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## Phenotypic characterization of the Creole goat in the Southern Highlands of Peru: A first step toward the sustainable use of a forgotten zoogenetic resource

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### ABSTRACT

**Background:** Five hundred years ago, goats were introduced to Peru, and since then, they have adapted to different climatic conditions, giving rise to the Creole goat, characterized by showing greater rusticity and better quality in both milk and meat than specialized breeds.

**Aim:** This study aimed to describe the phenotype of the Creole goat in the Highlands of Chincha province, Ica.

**Methods:** A total of 146 females aged >2 years without signs of crossbreeding with specialized breeds from the districts of San Juan de Yanac, San Pedro de Huacarpana, and Chavin were evaluated. Six pheneroptic characteristics, nine morphometric characteristics, and nine zoometric indices were registered. Tables and bar graphs were prepared. The chi-square test was performed to determine the association between districts and pheneroptic variables, ANOVA to identify differences between districts, correlation coefficients to evaluate morphostructural harmonicity, and multiple regression analysis to predict the live weight of animals.

**Results:** Of the goats, 61.6% had a spotted coat, 59.6% had no beard, 75.3% had horns, 57.5% had parallel teats, 90.4% had no wattles, and 80.8% had the correct number of teats, showing an association between district and absence/presence of beard ( $p = 0.001$ ). All morphometric parameters and zoometric indices were homogeneous within each district, with differences between districts ( $p < 0.05$ ).

**Conclusion:** The Creole goat of the high Andean area of Chincha is characterized by presenting a high morphostructural harmony, being medium to large in size, brevilineal, convexilinear and having a productive aptitude with a tendency to double purpose.

**Keywords:** Morphometry, Peruvian goat, Phaneroptics, Zoometric indexes.

### Introduction

Goat farming plays a significant role in Peru, particularly in rural communities (Aguirre *et al.*, 2021) that focus on dry forest regions, the central coast, and inter-Andean valleys and are dedicated to agriculture and livestock. In the country, goat breeding has historically been a traditional activity, maintaining a secondary status through an artisanal approach. This activity focuses on specific areas, and both the production and consumption of derived products are rooted in local culture (Ludeña *et al.*, 2021). Goat production is the main source of food, milk, and meat for subsistence farmers. Because of this, it is common to find it in arid and semiarid areas, usually in small herds (IICA, 2021).

The Ica region has a population of 78,866 goats, of which 77.5% belong to the provinces of Pisco and Chincha (MIDAGRI, 2022), with a predominance of Creole goats. The breeding of this species, which on the central coast follows an extensive system, has great

importance in the economy of low-income farmers (Bedada *et al.*, 2019, Jembere *et al.*, 2020), since it focuses on feeding with stubble of crops such as corn, cotton, cassava, asparagus, and natural grasses, still in many cases practicing transhumance that, depending on the time of year, take advantage of the availability of natural grasses in Andean bushes from March to July. In addition, producers in the Ica region are engaged in the production of dairy products, mainly cheese, which are demanded in some market segments. Undoubtedly, this activity plays an important role and is one of the main ones in the region. In the same way, goat-knit meat, weaned or older than 4 months of age, has a significant market demand (Sarria *et al.*, 2014).

On the other hand, the goats introduced to the country half a millennium ago adapted to different climatic conditions and gave rise to the so-called Creole goat (Gómez *et al.*, 2012), with unique and valuable characteristics such as greater rusticity, lower nutritional requirements, greater fertility, and better quality of milk and meat, compared to

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other goat breeds (Currò *et al.*, 2019; Migdal *et al.*, 2021). These qualities require characterization efforts for their conservation in order to use them in animal breeding programs and to maintain genetic diversity as part of food security (Torres-Hernández *et al.*, 2022). Lanari *et al.* (2003) stated that the characterization of livestock breeds is indispensable to achieve the sustainable use of animal genetic resources and consists of three sources of information: phenotypic, genetic, and historical (FAO, 2012). Within phenotypic characterization, the first step is knowledge of the variation of morphological characteristics (Delgado *et al.*, 2001), which allows the selection of animals with desirable characteristics and thus improves the productive parameters of the herd (Akounda *et al.*, 2023). Therefore, the objective of this study was to describe for the first time the phenotypic, morphometric, and zoometric characteristics of the Creole goat in the Highlands of the Chincha province, Ica region.

### Materials and Methods

#### Research area

The investigation was carried out in the districts of San Juan de Yanac (2,533 masl, 13°12'39"S 75°47'13"W),

San Pedro de Huacarpana (3,776 masl, 13°02'56"S 75°38'52"W) and Chavín (3,170 masl, 13°04'37"S 75°54'47"W), located in the mountains of Chincha province, Ica region, Peru (Fig. 1). According to INEI (2012), these districts are home to 60% of the goat population in Chincha, with a predominance of the Creole breed, which is raised under an extensive system and with a diet mainly based on stubble and natural grass.

#### Animals evaluated

A total of 146 goats over 2 years old based on their dentition, with no signs of crossing with specialized breeds (taking into account the color of the coat and level of production), from the districts of San Juan de Yanac ( $n = 91$ ), San Pedro de Huacarpana ( $n = 29$ ), and Chavín ( $n = 26$ ), were evaluated to determine the state of homogeneity or heterogeneity of their morphological characteristics, both qualitative and quantitative (SEZ, 2009).

#### Study variables

Data were collected from 16 goat farms considering the possibilities of geographical access, support from public institutions, predisposition of goat producers, and availability of transportation. Six phenotypic

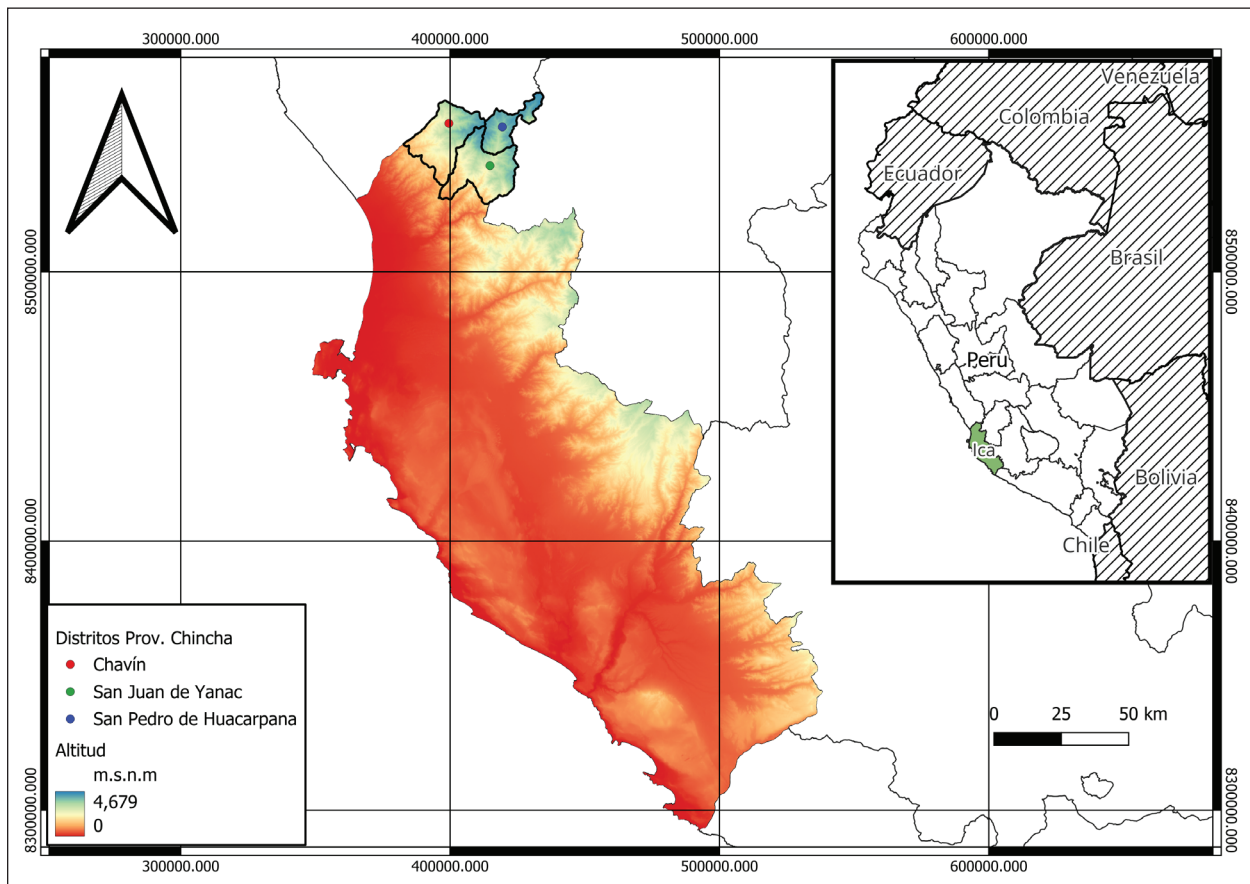


Fig. 1. Evaluated districts of Chincha province, Ica region, Peru.

variables were recorded on printed sheets: coat color (COC), absence or presence of beard (BER), absence or presence of horns (HOR), teat direction (DOT), correct number of teats (CNT), and absence or presence of wattles (MAM). In the same way, with the support of a zoometric cane and a tape measure, nine morphometric variables were recorded (FAO, 2012): height at the withers (WIH), chest width (CHW), rump length (RUL), rump height (RUH), rump width (RUW), body length (BOL), cannon perimeter (CAP), abdominal perimeter (ABP), and thoracic perimeter (THP) (Fig. 2).

With the above measures, nine zoometric indices were calculated (Parés, 2009): body index ( $BOI = (BOL / THP) \times 100$ ), pelvic index ( $PEI = (RUW / RUL) \times 100$ ), proportionality index ( $PRI = (WIH / BOL) \times 100$ ), dactyl–thoracic index ( $DTI = (CAP / THP) \times 100$ ), transverse pelvic index ( $TPI = (RUW / WIH) \times 100$ ), longitudinal pelvic index ( $LPI = (RUL / WIH) \times 100$ ), compactness index ( $COI = (BOW / WIH) \times 100$ ), relative cannon thickness index ( $CTI = (CAP / WIH) \times 100$ ), and cannon load index ( $CLI = (CAP / BOW) \times 100$ ).

### Statistical analysis

The database was systematized in Microsoft Excel and subsequently subjected to statistical analysis. For the pheneroptic variables, bar graphs were created and the chi-square test ( $\chi^2$ ) was used for interdistrict contrast. For morphometric variables and zoometric indices, measures of central tendency (mean), dispersion [SE, minima, maxima, and coefficient of variation (CV)], and 95% confidence intervals were calculated. Likewise, these variables were subjected to the assumptions of variance normality and homogeneity to perform the variance unidirectional analysis and identify possible significant differences between districts, and the Tukey test was used for the contrast of means. Likewise, quantitative morphostructural harmonicity was evaluated through Pearson's coefficients and multiple regression analysis to predict live weight based on the main morphometric measures using R Studio software, with a significance level of 0.05. The statistical model used to analyze the morphometric variables and zoometric indices was as follows:

$$Y_i = \mu + L_i + e_j$$

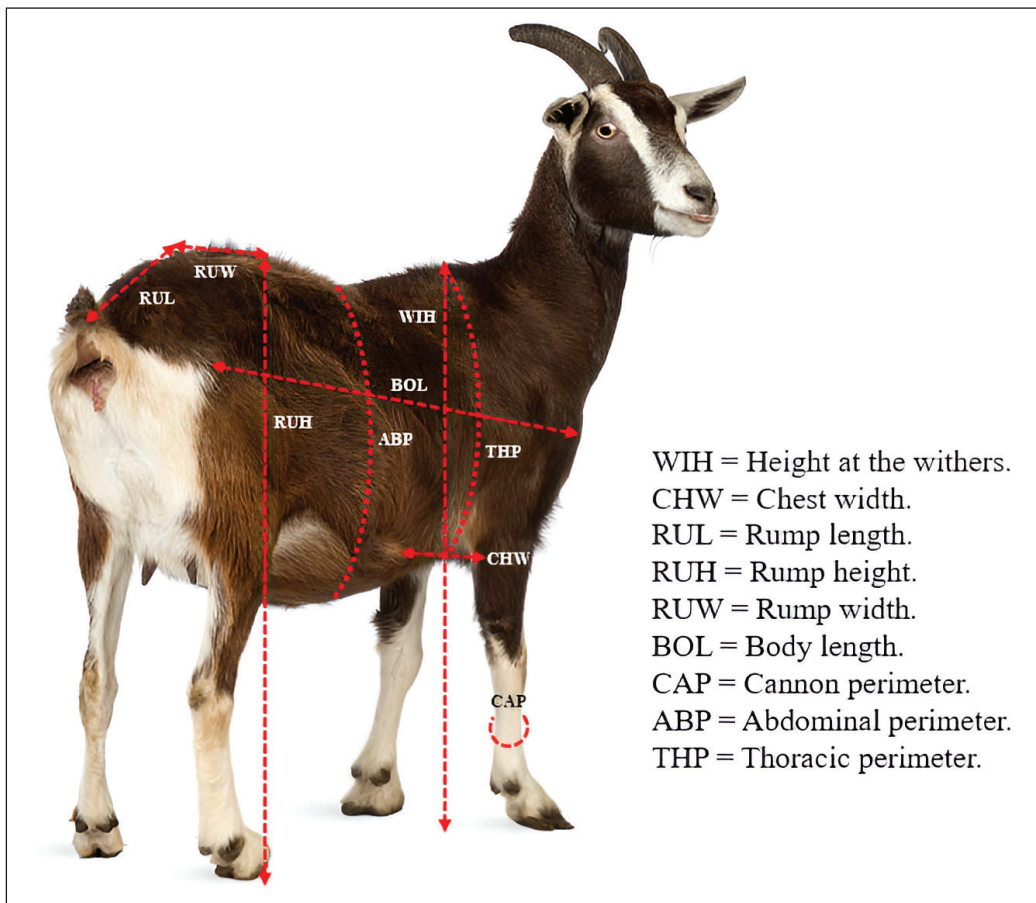


Fig. 2. Graphic representation of the anatomical points used to measure morphometric characteristics.

Where,  $Y_i$  = morfometric variable or zoometric index recorded,  $\mu$  = general mean,  $L_i$  = effect of the  $i$ -th district (San Juan de Yanac, San Pedro de Huacarpansa, Chavin),  $e_i$  = random error associated with each observation.

**Ethical approval**

Not needed for this study.

**Results**

**Phaneroptic parameters of the Creole goat in the Highlands of Chincha**

The results related to the color of the coat, beard, horns, parallel teats, wattles, and number of teats of the evaluated goats are shown in Figure 3. When comparing the results between districts, in Chavin, almost the same number of goats were observed with full color and spotted coats, and a greater number of them had divergent teats, and in San Juan de Yanac, almost the same number of goats were observed to have an absence or presence of a beard.

The only high association found was between the district and the BER ( $p = 0.001$ ), as shown in Table 1.

**Morphometric parameters of the Creole goat in the Highlands of Chincha**

Table 2 shows a summary of the main descriptive statistical measures for the morphometric parameters of

the Creole goats in the province of Chincha and shows that all presented a CV of less than 15%, which indicates that the population is very homogeneous (Herrera and Luque, 2009, Abd-Allah et al., 2019, Aguirre et al., 2021, Maksimović et al., 2023). However, there were differences between the districts evaluated ( $p \leq 0.01$ ) for the variables CHW, RUL, RUW, BOL, ABP, and THP (Table 3).

In general, the goats of the San Pedro de Huacarpansa district were characterized by having less strength, being shorter and shallower; the goats of San Juan de Yanac were the deepest, at the barrel level, in addition to having a wider and deeper chest, which showed their greater adaptability to the high Andean area, and the goats of Chavin had a larger rump, which translates into greater ease of calving.

The correlation analysis found positive associations between the majority of morphometric parameters evaluated (88.89%,  $p < 0.05$ ), which indicates that the Creole goat in the high Andean area of Chincha presented a high morphostructural harmony (Herrera and Luque, 2009), very similar to that reported by Silva-Jarquín et al. (2019), who mentioned that the black Creole goats of the central region of Mexico represented a morphologically homogeneous population, preserving a high harmonic model. In contrast, no significant

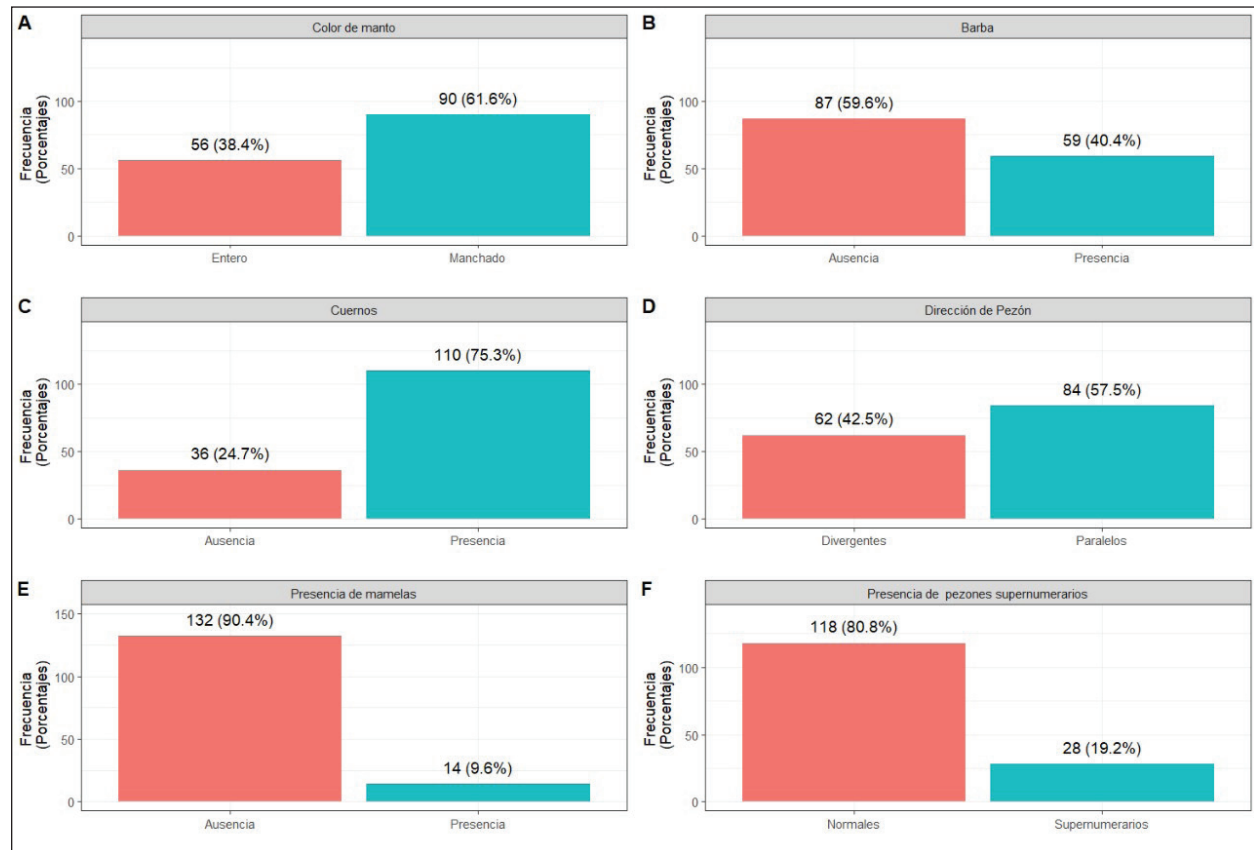


Fig. 3. Phaneroptic parameters of the Creole goat in the Highlands of Chincha province, Ica region, Peru.

**Table 1.** Association between the pheneroptic parameters of the Creole goat and the district in the Highlands of Chincha province, Ica region, Peru.

Phaneroptic parameter	District (n)			p-value
	San Juan de Yanac	San Pedro de Huacarpana	Chavin	
COC	Full	34	8	0.129
	Spotted	57	21	
BER	Absence	45	19	0.001
	Presence	46	10	
HOR	Absence	25	7	0.450
	Presence	66	22	
DOT	Diverging	34	12	0.088
	Parallel	57	17	
CNT	Normal	75	25	0.229
	Supernumerary	16	4	
MAM	Absence	79	28	0.165
	Presence	12	1	

COC = coat color, BER = absence/presence of beard, HOR = absence/presence of horns, dip = direction of teats, CNT = correct number of teats and MAM = absence/presence of wattles.

**Table 2.** Morphometric characteristics of Creole goat in the Highlands of Chincha province, Ica region, Peru.

Morphometric parameter	Mean ± S.E.M.	Min.	Max.	C.V. (%)	95% C	
					L.L.	U.L.
WIH	72.18 ± 0.32	63	84	5.32	71.55	72.81
CHW	19.82 ± 0.22	13	26.5	13.46	19.38	20.26
RUL	19.09 ± 0.21	15	28	13.23	18.68	19.51
RUH	75.13 ± 0.29	65	87	4.63	74.56	75.70
RUW	18.68 ± 0.16	13	23	10.34	18.37	19.00
BOL	73.00 ± 0.47	58	86	7.73	72.08	73.92
CAP	9.41 ± 0.05	8	11	6.22	9.32	9.51
ABP	107.79 ± 0.92	84	139	10.32	105.97	109.61
THP	88.46 ± 0.48	73	102	6.56	87.51	89.41

S.E.M. = standard error of the means, C.V. = coefficient of variation, C.I. = confidence interval, WIH = height at the withers, CHW = chest width, RUL = rump length, RUH = rump height, RUW = rump width, BOL = body length, CAP = cannon perimeter, ABP = abdominal perimeter, and THP = thoracic perimeter.

correlations were observed between CHW and RUL, CHW and CAP, RUL and ABP, RUL and THP, and RUL and BOW (Table 4).

**Zoometric indices of Creole goats in each district**

Table 5 shows a general summary of the zoometric indices of the Creole goat of Chincha, where it can be seen that the majority presented a CV of less than 15%, which again indicates that each population is very homogeneous (Aguirre et al., 2021), except for the CLI, which was slightly high. However, there were differences between the districts evaluated for the BOI, PEI, PRI, DTI, TPI, LPI, COI, and CLI indices

( $p \leq 0.01$ ) and differences for the CTI ( $p \leq 0.05$ ), as evidenced in Table 6.

The Creole goat of the Chincha high Andean area is characterized by being brevilinear (BOI < 85) (Parés, 2009); for presenting a convexilinear rump (PEI = 99.14) and according to the DTI = 10.67 and the PRI = 99.31, it can be concluded that it has a poorly defined productive aptitude, with a tendency to double purpose (Abarca-Vargas et al., 2020).

When comparing the three districts, it was observed that the goats of San Juan de Yanac had a rump that was wider than it was long (concavilinear), unlike the females of San Pedro de Huacarpana and Chavin

**Table 3.** Morphometric parameters of the Creole goat by district of the Highlands of Chincha province, Ica Region, Peru.

Morphometric parameter	District			p-value
	San Juan de Yanac	San Pedro de Huacarpana	Chavin	
WIH	72.35 ± 0.39 <sup>a</sup>	72.47 ± 0.61 <sup>a</sup>	71.25 ± 0.95 <sup>a</sup>	0.396
CHW	20.87 ± 0.23 <sup>a</sup>	16.93 ± 0.41 <sup>c</sup>	19.35 ± 0.39 <sup>b</sup>	0.000
RUL	18.64 ± 0.25 <sup>b</sup>	18.52 ± 0.39 <sup>b</sup>	21.33 ± 0.42 <sup>a</sup>	0.000
RUH	75.26 ± 0.38 <sup>a</sup>	75.41 ± 0.54 <sup>a</sup>	74.35 ± 0.70 <sup>a</sup>	0.444
RUW	19.15 ± 0.15 <sup>a</sup>	16.74 ± 0.45 <sup>b</sup>	19.19 ± 0.27 <sup>a</sup>	0.000
BOL	74.52 ± 0.55 <sup>a</sup>	68.17 ± 0.87 <sup>b</sup>	73.08 ± 1.00 <sup>a</sup>	0.000
CAP	9.34 ± 0.06 <sup>a</sup>	9.62 ± 0.10 <sup>a</sup>	9.44 ± 0.10 <sup>a</sup>	0.077
ABP	110.30 ± 1.19 <sup>a</sup>	102.00 ± 1.83 <sup>b</sup>	105.46 ± 1.76 <sup>ab</sup>	0.001
THP	89.56 ± 0.58 <sup>a</sup>	86.90 ± 1.00 <sup>ab</sup>	86.33 ± 1.24 <sup>b</sup>	0.011

Different superscripts within rows indicate statistical differences ( $p \leq 0.01$ ). WIH = height at the withers, CHW = chest width, RUL = rump length, RUH = rump height, RUW = rump width, BOL = body length, CAP = cannon perimeter, ABP = abdominal perimeter, and THP = thoracic perimeter.

**Table 4.** Pearson correlation coefficients of the morphometric parameters in Creole goats from the Highlands of Chincha province, Ica region, Peru.

Parameter	WIH	CHW	RUL	RUH	RUW	BOL	CAP	ABP	THP	PEV
WIH	1	0.222**	0.224**	0.805**	0.235**	0.417**	0.400**	0.414**	0.521**	0.548**
CHW		1	0.162	0.207*	0.495**	0.453**	0.040	0.445**	0.505**	0.479**
RUL			1	0.207*	0.240**	0.205*	0.221**	0.078	0.151	0.142
RUH				1	0.244**	0.287**	0.315**	0.345**	0.474**	0.423**
RUW					1	0.430**	0.064	0.434**	0.363**	0.450**
BOL						1	0.377**	0.694**	0.666**	0.724**
CAP							1	0.357**	0.414**	0.431**
ABP								1	0.822**	0.814**
THP									1	0.811**
PEV										1

\*  $p < 0.05$ , \*\*  $p < 0.01$ . WIH = height at the withers, CHW = chest width, RUL = rump length, RUH = rump height, RUW = rump width, BOL = body length, CAP = cannon perimeter, ABP = abdominal perimeter, and THP = thoracic perimeter.

(convexilinear). On the other hand, the goats of San Pedro de Huacarpana had higher PRI and lower TPI and LPI, indicating that they had more milk-producing aptitudes. Regarding legs, the goats of Chavin and San Pedro de Huacarpana had greater CTI and CLI, indicating greater limb strength, which gives them an advantage in high Andean areas above 3,000 m above sea level. A possible reason for the differences between the three districts could be the altitude and agroecology of each of them (Hankamo *et al.*, 2020).

Undoubtedly, genetic improvement programs in goat species should consider selection by zoometry in addition to production, to maximize genetic progress (Fernández *et al.*, 2023), since it defines longevity, resistance, improved productive capacity, and,

consequently, its long-term profitability (Luigi-Sierra *et al.*, 2019).

## Discussion

### Phaneroptic parameters

The results obtained in this study are consistent with those reported in other regions. Oyolo (2020) reported that the Creole goat from northern Lima is characterized by a predominantly nuanced COC, the presence of horns, the absence of beards, the absence of wattles, and the CNT. The same result was reported by Gómez *et al.* (2012), who found that goats of the Apurímac region had a spotted coat, horns, and the absence of wattles. In Nicaragua, goats were identified in greater proportion as having the CNT and, at the same time, not having horns and no wattles (Hernández *et al.*, 2022).

**Table 5.** Zoometric indices of the Creole goat in the Highlands of Chincha province, Ica region, Peru.

Zoometric index	Mean ± S.E.M.	Min.	Max.	C.V. (%)	95% C.I.	
					L.L.	U.L.
BOI	82.61 ± 0.41	67.44	97.47	6.01	81.79	83.42
PEI	99.14 ± 1.18	66.67	143.75	14.32	96.82	101.46
PRI	99.31 ± 0.62	82.50	122.95	7.51	98.09	100.53
DTI	10.67 ± 0.06	9.23	13.13	7.01	10.55	10.79
TPI	25.92 ± 0.23	18.57	35.11	10.56	25.48	26.37
LPI	26.49 ± 0.29	20.51	37.84	13.01	25.92	27.05
COI	73.67 ± 0.88	49.25	103.03	14.51	71.92	75.41
CTI	13.06 ± 0.07	11.27	15.71	6.36	12.93	13.20
CLI	18.10 ± 0.23	12.30	27.27	15.60	17.63	18.56

S.E.M. = standard error of means, C.V. = coefficient of variation, C.I. = confidence interval, BOI = body index, PEI = pelvic index, PRI = proportionality index, DTI = dactyl – thoracic index, TPI = transverse pelvic index, LPI = longitudinal pelvic index, COI = compactness index, CTI = cannon relative thickness index, and CLI = cannon load index.

**Table 6.** Zoometric indices of Creole goats by district in the Highlands of Chincha province, Ica region, Peru.

Zoometric index	District			p-value
	San Juan de Yanac	San Pedro de Huacarpana	Chavin	
BOI	83.27 ± 0.47 <sup>a</sup>	78.55 ± 0.86 <sup>b</sup>	84.79 ± 0.90 <sup>a</sup>	0.000
PEI	103.97 ± 1.26 <sup>a</sup>	91.79 ± 3.43 <sup>b</sup>	90.45 ± 1.31 <sup>b</sup>	0.000
PRI	97.43 ± 0.69 <sup>b</sup>	106.69 ± 1.39 <sup>a</sup>	97.65 ± 1.01 <sup>b</sup>	0.000
DTI	10.45 ± 0.07 <sup>b</sup>	11.10 ± 0.15 <sup>a</sup>	10.97 ± 0.12 <sup>a</sup>	0.000
TPI	26.49 ± 0.19 <sup>a</sup>	23.17 ± 0.71 <sup>b</sup>	27.00 ± 0.38 <sup>a</sup>	0.000
LPI	25.79 ± 0.35 <sup>b</sup>	25.55 ± 0.48 <sup>b</sup>	29.96 ± 0.51 <sup>a</sup>	0.000
COI	76.90 ± 1.04 <sup>a</sup>	68.08 ± 1.63 <sup>b</sup>	68.58 ± 2.18 <sup>b</sup>	0.000
CTI	12.93 ± 0.09 <sup>b</sup>	13.29 ± 0.14 <sup>a</sup>	13.28 ± 0.12 <sup>a</sup>	0.042
CLI	17.06 ± 0.24 <sup>b</sup>	19.79 ± 0.45 <sup>a</sup>	19.83 ± 0.64 <sup>a</sup>	0.000

BOI = body index, PEI = pelvic index, PRI = proportionality index, DTI = dactyl–thoracic index, TPI = transverse pelvic index, LPI = longitudinal pelvic index, COI = compactness index, CTI = cannon relative thickness index and CLI = cannon load index.

On the other hand, in Ecuador, the Creole goats of Loja were characterized by not having wattles or beards (Aguirre *et al.*, 2021), and Barragán *et al.* (2019) found that the Creole goat of the Colima Valley in Mexico had a mixed color coat, presence of horns, absence of wattles, and vertically arrayed teats.

**Morphometric parameters**

Creole goats from the Highlands of Chincha were slightly taller than goats from the north of Lima (Oyolo, 2020) and Apurímac (Gómez *et al.*, 2012), with WIH of 70.83 and 65 cm, respectively. Compared to Creole goats from other countries, Chincha goats were taller than goats from Nicaragua (Hernández *et al.*, 2022), Zacatecas, Mexico (Sánchez *et al.*, 2018); Mendoza, Argentina (Dayenoff *et al.*, 2020); and Lara, Venezuela (Muñoz *et al.*, 2014), with WIH of 70.83, 63.67, 66.41,

and 63.2 cm, respectively. The Chincha Creole goat is considered a medium-to-large animal (Devendra and McLeroy, 1986; Hernández *et al.*, 2022).

**Zoometric indexes**

Regarding the BOI, the results of the present study were similar to those found in Apurímac (Gómez *et al.*, 2012), Colima in Mexico (Abarca-Vargas *et al.*, 2020), and the northern region of Argentina (Revidatti *et al.* 2007), where goats were also considered to be brevilineal with a BOI greater than or equal to 80. On the other hand, the results differ from what was reported by Oyolo (2020) for Creole goats in the north of Lima, which are considered long-lined (BOI = 95.79), and in the case of native goats to the Amhara region in Ethiopia, they were classified as meso and long-lined with an BOI > 86 (Getaneh *et al.*, 2022).

These variations can be attributed to environmental factors, zootechnical management, and local adaptation processes to the agroecological conditions of each region.

### Conclusion

In the Creole goat of the Highlands of Chincha, the spotted coat, the absence of beard, the presence of horns, the parallel teats, the absence of wattles, and an appropriate number of teats for the species predominate, evidencing an association between the evaluated district and the BER. On the other hand, the morphometric parameters and zoometric indices were homogeneous within each district but differed between districts. Likewise, significant positive associations were found among most morphometric parameters. The above shows that the Creole goat from Chincha is characterized by presenting a high morphostructural harmony, being medium to large in size, brevilineal, convexilinear and having a poorly defined productive aptitude, which shows its tendency to double purpose, highlighting the need for conservation and genetic improvement strategies to optimize its contribution to high Andean production systems.

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### Conflict of interest

The authors declare no conflict of interest.

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### Authors' contributions

Y.L.M. and D.G.P.: Conceptualization, methodology, and revision of the manuscript. E.S.D.: Data collection, data analysis, and writing of the original manuscript. J.C.L.: Project management, fund acquisition, and revision of the manuscript. All authors have read the manuscript.

### Data availability

All data were provided in the manuscript and available from the corresponding author.

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