https://doi.org/10.22319/rmcp.v10i4.4850

Article

# Biometric study of Criollo Santa Elena Peninsula cattle (Ecuador)

Ronald Cabezas Congo [a]

Cecilio Barba Capote [b*]

Ana González Martínez [b]

Orly Cevallos Falquez [a]

José Manuel León Jurado [c]

José Manuel Aguilar Reyes [a]

Antón García Martínez [b]

[a] Universidad Técnica Estatal de Quevedo. Facultad de Ciencias Pecuarias., Quevedo. Ecuador.

[b] Universidad de Córdoba. Departamento de Producción Animal, Campus de Rabanales. Edificio Producción Animal. 14071. Córdoba. España.

[c] Universidad de Córdoba. Departamento de Genética, Córdoba, España.

* Corresponding author: cjbarba@uco.es

**Abstract:**

Biometric characterization is useful in describing cattle breeds, distinguishing between them and assessing their diversity. The Criollo Santa Elena Peninsula (Ecuador) breed was described with a biometric analysis of 217 adult animals (198 females and 19 females) involving fourteen morphometric variables, live weight and fourteen morphometric indices. An analysis of variance was run with only sex as the variation factor. Pearson correlation coefficients were estimated and principal components analysis run based on variable residuals. A multivariate analysis was then run to differentiate between four Ecuadorian Creole cattle populations with a canonical discriminant analysis. This involved fourteen morphometric variables and live weight in a sample of 1,388 adult females (Lojano: 198; Manabí: 794; Santa Elena: 198; Tsachilas: 198). The results indicate the Criollo Santa Elena Peninsula breed has a normal tendency and an

intermediate body format compared to other creole breeds. It is dolichocephalic type, has sublongilinear body proportions and a fine skeleton (particularly in females), highlighting its suitability for dairy production. Overall, the studied population exhibited moderate homogeneity and harmony, with moderate to high sexual dimorphism, suggesting different genetic management of the sexes. The discriminant function significance levels in conjunction with the Mahalanobis and Euclidean distances indicate that each breed in the analysis has a distinct morphometric pattern, suggesting clear morphometric differentiation between the four populations.

**Key words**: Biometric analysis, Creole breeds, Breed characterization.

Received: 09/04/2018

Accepted: 16/10/2018

# Introduction

Ecuador has one of the highest biodiversity index values in the world, although its domestic animal populations are poorly studied. These are vital resources essential to the country's food security and sovereignty[1]. However, the most recent national reports on biodiversity[2] and agrobiodiversity[3] state that deforestation, changes in land use, pollution and the introduction of exotic species are the main factors threatening agrobiodiversity. Incorporation of foreign livestock breeds is the main threat to conserving domestic food animal genetic resources.

The Domestic Animals Diversity Information System (DAD-IS) lists thirteen species of domestic food animals in Ecuador. Four of these are native Andean species (alpaca, 1; guinea pig, 1; llama, 1; vicuña, 1) and one is the native turkey (1). The remaining species are introduced: buffalo (1), cattle (21), goat (1), sheep (5), pig (8) and poultry (chicken, 1; and duck, 1). Cattle (*Bos* sp.) dominates Ecuadorian livestock production[4]. There are five European breed (*Bos taurus*) populations (Angus, Brown Swiss, Holstein, Jersey, and Normanda), and three Asian breed (*Bos indicus*) populations (Brahman, Gyr, Nelore). There are also ten creole-type populations (Bravo de Paramo, Chusco, Criollo Santa Elena Peninsula, Ecuadorian Creole, Esmeraldeño, Galapaqueño, Jaspeado Manabita, Macabea, Moro and Zarumeño), and three synthetic populations (Pizan, Sahiwal and Santa Gertrudis).

Research on the creole breeds of Latin America has found that the main problems reported by producers and technical advisors when using these breeds are lack of data and an

absence of characterization and productive behavior studies[5]. This definitely holds true for the Criollo Santa Elena Peninsula (CSEP) cattle population. Cattle production is the main livestock activity in Santa Elena Province, Ecuador, and is mainly done using dual-purpose systems. Producers mainly use medium-sized herds.

The FAO[6] considers it a priority to do breed characterization studies as the first phase in implementation of a livestock development program focused on a sustainability in traditional production systems that is linked to adequate land management. Characterization of animal genetic resources (AnGR) covers all activities associated with the identification, and quantitative and qualitative description of breed populations, and the natural habitat and production systems to which they are adapted[7].

Descriptive biometric analysis has been widely used for breed characterization; for example, in a recent breed characterization of Criollo Manabí cattle in Ecuador[8]. Principal components analysis (PCA) is useful both in determining the relationship between biometric variables within a population[9] and in differentiating between populations[10]. Discriminant analysis is normally used to analyze multivariate differences between groups, to determine the variables most useful in discriminating between groups, and to identify which groups are similar and which are different. It has recently been used in comparative morphometric studies of creole cattle breeds in Argentina[10] and Africa[11], and of other domestic species: horses[12]; sheep[13]; goats[14]; pigs[15]; dogs[16]; ducks[17]; and turkeys[18]. Canonical discriminant analysis has been applied to productive characteristics in beef cattle[19,20] and in milking suitability[21].

The present study objective study was to generate a biometric characterization of the Criollo Santa Elena Peninsula breed through a biometric analysis and morphometric differentiation of this breed compared to other Ecuadorian creole cattle breeds, with the goal of developing a purebred breeding program.

# Material and methods

## Data collection

Located on the central south coast of Ecuador, the study area consisted of Santa Elena Province, which covers 3,763 km$^2$, and has an average altitude above sea level of 62 meters (range= 0 - 800 m asl). Temperatures vary from 17 to 40 °C, and regional

vegetation is dry tropical forest. A total of 722 cattle ranches are located in the province and these contain a total of 10,454 adult animals, of which 7,265 are breeding females[22].

Morphometric characterization was done with a sample of 217 adult CSEP animals, of which 198 were female and 19 were male. A comparative and differentiation analysis was done between CSEP cattle and three other Ecuadorian cattle populations found in four different provinces. The analysis was run using a total of 1,388 adult females: Criollo Lojano (CL, n= 198); Criollo Manabi (CM, n= 794); Criollo Santa Elena Peninsula (CSEP, n= 198) and Criollo Santo Domingo de los Tsachilas (CSDT, n= 198).

After reviewing previous experiences and FAO protocols[23,24], breeders were asked which specimens they considered most characteristic of and adjusted to the CSEP biotype. These animals were measured and recorded. A random selection was made of three to six adult animals per farm, depending on ranch size (i.e. ≤20 or >20 breeding females per production unit).

## Morphometric variables

In addition to live weight (LW), fourteen morphometric variables were chosen from among those recommended by Parés[25]: head width (HW); head length (HL); face length (FL); cranium length (CL); withers height (WH); bicostal diameter (BCD); chest floor (CF), dorso-sternal diameter (DSD); thoracic perimeter (TP); cannon bone circumference (CBC); occipital-ischial length (OIL); rump height (RH); rump length (RL); and interiliac width (IIW). Field measurements were taken with a Hauptner measuring cane, a veterinary outside caliper, a non-flexible measuring tape and a scale (Gallagher W210, Uruguay).

## Morphometric indices

Fifteen morphometric indices were calculated. Four were ethnological: cephalic index (CEFI = HW * 100 / HL); thoracic index (TORI = BCD * 100 / DSD); pelvic index (PELI = RH * 100 / IIW); and relative weight index (compactness) (RWI = LW * 100 / WH). Five were focused on production: dactyl costal index (DCI = CBC * 100 / BCD); relative thorax depth index (RTDI = DSD * 100 / AC); relative cannon bone thickness index

(RCBI = CBC * 100 / WH); cannon bone load index (CBLI = CBC * 100 / LW); and dactyl thorax index (DTI = CBC * 100 / TP). Six additional indices were calculated: anamorphosis index (ANAI = $TP^2$ / WH); Alderson morphological index of inclined height (ALD1 = WH-RH); Alderson morphological index of front leg length evenness (ALD2 = WH-DSD), Skorkowski W1 index (W1 = WH * 100 / FL); Skorkowski W5 index (W5 = WH * 100 / DSD); and Skorkowski W6 index (W6 = DSD * 100 / CF). All indices were calculated following Parés[25].

### Statistical analysis

Initially, a descriptive statistical analysis of the studied quantitative variables was run, as well as a univariate variance analysis of the morphometric variables residuals to compare traits between males and females, using sex as the only fixed effect. Estimates were calculated of the Pearson's correlation coefficients for the morphometric variables residuals and LW. A PCA was also done of the residuals to determine the number of independent variables responsible for most of the variance in the studied morphometric traits. A univariate variance analysis between the sexes was done of the linear functions of the first six principal components. Finally, a canonical discriminant analysis was applied to morphometric variables to identify possible relationships between four Creole cattle populations in Ecuador, and Mahalanobis distances were calculated to estimate the degree of differentiation between these populations using only data for females. All statistical analyzes were run with the Statistica ver. 10 software[26].

## Results

Descriptive statistics of the morphometric variables and the ANOVA results using sex as the only variation factor showed that most of the variables exhibited moderate population variability (Table I). This largely confirms existence of discrete morphometric uniformity in the studied population, except for DSD, HL, IIW and FL in males, HW in females, and CF in both sexes. Variability was generally greater among the males. Most of the morphometric variables differed between males and females ($P$<0.001). The variables HW and RH differed moderately ($P$<0.05), and no difference was present for HL, CF, DSD, RH and IIW ($P$>0.05).

**Table 1**: Descriptive and ANOVA results for comparison of morphometric variables between the sexes in Criollo Santa Elena Peninsula cattle

| Variables | Males | | | | Females | | | | F | *P* |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Min. | Max. | Mean | SD | Min. | Max. | | |
| HW | 18.32 | 2.03 | 15.00 | 22.00 | 20.63 | 4.29 | 16.00 | 30.00 | 5.38 | 0.0213 * |
| HL | 44.63 | 11.92 | 20.00 | 56.00 | 45.62 | 2.92 | 41.00 | 51.00 | 0.84 | 0.3604 ns |
| FL | 19.74 | 3.99 | 20.00 | 36.00 | 16.84 | 1.53 | 14.00 | 20.00 | 99.40 | 0.0001** |
| CL | 29.18 | 3.45 | 14.00 | 26.00 | 28.18 | 2.76 | 20.00 | 34.00 | 53.10 | 0.0001** |
| WH | 132.00 | 5.59 | 120.00 | 141.00 | 124.21 | 5.27 | 114.00 | 133.00 | 35.67 | 0.0001** |
| BCD | 42.28 | 2.24 | 39.00 | 47.00 | 69.72 | 10.09 | 40.00 | 82.00 | 31.78 | 0.0001** |
| CF | 49.53 | 13.53 | 28.00 | 70.00 | 46.01 | 9.95 | 28.00 | 62.00 | 2.03 | 0.1558 ns |
| DSD | 62.58 | 19.42 | 40.00 | 95.00 | 61.95 | 8.78 | 45.00 | 73.00 | 0.07 | 0.7972 ns |
| TP | 173.05 | 8.85 | 156.00 | 185.00 | 156.21 | 10.92 | 90.00 | 180.00 | 42.08 | 0.0001** |
| CBC | 19.29 | 3.70 | 14.00 | 26.00 | 15.58 | 0.62 | 14.00 | 17.00 | 44.18 | 0.0001** |
| OIL | 183.61 | 7.28 | 172.00 | 195.00 | 162.55 | 12.83 | 136.00 | 181.00 | 46.99 | 0.0001** |
| RH | 137.37 | 7.46 | 127.00 | 150.00 | 130.51 | 5.23 | 121.00 | 139.00 | 27.39 | 0.0127* |
| RL | 43.05 | 6.03 | 36.00 | 55.00 | 43.26 | 3.31 | 38.00 | 50.00 | 0.06 | 0.8092 ns |
| IIW | 39.11 | 8.55 | 20.00 | 54.00 | 42.02 | 5.73 | 32.00 | 51.00 | 3.86 | 0.0509 ns |
| LW | 569.58 | 10.34 | 550.00 | 585.00 | 395.72 | 55.39 | 280.00 | 540.00 | 85.68 | 0.0001** |

HW= head width; HL= head length; FL= face length; CL= cranium length; WH= withers height; BCD= bicostal diameter; CF= chest floor; DSD= dorso-sternal diameter; TP= thorax perimeter; CBC= cannon bone circumference; OIL= occipital-ischial length; RH= rump height; RL= rump length; and IIW= interiliac width. All variables expressed in cm; LW= live weight (kg); N= number of data; CPV= coefficient of percentage variation; SD= standard deviation; Min= minimum value; Max= maximum value; **:$P<0.01$; ***: $P<0.001$; ns= not significant.

The descriptive statistics and ANOVA between the sexes for the CSEP morphometric indices showed all to have a generally moderate to high degree of variability in males, especially for the RTDI, ALD2, W5 and TORI (Table 2). The ALD1 and W6 indices were variable in both sexes, resulting in lower variability for the remaining indices for females. When compared between sexes almost all the indices differed ($P<0.001$), although the significance was lower in the RDIT ($P<0.05$), and no differences were apparent for PELI, ALD1 and W6 ($P>0.05$).

**Table 2.** Descriptive and ANOVA results for comparison of morphometric indices between the sexes in Criollo Santa Elena Peninsula cattle

| Variables | Males | | | | Females | | | | F | *P* |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Min. | Max. | Mean | SD | Min. | Max. | | |
| IIW | 36.50 | 3.61 | 27.78 | 40.82 | 43.13 | 6.98 | 32.00 | 61.36 | 13.17 | 0.0004*** |
| TORI | 74.31 | 18.22 | 48.42 | 107.50 | 116.15 | 12.85 | 98.63 | 150.98 | 54.48 | 0.0001*** |
| PELI | 48.18 | 8.28 | 34.00 | 60.61 | 49.54 | 7.83 | 34.00 | 64.10 | 0.46 | 0.4966 ns |
| RWI | 433.06 | 19.79 | 402.17 | 466.67 | 310.35 | 35.81 | 240.60 | 387.10 | 93.78 | 0.0001*** |
| DCI | 44.60 | 7.79 | 34.15 | 60.47 | 21.77 | 2.28 | 18.29 | 30.77 | 88.57 | 0.0001*** |
| RTDI | 47.74 | 14.98 | 29.63 | 70.77 | 51.52 | 5.21 | 40.16 | 60.68 | 5.26 | 0.0229* |
| RCBI | 14.91 | 2.55 | 11.36 | 18.98 | 12.53 | 0.71 | 11.28 | 13.93 | 83.31 | 0.0001*** |
| CBLI | 3.39 | 0.62 | 2.50 | 4.51 | 4.05 | 0.51 | 2.96 | 5.19 | 24.93 | 0.0001*** |
| DTI | 11.20 | 1.98 | 8.64 | 14.61 | 9.88 | 0.48 | 8.89 | 10.95 | 44.23 | 0.0001*** |
| ANAI | 229.78 | 15.99 | 198.82 | 248.07 | 200.94 | 11.91 | 178.32 | 223.21 | 79.81 | 0.0001*** |
| ALD1 | -5.29 | 3.98 | -13.00 | 2.00 | -5.98 | 4.14 | -14.00 | 3.00 | 0.43 | 0.5107 ns |
| ALD2 | 69.06 | 20.36 | 38.00 | 95.00 | 59.75 | 5.81 | 50.00 | 72.00 | 20.80 | 0.0001*** |
| W1 | 64.61 | 11.40 | 45.71 | 100.00 | 114.21 | 17.37 | 89.47 | 157.89 | 31.50 | 0.0001*** |
| W5 | 228.92 | 67.33 | 141.30 | 337.50 | 192.20 | 17.99 | 164.79 | 247.92 | 30.32 | 0.0001*** |
| W6 | 126.02 | 34.23 | 72.58 | 166.67 | 138.90 | 32.67 | 76.27 | 203.13 | 2.54 | 0.1124 ns |

CEFI= cephalic index; TORI= thoracic index; PELI= pelvic index; RWI= relative weight index (compactness); DCI= dactyl-costal index; RTDI= relative thorax depth index; RCBI= relative cannon bone thickness index; CBLI= cannon bone load index ; DTI= dactyl-thoracic index; ANAI= anamorphosis index; ALD1= Alderson 1 index; ALD2= Alderson 1 index; W1= Skorkowski W1 index; W5= Skorkowski W5 index; W6= Skorkowski W6 index; N= number of data; CPV= coefficient of percentage variation; SD= standard deviation; Min= minimum value; Max= maximum value; **: $P<0.01$; ***: $P<0.001$; ns= not significant.

The Pearson correlation coefficients for the residuals of the analyzed variables (Table 3), showed a moderate degree of harmony in this population, 55.24% of the coefficients being significant ($P<0.05$). The correlations were high for the CL and TP variables, but less so for WH, RH, OIL, RL and IIW. The highest phenotypic correlation coefficient values were between BCD and CL, and RL and IIW (r = 0.86), and to a lesser extent between CBC and FL (0.75), WH and RH (0.71) and CL and FL (0.70).

**Table 3.** Pearson correlation coefficients matrix for the residuals of the morphometric variables

| | HL | FL | CL | WH | BCD | CF | DSD | TP | CBC | OIL | RH | RL | IIW | LW |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **HW** | 0.05 | -0.02 | 0.05 | 0.09 | 0.06 | -0.08 | -0.09 | 0.01 | 0.01 | -0.10 | 0.01 | -0.05 | -0.06 | -0.04 |
| **HL** | | 0.24* | 0.16 | 0.34* | 0.10 | -0.16 | -0.21* | 0.22* | 0.03 | 0.25* | 0.25* | 0.51* | 0.41* | -0.01 |
| **FL** | | | -0.70* | 0.50* | -0.67* | 0.10 | -0.03 | 0.67* | 0.75* | 0.54* | 0.44* | 0.20* | 0.14 | 0.62* |
| **CL** | | | | -0.10 | 0.86* | 0.08 | 0.13 | -0.33* | -0.43* | -0.11 | -0.06 | 0.30* | 0.28* | -0.60* |
| **WH** | | | | | -0.07 | 0.23* | -0.09 | 0.64* | 0.28* | 0.53* | 0.71* | 0.52* | 0.40* | 0.18* |
| **BCD** | | | | | | 0.29* | 0.17 | -0.18* | -0.50* | 0.01 | 0.05 | 0.37* | 0.42* | -0.63* |
| **CF** | | | | | | | 0.15 | 0.39* | 0.09 | 0.32* | 0.14 | 0.48* | 0.53* | -0.04 |
| **DSD** | | | | | | | | 0.02 | 0.08 | 0.36* | 0.03 | 0.04 | 0.11 | -0.04 |
| **TP** | | | | | | | | | 0.49* | 0.62* | 0.59* | 0.48* | 0.42* | 0.37* |
| **CBC** | | | | | | | | | | 0.35* | 0.35* | 0.01 | -0.07 | 0.48* |
| **OIL** | | | | | | | | | | | 0.61* | 0.55* | 0.60* | 0.22* |
| **RH** | | | | | | | | | | | | 0.48* | 0.39* | 0.12 |
| **RL** | | | | | | | | | | | | | 0.86* | -0.12 |
| **IIW** | | | | | | | | | | | | | | -0.11 |

* = $P<0.05$.

The first six principal components explained 85 % of total variation (Table 4). Of all fourteen principal components (14), eight (57.0 %) had a value of less than 0.7. Four principal components (PC), accounted for 73.42 % of total variance (Table 5). Factor PC1 was identified with CL, which was characterized by negative correlations versus TP (-0.89), OIL (-0.82), WH (-0.75), RH (-0.75), RL (-0.74) and IWI (-0.70); that is, the animal's body condition decreased as CL increased. This first factor explained 33.46 % of the variation in the original variables. Factor PC2 was associated with BCD, where an increase in this variable corresponded to increased rump size (RL, IIW) and lower CBC. This factor explained 21.82 % of the total variation. The next two factors are PC3, which was associated with CF and explained 10.92 % of variation, and PC4, which was linked to HW and explained 7.22 % of variation. The analysis of variance of the linear functions of the first six PC confirmed the greater weight of PC1 and PC2 by identifying significant differences between sexes only for PC1 and PC2, with the remaining components exhibiting statistical homogeneity.

**Table 4**: Principal components analysis (PCA) of Criollo Santa Elena Peninsula cattle based on morphometric variables residuals

| Principal component | Eigenvalue | Variance explained | Cumulative Eigenvalue | Cumulative variance explained |
|---|---|---|---|---|
| 1 | 4.68 | 33.46 | 4.68 | 33.46 |
| 2 | 3.06 | 21.83 | 7.74 | 55.28 |
| 3 | 1.53 | 10.92 | 9.27 | 66.21 |
| 4 | 1.01 | 7.22 | 10.28 | 73.43 |
| 5 | 0.94 | 6.74 | 11.22 | 80.16 |
| 6 | 0.81 | 5.76 | 12.03 | 85.93 |
| 7 | 0.59 | 4.22 | 12.62 | 90.15 |
| 8 | 0.40 | 2.85 | 13.02 | 93.00 |
| 9 | 0.28 | 1.98 | 13.30 | 94.98 |
| 10 | 0.24 | 1.72 | 13.54 | 96.69 |
| 11 | 0.19 | 1.37 | 13.73 | 98.07 |
| 12 | 0.12 | 0.85 | 13.85 | 98.92 |
| 13 | 0.09 | 0.61 | 13.93 | 99.53 |
| 14 | 0.07 | 0.47 | 14.00 | 100.00 |

**Table 5.** Contribution of variable residuals to principal components analysis (PCA)

| Variables | Factor 1 | Factor 2 | Factor 3 | Factor 4 |
|---|---|---|---|---|
| HW | 0.05 | -0.02 | -0.24 | 0.86 |
| HL | -0.36 | 0.15 | -0.76 | -0.10 |
| FL | -0.69 | -0.66 | -0.05 | -0.07 |
| CL | 0.22 | 0.81 | -0.19 | 0.08 |
| WH | -0.75 | -0.02 | -0.24 | 0.11 |
| BCD | -0.01 | 0.91 | 0.11 | 0.15 |
| CF | -0.47 | 0.33 | 0.46 | -0.19 |
| DSD | -0.15 | 0.16 | 0.70 | 0.28 |
| TP | -0.85 | -0.17 | 0.08 | 0.02 |
| CBC | -0.46 | -0.62 | 0.09 | 0.09 |
| OIL | -0.83 | 0.06 | 0.22 | 0.11 |
| RH | -0.75 | 0.03 | -0.07 | 0.21 |
| AG | -0.74 | 0.50 | -0.17 | -0.13 |
| IIW | -0.70 | 0.55 | -0.00 | -0.14 |

Significance of the first two canonical discriminant functions produced was tested with Wilk's Lambda (λ) (values of 0.03 and 0.22, respectively) and chi-square tests ($\chi^2$) (2,457.67 and 1,008.03, respectively; $P \leq 0.001$) (Table 6). Function 1 explained 72.33% of total variation and Function 2 explained 25.68 %; Function 3 explained less than 2% of the variance. These results validate the discriminant analysis, highlighting that

Function 1 has the best linear combination of features that allow discrimination between the four studied populations.

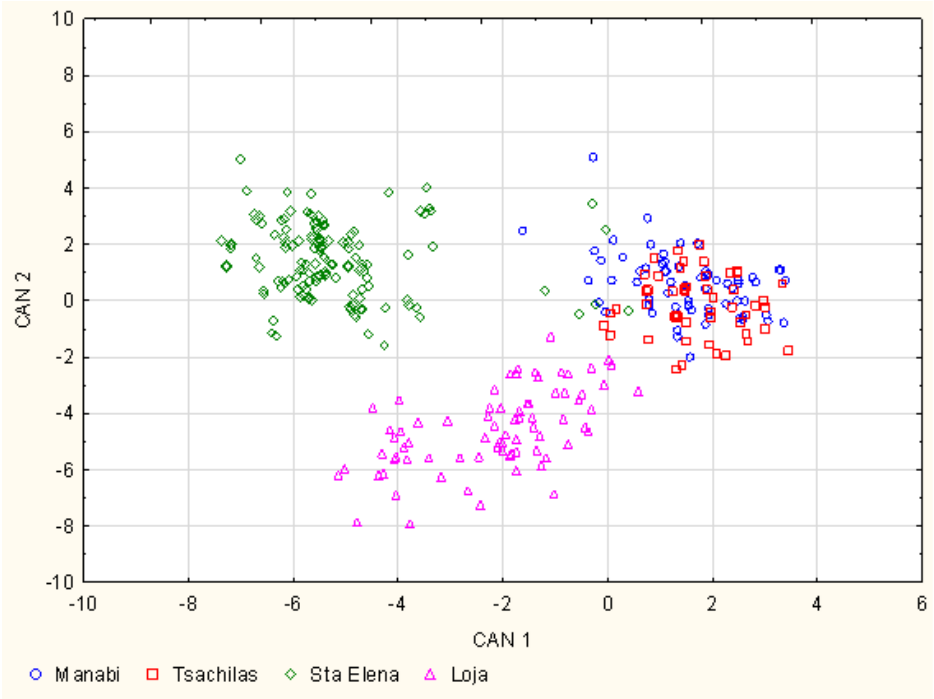
**Table 6.** Summary of canonical discriminant functions from samples from females

| Funtion | Eigenvalue | Variance explained (%) | Canonical correlation | λ | $\chi^2$ | Significance level |
|---|---|---|---|---|---|---|
| 1 | 7.58 | 72.33 | 0.94 | 0.03 | 2457.67 | *P*<0.001 |
| 2 | 2.69 | 25.69 | 0.85 | 0.22 | 1008.03 | *p*<0.001 |
| 3 | 0.21 | 1.98 | 0.41 | 0.83 | 127.16 | *p*<0.001 |

λ = Wilks'-Lambda; $X^2$= Chi-squared.

A bidimensional graph of variables CAN 1 and CAN 2 shows the relationships between the four populations, with significant overlap between CM and CSTD. The CL and CSEP variables are clearly separate from the other variables, creating distinct groups with no overlap.

**Figure 1:** Graph of canonical discriminant analysis based on morphometric variables of females from four populations of Ecuadorian Creole cattle




The Mahanalobis distances (upper diagonal) and Euclidean distances (lower diagonal) between the four populations clearly show the proximity between CM and CSDT (2.09)

and the greater distance between CSEP and CSDT (47.56), considering that all values are significant ($P<0.05$) (Table 7). The individual Euclidean distances confirm the proximity between CM and CSDT and between CSEP and CL, while highlighting the distance between these two groups. Correct classification of individuals was 86.61 % for CM, 43.40 % for CSDT, 93.42 % for CSEP and 83.50 % for CL.

**Table 7.** Mahalanobis and Euclidian distances between females from four populations of Ecuadorian Creole cattle

| Population | CM | CSDT | CSEP | CL |
|---|---|---|---|---|
| CM | | 2.09*** | 45.86*** | 39.71*** |
| CSDT | 31.8 | | 47.56*** | 34.92*** |
| CSEP | 66.2 | 56.2 | | 41.29*** |
| CL | 48.2 | 41.7 | 31.2 | |

CM= Criollo Manabis; CSDT= Criollo San Diego Tsachilas; CL= Criollo Lojano; *** = $P<0.001$.

# Discussion

Phenotypic variability among the morphometric variables for CSEP was higher than that reported in other Ecuadorian Creole cattle populations: Criollo Lojano[27]; Criollo Macabeo[28]; Criollo Manabita[8]; and Criollo of Santo Domingo de los Tsachilas[29]. This was also the case when compared to other Latin American Creole breeds: Patagonian Creole in Argentina[10]; Criollo Saavedra in Bolivia[30]; Criollo Pantaneiro in Brazil[31]; Criollo Casanare in Colombia[32]; Barroso or Salmeco Creole in Guatemala[33]; Chinampo[34] and Mixteco Creoles in Mexico[35]; Pampas Chaco Creole in Paraguay[36]; Criollo Limonero from Venezuela[37]; and Uruguayan Creole[38], among others. It was also higher than in native breeds from Spain such as the red and black Berrenda breeds[39]; the Serrana from Teruel[40]; the black Andalusian[41]; the Pallaresa[42]; and the Morucha[43].

The studied CSEP population was found to have an intermediate body format compared to other Ecuadorian Creole cattle breeds. It is larger than the Uruguayan Creole[38], Mixtec Creole[35] and Creole from Panama[5], among others, but somewhat smaller than the Patagonian Creole[10], Barroso or Salmeco Creole from Guatemala[33], and the Criollo Manabita[8], among other populations. It was also smaller than the native Spanish breeds red and black Berrenda[39]; Serrana de Teruel[40]; Pallaresa[42]; black Andalusian[41]; and Morucha[43]. The intermediate format and size of CSEP are similar to those of Portuguese native cattle breeds[44]. This population can therefore be characterized as having a

typically normal body format, probably in response to the influence of Iberian breeds[45] and as an adaptive advantage in tropical environmental conditions[8].

Among the morphometric indices, the studied population's average CEFI value identifies it as a dolichocephalic type with HL predominating over HW. This coincides with index values for other Latin American Creole breeds such as the Criollo Saavedra in Bolivia[30]; the Barroso or Salmeco Creole in Guatemala[33]; Criollo Limonero from Venezuela[37]; and Criollo Manabita in Ecuador[8]. It is also the case for native Spanish breeds such as the Asturian Valley, the Bruna of the Pyrenees, Parda de Montaña and Pirenaica[46], and the Serrana de Teruel[40]. Of note is that dolichocephaly is much more pronounced in males than in females.

Average RTDI and DCI values are indicative of skeleton fineness and its association with milk production suitability, especially in females. These values were used to characterize predisposition to milking fitness within the studied CSEP populations. The OIL / WH value indicated that this population has a sublongilineal body proportion, another trait compatible with milking fitness and particularly notable in females. Like most native Spanish and Latin American Creole environmental breeds, the CSEP has a dorsolumbar line with an ascending caudal inclination, which favors movement in rough terrain.

Presence of moderate to high sexual dimorphism in the studied CSEP population based on the ANOVA for morphometric variables coincided with the profile of environmental type breeds with minimal selection[47]. However, this dimorphism is not as pronounced as in the Uruguayan Creole[38], Criollo Macabeo[28] and Criollo Manabita breeds[8]. Diphorphism in the CSEP is also supported by the CEFI, TORI and RWI indices since they differ between the sexes ($P<0.001$). When considered in conjunction with the differences present between the remaining productive indices, this confirms the occurrence of low morphostructural uniformity between males and females in this population. This situation suggests that the CSEP may be undergoing a crossbreeding process through use of sires influenced by exotic breeds. Or, in what is essentially the same process, males and females in the CSEP are treated as two distinct subpopulations, receiving different genetic management. If this is the case it would explain the differences identified between the sexes for both the ethnological and productive type morphometric indices, as well as the greater intrinsic variability among males. In contrast, the PELI and ALD1 values were statistically homogeneous in both sexes. This coincides with the adaptive nature of the traits they represent since ascending caudal inclination of the dorsolumbar line is important to movement in difficult terrain (PELI), and pelvis width is linked to ease of parturition (ALD1).

The low level of correlation between the analyzed variables is indicative of the high underlying variability in this population. This is to be expected in this type of population, which historically has been heavily genetically manipulated by producers using mismatched criteria, without properly structured breeding programs, and in the complete absence of uniform breed trait selection criteria[47]. Similar results have been reported for Criollo Manabí cattle in Ecuador[8], as well as for the Spanish native Serrana de Teruel

breed[40]. This is another possible consequence of the use of sires influenced by improved exotic breeds.

The first principal component (PC1) explained more than one third of the observed variance. This component defined cephalic structure versus general animal morphostructure, such that the larger the CL the greater the reduction in their body format in terms of heights, lengths and diameters. The second principal component (PC2) was associated with body capacity, meaning that an increase in BCD improved rump morphostructure, which is linked to adequate pelvic canal width in females based on IIW and RL. Cranium length (CL) is therefore a defining variable in intuitive selection of animal morphostructure. In addition, BCD is clearly linked to body capacity and to rump size as an adaptive advantage for ease of parturition in females. Both variables must then be considered when establishing selection criteria in Ecuadorian Creole cattle.

The canonical discriminant analysis among females showed that each breed has a distinct morphometric pattern, implying clear morphometric differentiation between the four studied populations. This differentiation may be due to the reproductive isolation between them, as well as variation in body mass selection criteria, both of which are related to the geographical distance between these populations. These results are corroborated by the different Mahalanobis distances between the four populations, with CM and CSDT being nearest each other, CL in an intermediate position and CSEP the furthest from the rest.

## Conclusions and implications

The CSEP has a medium body format with a normal tendency, sublongilinear body proportions and a dolichocephalic-type cranium. Skeletal structure in females is fine, indicating their suitability for milk production. Clear differences between the sexes in both the morphometric variables and indices confirm the presence of moderate to high sexual dimorphism in the studied population. Indeed, this suggests the coexistence of males and females as two subpopulations subject to different genetic management. The discriminant analysis effectively differentiated between the four analyzed Ecuadorian Creole cattle populations, confirming that Criollo Santa Elena Peninsula cattle are a distinct population with a specific morphometric pattern. The present study suggests that the Criollo Santa Elena Peninsula is a separate breed within the double-purpose tropical creole cattle breeds.

## Literature cited:


1. MAE. Ministerio del Ambiente. Agrobiodiversidad, su integración en la gestión de las políticas públicas y su abordaje en la estrategia nacional de biodiversidad 2030. Agroambiente 2035. Aportes al debate de la política ambiental. 2017

2. MAE. Ministerio del Ambiente. Quinto Informe Nacional sobre Biodiversidad para el Convenio sobre la Diversidad Biológica. Quito. Ecuador. 2015.

3. INIAP. Instituto Nacional de Investigaciones Agropecuarias. Informe Técnico sobre Estado de la Biodiversidad para la Alimentación y la Agricultura en el Ecuador. Quito. 2015.

4. FAO. Food and Agriculture Organization of the United Nations (FAO). Domestical Animal Diversity Information System (DAD-IS). http://www.fao.org/dad-is/. 28/04/2016. Consultado 10 Mar, 2018.

5. Villalobos-Cortés A, Martínez MA, Vega-Pla JL, Landi V, Quiroz VJ, Martínez R, *et al*. Relationships between Panamanians and some creole cattle landraces in Latin America. Pesq Agrop Bras 2012**;**47(11):1637-1646.

6. FAO. Food and Agriculture Organization of the United Nations. Realización de encuestas y seguimiento de los recursos zoogenéticos. Directrices FAO: Producción y sanidad animal. Roma, Italia. 2012.

7. FAO. Food and Agriculture Organization of the United Nations. Plan de acción mundial sobre los recursos zoogenéticos y la Declaración de Interlaken. Roma, Italia. 2007.

8. Cevallos FOF, Barba CCJ, Delgado BJV, González MAM, Perea MJM, Angón SE, García MAR. Caracterización zoométrica y morfológica del ganado criollo de Manabí (Ecuador). Rev Científ FCV-LUZ 2016;18(5):313-323.

9. Goyache F, Gutierrez JP, Alvarez I. Analisis de componentes principales sobre los caracteres de tipo en reproductoras de raza Asturiana de los Valles. ITEA. 2001:127-129. http://www.aida-itea.org/aida-itea/files/jornadas/2001/comunicaciones/2001_Gen_42.pdf. Consultado 26 Feb, 2018.

10. Martínez R, Fernández E, Abbiati N, Broccoli A. Caracterización zoométrica de bovinos criollos: patagónicos vs. noroeste argentino. Rev MVZ Cordoba 2007;12 (2):1042-1049.

11. N'goran KE, Kouassi NC, Loukou NE, Dayo GSM, Yapi-Gnaore CV. Multivariate analysis for morphological caracteristics of N'Dama cattle breed in two agro-ecological zones of Côte d'Ivoire. European Sci J 2018;14(3):602-621.

12. Sobczuk D, Komosa M. Morphological differentiation of polish Arabian horses - multivariate analysis. Bull Vet Inst Pulawy 2012;56(4):623-629.

13. Asamoah-Boaheng M; Emmanuel Kofi SE. Morphological characterization of breeds of sheep: a discriminant analysis approach. Asamoah-Boaheng and Sam. Springer Plus 2016;5(69):1-12.

14. Vera TA, Ricarte AR, Díaz R, Arriba PN, Vélez, JA. Caracterización fenotípica de diferentes biotipos de razas presentes en la población caprina de La Rioja, Argentina [resumen]. Reunión de ALPA y IV Congreso Internacional de Producción Animal Tropical. La Habana. Cuba. 2013:13.

15. Cabello RA, León JM, Barba CJ. Contribución a la diferenciación morfológica de las variedades del cerdo Ibérico como base para su conservación. En: Dip. Córdoba editor. El cerdo Ibérico. Caracterización de sus variedades. 1ª ed. Diputación de Córdoba. Córdoba, España. 2007:31-87.

16. González MA, Luque MM, Herrera GM, Gonzalez GC, Angón SE, Rodero SE. Usefulness of discriminant analysis in the morphofunctional classification of Spanish dog breeds. Archiv Tierzucht 2014;57(2):1-16.

17. Oguntunji AO, Ayorinde KL. Multivariate analysis of morphological traits of the Nigerian Muscovy ducks (*Cairina moschata*). Arch Zootec 2014;63(243):483-493.

18. Adeyemi MA, Oseni, SO. Canonical discriminant analysis applied to biometric data of nigerian indigenous turkeys. Arch Zootec 2018;67(257):7-12.

19. Piedrafita J, Quintanilla R, Sañudo C, Olleta JL, Campo MM, Panea B, *et al*. Carcass quality of 10 beef cattle breeds of the Southwest of Europe in their typical production systems. Livest Prod Sci 2013;82(1):1–13.

20. Albertí P, Sañudo C, Mendizabal JA, Ripoll G, Olleta JL, Panea B, Alzón M, Indurain G. Caracterización de siete razas bovinas españolas por análisis multivariante a partir de medidas de análisis químico, instrumental, sensorial y desarrollo del tejido graso. Itea 2003;24(L):70-72.

21. Leota R. Use of linear discriminant analysis to characterise three dairy cattle breeds on the basis of several milk characteristics. Ital J Anim Sci 2004;3(4):377-383.

22. INEC. Instituto Nacional de Estadística y Censos. Encuesta de Superficie y Produccción Agropecuaria 2014. Ecuador. http://www.ecuadorencifras.gob. ec/estadisticas-agropecuarias-2/. Consultado 3 Mar, 2018.

23. FAO. Food and Agriculture Organization of the United Nations. Realización de encuestas y seguimiento de los recursos zoogenéticos. Directrices FAO: Producción y sanidad animal. Roma, Italia. 2012;(7):3-7.

24. Pilling D. Threats to animal genetic resources for food and agriculture – approaches to recording, description, classification and analysis. Anim Genet Res 2010;47:11–22.

25. Parés PM. Zoometría. En: Sañudo C. editor. Valoración morfológica de los animales domésticos. Ministerio de Medio Ambiente, Medio Rural y Marino. Madrid. 2009:167-198.

26. Statistica for windows. Stat Soft. Inc. Tulsa. USA. 2010.

27. Apolo GM, Chalco LE. Caracterización fenotípica y genotípica de las poblaciones de bovinos criollos en el cantón Gonzanamá de la provincia de Loja [tesis de grado]. Loja, Ecuador. Universidad Nacional de Loja; 2012.

28. Vargas JC, Delgado BJV, Gómez MM, Viamonte M, Ramírez A, Benítez J. Raza bovina autóctona Macabea, recurso genético para el mejoramiento y adaptación a los ecosistemas amazónicos ecuatorianos. AICA 2015;(6):184-191.

29. Cevallos FOF, Estupiñán k, Rizzo L, Merizalde D, González MAM, Delgado BJV, Barba CJC. Caracterización morfoestructural y faneróptica del bovino doble propósito de la provincia de Santo Domingo de los Tsáchilas. En: García MAR, Pomagualli D, editores. Proc Cong Int Cienc Tecnol Innov Emprend. Bolívar, Ecuador. 2015:111-116.

30. Centellas PD, Vaca RJL, Joaquín AJN, Peña CR, Pereira RJA. Caracterización morfométrica del bovino de Saavedra. En: Delgado BJV, Martínez DR, editores. Proc Simp Iberoam Conserv Utiliz Rec Zoogen. Buenos Aires, Argentina. 2008:145-152.

31. Abreu UGP, Santos AS, Sereno JRB, Comastri-Filho JA, Ravanelli MS. Caracterización morfométrica de los bovinos pantaneiros del núcleo de conservación in situ de Nhumirim. Arch Zoot 2005;54(206-207): 211-216.

32. Salamanca A, Crosby R. Phenotypic study of bovine creole biotype Casanare Araucano. Zoometric analysis. Zoot Trop 2013;31(3):201-208.

33. Jauregui-Jiménez R, Melgal-Davila R. El bovino criollo Barroso o Salmeco, compilación de la primera caracterización fenotípica y zoométrica en Guatemala. En: Alvarez RLA, Muñoz FJE editores. X Simp Iberoamer Conserv Utilizac Rec Zoogen. Palmira Valle, Colombia. 2009:221-225.

34. Espinoza JL, Guevara JA, Palacios A. Caracterización morfométrica y faneróptica del bovino criollo Chinampo de México. Arch Zoot 2009;58(222):277-279.

35. Méndez M, Serrano J; Ávila R, Rosas M, Mendez N. Morfometric characterisation of Mixteco creole cattle. Arch Zoot 2002;51:217-221.

36. Martínez-López OR, Lamas-Sosa V; Pereira WE, Macchi-Silveira AR, Zayas A, Niedhammer O, Serrati G. Estudio descriptivo de variables morfométricas de bovinos Pampa Chaqueño de Paraguay. En: Alvarez RLA, Muñoz FJE editores. X Simp Iberoamere Conserv Utiliz Rec Zoogen. Palmira Valle, Colombia. 2009:226-230.

37. Contreras G, Chirinos Z, Zambrano S, Molero E, Paéz A. Morphological characterization and zoometric indexes of criollo Limonero cows of Venezuela. Rev Fac Agron LUZ 2011;(28):91-103.

38. Rodriguez M, Fernandez G, Silveira CC, Delgado BJV. Estudio étnico de los bovinos criollos del Uruguay: I. Análisis biométrico. Arch Zoot 2001;50(189-190):113-118.

39. González A. Caracterización de las razas bovinas Berrendas en el área de Despeñaperros como base para su conservación [tesis doctoral]. Córdoba, España. Universidad de Córdoba; 2007.

40. Vijil E, Picot A, Hernández M, Pastor F, Quintín F, Sevilla E, Abril F, Sanz A. The Serrana de Teruel cattle breed: phaneroptical, morphological and morphostructural characterization. Arch Zoot 2009;58(Supl1):517-520.

41. Nogales S, Albardonedo D, Recio JM, Delgado BJV, Camacho VME. Primeros resultados en el estudio del estado actual de la morfología en la raza bovina negra andaluza. Arch Zootec 2011;60(231):397-399.

42. Jordana J, Ferrando A, Marmi J, Avellanet R, Aranguren R, Méndez JA, Goyache F. Molecular, genealogical and morphometric characterisation of the Pallaresa, a Pyrenean relic cattle breed: Insights for conservation. Livest Sci 2010(132):65-72.

43. De la Fuente LF, Sánchez RJM, Rodríguez LE. Características morfológicas de la raza Morucha actual. http:/www.morucha.com. Consultado Mar 7, 2018.

44. Carolino N. Caracterizaçao fenotípica de raças bovinas autóctones portuguesas. Em: Delgado BJV editor. Proc XI Simp Iberoamer Conserv y Utiliz Rec Zoogen. Joao Pessoa-Paraíba, Brasil. 2010:298-302.

45. Rodero A, Delgado, BJV, Rodero E. El ganado andaluz primitivo y sus implicaciones en el descubrimiento de América. Arch Zoot 1992;41(154):383-400.

46. Parés PM, Jordana J. Zoometric measurements of cephalic conformation in adult bovine males and females (*Bos taurus*). Vet ir Zootec T 2008;(43):65-73.

47. Herrera GM. Metodología de caracterización zooetnológica. En: Rodero E, Valera M, editores. La ganadería andaluza en el siglo XXI. Patrimonio Ganadero Andaluza. 2007:435-448.