis spp*.); occasionally the flocks had access to agricultural wastes of melon (*Cucumis melo*), watermelon (*Citrillus lanatus*), forage oats (*Avena sativa*) and sorghum (*Sorghum halepense*).

The presence or absence of wattle, beard, and horns, head profile (straight, concave, convex), type of ears (erect, hanging, absent), type of horns (erect, curved, absent), and horn orientation (upward, backward, spiral) were the morpho-structural qualitative traits recorded.

The phenotypic traits were coat colour (15 variants), coat pattern (flat, patchy, mottled), pigmentation of skin, hooves, mucous, and udder (present or absent), hair length (short, long), and type of hair (straight, curly). Age (by dental observation), body weight (BW), and body condition score (BCS) were recorded. Body condition (BCS) was defined according to the scale of 1 to 4, as described by Rivas-Muñoz *et al*. (2010), where 1 represents an extremely thin animal and 4, an obese animal. Fasting body weight was taken with an electronic hanging scale, model BAC-300, with a capacity of 300 kg ± 100 g (Rhino, Mexico).

A total of 33 zoometric traits were considered (Figure 2), according to Moyao-Ariza *et al.* (2022) and included ear length (EL-1), ear width (EW-2), neck length (NL-3), neck width (NW-4), scapula width (SPW-5), body length (BL-6), chest width (CW-7), height at the sternum (HS-8), height at withers (HW-9), chest circumference (CC-10), flank diameter (FDm-11), barrel circumference (BC-12), lumbar sacral height (LSH-13), rump width (RW-14), rump length (RL-15), tail length (TLL-16), leg length (LL-17), flank depth (referring to the bicostal diameter and was measured from rib to rib in the middle portion of the thoracic cage [FDp-18]), leg width (LW-19), shank perimeter (SP-20), horn length (HL-21), horn width (HoW-22), skull width (SW-23), skull length (SL-24), face length (FL-25), face width (FW-26), snout diameter (SD-27), udder length (UL-28), udder width (UW-29), teat length (TTL-30), teat width (TW-31), distance between teats (DBT-32), and udder depth (UD), which was calculated as the difference between HW and HS. The measurement of these variables was carried out using a zoometric rod and a soft flexible measuring tape (Selanusa, Mexico).

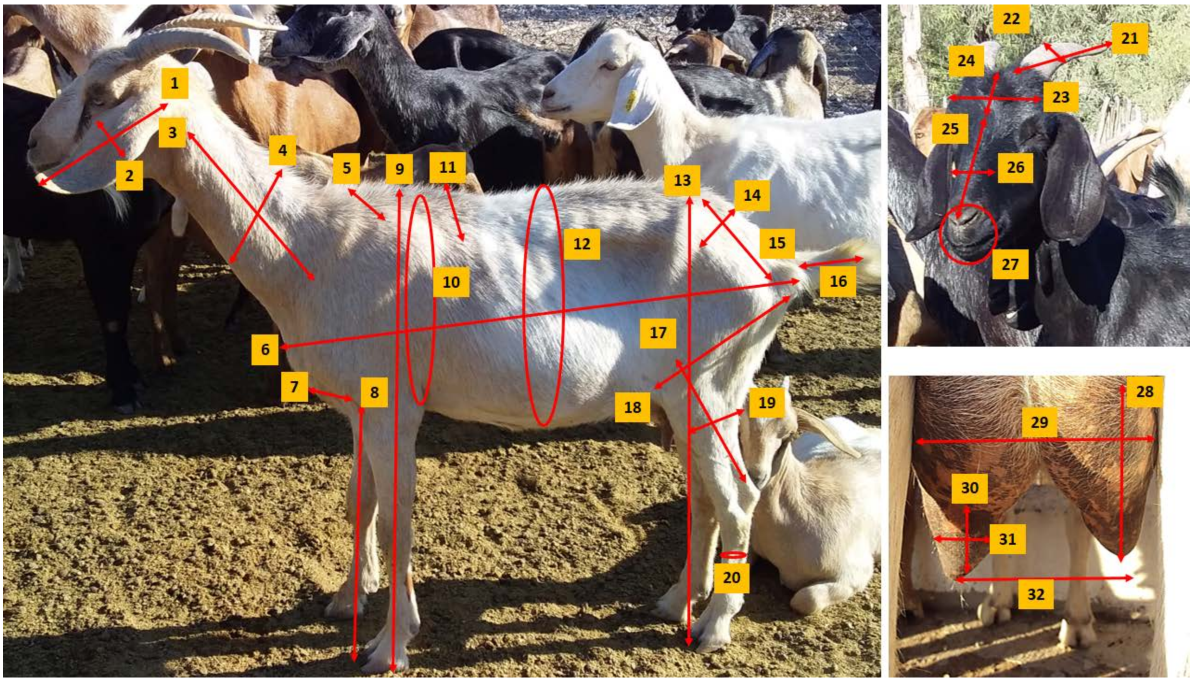

Figure 2. Zoometric traits measured in local female goats from the Comarca Lagunera, in northern Mexico

Qualitative variables were coded, processed, and analysed according to the recommendations of Jordana *et al*. (1993); descriptive and inferential statistics were obtained. The mean, standard error (SE), coefficient of variation (CV), and maximum and minimum values were determined for the quantitative variables. The phenotypic correlations and variance–covariance values were calculated. Data were generated from the correlation matrix to perform principal component (PCA) and factor (FA) analyses. The matrix correlation determinants were used for the multicollinearity and singularity test. The Kaiser–Meyer–Olkin (KMO) measures of sampling adequacy and sphericity test were calculated to establish the dataset validity and determine if the model was appropriate. KMOs must be between 0.5 and 1.0 to proceed with a satisfactory factor analysis (Putra and Ilham, 2019). To determine the number of principal components to extract, the proportion of accumulated variance criterion was used. To improve the interpretability of the principal components, the varimax orthogonal rotation method was used in the rotation of the factor matrix. With the results of the FA and PCA, a cluster analysis was performed using the hierarchical agglomerative method based on Euclidean distances with the Ward method. A dendrogram was obtained in which the cut-off point that defined the clusters was determined where the relative loss of inertia was greater. All the analyses were carried out with the statistical package, R Studio v.1.3.1093.

Results and Discussion

The phaneroptic and morpho-structural characteristics showed great variation (Table 1). However, the predominant phenotype corresponded to bearded animals without a wattle, erect backward horns, short hair, hanging tail and ears, straight head profile, with pigmented skin, hooves, mucous membranes, and udder, with a patchy coat pattern (48%), although a large number of animals had a plain coat (43%). Two-coloured coat goats were predominant (61%), followed by animals with one colour (37%). The most frequent colours were patched brown (26%), white (14%), patched white (12%), patched black (11%), brown (11%) and combinations of three colours (9%). The rest of the colours (mottled white, mottled brown, moor, and black) had a frequency of less than 5% in the population.

The results found for cephalic profile, and size and orientation of the ears indicate a common European origin for the local goats of northern Mexico, though the double-coloured coat is indicative of Asian origin (Lanari *et al*., 2019), so a single origin cannot be specified for this population. The results concur with the study of Ali Rather *et al*. (2020) for indigenous goats from the Budgam district, Kashmir, India, where the predominant colour was brown with a similar percentage (27%) found in our study, followed by white (24%). Furthermore, our results coincide concur with those reported by Karnuah *et al*. (2018) in West African pygmy goats from Liberia and Lanari *et al*. (2019) in Argentine Creoles, which mostly have curved horns, a straight head profile, and hanging ears. Ginja *et al*. (2017) found that the levels of genetic diversity observed in the Creole goats of the American continent were not high, compared to breeds from other parts of the world. This is possibly due to the fact that the Creole goats were very far from the centre of domestication and represent the last stages of dispersion and evolution but can also be due to "founding effects", which are related to the colonization process, thus defining their origin.

Table 1. Absolute (proportion) and relative (%) frequencies of phaneroptic and morpho-structural variables of local goats from Comarca Lagunera, Mexico

Variable	AF	RF	Variable	AF	RF	Variable	AF	RF
Wattle			Beard			Horns		
Presence	49	0.24	Presence	138	0.67	Presence	129	0.63
Absence	156	0.76	Absence	67	0.33	Absence	76	0.37
Skin pigmentation			Hoof pigmentation			Mucous pigmentation		
Presence	150	0.73	Presence	147	0.72	Presence	153	0.75
Absence	55	0.27	Absence	58	0.28	Absence	52	0.25
Udder pigmentation			Hair length			Tail type		
Presence	177	0.86	Short	198	0.97	Hanging	167	0.81
Absence	28	0.14	Long	7	0.03	Curved	38	0.19
Head profile			Horn type			Coat pattern		
Concave	8	0.04	Absent	77	0.38	Mottled	18	0.09
Convex	10	0.05	Curved	55	0.27	Patched	99	0.48
Straight	187	0.91	Erect	73	0.35	Plain	88	0.43
Ear type			Horn orientation					
Horizontal	64	0.31	Upwards	32	0.15			
Absent	3	0.02	Backwards	96	0.47			
Hanging	76	0.37	Absent	73	0.36			
Erect	62	0.30	Spiral	4	0.02			

Table 2 shows the zoometric characteristics of the local female goats of Comarca Lagunera. HW, CC, UD, and LSH had the lowest variation (<10%), twenty-two variables had a moderate variation (between 10 and 20%). Age, BW, BCS, EL, HL, LW, UW, TW, TTL, and DBT had the greatest variation (>20%). These results coincide with the study by Hilal *et al*. (2016), who reported coefficients of variation for Hamra goats in Morocco between 8.7 and 30.7%. Although some characteristics in our study (HL, TW, and TTL) exceed these values, possibly influenced by the crossbreeding that the animals have experienced, suggesting the development of unique characteristics of biological adaptation (Peña *et al*., 2017). They could potentially be used in the establishment of the first selection programs to try to decrease their variability (Abarca-Vargas *et al*., 2020), but without neglecting the productive goal, as TW and TTL are directly related to milk production (Kouri *et al*., 2019).

The results of the present study concur with those reported by Laouadi *et al*. (2021) for a population of Arabian goats in Algeria, where they detected sufficient heterogeneity to identify several genetic types in the same population. Other studies (Depison *et al*., 2020) indicate that Kacang goats from Indonesia are the same length as local goats from northern Mexico, but BW and HW were smaller. Similarly, Draa goats in Morocco (Ibnelbachyr *et al*., 2015) had a similar HW, lower CC, and BW, and higher BL than the values found in the local goats of the present study.

Table 2. Age, body weight, body condition score, and zoometric traits of local goats in Comarca Lagunera, Mexico

Variables (cm)	N	Mean	SE	CV	Min	Max
Age (months)	205	46.7	1.12	34.4	24.0	120.0
BW (kg)	205	47.4	0.68	20.4	25.0	78.0
BCS	205	1.9	0.03	23.8	1.3	3.5
FL	205	17.2	0.13	10.5	12.0	26.0
FW	205	8.1	0.07	13.2	5.5	12.0
SW	205	8.8	0.09	14.1	5.0	12.5
SL	205	9.9	0.08	12.2	7.0	14.0
EL	203	16.3	0.24	21.3	7.5	26.5
EW	203	7.8	0.09	16.2	4.0	17.0
NL	205	29.2	0.21	10.5	16.0	37.0
NW	205	33.4	0.24	10.1	25.0	43.0
NL	132	21.8	0.61	32.4	2.5	45.0
HoW	132	9.9	0.12	13.8	7.0	15.0
SD	205	22.0	0.17	11.0	17.0	32.5
FDm	205	25.6	0.21	11.7	17.5	36.0
BL	205	51.1	0.4	11.2	23.0	97.5
HW	205	69.7	0.35	7.2	40.0	82.5
HS	205	39.2	0.32	11.6	28.0	76.0
CW	205	12.1	0.15	17.5	7.0	20.0
SPW	205	13.9	0.16	16.8	4.8	19.0
CC	205	87.0	0.57	9.3	34.5	107.0
UD	205	57.6	0.39	9.6	30.0	72.0
BC	205	99.8	0.77	11.0	14.0	130.0
FDp	205	27.6	0.29	15.2	18.0	67.0
LSH	205	69.3	0.43	8.9	24.0	80.0
RL	205	22.6	0.29	18.2	17.0	72.0
RW	205	16.0	0.13	11.5	9.4	20.0
LW	205	11.2	0.17	21.5	8.0	36.0
LL	205	32.3	0.24	10.8	10.5	39.0
TLL	205	14.1	0.18	17.8	5.0	30.5
SP	205	9.6	0.09	12.9	6.5	16.0
UW	205	10.1	0.14	20.4	5.5	19.0
UL	205	25.1	0.33	18.6	12.0	38.0
TW	205	3.2	0.19	83.9	1.0	25.0
TTL	205	5.7	0.19	48.6	2.0	21.0
DBT	205	11.3	0.18	22.9	1.4	18.0

The PCA was significant (P <0.05) under the Kaiser criterion with eigenvalues of 0.78. Three main components explained 34.4% of the total variability observed (Table 3). The PC1 represented 17.0% of the total variation (eigenvalue of 6.118) and mainly described the BW and characteristics of the head, neck, and trunk of the animal, because of the high load (>0.500) of variables such as BW, BCS, NW, SD, FDm, CC, and BC. For this component, the characteristics with the lowest load (<0.05) were HL, HoW, TTL, and TW. The PC2 explained 9.9% of the variation (eigenvalue of 3.546), and the characteristics that had the greatest contribution (>0.400) were FL, HL, HoW, HW, HS, and FDp. For PC3, the variables that had the greatest contribution (>0.500) corresponded to the description of the structure of the head and horns (FW, HL, and HoW).

These results concur with the report by Sankhyan *et al*. (2018), in which some variables that contribute a greater load to the main components are BW, HW, CC, BC, and BL. They also concur with the study by Lanari *et al*. (2019), who analysed 25 variables in six breeds of Argentine Creole goats, which explained 28.1% of the total variability observed. It should be noted that, although the analysis explains a third of the total variability in the first three components, this data is extremely important, since it considers multiple characteristics; those that can be easily adapted to the selection criteria sought by the individual producer can be identified more efficiently (Mueller *et al*., 2021).

With the Euclidean distances of the PCA and FA, the dendrogram (Figure 3) obtained from the cluster analysis is shown, with the cut-off point defined where the loss of inertia was greater. The cluster analysis generated four groups, considering the variables in the study by similarity. This concurs with the study by Loubna and Adbelmadjid (2018), where the PCA and cluster analysis identified four subpopulations in Arbia goat females from Algeria (Figure 4). However, there is a degree of nearness at the level of centroids, which indicates that a part of the population has a common origin (European or Asian, as noted above), but with a clear differentiation associated with the physical structure of the animals, which suggests adaptation to different environmental conditions (Laouadi *et al*., 2021).

Table 3. Correlation of original variables with the three main components and contribution of variance in local does goats from the Comarca Lagunera, Mexico

Variable	PC1	PC2	PC3	Communality
Age	0.237	0.11	0.327	0.18
BW	0.838	-0.12	-0.277	0.79
BCS	0.548	-0.143	-0.229	0.37
FL	0.51	0.426	0.039	0.44
FW	0.134	-0.316	0.558	0.43
SW	0.463	-0.191	-0.24	0.31
SL	0.411	0.23	0.39	0.37
EL	0.205	0.264	0.289	0.20
EW	0.269	0.131	0.285	0.17
NL	0.443	-0.039	0.083	0.20
NW	0.763	0.127	0.107	0.61
HL	0.007	0.423	0.631	0.57
HoW	0.007	0.451	0.638	0.61
SD	0.593	0.182	0.063	0.38
FDm	0.579	-0.391	-0.117	0.50
BL	0.388	0.387	-0.142	0.32
HW	0.385	0.491	-0.067	0.39
HS	0.123	0.488	-0.361	0.38
CW	0.434	-0.604	0.241	0.61
SPW	0.226	-0.492	0.38	0.43
CC	0.681	-0.31	0.152	0.58
UD	0.182	0.674	-0.153	0.51
BC	0.637	-0.287	-0.068	0.49
FDp	0.377	0.196	-0.264	0.25
LSH	0.321	0.283	0.265	0.25
RL	0.346	0.071	-0.297	0.21
RW	0.495	0.286	-0.363	0.45
LW	0.26	-0.129	0.072	0.09
LL	0.234	0.18	-0.018	0.09
TLL	0.126	0.337	0.256	0.19
SP	0.52	-0.074	0.063	0.28
UW	0.27	-0.438	0.086	0.27
UL	0.401	-0.041	-0.043	0.16
TW	-0.124	0.062	-0.177	0.05
TTL	-0.028	0.052	-0.19	0.04
DBT	0.307	-0.124	-0.028	0.11
Eigenvalue	6.118	3.546	2.686	
%Variance	17.0	9.9	7.5	
Accumulated Variance	17.0	26.8	34.3	

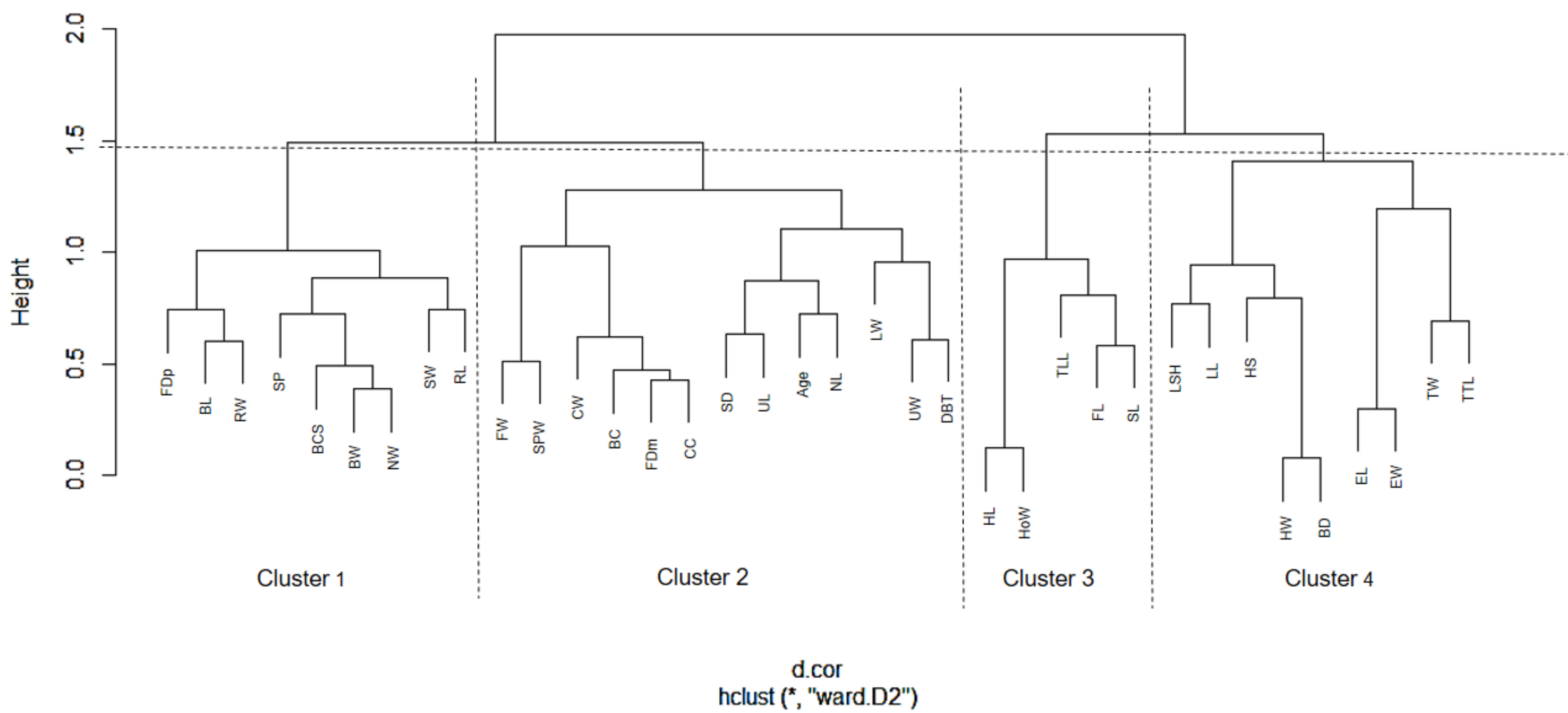

Figure 3. Dendrogram of classification by similarity in the variables considered to describe the phenotypic diversity in local goats of Comarca Lagunera, in northern Mexico

Cluster 1 described mostly characteristics of the anterior portion of the animal and grouped traits like trunk, neck, and head of the animals with FDp, BL, RW, SP, BCS, BW, NW, SW, and RL. Cluster 2 also grouped head characteristics, but also included mid-body projection variables and included traits such as FW, SPW, BC, FDm, CW, CC, SD, UL, Age, NL, LW, UW, and DBT. Cluster 3 considered variables that describe the extremities of the animals' bodies (HL, HoW, BL, FL, and SL). Cluster 4 identified variables from the rest of the body and included characteristics such as LSH, LL, HS, HW, UD, EL, EW, TW, and TTL, which represent the animals that stand out for having different characteristics of adaptation to heat (El-Moutchou *et al*., 2017), since they present greater height and area of skin exposure (greater size of ears and greater dimension of teats). This suggests more efficient thermoregulation mechanisms (Lenis-Sanin *et al*., 2016). Moreover, these findings concur with what Sánchez-Gutiérrez *et al*. (2018) reported in Celtiberian White goats from Mexico, where some of the variables that showed greater discriminating power to group by similarity were BW, TTL, FDp, EL, RL, SD, and HS.

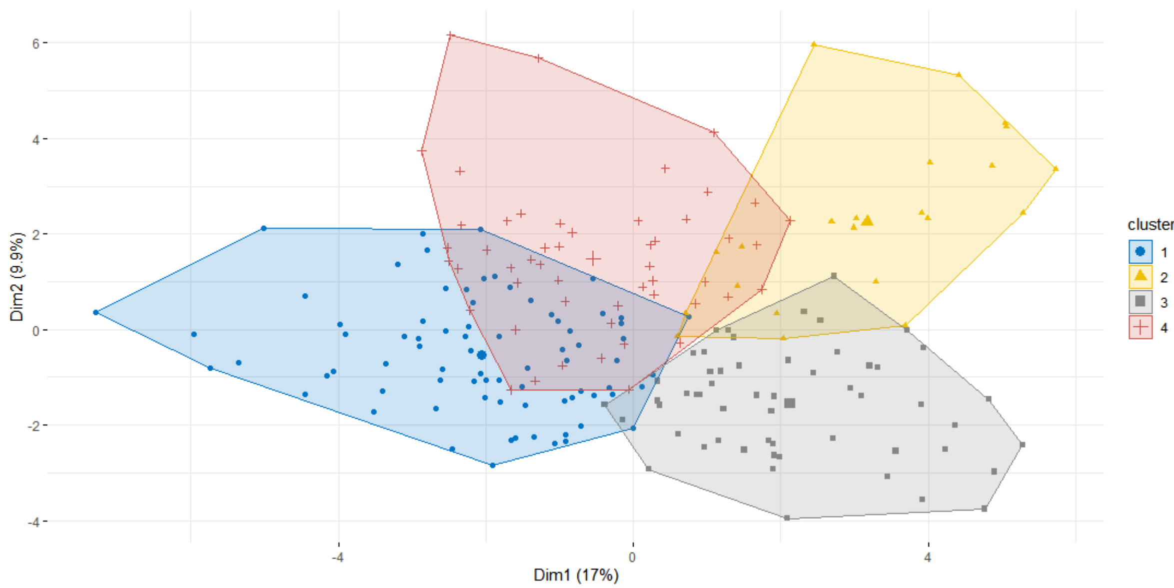

Figure 4. Groups of individuals classified by cluster in the plane of principal components 1 and 2

Figure 5 shows the individuals evaluated between locations. There was no clear differentiation between localities, which indicates that this population did not differ on the basis of locality. This suggests that the differences between variables and between clusters were induced by evolutionary processes of adaptation to particular microclimates. In this sense, the analysis between localities offers a focused vision, where the cluster within each group between localities suggests that there is no clear separation (Sanni *et al*., 2018). This makes it extremely complex to point out the existence of a "local breed or genotype" as a single genetic group and concurs with what the literature has described as "Lagunero Mosaic," where the influence of a specific breed is not observed (Vargas-López, 2015). The differences between the animals can occur due to various factors related to the environment or management practices (Laouadi *et al*., 2021). Nevertheless, as previously discussed, the heterogeneity in the characteristics suggests a gene flow and extensive crossing that have given rise to well-differentiated ecotypes. Therefore, actions should be taken in the immediate future to preserve the distinctive/unique characteristics of the local goats of Comarca Lagunera in northern Mexico, as well as to limit the genetic flow through strict control of the introduction of different "exotic" breeds (Ojo *et al*., 2015) that are not adapted to the extensive management conditions of the arid north of Mexico.

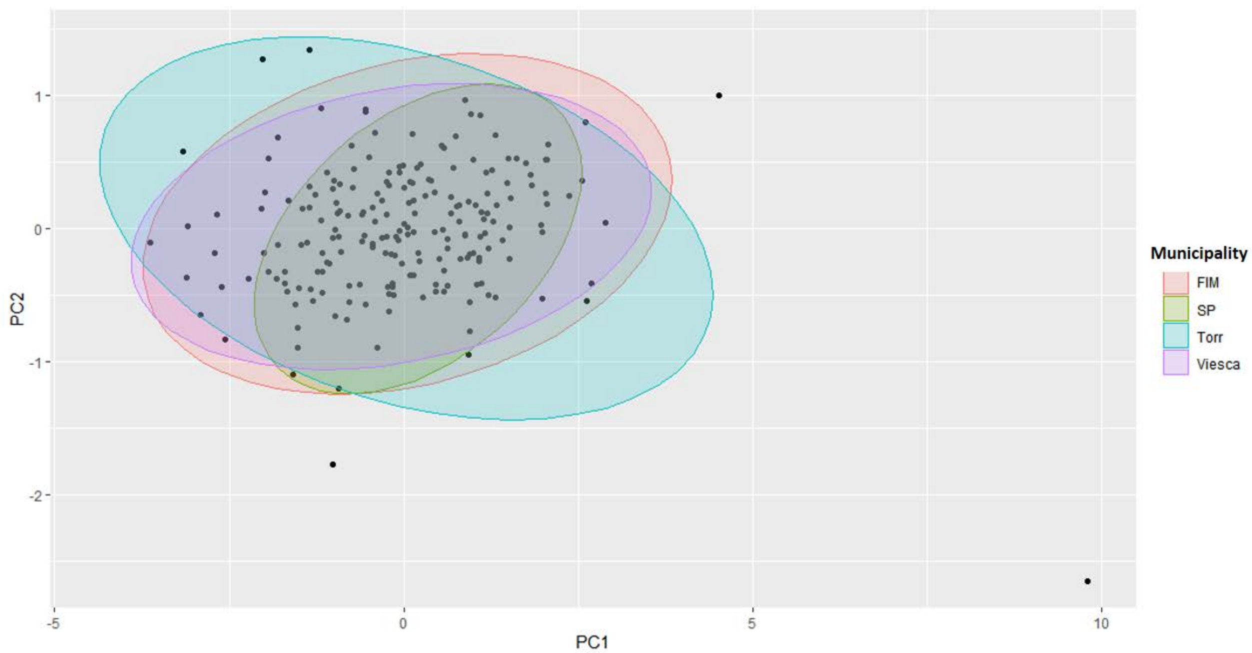

Figure 5. Distribution of phenotypic diversity of local goats according to their location by municipality in Comarca Lagunera in northern Mexico. FIM = Francisco I. Madero; SP = San Pedro de las Colonias; Torr = Torreón

Conclusions

The results show a moderate intrapopulation phenotypic variability, enough to differentiate various groups; a variability that has probably originated from adaptation mechanisms to the arid environment of the region, as well as from the indiscriminate crossing that has occurred in the population. This can be used as a basis for the definition of ecotypes in which the productive behaviour of each particular group is evaluated *a posteriori*.

This study provides baseline information on the local goat population of Comarca Lagunera in northern Mexico and should be used to plan future conservation programs and genetic improvement schemes. It should be noted that ignorance of these genetic resources risks the disappearance of particular adaptation characteristics due to the genetic erosion that occurs when introducing exotic genetic material, especially without any clearly defined objective.

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Author contributions

All authors contributed to the study’s conception. GTH, LDGR, and JAMJ designed the experiment, supervised and monitored the experimental work. JGM and PAB developed the statistical analysis. JAMJ and GHC wrote the first draft of the manuscript. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Conflict of Interest Declaration

None of the authors has any conflict of interest to declare.

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