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Effect of coat and skin color variation on longevity, ethnological and functional indices in local goats

Efecto del color de capa y piel en la longevidad e índices etnológicos y funcionales del ganado caprino local

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ABSTRACT

The aim of this research was to evaluate the effect of variation in number and diversity of colors, coat pattern, and skin color and its effect on longevity and etnological indices in local goats from Northern Mexico. Two hundred fifty-one adult goats were chosen. The aforementioned variables were recorded in addition to age, live weight (LW), body condition (BC), and fifteen zoometric traits. Seventeen indices were calculated. The group with two colors was different (P<0.05) in age and BC. Skin color was different in LW and BC (P<0.05). BC was higher in white coat mottled animals (P<0.05). The one-color group presented the highest Facial Index. Flat-coated Animals had higher Index of horns. Cephalic, pelvic, facial, compactness, relative chest depth, substernal slenderness, and relative shortness indices were different in coat color. It is concluded that this population was phaneroptically heterogeneous and the number, diversity of colors, coat pattern, and skin color influence the longevity and ethnological and functional indices.

Key words: Characterization; conservation; morphostructure; arid zones; goats

RESUMEN

El objetivo del estudio fue evaluar el efecto que tiene la variación en número y diversidad de colores, patrón de la capa y color de piel y sus efectos sobre longevidad, índices etnológicos y funcionales en cabras locales de la Comarca Lagunera, al norte de México. Se eligieron al azar 251 caprinos locales adultos. Se registraron las variables antes mencionadas además de edad, peso vivo (PV), condición corporal (CC) y 15 variables zoométricas. Se calcularon 17 índices: Corporal (ICor); cefálico (ICF); pelviano (IPV); torácico (ITo); facial (IF); de cuernos (ICur); de compacidad (IComp); peso relativo (IPR); proporcionalidad (IProp); profundidad relativa de tórax (IPRT); grupa transversal (IGT); grupa longitudinal (IGL); diferencia de alturas (IDA); orejas (IO); torácico auricular (ITA); esbeltez subesternal (IES) y cortedad relativa (ICR). Los datos fueron analizados con ANOVA y la prueba de Tukey. El grupo con dos colores fue diferente (P<0,05) en edad y CC. Color de piel fue diferente en PV y CC (P<0,05). No se encontraron diferencias (P>0.05) en edad, peso y CC debido al patrón de capa. Animales con capa marrón y marrón con parche tuvieron la mayor edad dentro de los hatos (P<0,05). La CC fue mayor en animales con capa blanca moteada (P<0,05). El grupo de un color presentó el mayor IF. Animales con capa plana tuvieron mayor ICur. ICF, IPV, IF, IComp, IPRT, IDA, IES e ICR fueron diferentes en color de la capa. IO e ITA tuvieron mayores valores en animales con dos colores, IO en animales de piel rosada, ITA en ejemplares de piel negra y rosada (P<0,05) e IES en animales con piel rosada y blanca (P<0,05). Se concluye que esta población es fanerópticamente heterogénea y el número, diversidad de colores, patrón de capa y color de piel influyen en la longevidad, índices etnológicos y funcionales de esta población.

Palabras clave: Caracterización; conservación; fenotipo; morfoestructura; zonas áridas; caprinos

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INTRODUCTION

The main challenges for the genetic improvement of local breeds are the implementation of selection schemes and classical breeding of small populations [4]. However, before planning such schemes to increase the productivity, it is essential to know the available genetic resources [12], through phenotype characterizations of the racial profile of individuals, including productive function, and genetic characterizations to deoxyribonucleic acid (DNA) level that reveals the extension of genetic diversity and the relationships among breeds [3].

Since the phenotypic variation arises from the combination of the genotype and enviroment along with their possible interaction, the evaluation of the magnitude of such phenotypic variability is important due differences between environments and breeds. In a conventional breeding scheme, two suites of traits have been used to evaluate the phenotype variability, one related with phaneroptic traits and the other one related with morphological traits. Both are essential components of phenotype characterization in local populations [6]. In this sense, the coat color in goats *(Capra hircus)* is known as a genetic adaptation propelled by environmental conditions [10], therefore, the changes that are perceived in the climate suggest a deeper interaction between traits such as skin and hair color with productive and reproductive aspects and the general behavior of the animals [7]. However, the studies that consider these characteristics and their effect in both productive and reproductive traits in local goats are scarce, particularly in Mexico, since all these studies are merely descriptive [9, 14, 15].

Therefore, the objectives of this research were to evaluate the effects of the number and diversity of colors; coat pattern, and skin color of goats on longevity; ethnological and functional indices in local goats from Comarca Lagunera in Northern Mexico.

MATERIALS AND METHODS

The study was carried out in the of Coahuila State, in Northern Mexico, located at 24°22' N and 102°22' W, at an average altitude of 1,139 meters above sea level (m.a.s.l.). The climate is desert, semi-warm with cool winter, and average annual rainfall of 240 milimeters (mm).

Two hundred fifty-one local adult goats (46 males and 205 females) were randomly chosen from a core of 2,980 animals from 26 production units located in four Municipalities of Coahuila: San Pedro de las Colonias (n=49), Francisco I. Madero (n=38), Torreón (n=73) and Viesca (n=91). The sample size of each region was not uniform and was relatively unbalanced due to the characteristics of the herds chosen randomly from each place. The phaneroptic variables recorded included: number of coat colors (1, 2, or 3); coat color diversity (9 variants); coat pattern (flat, patchy, mottled) and skin color (black, pink, white), as well as age of life (months), live weight (LW; kilograms –kg–), body condition score (BC) and 15 zoometric variables. All zoometric measurements were recorded in centimeters (cm) with a soft measuring tape (Selanusa, México). The body condition score (BC), defined according to the scale described by Rivas-Muñoz *et al*. [13]. The LW was taken fasting with an electronic hanging scale (model BAC-300, Rhino, México) with a capacity of 300 kg ± 100 grams –g–). The zoometric measures considered were: skull length (SL), skull width (SW), horns length (HL), mean perimeter of horns (MPH), face length (FL), face width (FW), bicoastal diameter (BiDi), body length (BL), chest girth (ChG), height at the withers (HAW), rump length (RL), rump width (RW), sacro-lumbar height (SLH), ears length (EL) and chest depth (CD) (FIG. 1).

FIGURE 1. Measurement of body measurements in local goats from Northeast Mexico

Seventeen indices were calculated (6 ethnological and 11 functional), which express relationships between two linear dimensions. The ethnological indices were:

- body index (BI=BL/ChG*100);
- cephalic (CI=SW/SL*100);
- pelvic (PI=RW/RL*100);
- thoracic (THI=BiDi/CD*100);
- facial (FI= FW/FL*100);
- horns (HI=MPH/HL*100).

The functional indices were:

- compactness (CompI=LW/BL*100);
- relative weight (RWI=LW/HAW*100);
- proportionality (PropI= BL/HAW*100)=;
- relative chest depth (RCDI=CD/HAW*100);
- transverse rump (TRI=RW/HAW*100);
- longitudinal rump (LRI=RL/HAW*100);
- height difference (HDI=SLH/HAW*100);
- ears (EI=EL/HAW*100);
- atrial thoracic (ATI=EL/CD*100);
- substernal slenderness (SSI=HAW+CD/HAW);
- relative shortness (RSI=HAW/BiDi*100).

Analysis of variance were performed using the statistical package SAS v9.4 [16]. Differences between means were calculated through the Tukey test (α=0.05).

RESULTS AND DISCUSSION

An effect (P<0.05) of the number of colors of the coat was found for the variable age and BC. The highest values were found in the two-color group (FIG. 2).

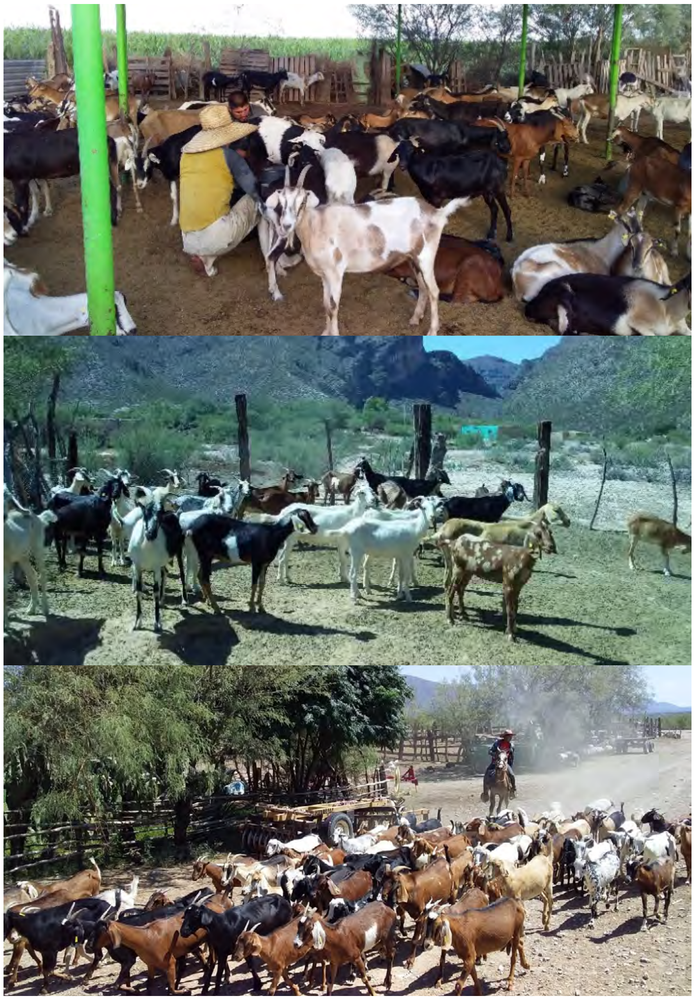

FIGURE 2. Color types and coat pattern of local goats in Northeastern Mexico

Likewise, the skin color was different (P<0.05) in LW and BC. The highest weight was found in animals with white skin and the highest BC in the group of animals with pink skin. No differences (P>0.05) were found in age, weight and BC due to the coat pattern (TABLE I). The results showed a high degree of heterogeneity in the population since the coefficients of variation were high and had the possibility of having been influenced by the numerous crosses between different breeds in the population [3]. This suggests the development of unique phenotypic characteristics related to biological adaptation to the environment and the management they receive [12]. Thus, the variability found in local goats of this study was higher than those found by Bravo and Sepúlveda [3] for different zoometric indices in Araucano creole sheeps, this variability is interesting depending on use since a variation between 5 and 9% is an important starting point for purposes of breeding, but at the same time it represents a valuable resource in terms of germplasm protection.

TABLE I
Number of colors, coat pattern and skin color by age, weight and body condition of local goats from Comarca Lagunera in Northern Mexico

Variable	Number of colors			P-value	R^2	CV
	One color	Two colors	Three colors			
Age (months)	37.0 ± 2.6^{b}	44.3 ± 2.0^{a}	40.1 ± 4.1^{ab}	0.0168	0.09	40.25
Weight (kg)	48.1 ± 1.6	48.2 ± 1.2	49.8 ± 2.5	0.7368	0.08	21.82
BC	1.9 ± 0.1^{b}	2.2 ± 0.1^{a}	1.9 ± 0.2^{ab}	0.0412	0.06	36.48
APG	82	146	23	-	-	-
	Coat pattern					
	Flat	**Patched**	**Mottled**			
Age (months)	42.8 ± 2.1	40.4 ± 2.4	43.6 ± 4.2	0.8309	0.09	40.25
Weight (kg)	48.1 ± 1.3	49.0 ± 1.5	46.4 ± 2.5	0.2923	0.08	21.82
BC	2.1 ± 0.1	2.1 ± 0.1	1.9 ± 0.2	0.3112	0.06	36.48
APG	111	119	21	-	-	-
	Skin color					
	Black	**Pink**	**White**			
Age (months)	42.9 ± 1.7	41.5 ± 2.8	35.5 ± 6.6	0.4060	0.09	40.25
Weight (kg)	47.3 ± 1.0^{b}	48.1 ± 1.7^{b}	57.8 ± 3.8^{a}	0.0111	0.08	21.82
BC	1.9 ± 0.1^{b}	2.3 ± 0.1^{a}	2.3 ± 0.3^{ab}	0.0452	0.06	36.48
APG	177	66	8	-	-	-

APG: Animals per group. ^{abc}: Different letters between columns indicate difference (P<0.05), R^2: Determination coefficient, CV: Coefficient of variation.

Differences (P<0.05) were found due to the diversity of the coat color. The highest values for age were found in the animals with a brown and patchy brown coat. In BC, it was found that the animals with a mottled white coat had the highest averages (TABLE II).

Regarding the coat color, Lee *et al.* [7] found results with similar trends in Holstein cattle (*Bos taurus*) and where animals with a mostly black coat present greater longevity and therefore a greater milk production, determining a positive relationship between these variables, since greater longevity presents an increase in the productivity of animals. On the other hand, Ozoje and Mgbere [11] suggested that black goats take up more heat, drink more water, lose less weight in the dry season and gain more weight than light-colored animals, all of which is directly related to productivity.

TABLE II
Means ± Standard Deviations for: Age; Weight and Body Condition for local goats from the Comarca Lagunera in Northern Mexico

Coat color	Variable			
	N	Age (Months)	Weight (kg)	BC
Black	19	42.0±4.4[ab]	48.1±2.7	1.9±0.2[b]
Brown	26	48.8±3.9[a]	50.5±2.4	2.0±0.2[b]
White	38	45.9±3.8[ab]	51.3±2.3	1.9±0.2[b]
Moor	5	47.6±7.9[ab]	47.1±4.8	1.8±0.3[b]
Mottled white	11	39.4±5.6[ab]	45.4±3.4	3.1±0.2[a]
White / patch	31	40.9±3.8[ab]	46.6±2.3	1.8±0.2[b]
Brown / patch	58	48.4±2.9[a]	49.3±1.8	2.0±0.2[b]
Mottled brown	11	35.2±5.3[b]	46.3±2.1	2.0±0.2[b]
Black / patch	29	35.4±3.7[b]	50.5±2.3	2.0±0.2[b]
Three colors	23	40.1±4.1[ab]	49.8±2.5	1.9±0.2[b]
P-value		0.0420	0.3957	0.0141

Regarding the ethnological indices, differences were found in the number of coat colors only for face index (IF), where goats of one and three colors had the highest values and where goats of one and two colors were different ($P<0.05$). According to the coat pattern, HI had the highest value ($P<0.05$) in the flat coat animals (TABLE III). Findings of this study could be used in the design and establishment of practical selection schemes into conventional breeding strategies. In particular, the brown color predominated over other colors similar to that reported by Adalsteinsson *et al.* [1]; it means to provide to the producer a practical tool to select specimens based on their appearance in order to improve productivity. It has been reported that the genes that determine coat color have an impact on the zoometric traits of animals and could be used as biomarkers to perform efficient selections in breeding programs [10]. Thus, a genetically fixed condition (coat color) would be chosen, which would favor survival in a particular environment [2] and the identification of breed attributes for a specific environment [17].

On the other hand, no trend was found regarding to the number of colors in the local goats of Northern Mexico. This resembles that reported by Mashner *et al.* [8], who point out that the local goat populations in Moldova were characterized by high heterogeneity in hair color, which is common in non-improved local breeds. This information differs from the study of Hossain *et al.* [6], which indicated that certain genotypes, such as Black Bengal goats, present a relative homogeneity, since 80% of their population were black, but a small portion included white, brown, moor, and mottled specimens, however, it is unknown whether the animals were subjected to any genetic improvement program, which would strengthens the previous argument.

Related to ethnological indices, differences were found ($P<0.05$) for the CI, PI, and FI indices for coat color (TABLE IV). For CI, the highest values were found in animals with white and white mottled coats, without differences with the rest of the colors ($P>0.05$), except for black color ($P<0.05$). In PI, the highest value was found in patchy brown coat animals, without differences among the other colors ($P> 0.05$), and in

TABLE III
Ethnological indices for number of colors, coat pattern and skin color in local goats from Comarca Lagunera in Northern Mexico

Index	Number of coat colors			*P*-value	R^2	CV
	One color	Two colors	Three colors			
IB	59.9±1.4	59.8±1.1	60.0±2.2	0.8640	0.04	15.30
IC	85.9±2.3	88.8±1.8	86.4±3.7	0.9009	0.06	17.35
IP	70.3±1.4	70.5±1.1	70.0±2.2	0.7185	0.06	13.01
ITh	29.1±0.6	29.1±0.5	29.5±0.9	0.8119	0.03	14.1
IF	50.9±1.5[a]	47.7±1.1[b]	49.4±2.3[ab]	0.0148	0.08	19.86
IH	54.4±8.9	55.9±6.5	69.8±12.6	0.2379	0.07	86.60
	Coat pattern					
	Flat	**Patched**	**Mottled**			
IB	59.8±1.1	59.6±1.3	60.71±2.2	0.9707	0.04	15.30
IC	89.3±1.9	88.6±2.1	84.3±3.8	0.9009	0.06	17.35
IP	69.8±1.1	70.6±1.3	71.3±2.2	0.9609	0.06	13.01
ITh	29.2±0.5	29.4±0.6	28.8±0.9	0.8879	0.03	14.1
IF	49.5±1.2	49.6±1.3	46.6±2.3	0.7413	0.08	19.86
IH	67.4±7.3[a]	48.0±7.7[b]	52.9±12.6[ab]	0.0218	0.07	86.60
	Skin color					
	Black	**Pink**	**White**			
IB	59.9±0.8	59.7±1.5	60.1±3.27	0.9661	0.04	15.30
IC	86.4±1.5	90.2±2.4	87.8±5.5	0.9009	0.06	17.35
IP	70.7±0.9	70.9±1.5	66.0±3.3	0.3310	0.06	13.01
ITh	29.4±0.4	28.6±0.7	29.4±1.5	0.3740	0.03	14.1
IF	48.8±1.0	49.6±1.6	47.1±3.5	0.4918	0.08	19.86
IH	56.8±5.4	54.0±9.5	76.4±22.3	0.7882	0.07	86.60

[ab]: Different letters between columns indicate difference ($P<0.05$), R^2: Determination coefficient, CV: Coefficient of variation, IB: body index, IC: cephalic index, IP:pelvic index, ITh: thoracic index, IF: facial index, IH: horns index.

FI, black, brown, patchy white and a combination of three colors had the highest values with no differences between colors ($P> 0.05$) except with brown animals ($P<0.05$). In terms of ethnological characteristics, these are important because their variation is not influenced by environmental or management factors [5]. These indices indicate the racial homogeneity degree on their structure and proportions (compactness, height and length), and in this study they mostly do not differ, showing that goats have a common genetic origin, which means that they maintain similar proportions [12] and regardless of color, goats have the same conformation [8]. However, if the variation within each index is considered, the possibility of formation (through an evolutionary process) of a different local breed could be explored. But this must be done by comparing different genotypes, identifying divisions between groups, and the participation of different breeds, which can be done with the support of ethnological and functional indices, as well as with the support of molecular tools. The above information is essential to develop actions that guarantee the conservation of genetic variability and the reduction of the erosion that strongly impact the adaptation characteristics of these local populations [14].

TABLE IV
Coat color by ethnological indices and functional indices in local goats from the Comarca Lagunera in Northern Mexico

	Black	Brown	White	Moor	Mottled white	White / patch	Brown / patch	Mottled brown	Black / patch	Three colors	*P*-value
Ethnological índices											
IB	57.2±2.0	59.6±2.1	57.2±2.0	61.3±4.13	63.1±2.9	62.9±2.0	58.1±1.5	57.3±2.8	60.7±1.9	60.0±2.2	0.8640
IC	81.9±3.9^{b}	87.3±3.5^{ab}	93.9±3.4^{a}	82.7±6.9^{ab}	95.9±4.9^{a}	84.7±3.4^{ab}	87.3±2.6^{ab}	87.4±4.7^{ab}	90.1±3.3^{ab}	86.7±3.4^{ab}	0.0238
IP	69.2±2.3^{abc}	73.1±2.1^{bc}	67.6±2.0^{b}	70.4±4.2^{abc}	72.1±2.3^{abc}	70.3±2.0^{abc}	73.1±1.5^{a}	69.5±2.8^{abc}	68.4±1.9^{ab}	70.0±2.2^{abc}	0.0197
ITh	29.9±1.1	28.1±0.9	29.7±0.9	30.8±1.9	28.7±1.3	29.0±0.9	28.7±0.7	28.7±1.3	28.9±0.9	29.5±0.9	0.9197
IF	51.8±2.5^{a}	44.7±2.2 ^{b}	47.9±2.2^{ab}	55.0±4.4^{a}	45.0±3.1^{ab}	50.2±2.1^{a}	48.2±1.6^{ab}	46.4±2.9^{ab}	49.2±2.1^{ab}	50.4±2.3^{a}	0.0114
IHr	48.0±15.5	58.4±13.2	45.3±12.8	42.6±22.3	51.6±17.9	63.5±11.9	69.8±9.5	56.5±17.6	58.1±14.0	69.8±12.6	0.9561
Functional Indices											
IComp	95.9±4.7^{ab}	95.1±4.4^{ab}	99.3±4.3^{a}	92.6±8.9^{ab}	86.0±6.3^{b}	89.4±4.3^{b}	97.3±3.3^{ab}	93.4±6.0^{ab}	100.3±4.2^{a}	95.9±4.7^{ab}	0.0371
IRW	67.9±3.8	70.1±3.4	73.8±3.3	67.0±6.8	63.6±4.8	65.2±3.3	70.9±2.5	65.9±4.6	74.0±3.2	68.7±3.6	0.1994
IProp	70.8±2.3	74.1±2.0	75.1±1.9	72.5±4.1	74.5±.2.9	72.5±1.9	73.2±1.5	70.8±2.8	74.9±1.9	71.9±2.1	0.6613
IRCD	82.2±0.9^{bc}	82.4±0.8^{bc}	81.0±0.8^{c}	83.9±1.6^{ab}	84.1±1.1^{a}	83.5±0.8^{ab}	82.6±0.6^{bc}	82.0±1.1^{bc}	82.6±0.8^{bc}	83.2±0.8^{ab}	0.0345
ITR	22.5±0.8	23.3±0.7	22.5±0.7	22.0±1.4	23.8±1.0	22.1±0.7	22.9±0.5	21.4±0.9	22.8±0.7	22.1±1.4	0.3986
ILR	25.0±1.0	24.5±0.9	24.8±0.9	23.3±1.8	25.1±1.3	24.7±0.9	23.1±0.7	23.1±1.2	24.3±0.9	24.1±0.9	0.8645
IHD	99.8±2.5^{ab}	101.3±2.2^{ab}	102.4±2.2^{a}	102.8±1.6^{ab}	98.4±3.2^{ab}	97.4±2.2^{b}	102.8±1.6^{a}	94.3±2.9^{b}	101.8±2.^{ab}	98.5±2.3^{ab}	0.0175
IE	10.5±0.5	10.7±0.5	10.8±0.5	11.1±0.9	11.8±0.7	11.0±0.5	11.5±1.0	11.6±0.7	10.7±0.5	10.6±0.5	0.9818
IAT	0.26±0.02^{b}	0.29±0.02^{ab}	0.27±0.02^{ab}	0.31±0.03^{ab}	0.32±0.02^{a}	0.28±0.02^{ab}	0.29±0.02^{ab}	0.30±0.02^{ab}	0.26±0.01^{b}	0.27±0.01^{ab}	0.0468
ISS	69.9±1.4^{ab}	71.0±1.2^{ab}	68.7±1.2^{ab}	69.2±2.4^{ab}	69.8±1.7^{ab}	69.7±1.2^{ab}	68.9±0.9^{ab}	64.2±1.6^{b}	68.2±1.1^{b}	71.3±1.2^{a}	0.0371
IRS	272.9±9.5^{ab}	287.5±8.5^{bc}	257.4±8.3^{b}	277.6±17.1^{abc}	296.7±12.1^{bc}	303.3±8.3^{a}	280.9±6.3^{bc}	284.4±11.5^{abc}	276.0±8.0^{ab}	285.2±8.9^{bc}	0.0126

^{abc}: Different letters between columns indicate difference (*P*<0.05), IB: body index, IC: cephalic index, IP: pelvic index, ITh: thoracic index, IF: facial index, IH: horns index, IComp: compactness index, Iprop: proportionality index, IRCD:: relative chest depth index, ITR: transverse rump index, ILR: longitudinal rump index, IHD: height difference index, IE: ears index, IAT: atrial thoracic index, ISS: subesternal slenderness index, IRS: relative shortness index

Regarding the functional indices, CompI, RCDI, HDI, ATI, SSI, and RSI indices were different (*P*<0.05) when the coat color was evaluated. CompI was higher in black coat and was different only from animals with white mottled and patchy white coats (*P*<0.05). IRCD and ATI presented the highest value in white mottled coat animals, and where ATI was different from black and patchy black animals (*P*<0.05). HDI was higher in animals with a white and patchy brown coat and differences were found only with white patchy and brown mottled animals (*P*<0.05). SSI was higher in animals with a three-color coat and differed only from brown mottled and black patchy animals (*P*<0.05) and RSI in white patchy animals (TABLE IV). The relationship between body measurements can indicate the productive aptitude of the animals, in this regard indices such as PI indicates the relationship between width and length of the pelvis, and CI allows classifying dolichocephalic animals (width predominates overhead length) and mesocephalic (head width and length are similar), IRCD relates the diameter sternal back and raised to the withers; and IRS indicates that the lower the value the closer the animal is to a rectangle, the predominant shape in animals with meat aptitude [12], which according to the obtained results, suggest animals with merely dairy aptitude. The measurements related to height (withers and rump), allow identifying the productive profile of the animals. When the external iliac tuberosities are raised and contribute to a greater inclination of the rump and a slight narrowing of the buttock musculature [5] and refers to animals prone to meat fitness. Therefore, considering these findings, the functional indices suggest that the dimensions of the animals in all groups correspond to animals with an aptitude for milk production, as indicated above, but with considerable intra-population variability [12].

Regarding the functional indices, EI and ATI were higher in two-color animals which differed only from one-color animals (*P*<0.05). Likewise, EI was higher in the group of animals with pink and black skin and where only the pink-skinned group was different from the white-skinned group (*P*<0.05), ATI in the groups of black and pink skin (*P*<0.05) and SSI was higher (*P*<0.05) in the groups of animals with pink and white skin (TABLE V). Finally, indices such as IRCD, IE, IAT, and ISS, are considered as indicators of adaptation to heat and the arid environment. Therefore, the knowledge of these indices is of utmost importance in the phenotype characterization of local populations, since the evolutionary mechanisms that these genetic groups have developed to carry out more efficient thermoregulation processes,

TABLE V
Functional indices for number of colors, coat pattern and skin color in local goats from Comarca Lagunera in Northern Mexico

Variable	Number of colors			*P*-value	R^2	CV
	One color	Two colors	Three colors			
IComp	93.4±2.9	94.4±2.3	95.9±4.6	0.3463	0.01	20.60
IRW	67.4±2.3	68.9±1.8	68.7±3.6	0.2981	0.08	21.65
IProp	72.3±1.4	73.4±1.1	71.9±2.1	0.5523	0.03	12.25
IRCD	82.9±0.5	82.7±0.4	83.2±0.8	0.2251	0.06	4.24
ITR	22.8±0.5	22.6±0.4	22.1±0.8	0.4282	0.05	13.82
ILR	24.8±0.6	24.1±0.5	24.1±1.0	0.5553	0.04	16.54
IHD	98.3±1.5	100.4±1.1	98.5±2.3	0.7292	0.06	9.77
IE	10.3±0.3[b]	11.4±0.3[a]	10.6±0.5[ab]	0.0478	0.06	19.26
IAT	0.25±0.01[b]	0.30±0.01[a]	0.27±0.02[ab]	0.0340	0.08	24.45
ISS	70.5±0.8	69.1±0.6	71.3±1.3	0.1721	0.07	7.74
IRS	288.8±5.6	280.9±4.4	285.2±8.9	0.6204	0.10	13.42
	Coat pattern					
	Flat	Patched	Mottled			
IComp	93.2±2.4	96.4±2.7	91.1±4.7	0.5435	0.01	20.60
IRW	67.3±1.8	70.4±2.1	66.4±3.6	0.4850	0.08	21.65
IProp	72.4±1.1	73.5±1.2	73.2±1.2	0.9093	0.03	12.25
IRCD	82.9±0.4	82.6±0.5	83.5±0.8	0.4404	0.06	4.24
ITR	22.3±0.3	22.8±0.5	21.7±1.1	0.7489	0.05	13.82
ILR	24.±0.5	24.3±0.6	23.6±1.0	0.8645	0.04	16.54
IHD	99.5±1.2	99.1±1.4	101.5±2.3	0.4813	0.06	9.77
IE	11.1±0.3	10.9±0.3	11.3±0.5	0.2817	0.06	19.26
IAT	0.29±0.01	0.29±0.01	0.28±0.02	0.7785	0.08	24.45
ISS	70.3±0.7	69.1±0.7	69.1±0.7	0.2883	0.07	7.74
IRS	284.8±4.6	277.5±5.2	290.6±8.9	0.5807	0.05	13.82
	Skin color					
	Black	Pink	White			
IComp	92.8±1.9[b]	93.9±3.1[ab]	107.0±7.0[a]	0.0094	0.01	20.60
IRW	67.4±1.5	68.0±2.4	77.9±5.4	0.1039	0.08	21.65
IProp	72.9±0.9	72.8±1.4	72.9±3.2	0.8557	0.03	12.25
IRCD	82.9±0.3	82.9±0.6	82.4±1.3	0.8267	0.06	4.24
ITR	22.8±0.3	22.3±0.5	21.9±1.1	0.3221	0.05	13.82
ILR	24.2±0.4	23.7±0.6	26.4±1.4	0.1435	0.04	16.54
IHD	99.2±0.9	100.5±1.6	99.4±3.5	0.7919	0.06	9.77
IE	11.0±0.2[ab]	11.4±0.3[a]	9.6±0.8[b]	0.0139	0.06	19.26
IAT	0.29±0.01[a]	0.29±0.01[a]	0.22±0.02[b]	0.0085	0.08	24.45
ISS	69.3±0.5[b]	69.6±0.9[a]	73.6±1.9[a]	0.0073	0.07	7.74
IRS	281.5±3.7	287.5±6.0	281.9±13.5	0.2371	0.05	13.82

[ab]: Different letters between columns indicate difference ($P<0.05$), R^2: Determination coefficient, CV: Coefficient of variation, IComp: compactness index, Iprop: proportionality index, IRCD: relative chest depth index, ITR: transverse rump index, ILR: longitudinal rump index, IHD: height difference index, IE: ears index, IAT: atrial thoracic index, ISS: substernal slenderness index, IRS: relative shortness index

that include morphological adaptations such as the increase in surface skin exposure, histology adaptations for increasing blood flow to the extremities, and color adaptations to better dissipate heat deserve special attention particularly in the context of climate change [6]. Higher value in these indices is indicative of a better adaptation to environmental conditions, which coincides with the findings of the present study in all groups studied.

CONCLUSIONS

The local goats of Northern Mexico, specifically from Comarca Lagunera, are phaneroptically heterogeneous.

The number of coat colors, their diversity of coat colors, coat pattern, and skin color influence longevity, as well as the ethnological, and functional indices.

This preliminary study a suitable tool for animal breeding based on phenotype qualifications of productive traits (indices) for the identification of outstanding breed genotypes well-adapted to desert conditions of northern Mexico.

These results are part of a pioneering study of genetic characterization of local populations of goats in Comarca Lagunera, the main goat milk-producing region under extensive grazing in Northern Mexico, where goats are key species for food security in rural communities into climate change scenario, for which its study and characterization should be considered a priority.

Conflict of interest

The authors declare that they have no conflict of interest.

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