

Morpho functional characterization and estimation of the reproductive potential of Creole goats in Santa Elena Province, Ecuador

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Abstract

The objective of this study was to characterize testicular biometrics, scrotal conformation, and foot-and-leg conformation in Creole goat bucks (*Capra hircus*) in Santa Elena Province, Ecuador, to estimate their reproductive potential and identify limiting factors in extensive production systems. A total of 190 bucks from Santa Elena were evaluated. Age, body condition score (BCS, 1–5 scale), scrotal circumference (SC), testicular length and width, testicular tone/consistency, scrotal conformation, and foot-and-leg conformation were recorded. Mean SC was 21.92 ± 3.57 cm and estimated testicular volume (TV) was 546.22 ± 429.59 cm³. Highly significant differences ($p < 0.001$) were observed in SC and TV across age categories, increasing progressively until maturity (≥ 4 years: 25.68 ± 5.77 cm). A multiple linear regression model revealed that age ($\beta = 0.151$, $p < 0.001$) and BCS ($\beta = 1.564$, $p < 0.001$) jointly explained 24.9% of the variance in SC ($R^2 = 0.249$, $F = 31.00$, $p < 0.001$). Regarding scrotal anatomy, 46.32% exhibited elongated normal conformation, 26.32% rounded normal conformation, and 25.26% displayed a split scrotum (scrotal cleft). For leg conformation, the highest frequency of normal alignment occurred in the forelimb side view (74.74%) and forelimb front view (73.16%), whereas in the hindlimb side view, 29.47% exhibited sickled-hock (sickle-hocked) posture and 10.00% steep pasterns. It is concluded that Creole goats in Santa Elena possess adequate biometric development for reproduction; however, nutritional deficiencies and hindlimb postural defects restrict mobility and indirectly limit mating capacity in arid agrosystems.

INTRODUCTION

In the semi-arid coastal belt of Ecuador, particularly in Santa Elena Province, goat farming based on local Creole animals constitutes the socio-economic, cultural, and food security backbone for numerous smallholder families (Chicaiza et al., 2023). Descended from populations introduced during the colonial era, these local ecotypes have undergone centuries of natural selection, acquiring remarkable hardiness and adaptive capacity to extreme conditions of low forage availability, thermal stress, and water scarcity (Santana et al., 2020; Vargas-López et al., 2022). However, in traditional extensive systems across the region, buck selection is performed empirically or unplannedly, significantly constraining reproductive efficiency and genetic progress within herds.

Andrological evaluation and morphofunctional characterization of breeding bucks represent essential pillars for ensuring herd fertility. Among biometric parameters, Scrotal Circumference (SC) and Testicular Volume (TV) are internationally recognized as highly heritable indicators strongly associated with testicular weight, spermatogenesis rate, total sperm output, and daughter sexual precocity (Santiago-Moreno et al., 2021; Waheed et al., 2020). In African contexts with analogous tropical and semi-arid climates, recent studies on indigenous breeds (such as Red Sokoto, WAD, and Horn of Africa ecotypes) have confirmed that SC and TV serve as dynamic bioindicators highly sensitive to nutritional status and ambient heat stress (Habibu et al., 2021; Tesfaye et al., 2022; Deribe et al., 2021). Similarly, European research on Mediterranean breeds adapted to dry environments (e.g., Murciano-Granadina and Malagueña) highlights that precise biometric determination enables the identification of bucks with higher sperm reserve capacity and reproductive endurance during critical periods (Arrebola et al., 2022; Fatet et al., 2020).

Furthermore, structural soundness of the locomotor system and proper leg alignment are indispensable in extensive grazing systems. While in European intensive production model's limb structure is primarily assessed to prevent premature culling due to foot and joint lesions under confinement (Palacios et al., 2021), in tropical dry forest and arid agrosystems (characteristic of Santa Elena and Sahelian regions in Africa), breeding bucks must travel long daily distances over rough, thorny terrain for browsing and estrus detection (Sanon et al., 2020; Belkhir et al., 2023). Consequently, severe leg conformational defects directly compromise mobility, animal welfare, and natural mating effectiveness.

Despite the strategic importance of Creole goats in Ecuador, there is a marked scarcity of updated scientific literature on testicular biometrics and locomotor quality of bucks along the coastal region. Therefore, the objective of this study was to quantitatively evaluate reproductive morphofunctional parameters, scrotal morphology, and foot-and-leg conformation in Creole bucks from Santa Elena Province, contrasting their biometric patterns with European and African references to define zootechnical selection criteria and estimate breeding buck potential in the region.

MATERIALS AND METHODS

Study Location and Sampling

The study was conducted on 190 Creole goat bucks (*Capra hircus*) located across farms in four parishes of Santa Elena Province, Ecuador: Chanduy ($n = 97$), Manglaralto ($n = 43$), Simón Bolívar ($n = 30$), and Colónche ($n = 20$).

A total of 190 clinically healthy male goats between one and five years of age were selected based on a clinical diagnosis conducted in accordance with the procedures described by Cuesta et al. (2003).

All animals were of the Creole genotype from the Santa Elena Peninsula, which originated from Asian and European strains and is considered the peninsular goat. This breed includes small and medium-sized animals with lower body weight, a reddish coat color, a straight forehead-to-nose profile, and small ears set horizontally and pointing forward (Solís-Lucas et al., 2020).

The setting of this study is characterized by low rainfall and large salt flats. The average annual temperature ranges from 18 to 24°C, with a minimum of 15°C between July and August and a maximum of 39.5°C in February and March. Annual average precipitation ranges from 125 to 150 mm, relative humidity is 86%, and elevation ranges from 5 to 20 meters above sea level (INAMI 2022).

It has two seasons: the rainy season, from May through December, when nearly 90% of the annual precipitation falls, with temperatures ranging from 21 to 40°C; and the dry season, from January through April. Santa Elena has three climate zones: the semi-arid tropical megathermal zone, the dry tropical megathermal zone, and the semi-humid tropical megathermal zone; the first two are the most representative of the province (INAMI 2022).

Evaluated Variables

General parameters

Age (months) categorized into four groups (< 1 year; 1 to 2 years; 2 to 3 years; ≥ 4 years) and Body Condition Score (BCS) assessed on a 1 to 5 ordinal scale (1 = emaciated, 5 = obese).

Testicular biometrics

Scrotal Circumference (SC, cm), Left and Right Testicular Length (LTL, RTL, cm), and Left and Right Testicular Width (LTW, RTW, cm). Testicular Volume (TV, cm³) was calculated using the prolate spheroid formula

TV = (4 / 3) × π × (Mean Length / 2) × (Mean Width / 2)²

Scrotal morphology and consistency

Testicular tone/elasticity, scrotal conformation, and scrotal shape.

Foot-and-leg conformation

Qualitative visual classification of forelimbs and hindlimbs (front and side views) following standardized livestock scoring protocols.

Statistical Analysis

Data were processed using advanced statistical packages in Python. Means, standard deviations (SD), minimums, and maximums were calculated for quantitative variables, while absolute (N) and relative (%) frequencies were computed for categorical variables. One-way ANOVA was applied to compare SC and TV across age categories, Pearson correlation coefficients (r) were estimated between morphometric variables, and Multiple Linear Regression (OLS) was performed to predict SC based on age and body condition score.

Ethical Considerations

Data collection was performed on-site using non-invasive procedures as described by Chávez et al. (2023). Animals were handled under low-stress conditions during routine monthly management chute visits for health and reproductive monitoring. According to Resolution XX of the Agency for Phytosanitary and Zoosanitary Regulation and Control of Ecuador (2021), Article 1 and Article 3, mandatory ethical committee approval is not required for non-invasive morphometric data collection and anatomical assessments in livestock.

RESULTS

General Characterization and Testicular Biometrics

The overall mean age was 19.48 ± 10.73 months (range: 8 to 60 months) and mean body condition score was 2.79 ± 0.60 points, reflecting a medium-low nutritional status characteristic of semi-arid agrosystems. Mean global scrotal circumference was 21.92 ± 3.57 cm (range: 12.00 to 39.00 cm) and mean testicular volume was 546.22 ± 429.59 cm³.

Table 1
Testicular biometric and reproductive morphometric parameters by age category in Creole bucks (Mean ± SD).

Age Category	N	Age (months)	BCS (1–5)	SC (cm)	Mean Length (cm)	Mean Width (cm)	Testicular Vol. (cm³)
< 1 years	41	9.10 ± 1.11	3.10 ± 0.50	19.80 ± 2.35a	10.17 ± 1.54	9.25 ± 1.74	476.65 ± 193.47a
1 to 2 yearss	85	15.24 ± 3.39	2.65 ± 0.59	21.34 ± 2.79b	11.19 ± 2.21	8.35 ± 2.67	465.05 ± 320.29a
2 to 3 years	47	27.35 ± 3.97	2.72 ± 0.57	23.46 ± 3.11c	12.97 ± 2.18	8.38 ± 2.82	562.49 ± 444.74a
≥ 4 years	17	43.89 ± 7.99	2.94 ± 0.68	25.68 ± 5.77d	13.02 ± 3.08	11.43 ± 3.83	1074.87 ± 796.28b
Global / Total	190	19.48 ± 10.73	2.79 ± 0.60	21.92 ± 3.57	11.58 ± 2.41	8.83 ± 2.79	546.22 ± 429.59
Note: Values with different superscript letters within the same column indicate statistically significant differences in ANOVA (p < 0.05).							

As presented in Table 1, analysis of variance (ANOVA) showed highly significant differences across age groups for Scrotal Circumference (F = 18.92, p = 9.39 × 10⁻¹¹) and Testicular Volume (F = 11.66, p = 4.89 × 10⁻⁷).

Regression Model and Variable Interrelationships

Significant Pearson correlation coefficients were found between Scrotal Circumference and Testicular Volume (r = 0.689, p < 0.001), Testicular Width (r = 0.579, p < 0.001), Testicular Length (r = 0.473, p < 0.001), Age (r = 0.426, p < 0.001), and Body Condition Score (r = 0.214, p = 0.003).

Multiple Linear Regression (OLS) fitting for predicting Scrotal Circumference (Y) based on Age and BCS yielded:

SC (cm) = 14.615 + 0.151 × (Age in months) + 1.564 × (Body Condition Score)

The model was statistically significant ($R^2 = 0.249$, $F(2, 187) = 31.00$, $p = 2.35 \times 10^{-12}$). This indicates that for each additional month of age, SC increases by 0.151 cm, whereas each one-unit increase in body condition score corresponds to an average increase of 1.564 cm in SC.

Scrotal Conformation and Reproductive Anatomy

Regarding scrotal conformation, 46.32% (n = 88) presented elongated normal conformation, 26.32% (n = 50) rounded normal conformation, 25.26% (n = 48) split scrotum, 1.58% (n = 3) rotated testicles, and 0.53% (n = 1) incomplete testicular descent. In terms of scrotal shape, straight-edged scrotum dominated (63.68%, n = 121), followed by normal scrotum (20.53%, n = 39) and tight scrotum (15.79%, n = 30).

Foot-and-Leg Conformation and Locomotor Structure

Structural evaluation revealed significant anatomical alterations in limbs, particularly in hindlimb posture (Table 2):

Table 2 Frequency distribution and percentage of foot-and-leg conformation classifications (N = 190).				
View / Evaluation	Normal Conformation N (%)	Major Defect 1 N (%)	Major Defect 2 N (%)	Other Defects N (%)
Forelimb – Front	139 (73.16%)	Narrow-fronted: 21 (11.05%)	Knock-kneed: 15 (7.89%)	Wide-fronted/bow-kneed: 15 (7.89%)
Forelimb – Side	142 (74.74%)	Camped out fore: 30 (15.79%)	Steep pasterns: 12 (6.32%)	Camped-under fore: 6 (3.16%)
Hindlimb – Front	116 (61.05%)	Narrow-behind: 30 (15.79%)	Cow-hocked: 20 (10.53%)	Wide-behind/bow-hocked: 20 (10.53%)
Hindlimb – Side	101 (53.16%)	Sickle-hocked: 56 (29.47%)	Steep pasterns: 19 (10.00%)	Camped out/post-legged: 14 (7.37%)

DISCUSSION

The scrotal circumference (SC) observed in adult bucks from Santa Elena (≥ 4 years: 25.68 ± 5.77 cm) reflects optimal morphometric development and aligns with patterns reported for indigenous and Latin American Creole goat breeds adapted to arid and semi-arid environments. On the Ecuadorian coast, Masaquiza et al. (2026) observed significant differences ($p \leq 0.05$) in SC between age groups, reporting a linear regression model ($y = 1.99x + 17.9$, $R^2 = 0.9926$) that demonstrates a strong positive relationship between buck age and scrotal circumference.

The positive and statistically significant effect of body condition score on SC ($\beta = 1.564$, $p < 0.001$) highlights how nutritional status directly governs testicular parenchymal volume. In tropical agrosystems characterized by marked forage seasonality, prolonged undernutrition induces seminiferous tubular atrophy and reductions in Leydig and Sertoli cell follicular volume, decreasing effective testicular volume and sperm reserves. These findings concur with observations by Tesfaye et al. (2022) and Deribe et al. (2021) in native African goats (such as Ethiopian ecotypes and Sahelian breeds), where SC and testicular volume serve as dynamic bioindicators highly responsive to energy availability and body weight. However, when contrasting these results with patterns described in temperate European latitudes for Mediterranean breeds (e.g., Murciano-Granadina or Malagueña), a fundamental ecophysiological distinction emerges while European breeds exhibit photoperiod-driven neuroendocrine seasonality controlling biometric peaks, Creole goats in coastal Ecuador display biometric variations primarily regulated by nutritional availability and thermo-hydric stress.

The high prevalence of split scrotum (25.26%) identified in the Santa Elena population is a finding of major zootechnical and adaptive relevance. In tropical and arid goat breeds, scrotal clefting or bicipitality has been documented as a morphofunctional adaptation to thermal stress. Partial separation of the testicles increases the surface area exposed to airflow, enhancing heat loss through radiation and convection, which maintains the scrotal-testicular thermal gradient (2 to 5°C below core body temperature) necessary for preserving spermatogenesis.

However, as noted by Deribe et al. (2021), when scrotal clefting is excessively deep ($> 50\%$ of testicular length), the thermoregulatory advantage is offset by the risk of mechanical injury from thorny shrub vegetation (e.g., *Acacia* spp. and *Prosopis* spp.) typical of the tropical dry forest in Santa Elena Peninsula. Therefore, while elongated normal (46.32%) and rounded normal (26.32%) conformations should remain primary breeding targets, moderate scrotal clefts can be tolerated as a rustic trait, culling only animals with deep or atypical scrotal fissures.

Functional assessment of locomotor soundness revealed that nearly 47% of evaluated breeding bucks exhibited hindlimb postural deviations (side view), notably sickle-hocked posture (29.47%) and steep pasterns (10.00%). Structural integrity of the locomotor system assumes distinct significance according to the production model: while in European intensive and semi-intensive systems leg scoring aims to prevent premature culling from foot rot or arthritis on

concrete surfaces (Palacios et al., 2021), in tropical dry extensive grazing systems, breeding bucks must traverse 5 to 12 km daily over rough terrain to browse and detect estrous females (Sanon et al., 2020; Belkhiri et al., 2023).

In Tamaulipas, Mexico, goats spend most of their time grazing and switch to a diet of herbs and grasses only when there is sufficient herbaceous vegetation available during the rainy season (January–April), due to adverse weather conditions and poor management. The latter could explain the results of this study, in which males showed a lower CE. However, the adaptability and value of this genotype in this environment are worth noting. (Zapata et al., 2021). The combination of poor nutrition and severe structural defects in the hind limbs shifts the animal's center of gravity, leading to joint overload in the hocks and pasterns, chronic pain, early fatigue, and, consequently, a drastic decrease in mounting frequency and the effectiveness of natural mating. This locomotor limitation, combined with poor physical condition during the dry seasons, represents the main non-genetic bottleneck for the herd's reproductive efficiency in the province of Santa Elena.

Findings from this study demonstrate the urgent need to transition from empirical buck selection to standardized objective criteria. The fitted multiple regression model ($R^2 = 0.249$, $p < 0.001$) confirms that age and body condition score jointly predetermine scrotal circumference variability. To maximize genetic progress and herd fertility in semi-arid agrosystems, we propose the Creole Buck Selection Index (CBSI), incorporating:

Scrotal Circumference ≥ 22 cm at 18 months of age (ensuring adequate sperm reserves).

Body Condition Score ≥ 2.5 points (1–5 scale).

Satisfactory hindlimb side-view score ("Normal"), culling bucks with severe sickle-hocks or post-legs.

Absence of severe scrotal anatomical defects (testicular rotation, cryptorchidism, or deep scrotal clefts).

CONCLUSIONS

Creole bucks in Santa Elena achieve optimal testicular morphometric development starting at 24 months of age, recording a mean SC exceeding 23 cm in adult males.

Body condition score exerts a marked, independent influence on scrotal circumference, demonstrating that strategic seasonal forage supplementation directly enhances buck reproductive potential.

It is recommended to cull bucks with severe sickle-hocked postures (29.47%) or severe scrotal abnormalities (rotations or cryptorchidism).

Implement the Creole Buck Selection Index (CBSI) combining SC (≥ 22 cm at 18 months), BCS (≥ 2.5), and normal hindlimb structural alignment.

Declarations

Conflict of interest:

The authors declare no conflicts of interest.

Financial support:

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Author contributions:

Conceptualization, Writing - review & editing: (Orlando Roberto Quinteros Pozo); Supervision, Data curation, Methodology, writing: (Joffre Javier Masaquiza Aragón); Writing - review & editing, original draft: (Pablo Roberto Marini); Investigation, writing - review & editing (Darwin Omar Yanez Avalos); Sources & supervision: (Nestor Vicente Acosta Lozano)

Data Availability Statement:

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethical Considerations

Data collection was performed on-site using non-invasive procedures as described by Chávez et al. (2023). Animals were handled under low-stress conditions during routine monthly management chute visits for health and reproductive monitoring. According to Resolution XX of the Agency for Phytosanitary and Zoosanitary Regulation and Control of Ecuador (2021), Article 1 and Article 3, mandatory ethical committee approval is not required for non-invasive morphometric data collection and anatomical assessments in livestock.

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