Chilean J. Agric. Anim. Sci., (2026) 42(1): 26-39.
https://doi.org/10.29393/CHJAAS42-3SGSV60003

ISSN 0719-3890 online

STRUCTURAL INDICES IN LOCAL GOATS UNDER EXTENSIVE GRAZING SYSTEMS IN THREE GEOGRAPHIC REGIONS OF MEXICO

Irlanda J. Siliceo-Cantero[1a], Samuel Vargas-López[2], Omar Hernández-Mendo[1b], Javier Suárez-Espinosa[1c], Ricardo Lobato-Ortiz[1d], Jorge A. Maldonado-Jáquez[3], and Glafiro Torres-Hernández[1e]*

[1a] Colegio de Postgraduados-Campus Montecillo, CP: 56264. Montecillo, Mexico
https://orcid.org/0000-0003-4161-0801
[1b] Colegio de Postgraduados-Campus Montecillo, CP: 56264. Montecillo, Mexico
https://orcid.org/0000-0003-0756-7387
[1c] Colegio de Postgraduados-Campus Montecillo, CP: 56264. Montecillo, Mexico
https://orcid.org/0000-0001-8711-7436
[1d] Colegio de Postgraduados-Campus Montecillo, CP: 56264. Montecillo, Mexico
https://orcid.org/0000-0002-0944-165X
[1e] Colegio de Postgraduados-Campus Montecillo, CP: 56264. Montecillo, Mexico
https://orcid.org/0000-0002-0479-1191
[2] Colegio de Postgraduados-Campus Puebla. CP: 72760. Puebla, Mexico
https://orcid.org/0000-0002-8303-3128
[3] Campo Experimental La Laguna, INIFAP, CP: 27440. Coahuila, Mexico
https://orcid.org/0000-0001-8173-1048
* Corresponding author: glatohe@colpos.mx

ABSTRACT

The objective of the study was to evaluate morphometric variables (MV) and structural indices (SI) in local goat populations from three geographic regions of Mexico: Coahuila, Zacatecas, and Guerrero. Al total of 194 adult, non-pregnant goats, owned by smallholder farmers and managed under extensive conditions were utilized in the study without prior sampling selection. The sample included 71 goats from Coahuila, 50 from Zacatecas, and 73 from Guerrero. Live weight (LW) and 12 MV were recorded for each animal and used to calculate 14 SI: body index, compactness index, cephalic index, cranial index, pelvic index, dactyl-thoracic index, dactyl-costal index, relative shortness index, length index, longitudinal pelvic index, transverse pelvic index, relative cannon thickness index, and body capacity indices 1 and 2. Statistical analyses included analysis of variance (ANOVA) to assess differences among regions and correlation analysis to evaluate relationships between MV and SI. Significant differences (P≤0.05) in LW and 10 of the 12 morphological variables were observed among regions. Higher values for LW, chest width, head width, and cannon bone perimeter were recorded in goats from Coahuila and Zacatecas. Skull and rump lengths were greater (P≤0.05) in goats from Zacatecas and Guerrero, whereas head length and skull width were higher (P≤0.05) in Guerrero. In contrast, body length and withers height were greater in goats from Coahuila (P≤0.05). Phenotypic correlations among MV indicated a high degree of body harmony within these populations. Ethnological SI indicated that goats across the three regions are classified as brevilinear, dolichocephalous, and convexilinear. SI related to productive aptitude indicated that goats from Guerrero are primarily dairy animals, while those from Coahuila and Zacatecas are dual-purpose animals (meat and milk production).

Keywords: Morphometric variables, non-linear variables, productive aptitude, population harmony.

Received: August 19, 2025 Accepted: April 14, 2026

INTRODUCTION

The large area in Latin America and the Caribbean currently occupied by ecosystems with adverse environmental conditions is expected to expand due to the effects of climate change, which represents an opportunity to develop resilient food production systems based on native zoogenetic resources (Núñez-Domínguez et al., 2016). The first domestic animals introduced to the American continent from Europe and Africa at the beginning of the 16th century included chickens, pigs, goats, sheep, and cattle (Rodero et al., 1992). In Mexico, most goats in Mexico are Criollo, originating from the crossbreeding of animals introduced by Spanish colonizers (Mason, 1991), including breeds such as Murciano-Granadina, Blanca Celtibérica, and Castellana de Extremadura. Goats are multi-purpose animals that provide milk, meat, skins, and fiber, and are mainly raised by low-income rural producers (Dubeuf and Boyazoglu, 2009). Within these systems, Criollo goats (also referred to as local, indigenous, or native) play a key role in small ruminant production, especially in regions characterized by limited feed availability and adverse agroecological conditions (Martín Bellido et al., 2001). In addition, goats, particularly those belonging to local populations and breeds, exhibit a remarkable ability, compared with other ruminants, to use forage resources (grass, shrubs, crop or feed residues), included those with limited alternative uses, thus contributing to the valorization of biomass and mitigation of greenhouse gases (Dubeuf, 2023).

The importance of local goat populations for low-income rural producers in Latin America and the Caribbean has been widely documented by Torres-Hernández et al. (2022b). In this context, there is a clear need to conduct in-depth studies on the productive and functional characterization of local goat populations across diverse environmental conditions. Such efforts are essential to support the development of effective genetic improvement programs, whose progress remains limited at the international level (Montaldo et al., 2010; Torres-Hernández et al., 2022a), as well as conservation programs aimed at preserving the most valuable germplasm, whose first efforts have been initiated in Mexico with local goats from the Montaña de Guerrero region (Vargas-López et al., 2022).

The criteria required to implement genetic improvement and conservation programs have been discussed by Assefa et al. (2023) in an effort to better understand the type and zootechnical function of these genotypes, since available information highlights that local goat populations have a high potential for genetic improvement (Argyriadou et al., 2020; Torres-Hernández et al., 2022b). According to FAO (2012), information derived from morphometric variables (MV) constitutes an important component for the development of genetic improvement programs, as well as for the sustainable use and conservation of these populations. In this sense, zoometry is defined as the study of the structure and conformation of animals based on established morphometric measurements (Macedo, 2017; Ilham et al., 2023). Over time, this discipline has evolved, and its primary application is to predict traits of economic importance in animal production, such as live weight, daily weight gain, reproductive performance, productive aptitude, body size, breed characterization, and the origin of the animal and relationships among animals (Khargharia et al., 2015; Yemane et al., 2020).

In recent years, non-linear combinations of MV have been used in goats in the form of structural indices (SI) to evaluate productive performance, functional traits, morphological type, and zootechnical aptitude (Chiemela et al., 2016; Putra and Ilham, 2019; Tade et al., 2021). SI are considered more reliable than MV and are generally independent of the animal's age (Salako, 2006). In Mexico, studies have investigated MV in local goats populations (Dorantes-Coronado et al., 2015; Vargas-López et al., 2022, Torres-Hernández et al., 2023). However, studies on SI in local Mexican goats are scarce (Silva-Jarqu◎ín et al., 2019b; Maldonado-Jáquez et al., 2023). The objectives of this study were to: 1) assess morphometric variables in three local goat populations, 2) determine their body harmony, and 3) analyze structural indices derived from morphometric variables. The findings are expected to provide valuable information for the design of targeted genetic improvement and conservation programs. The proposed hypothesis was that significant differences ($P \leq 0.05$) exist among the studied populations in terms of morphometric measurements, body harmony, and structural indices.

MATERIALS AND METHODS

Description of the study location

This study was carried out from March to September 2023 on eight goat farms that belong to smallholder farmers in rural areas of the states of Coahuila (northern region), Zacatecas (central-northern region) and Guerrero (southern region), Mexico. Three of these goat farms were located in the area known as "Comarca Lagunera", Coahuila, characterized by a semi-warm climate with an annual precipitation of approximately 240 mm. The production system in this area focuses on the sale of raw milk and "cabrito" (suckling kids marketed at one-month of age). Three goat farms were visited in Zacatecas, a semi-arid region, with an annual precipitation of approximately 340 mm. Finally, two goat farms were visited in Guerrero, in the area known as the "Montaña de Gerrero", which is characterized by a temperate sub-humid climate and an annual precipitation ranging from 900 to 1,200 mm. In both Zacatecas and Guerrero, the dominant production system focuses on meat production from adult animals.

Population size

A total of 194 adult, non-pregnant local (non-improved) goats (> 3 years of age) were included in this study. Of these, 71 goats were sampled in Coahuila, existing phenotypic characteristics associated with the Saanen, Alpine, Toggenburg and Nubian breeds, and to a lesser extent the Blanca Celtibérica breed. These breeds were brought from the National Goat Center of Tlahualilo, Durango, Mexico (Montaldo et al., 1995; Pérez-Razo et al., 2004). In Zacatecas, 50 goats were evaluated, showing phenotypic traits similar primarily to the Blanca Celtibérica breed, and to a lesser extent, to the Nubian and Alpine breeds. In Guerrero, 73 goats were studied; this population was the most homogeneous among the three regions, as the predominant genotype corresponds to the Blanca Celtibérica breed. According to information provided by the local farmers, these goats are estimated to have approximately 7/8 breed purity, reflecting a long-term, gradual grading-up crossbreeding program implemented over several years.

Animal management

Goats were managed under an extensive production system, characterized by daytime grazing on rangelands with native vegetation, without nutritional supplementation, and night-time confinement. Animals had free access to mineral salts and clean water. Health management was limited to vaccination against brucellosis and routine control of internal and external parasites through deworming every six months.

Data collection

Live weight (LW, kg) and the following MV (cm) were recorded: body length (BL), hearth girth (HG), chest width (CW), head width (HW), head length (HL), skull width (SW), skull length (SL), rump width (RW), rump length (RL), cannon bone perimeter (CBP), and withers height (WH). Measurements were obtained using an electronic hook scale with a capacity of 300 kg ± 100 g (BAC-300, Rhino, Mexico), a zoometric stick, and a soft flexible measuring tape (Selanusa, Mexico), following procedures indicated by FAO (FAO, 2012). Animal care and handling was carried out in accordance with established guidelines from official standards (Kendall et al., 2018).

Means and standard deviations of LW and MV were obtained, along with Pearson's phenotypic correlations between LW and MV. SI were then obtained from the MV (Table 1). Indices related to ethnological type included: body index (BI), compactness index (COI), cephalic index (CEI), cranial index (CRI), and pelvic index (PEI). Indices associated with dairy aptitude included: dactyl-thoracic index (DTI) and dactyl-costal index (DCI). Indices indicative of meat aptitude included: relative shortness index (RSI, also called proportionality index), length index (LI), longitudinal pelvic index (LPI), transverse pelvic index (TPI), relative cannon thickness index (RCI), body capacity index-1 (BCI-1), and body capacity index-2 (BCI-2). All indices were calculated following procedures described in the literature (Khargharia et al., 2015; Dauda et al., 2018).

Statistical analysis

For Objective 1, a one-way analysis of variance (ANOVA) was performed, with LW and MV as

Table 1. Structural indices used to characterize local goat populations across three geographical regions of Mexico.

Index	Formula
BI	(BL/HG) x 100
COI	(LW/WH) x 100
CEI	(HW/HL) x 100
CRI	(SW/SL) x 100
PEI	(RW/RL) x 100
DTI	(CBP/HG) x 100
DCI	(CBP/CW) x 100
RSI	(WH/BL) x 100
LI	(BL/WH) x 100
LPI	(RL/WH) x 100
TPI	(RW/WH) x 100
RCI	(CBP/WH) x 100
BCI-1	(LW/BL) x 100
BCI-2	(LW/HG) x 100

BI: body index, COI: compactness index, CEI: cephalic index, CRI: cranial index, PEI: pelvic index, DTI: dactyl-thoracic index, DCI: dactyl-costal index, RSI: relative shortness index, LI: length index, LPI: longitudinal pelvic index, TPI: transverse pelvic index, RCI: relative cannon thickness index, BCI-1: body capacity index-1, BCI-2: body capacity index-2.

response variables and region as the independent variable. Means ± standard deviations were calculated, and mean comparisons were performed using the Tukey test at 5% of significance. For Objective 2, a Pearson's correlation analysis was carried out between LW and MV to determine body harmony of each population, based on the number of positive and significant (P≤0.05) correlations, according to Herrera and Luque (2009). For Objective 3, a one-way ANOVA was carried out with SI as the response variable and region as the independent variable. Means ± standard deviations, minimum and maximum values, and coefficients of variation were obtained for each response variable. The R-studio software (R Core Team, 2020) was used in all analyses.

RESULTS AND DISCUSSION

Morphometric variables

Results on LW and MV from the three regions are shown in Table 2. The three populations were similar (P>0.05) only in HG, which indicates substantial morphological heterogeneity among them. This finding is consistent with Sevane et al. (2018), who reported patterns associated with ancestral genetic contributions in Criollo goat populations in the American continent. Their results revealed: i) a lack of clear geographical patterns in the distribution of goat genetic diversity in America; ii) marked differentiation among several Criollo breeds; iii) significant Iberian autosomal contributions in most populations studied; iv) a surprisingly high contribution of the African genetic pools, particularly in the Cuban Criollo goat, and v) the relative genetic isolation of Brazilian breeds, with a certain influence from Cape Verde goats.

Goats from Coahuila surpassed (P≤0.0001) those from Zacatecas and Guerrero for BL, RW, and WH. They were similar to goats from Zacatecas (P>0.05), and both groups exceeded (P≤0.001) goats from Guerrero in LW, CW, HW, and CBP. Conversely, goats from Guerrero exceeded (P≤0.0001) those from Coahuila and Zacatecas in HL and WH; they did not differ from the Zacatecas goats (P>0.05) and both groups surpassed (P≤0.001) goats from Coahuila in SL and RL.

Martínez-Rojero et al. (2014) reported greater WH (78.8 cm) in purebred Blanca Celtibérica goats from Guerrero than in goats from the three regions evaluated in the present study. They also reported similar LW (43.0 kg) to that observed in goats from Coahuila and Zacatecas, but a slightly lower HG (82.0 cm) than that found in all populations of the present study. In terms of SL and RL, goats from Guerrero surpassed (P≤0.001) those from the Coahuila. Vargas-López et al. (2007) reported an RW value (11.9 cm) in Creole goats from Puebla, Mexico, that is similar to that observed in goats from Guerrero but lower than that of goats from Coahuila and Zacatecas. In the same study, BL (51.0 cm) and RW (12.5 cm) values were similar to those of goats from

Table 2. Least-squares means (mean ± s.d.) for live weight (kg) and morphometric variables (cm) of local goats from three geographical regions of Mexico.

Variable	Coahuila Mean ± s.d. n=71	Zacatecas Mean ± s.d. n=50	Guerrero Media ± s.d. n=73	p-value
LW	44.0 ± 9.9a	43.4 ± 9.4a	35.2 ± 6.8b	<0.0001
BL	57.1 ± 5.2a	51.1 ± 5.7b	48.1 ± 4.2c	<0.0001
HG	82.6 ± 6.3	82.8 ± 5.8	82.9 ± 5.8	0.9596
CW	25.9 ± 3.9a	26.8 ± 3.9a	23.7 ± 2.2b	<0.0001
HW	11.9 ± 0.9a	11.8 ± 1.0a	11.3 ± 1.0b	0.0035
HL	15.4 ± 2.1b	13.9 ± 1.6c	18.8 ± 1.3a	<0.0001
SW	9.6 ± 1.1b	9.4 ± 0.8b	10.7 ± 1.2a	<0.0001
SL	11.4 ± 1.1b	12.2 ± 1.3a	12.0 ± 1.5a	0.0022
RW	18.9 ± 1.5a	17.7 ± 3.1b	12.7 ± 1.4c	<0.0001
RL	20.6 ± 1.6b	21.0 ± 2.0ab	21.3 ± 1.4a	0.0464
CBP	9.8 ± 1.0a	9.7 ± 1.0a	8.8 ± 1.0b	0.0001
WH	70.8 ± 4.1a	68.0 ± 3.4b	63.8 ± 4.3c	<0.0001

LW: live weight, BL: body length, HG: hearth girth, CW: chest width, HW: head width, HL: head length, SW: skull width, SL: skull length, RW: rump width, RL: rump length, CBP: cannon bone perimeter, WH: withers height. Means with different letters differ significantly (P≤0.05).

Guerrero but lower than those recorded for goats from Coahuila and Zacatecas. Likewise, WH (60.7 cm) was lower than that observed in goats from the three regions of the present study. Dorantes-Coronado et al. (2015) reported a lower LW (33.0 kg) in local goats from southern Mexico than the average observed across the three regions of the present study. They also reported a WH (66.2 cm) similar to that of goats from Zacatecas, lower than that of goats from Coahuila, and greater than the average of goats from Guerrero.

Silva-Jarqu◎ín et al. (2019a) reported a BL (71.2 cm) in Criolla Negra goats from central Mexico, being greater than that observed in goats from the three regions of the present study. They also reported a WH (70.1 cm) comparable to that of goats from Coahuila and Zacatecas, and a CBP (8.5 cm) similar to that of goats from Guerrero. In addition to the differences found between LW and MV among local goats from the three regions in the present study, variations (either lower or higher) were also observed when comparing these populations with local goats from other Latin American countries, such as Venezuela (Pariacote et al., 2004), Argentina (Revidatti et al., 2007), and Cuba (Chacón et al., 2011). These differences may be partly explained not only by genetic variation among goat populations but also by environmental factors. Specifically, climate-related variables such as temperature and humidity strongly influence the quality and quantity of plant species available in rangelands, contributing to the development of different ecotypes, as reported by Dossa et al. (2007) and Dea et al. (2019).

Body harmony of populations

The proportion of positive and significant correlations (P≤0.05) between LW and MV was 78.7% in Coahuila, 71.2% in Zacatecas, and 86.3% in Guerrero. According to Herrera and Luque (2009), the magnitude of these correlations indicates that these populations have a high degree of body harmony and suggest the absence of a structured genetic selection program or the application of inadequate selection criteria. Based on field observation and repeated annual visits to the farms, it can be inferred that no formal genetic selection program has been implemented in any of these populations. Based on the magnitude of correlations, the highest degree of body harmony was obtained in the Guerrero goat population. This finding coincides with the description of this population genotype, as these goats show a high level of homogeneity due to the progressive use of Blanca Celtibérica rams for mating. Silva-Jarquín et al. (2019b) reported that 91.2% of the correlations among the MV analyzed in Criolla Negra goats from central Mexico were positive and significant (P≤0.05). This result indicated a highly harmonious model in this population, which the authors attributed to the high degree of homogeneity, mainly due to the shared ancestry with the Murciano-Granadina breed. Chacón et al. (2011) estimated phenotypic correlations among linear body measurements of Criollo goats and crosses with Nubian in Cuba, reporting that 46.6% of these correlations were positive and significant (P≤0.05), which indicated a moderate level of body harmony in this population. Similarly, Abarca-Vargas et al. (2020) analyzed 10 body measurements in crossbred goats from Colima, Mexico, reporting that all the estimated correlations were positive and significant (P≤0.05), which led the authors to conclude that this population exhibited a high degree of body harmony. However, they later indicated that such results would imply the use of selection criteria within the population, criteria that in fact were not implemented, as goat producers have carried out intensive crossbreeding with meat breeds. Therefore, this result appears contradictory to the criteria proposed by Herrera and Luque (2009).

Structural indices

Results of the SI are shown in Table 3, where significant differences (P≤0.05) were observed among the three goat populations. The coefficients of variation were more stable in the Guerrero population, with only 9.7% of the total variation above 10%. In contrast, the Coahuila and Zacatecas populations showed greater variability, with 50% and 78.5% of their coefficient of variation exceeding 10%, respectively.

Ethnological indices

The BI reflects the proportional relationships among body components of the animals. Based on criteria by Pares (2009) and Cerqueira (2011), goats from the three regions can be classified as brevilineous or compact (COI <85). The BI also serves as an indicator of the animal's foraging capacity, especially in environments with rugged topography (Banerjee et al., 2014; Khargharia et al., 2015). In addition, the COI is related to a body structure suitable for milk production (Herrera-Cáceres and Hernández-Corredor, 2022). The values obtained in the present study are similar to those reported by the same authors for the Motilona goat from Norte de Santander, Colombia, which is used for dual-purpose production (meat and milk), as well as those described for Creole goats from Argentina (Revidatti et al., 2007). The CEI values were < 100 in goats from the three regions studied; therefore, they are classified as dolichocephalic according

Table 3. Structural indices of local goat populations across three geographic regions of Mexico.

	Coahuila (n=71)				Zacatecas (n=50)				Guerrero (n=73)				
Index	**Mean±s.d.**	**Min**	**Max**	**CV**	**Mean±s.d.**	**Min**	**Max**	**CV**	**Mean±s.d.**	**Min**	**Max**	**CV**	**p- value**
BI	69.3 ± 0.7ª	55.6	94.9	9.2	61.6 ± 0.7b	48.0	77.0	8.2	58.0 ± 0.5c	43.0	65.6	7.2	<0.0001
COI	62.0 ± 1.5	38.0	101.5	21.0	63.7 ± 1.8	36.7	93.2	19.9	64.5 ± 8.4	40.5	78.3	9.6	0.9354
CEI	78.7 ± 1.5b	57.1	118.2	16.7	86.5 ± 2.2a	64.5	166.6	18.5	60.3 ± 0.5c	52.3	73.7	6.4	<0.0001
CRI	85.3 ± 1.2ª	66.7	114.3	11.9	78.1 ± 1.2b	53.3	95.6	11.2	89.1 ± 1.9a	79.1	94.8	7.6	<0.0001
PEI	91.8 ± 0.8ª	75.5	105.7	7.7	84.0 ± 1.6b	57.8	104.7	13.6	59.5 ± 0.7c	50.0	80.9	10.4	<0.0001
DTI	11.9 ± 0.1ª	9.8	14.6	8.2	11.7 ± 0.1a	10.2	14.3	8.5	10.6 ± 0.1b	8.9	12.3	6.2	<0.0001
DCI	38.6 ± 0.6	28.5	50.0	14.3	36.6 ± 0.7	28.3	46.0	13.9	37.3 ± 0.4	29.6	43.5	8.1	0.0587
RSI	124.8 ± 1.3b	94.6	152.1	8.7	134.3 ± 1.9a	97.0	167.5	10.1	130.1 ± 2.6ab	127.1	140.5	15.9	0.0049
LI	80.7 ± 0.8	65.7	105.7	8.9	75.2 ± 1.1	59.6	103.0	10.4	88.5 ± 11.1	75.4	90.4	9.3	0.4074
LPI	29.2 ± 0.3c	24.8	34.3	7.6	30.9 ± 0.4b	22.2	36.7	9.5	39.5 ± 5.1a	28.2	43.8	11.7	0.0388
TPI	26.7 ± 0.3	21.3	32.8	8.8	26.0 ± 0.6	16.4	33.6	16.3	23.1 ± 2.8	18.7	29.0	8.5	0.2689
RCI	13.9 ± 0.2	10.9	17.2	10.0	14.2 ± 0.2	11.1	18.6	11.3	16.3 ± 2.1	12.1	19.7	16.8	0.3538
BCI-1	76.9 ± 1.8b	47.5	119.4	19.6	84.6 ± 2.0a	56.5	122.6	16.7	72.9 ± 1.2b	64.5	78.7	9.6	<0.0001
BCI-2	52.8 ± 1.1ª	35.5	75.5	17.0	51.9 ± 1.1a	32.8	71.9	15.8	42.2 ± 0.7b	37.7	53.1	8.9	<0.0001

BI: body index, COI: compactness index, CEI: cephalic index, CRI: cranial index, PEI: pelvic index, DTI: dactyl-thoracic index, DCI: dactyl-costal index, RSI: relative shortness index, LI: length index, LPI: longitudinal pelvic index, TPI: transverse pelvic index, RCI: relative cannon thickness index, BCI-1: body capacity index-1, BCI-2: body capacity index-2. CV: coefficient of variation, a,b,c: means with different letters within rows differ significantly ($P \leq 0.05$).

to Pares (2009). These values are comparable to those reported by Revidatti et al. (2007) for Creole goats from Argentina. No studies were found in the literature addressing analysis of the CRI in goats. However, findings from Goodarzi and Hoseini (2014), based on analyses of skulls from Markhoz goats (Iranian Angora,) indicate that morphological and osteometric characteristics of this breed are comparable to those of Kagani, West African Dwarf and Red Sokoto goats, as well as Mehraban sheep. Furthermore, Balcarcel et al. (2024) found that the skull shape differs markedly between domesticated and wild goats, with differences that are attributed to domestication rather than to the breed *per se*. The PEI provides an estimate of rump structure and is related to the reproductive fitness of the animal (Pares, 2009; Silva-Jarquín et al., 2019b), as well as suitability for meat production (Dauda, 2018). In the present study, PEI values were < 100 in the three populations evaluated; therefore, the goats are classified as convexilinear. In addition, the CEI and PEI values observed in the Coahuila and Zacatecas populations, respectively, are comparable to those reported by Silva-Jarquín et al. (2019b) for Criolla Negra goats from the central region of Mexico.

Dairy aptitude indices

The DTI and DCI indices are used to assess the animal's aptitude for milk production by establishing the relationship between pectoral mass and the supporting limbs (Abarca-Vargas et al., 2020), thus determining whether body volume is proportional to bone development (Moreno et al., 2013). Regarding the DCI, Abarca-Vargas et al. (2020) found that values between 40 and 45, or lower, indicate good aptitude for milk production. Based on DTI values, goats from the Guerrero population tend to be eumetric (< 11), suggesting a tendency toward milk production. In contrast, according to these indices (Macedo Barragán, 2017), goats from the Coahuila and Zacatecas populations show a tendency toward a meat production phenotype.

Meat aptitude indices

Based on the overall RSI values obtained for the three regions studied (range: 124.8-134.3), goats can be classified as long-lined (RSI >100). These values are also higher than those reported by Morales-delaNuez et al. (2012) for three biotypes from the Canary Islands (range: 88.8-92.4). This difference can be explained by the fact that goats in the present study have a higher average WH than BL, which contrasts with the patterns observed in goats from the Canary Islands. This advantage of a higher WH in relation to BL allows their classification as goats with dairy aptitude (Parés, 2009). Regarding LI, Ilham et al. (2023) indicated that values < 1 correspond to tall animals, whereas values > 1 indicate long animals. Therefore, goats from the three regions of the present study are classified as long-lined, which is consistent with the RSI classification. The LPI and TPI indices are associated with suitability for meat production (Silva-Jarquín et al., 2019b). According to these authors, LPI values < 37 and PTI values > 33 are indicators of meat breeds. Based on the LPI results, goats from the Coahuila and Zacatecas populations are suitable for meat production, which agrees with the tendency observed for the DTI in the same populations. Additionally, Takele et al. (2022) reported that higher RCI values are characteristic of breeds with aptitude for meat production. Therefore, the RCI values obtained in the present study (13.9-16.3) indicate that goats from Coahuila and Zacatecas have characteristics associated with meat production. However, based on the combined results of the DTI, LPI, RSI and RCI indices, goats from both populations can be classified as dual-purpose animals (meat and milk). With respect to goats from Coahuila, it is important to highlight that the "Comarca Lagunera" (the region from which the goats were sampled) is the main goat milk production basin in Mexico.

No studies were found in the literature reporting BCI-1 and BCI-2 indices in goats. However, da Silva et al. (2019) mentioned that, in sheep, these indices are related to body capacity and served as objective measures of conformation. Furthermore, da Silva et al. (2006) indicated that increases in BCI-1 in adult sheep are associated with muscle and fat deposition. In addition, da Costa et al. (2014) concluded that BCI-1 and BCI-2 are adequate indices for evaluating conformation in Santa Inés sheep from Brazil.

According to the results shown in Tables 4, 5, and 6, the highest and most common significant correlations (P≤0.05) for the three goat populations were observed between LW and both BCI-1 and BCI-2 (range: 0.87-0.98), which can be explained by the shared inclusion of MV in these indices. Similar patters were identified for several other index combinations: LW-COI (Coahuila and Zacatecas); BI-RSI (Coahuila and Zacatecas); COI with BCI-1 and BCI-2 (Coahuila and Zacatecas): COI with LPI and TPI (the three regions); PEI with TPI, BCI-1 and BCI-2 (Coahuila and Zacatecas); DTI with DCI (the three regions); DTI-RCI (Coahuila and Zacatecas); DCI-RCI (Coahuila and Zacatecas); RSI with LI, LPI, and RCI (the three regions); LI with LPI, TPI and RCI (the three regions); LPI with TPI, RCI, BCI-1 and BCI-2 (Coahuila and Zacatecas); TPI with RCI

Table 4. Phenotypic correlation matrix between live weight and structural indices in local goats from Coahuila, Mexico.

	LW	BI	COI	CEI	CRI	PEI	DTI	DCI	RSI	LI	LPI	TPI	RCI	BCI-1	BCI-2
LW	1	-0.17ns	0.96**	0.25ns	0.18ns	0.38*	0.05ns	-0.24ns	-0.25ns	0.27ns	0.14ns	0.45*	0.42*	0.90**	0.95**
BI		1	-0.20ns	-0.43*	0	-0.18ns	-0.19ns	0.22ns	-0.62**	0.62**	0.18ns	0	-0.19ns	-0.50*	-0.03ns
COI			1	0.24ns	0.10ns	0.41*	0.03ns	-0.25ns	-0.35*	0.37*	0.29*	0.61**	0.52*	0.89**	0.92**
CEI				1	0.09ns	0.23ns	-0.01ns	-0.15ns	0.23ns	-0.23ns	-0.18ns	0.04ns	0.18ns	0.38*	0.19ns
CRI					1	0.14ns	0.20ns	0.16ns	0.11ns	-0.11ns	-0.19ns	-0.05ns	0.06ns	0.14ns	0.19ns
PEI						1	-0.04ns	-0.19ns	-0.16ns	0.13ns	-0.37*	0.56*	0.26ns	0.38*	0.33*
DTI							1	0.62**	-0.01ns	0.01ns	0.12ns	0.08ns	0.66**	0.02ns	0.16ns
DCI								1	-0.06ns	0.05ns	0.09ns	-0.09ns	0.35*	-0.27ns	-0.19ns
RSI									1	-0.99**	0.46*	-0.55*	-0.33*	0.09ns	-0.24ns
LI										1	0.49*	0.55*	0.33*	-0.08ns	0.26ns
LPI											1	0.56*	0.56*	0.39*	0.46*
TPI												1	0.36*	0.07ns	0.20ns
RCI													1	0.40*	0.38*
BCI-1														1	0.87**
BCI-2															1

LW: live weight, BI: body index, COI: compactness index, CEI: cephalic index, CRI: cranial index, PEI: pelvic index, DTI: dactyl-thoracic index, DCI: dactyl-costal index, RSI: relative shortness index, LI: length index, LPI: longitudinal pelvic index, TPI: transverse pelvic index, RCI: relative cannon thickness index, BCI-1: body capacity index-1, BCI-2: body capacity index-2. *: (P≤0.05), **: (P≤0.01), ns: (P>0.05).

Table 5. Phenotypic correlation matrix between live weight and structural indices in local goats from Zacatecas, Mexico.

	LW	BI	COI	CEI	CRI	PEI	DTI	DCI	RSI	LI	LPI	TPI	RCI	BCI-1	BCI-2
LW	1	0.13ns	0.97**	0.02ns	0.44*	0.64**	-0.06ns	0.30*	-0.52*	0.49*	0.47*	0.77**	0.28*	0.88**	0.98**
BI		1	0.10ns	0.18ns	0.10ns	0.33*	0.07ns	-0.01ns	-0.73**	0.74**	-0.06ns	0.25ns	0	-0.32*	0.16ns
COI			1	0.06ns	0.46*	0.59*	0	-0.28*	-0.59*	0.57*	0.60**	0.81**	0.42*	0.87**	0.95**
CEI				1	0.19ns	0.11ns	0.27*	-0.18ns	-0.14ns	0.22ns	0.09ns	0.15ns	0.24ns	-0.07ns	0.03ns
CRI					1	0.46*	0.03ns	-0.08ns	-0.37*	0.35*	0.39*	0.58*	0.25ns	0.35*	0.43*
PEI						1	-0.04ns	-0.10ns	-0.47*	0.45*	0.04ns	0.83**	0.12ns	0.46*	0.64**
DTI							1	0.58*	-0.10ns	0.11ns	0.34*	0.15ns	0.80**	-0.05ns	0
DCI								1	0.09ns	-0.07ns	0.04ns	-0.07ns	0.39*	-0.29*	-0.30*
RSI									1	-0.99**	-0.42*	-0.63**	-0.43*	-0.13ns	-0.50*
LI										1	0.41*	0.61**	0.45*	0.09ns	0.46*
LPI											1	0.59*	0.46*	0.63**	0.78**
TPI												1	0.66**	0.48*	0.48*
RCI													1	0.26*	0.28*
BCI-1														1	0.88**
BCI-2															1

LW: live weight, BI: body index, COI: compactness index, CEI: cephalic index, CRI: cranial index, PEI: pelvic index, DTI: dactyl-thoracic index, DCI: dactyl-costal index, RSI: relative shortness index, LI: length index, LPI: longitudinal pelvic index, TPI: transverse pelvic index, RCI: relative cannon thickness index, BCI-1: body capacity index-1, BCI-2: body capacity index-2. *: (P≤0.05), **: (P≤0.01), ns: (P>0.05).

Table 6. Phenotypic correlation matrix between live weight and structural indices in local goats from Guerrero, Mexico.

	LW	BI	COI	CEI	CRI	PEI	DTI	DCI	RSI	LI	LPI	TPI	RCI	BCI-1	BCI-2
LW	1	0.09ns	0.11ns	0.35*	0.14ns	0.18ns	-0.08ns	0	-0.07ns	0.02ns	0	0.02ns	0.01ns	0.87**	0.96**
BI		1	-0.16ns	0.08ns	-0.13ns	-0.04ns	0.30*	0.02ns	-0.23ns	-0.12ns	-0.16ns	-0.17ns	-0.17ns	-0.34*	0.24ns
COI			1	-0.23ns	-0.03ns	-0.11ns	-0.15ns	0.10ns	-0.80**	0.99**	0.99**	0.99**	0.99**	0.11ns	0.03ns
CEI				1	0.18ns	0.49*	0.03ns	0.20ns	0.16ns	-0.26ns	-0.27ns	-0.23ns	-0.26ns	0.25ns	0.30*
CRI					1	0.10ns	-0.01ns	0.25ns	0.06ns	-0.05ns	-0.06ns	-0.05ns	-0.05ns	0.18ns	0.10ns
PEI						1	-0.07ns	0.07ns	0.14ns	-0.12ns	-0.15ns	-0.06ns	-0.12ns	0.12ns	0.09ns
DTI							1	0.56*	0.04ns	-0.13ns	-0.13ns	-0.14ns	0.10ns	-0.13ns	0.05ns
DCI								1	-0.11ns	0.10ns	0.10ns	0.11ns	0.13ns	0.03ns	0.05ns
RSI									1	-0.82**	-0.81**	-0.80**	-0.81**	0.10ns	-0.04ns
LI										1	1	1	1	0.01ns	-0.06ns
LPI											1	1	1	0.03ns	-0.07ns
TPI												1	1	0.02ns	-0.07ns
RCI													1	0.02ns	-0.07ns
BCI-1														1	0.83**
BCI-2															1

LW: live weight, BI: body index, COI: compactness index, CEI: cephalic index, CRI: cranial index, PEI: pelvic index, DTI: dactyl-thoracic index, DCI: dactyl-costal index, RSI: relative shortness index, LI: length index, LPI: longitudinal pelvic index, TPI: transverse pelvic index, RCI: relative cannon thickness index, BCI-1: body capacity index-1, BCI-2: body capacity index-2. *: ($P \leq 0.05$), **: ($P \leq 0.01$), ns: ($P > 0.05$).

(the three regions); RCI with BCI-1 and BCI-2 (Coahuila and Zacatecas), and finally BCI-1 with BCI-2.

Six perfect correlations were obtained in the Guerrero population (LI-LPI, LI-TPI, LI-RCI, LPI-TPI, LPI-RCI, and TPI-RCI. In case of high, positive, and significant correlations ($P \leq 0.05$), one SI can be the indicator of the other, allowing selection to be based on a single index (Assefa et al., 2023). Under such conditions, it is advisable to use the SI that is the easiest to measure or the most-cost effective. According to Depison et al. (2020), differences in SI can be attributed mainly to differences in goat genotypes, animal management practices, geographic regions, agro-climatic conditions, and the availability of natural resources.

Of the 105 total correlations among the SI estimated in each region, 41 were significant ($P \leq 0.05$) in Coahuila (34 positive and 7 negative), 61 in Zacatecas (47 positive and 14 negative), and 17 in Guerrero (11 positive and 6 negative). Depison et al. (2020), Getaneh et al. (2022) and Assefa et al. (2023) reported a predominance of positive correlations among SI measured in goats of different genotypes. In contrast, Tyasi and Putra (2021) found a higher number of negative than positive correlations in South African Creole goats. These discrepancies in the literature can be largely attributed to differences in genotype, as populations subjected to genetic improvement through genetic selection tend to exhibit comparatively greater morphological harmony (Bertaglia et al., 2007).

CONCLUSIONS

This study revealed significant differences in morphometric variables, body harmony, and structural indices among local goat populations from the three regions of Mexico. The results indicate that these goats are divided into distint subpopulations, a factor that should be considered when designing genetic improvement and conservation programs. Furthermore, the findings highlight the need for continued research focused on characterizing production systems in marginal rural areas, as these systems are a reservoir of valuable genetic resources. Such resources may provide key insights for addressing food security challenges in highly marginalized rural communities. Further studies on local goat populations should adopt a sustainable and holistic approach.

ACKNOWLEDGMENTS

We thank the goat producers from the three regions studied for their invaluable support. We also thank the National Council of Humanities, Science and Technology (CONAHCyT-Mexico) for the scholarship awarded to the first author (IJSC) for PhD studies in Animal Science. This project was conducted within the Line of Generation and Application of Knowledge entitled “Technological Innovation and Food Safety in Livestock” of Colegio de Postgraduados.

Author contributions

Participation in Literature Review: Glafiro Torres-Hernández, and Omar Hernández-Mendo. Study conception and design: Irlanda J. Siliceo-Cantero, and Glafiro Torres-Hernández. Material preparation, data collection and analysis: Jorge A. Maldonado-Jáquez, Glafiro Torres-Hernández, and Javier Suárez-Espinosa. Methodology development: Ricardo Lobato-Ortiz, and Samuel Vargas-López. The first draft of the manuscript was written by Irlanda J. Siliceo-Cantero, and Glafiro Torres-Hernández. All authors commented on previous versions of the manuscript. All authors read and approved the last version of the manuscript.

Data availability: The dataset is available from the corresponding author on reasonable request.
Conflict of Interest: The authors declare that they have no conflict of interest.

LITERATURE CITED

Abarca-Vargas, D., R. Macedo-Barragán, V. Arredondo-Ruiz, M. Valencia-Posadas, M.A. Ayala-Valdovinos y J.A. Hernández-Rivera. 2020. Análisis de la morfología de la cabra mestiza de la subprovincia fisiográfica Volcanes de Colima, México. Rev Invest Vet Perú. 31(3):e16935. http://dx.doi.org/10.15381/rivep.v31i3.16935

Argyriadou, A., A.I. Gelasakis, G. Banos and G. Arsenos. 2020. Genetic improvement of indigenous Greek sheep and goat breeds. J. Hell. Vet. Med. Soc. 71:2063-2072. https://doi.org/10.12681/jhvms.22967

Assefa, T., K. Alemayehu and Z. Tesema. 2023. Towards understanding the type and function of indigenous goats: input for genetic improvement and conservation programme. J. Appl. Anim. Res. 51(1):588-598. https://doi.org/10.1080/09712119.2023.2254368

Balcarcel, A.M., M. Geiger and M.R. Sánchez-Villagra. 2024. Cranial form differences in goats by breed and domestic status. Scientific Reports. 14:917. https://doi.org/10.1038/s41598-023-50357-0

Banerjee, S., M. Beyan and H. Bekele. 2014. Some traditional livestock selection criteria as practiced by several indigenous communities of Southern Ethiopia. Anim. Gen. Res. 54:153-162. doi: 10.1017/S2078633614000083

Bertaglia, M., S. Joost, J. Roosen and Econogene Consortium. 2007. Identifying European marginal areas in the context of local sheep and goat breeds conservation: A geographic information system approach. Agric. Syst. 94(3):656-670. https://doi.org/10.1016/j.agsy.2007.02.006

Cerqueira, J.O.L., X. Feás, A. Iglesia, L.F. Pacheco and J.P.P. Araujo. 2011. Morphological traits in Portuguese Bordaleira de Entre Douro e Minho sheep: divergence of the breed. Anim. Prod. Sci. 51:635-641. doi:10.1071/AN10147

Chacón, E., F. Macedo, F. Velázquez, S.R. Paiva, E. Pineda and C. McManus. 2011. Morphological measurements and body indices for Cuban Creole goats and their crossbreds. Rev. Bras. Zoot. 40(8):1671-1679. https://doi.org/10.1590/S1516-35982011000800007

Chiemela, P.N., B. Sandip, T.A. Mestawet, C.F. Egbu, E.H. Ugbo, E. Akpolu and I.J. Umanah. 2016. Structural indices of Boer, Central highland and their F1 crossbred goats reared at Ataye farm, Ethiopia. J. Agr. Res. 2(2):1-21. doi: https://doi.org/10.53555/ar.v2i2.15

da Costa, R.L.D., C.R. Quirino, V. Alves Costa Afonso, A. Pacheco, R.T. Beltrame, A.F. Madella-Oliveira, A. Mineiro Costa and R.M.C. da Silva. 2014. Morphometric indices in Santa Ines sheep. Int. J. Morphol. 32(4):1370-1376. doi:10.4067/S0717-95022014000400039

da Silva, C.J.G., C.J.E. Guimarães, R.A.D.M. Machado, F.R. Martins, R.R. Cavalcante, L.J. Batista and M.E. de Oliveira. 2006. Morphometric characterization of Santa Inês sheep raised in the regions of Teresina and Campo Maior, Piauí. Ver. Bras. Zoot. 35(6):2260-2267. https://doi.org/10.1590/S1516- 35982006000800009

da Silva, S.J.D., D.G. do Santos, N.J.V. Emerenciano, L.A.M. Quintão, R.F.F. da Silva and R.P.H. Cavalcante. 2019. Biometric measurements of Santa Inês meat sheep reared on *Brachiaria brizantha* pastures in Northeast Brazil. PLoS ONE 14(7):e0219343. https://doi. org/10.1371/journal.pone.0219343

Dauda, A. 2018. Morphological indices and stepwise regression for assessment of function and type of Uda sheep. J. Res. Rep. Genet. 2(3):1-14. http://www.alliedacademies.org/research-reports-on-genetics/

Dea, D., A. Melesse and Y. Mekasha. 2019. Application of morphometric traits and body indices in assessing the type and function of local goats reared in two districts of Gamo-Gofa Zone, South Ethiopia. Ethiopian J. Anim. Prod. 19(1):73-90.

Depison, D., W.P.B. Putra, G. Gushairiyanto, Y. Alwi and H. Suryani. 2020. Morphometric characterization of Kacang goats raised in lowland and highland areas of Jambi Province, Indonesia. J. Adv. Vet. Anim. Res. 7(4):734-743. http://doi.org/10.5455/javar.2020.g475

Dorantes-Coronado, E.J., G. Torres-Hernández, O. Hernández-Mendo and R. Rojo-Rubio. 2015. Zoometric measures and their utilization in prediction of live weight of local goats in southern Mexico. SpringerPlus 4:695. https://doi.org/10.1186/s40064-015-1424-6

Dossa, L.H., C. Wollny and M. Gauly. 2007. Spatial variation in goat populations from Benin as revealed by multivariate analysis of morphological traits. Small Rumin. Res. 73:150-159. doi:10.1016/j.smallrumres.2007.01.003

Dubeuf, J.P. and J. Boyazoglu. 2009. An international panorama of goat selection and breeds. Livest Sci. 120:225-231. https://doi.org/10.1016/j.livsci.2008.07.005

Dubeuf, J.P. 2023. Future prospects on the goat activities for the coming decades in the context of a word in transition. Goat Science – Environment, Health and Economy. IntechOpen. http://dx.doi.org/10.5772/intechopen.98651

FAO. 2012. Phenotypic characterization of Animal Genetic Resources. FAO Animal Production and Health Guidelines No. 11. FAO, Rome. www.fao.org/docrep/015/i2686e/i2686e00.pdf

Getaneh, M., M. Taye, D. Kebede and D. Andualem. 2022. Structural indices of indigenous goats reared under traditional management systems in East Gojjam Zone, Amhara Region, Ethiopia. Heliyon 8:e09180. https://doi.org/10.1016/j.heliyon.2022.e09180

Goodarzi, N. and T.S. Hoseini. 2014. Morphologic and osteometric analysis of the skull of Markhoz goat (Iranian Angora). Vet. Med. Int. 972682:1-5. http://dx.doi.org/10.1155/2014/972682

Hankamo, A., T, Woldeyohannes and S. Banerjee. 2020. Morphometrical characterization and structural indices of indigenous goats reared in two production systems in Sidama Zone, Southern Ethiopia. Int. J. Anim. Sci. Tech. 4(1):6-16. doi:10.11648/j.ijast.20200401.12

Herrera, M. y M. Luque. 2009. Capítulo 3: Morfoestructura y sistemas para el futuro en la valoración morfológica. *In*: Sañudo, A.C. (Coord.). Valoración Morfológica de los Animales Domésticos. Madrid: Ministerio de Medio Ambiente y Medio Rural y Marino. https://www.mapa.gob.es/es/ganaderia/temas/zootecnia/LIBRO%20valoracion%20%20morfologica%20SEZ_tcm30-119157.pdf

Herrera-Cáceres, W and L. Hernández-Corredor. 2022. Morphological characterization of the Motilona goat from Norte de Santander, Colombia. Rev MVZ Córdoba. 27(1):e2149. https://doi.org/10.21897/rmvz.2149

Ilham, F., G. Ciptadi, T.E. Susilorini and W.P.B.P. Suyadi. 2023. Morphology and morphometric diversity of three local goats in Gorontalo, Indonesia. Biodiversitas. 24(3):1266-1375. doi**:** https://doi.org/10.13057/biodiv/d240305

Kendall, L.V., N. Petervary, V.K. Bergdall, R.L. Page and P.J.R. Baneux. 2018. Institutional animal care and use committee review of clinical studies. J. Am. Vet. Med. Assoc. 253(8):980-984. http://dx.doi. org/10.2460/javma.253.8.980

Khargharia, G., G. Kadirvel, S. Kumar, S. Doley, P.K. Bharti and D. Mukut. 2015. Principal component analysis of morphological traits of Assam Hill goat in Eastern Himalayan India. J. Anim. Plant Sci. 25(5):1251-1258. https://api.semanticscholar.org/CorpusID:90245802

Macedo, R. 2017. Zoometry: a useful tool for determining the productive aptitude of domestic ruminants. J. Dairy Vet. Anim. Res. 5(3):00140. https://doi.org/10.15406/jdvar.2017.05.00140

Maldonado-Jáquez, J.A., G. Torres-Hernández, Y. Bautista-Martínez, P. Arenas-Báez and L.D. Granados-Rivera. 2023. Effect of coat and skin color variation on longevity, ethnological and functional indices in local goats. Rev. Cient. FCV-LUZ 33:1-7. https://doi.org/10.52973/rcfcv-e33241

Martin Bellido, M., M. Escribano Sánchez, F.J. Mesías Díaz, A. Rodríguez de Ledesma Vega y F. Pulido García. 2001. Sistemas extensivos de producción animal. Arch. Zoot. 50(192):465-489. https://www.redalyc.org/artículo.oa?id=49519203

Martínez-Rojero, R.D., G. Torres-Hernández y S. Martínez-Hernández. 2013. Caracterización fenotípica, productiva y reproductiva de la cabra Blanca Criolla del "Filo Mayor" de la Sierra Madre del Sur en el estado de Guerrero. Nova Scientia 6(11):25. https://novascientia.lasallebajio.edu.mx/ojs/index.php/Nova/article/view/64/26

Mason, I.L. 1981. Breeds. In: Gall C (Ed.). Goat Production. Academic Press, London. pp: 57-110.

Montaldo, H., A. Juárez, J.M. Berruecos and F. Sánchez. 1995. Performance of local goats and their backcrosses with several breeds in Mexico. Small Rumin. Res. 16:97-105. doi:10.1016/0921-4488(95)00624-T

Montaldo, H.H., G. Torres-Hernández and M. Valencia-Posadas. 2010. Goat breeding research in Mexico. Small Rumin. Res. 89:155-163. https:/doi.org/10.1016/j.smallrumres.2009.12.039

Morales-delaNuez, A., C. Rodríguez, M. Santana, L.E. Hernández-Castellano, T. Niño, R.J. Reyes-Chacón, I. Moreno-Indias, N. Castro and J. Capote. 2012. Morphological measurements and indexes as a tool to support molecular genetic studies: an example in Canary Islands. J. Appl. Anim. Res. 40(3):215-221. http://dx.doi.org/10.1080/09712119.2012.658062

Moreno, M.J., V.D. Montes, P.J. Ucros, Q.A. Fernández and ÁJ Cardona. 2013. Variabilidad morfoestructural de la hembra ovina de pelo criollo colombiana. Livest Res. Rural Develop. 25:83 http://www.lrrd. org/lrrd25/5/more25083.htm

Núñez-Domínguez, R., R. Ramírez-Valverde, L.A. Saavedra-Jiménez y J.G. García-Muñiz. 2016. La adaptabilidad de los recursos zoogenéticos Criollos, base para enfrentar los desafíos de la producción animal. Arch. Zoot. 65(251):461-468. http://www.ciap.org.ar/Sitio/Archivos/criollo%20recursos.pdf

Pares, P.M. 2009. Zoometría. *In*: Valoración Morfológica de los Animales Domésticos. Sañudo, C. (Ed.). Ministerio de Medio Ambiente y Medio Rural y Marino. Madrid, España. pp:171-198.

Pariacote, F.A., L. Ruiz, D.C.D. Ascencao, C. Borges y X. Pimentel. 2004. Características morfológicas del caprino Criollo venezolano. Arch. Latinoam. Prod. Anim. 12:16-21.

Pérez-Razo, M., F. Sánchez, G. Torres-Hernández, C. Becerril-Pérez, J. Gallegos-Sánchez, F. González-Cosío and C. Meza-Herrera. 2004. Risk factors associated with dairy goats stayability. Livest Prod. Sci. 89:139-146. doi:10.1016/j.livprodsci.2004.02.008

Putra, W.P.B. and F. Ilham. 2019. Principal component analysis of body measurements and body indices and their correlation with body weight in Katjang does of Indonesia. J. Dairy Vet. Anim. Res. 8(3):124-134. https://doi.org/10.15406/jdvar.2019.08.00254

R Core Team. 2020. R: A language and environment for statistical computing. R Foundation for Statistical Computing. Vienna, Austria. https://www.R-project.org/

Revidatti, M.A., P.N. Prieto, S. de La Rosa, M.N. Ribeiro y A. Capellari. 2007. Cabras Criollas de la región norte de Argentina. Estudio de variables e índices zoométricos, Arch. Zoot. 56(1):479-482. http://www.redalyc.org/articulo.oa?id=49509919

Rodero, A., J.V. Delgado and E. Rodero. 1992. Primitive Andalusian livestock and their implications in the discovery of America. Arch. Zoot. 41(154):383-400. http://hdl.handle.net/10396/3294

Salako, A.E. 2006. Application of morphological indices in the assessment of type and function in sheep. Int. J. Morphol. 24(1):13-18. https://doi.org/10.4067/S0717-95022006000100003

Sevane, N., O. Cortés, L.T. Gama, A. Martínez, P. Zaragoza, M. Amills, D.O. Bedotti, C. Bruno de Sousa, J. Cañon, S. Dunner, C. Ginja, M.R. Lanari, V. Landi, P. Sponenberg, J.V. Delgado and The BioGoat Consortium. 2018. Dissection of ancestral genetic contributions to Creole goat populations. Animal 12(10):2017-2026. doi:10.1017/S1751731117003627

Silva-Jarquin, J.C., S.I. Román-Ponce, M. Durán-Aguilar, H.R. Vera-Ávila, V.H. Cambrón-Sandoval and H.M. Andrade-Montemayor. 2019a. Morphostructural characterization of the Black Creole goat raised in Central Mexico, a currently threatened zoogenetic resource. Animals 9(7):Article 7. https://doi.org/10.3390/ani9070459

Silva-Jarquín, J.C., H.M. Andrade-Montemayor, H.R. Vera-Ávila, M. Durán-Aguilar, H.I. Román-Ponce, V. Landi, A. Martínez-Martínez, J.V. Delgado-Bermejo and BioGoat Consortium. 2019b. Genetic diversity and structure in Criolla Negra goats in Querétaro, Mexico. Rev. Mexicana Cienc. Pec. 10(4):801-818. https://doi.org/10.22319/rmcp.v10i4.4908

Tade, B., A. Melesse and S. Betsha. 2021. Differentiation of the indigenous goat populations in Ethiopia based on morphometric features and zoometric indices: The primary step for conservation. Agric. Sci. Tech. 13(4):344-351. doi:10.15547/ast.2021.04.056

Takele, A., A. Melesse and M. Taye. 2022. Morphological traits and structural indices of Hararghe highland goat populations reared in the West Hararghe zone, Ethiopia. Ethiopian J. Appl. Sci. Tech. 13(2):1-10. https://journals.ju.edu.et/index.php/ejast/article/view/4217

Torres-Hernández, G., J.A. Maldonado-Jáquez, L.D. Granados-Rivera, H. Salinas-González and G. Castillo-Hernández. 2022a. Status quo of genetic improvement in local goats: a review. Arch. Anim. Breed. 65(2):207-221. doi: 10.5194/aab-65-207-2022

Torres-Hernández, G., J.A. Maldonado-Jáquez, L.D. Granados-Rivera, M. Wurzinger and A.A. Cruz-Tamayo. 2022b. Creole goats in Latin America and the Caribbean: a priceless resource to ensure the well-being of rural communities. Int. J. Agric. Sust. 20(4):368-380. https://doi.org/10.1080/14735903.2021.1933361

Torres-Hernández, G., L.D. Granados-Rivera, G. Castillo-Hernández, J. González-Maldonado, P. Arenas-Báez and J.A. Maldonado-Jáquez. 2023. Phenotypic diversity of local goats in northern Mexico. South Afr. J. Anim. Sci. 53(2):1-13. http://dx.doi.org/10.4314/sajas.v53i2.02

Tyasi, T.L. and W.P.B. Putra. 2021. Morphological structure of South African Non-Descript does raised in Syferkuil Farm, Capricorn District of Limpopo Province using factor analysis. Adv. Anim. Vet. Sci. 9(4):555-562. http://dx.doi.org/10.17582/journal.aavs/2021/9.4.555.562

Vargas-López, S., A. Larbi and M. Sánchez. 2007. Analysis of size and conformation of native Creole goat breeds and crossbreds used in smallholder agrosilvopastoral systems in Puebla, Mexico. Trop. Anim. Hlth. Prod. 39:279-286. https://doi.org/10.1007/s11250-007-9012-6

Vargas-López, S., A. Bustamante-González, J.E. Ramírez-Bribiesca, G. Torres-Hernández, A. Larbi, J.A. Maldonado-Jáquez and Z.G. López-Tecpoyotl. 2022. Rescue and participatory conservation of Creole goats in the agro-silvopastoral systems of the Mountains of Guerrero, Mexico. Rev. Fac. Cienc. Agrar. Univ. Nac. Cuyo 54(1):153-162. doi: https://doi.org/10.48162/rev.39.074

Yemane, G., A. Melesse and M. Taye. 2020. Characterization of indigenous goat populations by applying morphometrical traits and structural indices. J. Vet. Res. Adv. 02(01):22-31. https://www.researchgate.net/publication/357394580