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Original

Morphological, phaneroptic, and dominant gene characterization of the naked neck creole hen *nudicollis* in Sucre, Colombia

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ABSTRACT

Objective. Estimate the morphometric, phaneroptic, and four dominant gene diversity in backyard native birds with naked neck (*Gallus domesticus L. Subspecie nudicollis*) in the Sabanas subregion, department of Sucre - Colombia. **Materials and methods.** Overall, 650 adult birds (480 hens and 170 roosters) from 10 different locations, 14 morphometric variables, eight phaneroptics, and four dominant genes were measured. The data were subjected to descriptive analysis. Animals were compared between localities by means of the analysis of variance and Duncan test. Sexual dimorphism was evaluated from body weight and tarsal size, morphostructural harmony was evaluated from the correlations between the measurements, and the frequencies of the *Frizzled feather, silky feather, pilopody,* and *polydactyly* genes and their influence were estimated on four morphometric variables. Phaneroptic variables were evaluated using frequencies. **Results.** The analyzed descriptors showed a superiority in roosters than over hens as well as between localities ($p<0.001$). Bodyweight and tarsal length were sexual differentiators ($p<0.001$). Low bodily harmony was evidenced. The estimated allele frequencies were low except for the *Polydactyly* gene, because the birds with this gene were significantly larger ($p<0.001$). The phaneroptic characteristics describe a bird with normal brown plumage, white tarsi, a red lobe color, and a red-orange eye, with a simple crest and small-medium size in hens and medium-large in roosters. **Conclusions.** A heterogeneous population with great phaneroptic variability was found. There are indications of introgression of specialized breeds. The frequencies of the dominant genes were low, with higher performance for the characteristics BW, BL, TP, LL and WL in birds with polydactyly genotype.

Keywords: Genetic diversity; morphometry; naked neck; turken-naked neck (*Source: CAB*).

RESUMEN

Objetivo. Estimar la diversidad morfométrica, faneróptica y de cuatro genes dominantes en aves criollas de pescuezo desnudo (*Gallus domesticus L*. Subespecie *nudicollis*) de traspatio en la subregión Sabana, departamento de Sucre (Colombia). **Materiales y métodos.** En 650 aves adultas (480

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gallinas y 170 gallos) de 10 localidades, se midieron 14 variables morfométricas, ocho fanerópticas y cuatro genes dominantes. Los datos fueron sometidos a análisis descriptivos. Mediante análisis de varianza y test de Ducan se compararon las aves entre localidades, se evaluó el dimorfísmo sexual a partir del peso corporal y tamaño del tarso. Se evaluó la armonia morfoestructural a partir de las correlaciones entre las mediciones. Se estimaron las frecuencias de los genes *Frizzled feather*, *silky feather*, *ptilopody*, y *polydactyly* y su influencia, sobre cuatro variables mofométricas. Las variables fanerópticas se evaluaron mediante frecuencias. **Resultados.** Los descriptores analizados mostraron superioridad de los gallos sobre las gallinas al igual que entre localidades ($p<0.01$). El peso corporal y longitud del tarso, fueron diferenciadores sexuales ($p<0.01$). Se evidenció baja armonia corporal. Las frecuencias alélicas estimadas fueron bajas excepto para el gen *Polydactyly*. Las aves con este gen fueron significativamente más grandes ($p<0.01$). Las características fanerópticas, describen un ave de plumaje normal de color marrón, de tarsos blancos, con color de lobulo rojo y ojo rojo-naranja, de cresta simple y tamaño pequeño-mediano en gallinas y mediano-grande en gallos. **Conclusiones.** Se encontró una población heterogénea con gran variabilidad fanerópticas, hay indicios de introgresión de razas especializadas. Las frecuencias de los genes dominantes fueron bajas, con mayor rendimiento para las características peso, largo corporal, perímetro torácico, largo de la pierna y largo del ala en las aves con genotipo *polydactyly*.

Palabras clave: Diversidad genética; morfometría; pescuezo desnudo; recursos zoogenéticos (*Fuente: CAB*).

INTRODUCTION

In Colombia, for the year 2020 (1), the avian population was distributed in 469140 farms, of which 463113 (98.7%) are backyard avian system (BAS) and the remaining 6027 (1.3%) correspond to technical farms. The total number of registered animals amounted to 201600918 birds, of which 95.4% correspond to technified production systems and 4.6% to birds developed in BAS. BAS is developed by the peasant family in their backyard or neighboring plots. Actually, this practice could conduce to generates security and food sovereignty. BAS productivity is limited by different factors, among which the following stand out: food, poor technical-administrative management, and little application of biosafety programs (2). In addition, the increase in intensive poultry farming over BAS poultry in the world, causes concern regarding the conservation of local animal genetic resources (3), threatening traditional breeds, decreasing genetic variability, promoting the rapid disappearance of local lines, and the possible adaptability to climate change, which would allow the future establishment of new commercial lines (4).

Among the set of domestic birds managed in the BASs in Colombia, there is the turken-naked neck creole hens (*Gallus domesticus L. Subspecies nudicollis*), whose origin is unknown and, according to the physiographic region where it is produced, it receives different names, in Spanish: *pescuezo pelado*, *pelonga*, *carioca, cuello desnudo, cuelli pelada*; in French, *cou-nu*; in German, *nackthälse* (5,6). They are animals adapted to diverse ecosystems, rustic, have good maternal ability, resistant to diseases, maintain their reproductive capacity (7,8), birds are classified as semi-heavy, and do not belong to any specific breed (9). The turken-naked neck characteristic is encoded by a gene that restricts the appearance of feathers (*Na*) with approximately 40% less feather coverage overall and on the lower part of the neck. In the homozygous state, the *Na* gene has a high embryonic mortality, decreases hatchability and limits the floatation and flight capacity of the bird. However, this significant decrease in plumage considerably reduces the need to supply protein for the production of feathers, therefore, this characteristic can be transferred to the production of meat and eggs. (7,10).

The comparative advantage of the *Na* gene should be studied not only from a temperature perspective but also from humidity, body weight, food intake (absolute and relative to body weight), age, agroecological knowledge, and conditions of cultivation. countryside. Due to the incomplete dominant inheritance pattern of the Na gene, studies should separately report their findings for homozygous and heterozygous naked-neck chickens (7). In addition, the conservation of naturalized breeds, both in the wild and in the protected environment, arises as an alternative to developing various studies, which must present as a baseline, the identification, and characterization of the exploited varieties, maximizing their genetic

variability. Thus, the characterization of the animals is the initial step for long-term genetic improvement, since it provides the basis for the formation of any other breed and provides information to design suitable breeding programs (11,12).

Therefore, the aim of this work was to characterize morphometrically and phaneroptically the turken-naked neck creole hen (*Gallus domesticus L. Subspecie nudicollis*) in the backyard production system from Sucre State (Colombia), as a strategy to facilitate rational development of these locally important productive resources, and establish the foundations for directing conservation strategies in order to ensure their survival in the competitive world of poultry production.

MATERIALS AND METHODS

Location. The work was carried out during 2018-2020 in 9 municipalities from the Sabanas subregion (*Sincé, El Roble, San Pedro, Sampués, Los Palmitos, Galeras, Buenavista, Corozal y San Juan de Betulia*), and Sincelejo city in the department of Sucre (Figure 1). The weather of the study area is characteristic of the tropical dry forest areas (td-f), the annual average temperature oscillates between 25.5°C and 28.7°C, the precipitation fluctuates between 990 and 1275 mm per year, defining a period dry (January, February, March, and July) and a rainy one (April, May, June, August, September, October, and November), relative humidity of 80% (12). This region is characterized by having commercial avian farms (2%) and a considerable number of BAS (98%).

Sample size and study population. Considering that Sincelejo city and the Sabanas subregion is conformed by 9 municipalities and presents a backyard avian census of 42624 birds, distributed in 794 farms (1), the sample size (n = number of farms) was determined, using a confidence level of 95 % (Z=1.96) and a maximum margin of error of 10% in 86 properties. 650 adult birds were characterized, using a stratified random sampling corresponding to 480 hens and 170 roosters from *Subspecies nudicollis*. The production units selected by the municipality usually carried out traditional management (backyard) for the rearing of Creole chickens (*Gallus gallus domesticus - Phasianidae*) within which were the *Subspecies nudicollis* (Figure 2).

Morphometric and phaneroptic characterization. The morphometric descriptors evaluated corresponded to 14 quantitative variables suggested by FAO (13), for the characterization of the poultry resource (12,14,15). Such as body weight (BW - kg), obtained through a portable electronic scale (with 10 kg of capacity and precision of 0.05 kg), body length (BL), thoracic perimeter (TP), thigh length (TL), leg length (LL), tarsal length (TaL), wing length (WL), wing width (WW), crest height (CH), appendage length (AL), appendage width (AW), length chin-length (LCL), chin width (CW) and tail length (TailL); body measurements were expressed in centimeters and were taken with a plastic tape measure and a scale with 0.03 mm precision.

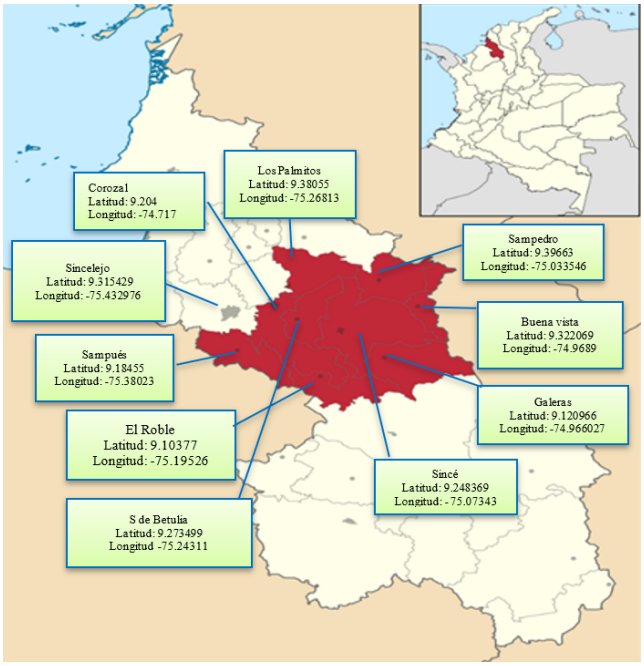

Figure 1. Study area. Sincelejo and Sabana Subregion, department of Sucre, Colombia. Source: wikimedia.org (2021).

Phaneroptic characteristics were obtained by direct observation. The qualitative variables recorded for each bird were: plumage type, pattern, and color; tarsal, ear, and eye color; ridge size and shape (8). Likewise, the presence of the following genes *Frizzled feather* (F/f+), *silky feather*, (H+/h), *ptilopody* (Pti/pti+), and *polydactyly* (Po/po+) were assessed. In the data collection, it was taken into account for the collection of measurements, management, and conservation, the ethical, technical, scientific, and administrative standards for research in animals contained in Law 84 of the National Congress of Colombia, 1989.

Figure 2. Turken-naked neck creole's biotypes of *Gallus domesticus L. Subspecies nudicollis*, department of Sucre - Colombia.

Statistical analysis. The normality of the morphometric features was verified by the Shapiro Wilk test ($p<0.05$) and the visual inspection of the histograms. Levene's test was used to confirm the homogeneity of the variances ($p>0.05$). Data were subjected to univariate descriptive analysis for independent samples, with which the arithmetic mean, standard deviation (SD), and coefficient of variation (CV) for the sexes were determined separately. An analysis of variance (ANOVA) was performed to compare the effect of sex and the locality, differentiating sexes, on the morphometric measures. The averages were compared by Duncan's test and differences were considered significant when $p<0.05$.

The descriptors such as body weight and tarsal length were tested as morphological differentiators of sex. In this sense, males and females were classified according to their weight two groups for males (heavy: greater than 3.0 kg and semi-heavy: less than 3.0 kg) and three groups for females (heavy: greater than 2.5 kg; semi-heavy: between 1.7 and 2.5 kg; and light: less than 1.7 kg) (12,15,16). Similarly, for the tarsal length variable, three groups were formed (large: greater than 9 cm; medium: between 9 and 7 cm; and small: less than 7 cm). The linear model used was

$$Y_{kj} = \mu + a_k + e_{kj},$$

where: Y_{kj} = expected response in the dependent variable (Weight - Tarsus Length), μ= effect of the population mean, a_k = effect of the group factor for the level k y e_{kj} = is the effect of experimental error. A Pearson correlation matrix was conducted for body measurements, in order to determine the degree of harmony or morphostructural proportionality.

Allele frequencies were calculated (*p* dominant alleles, *q* recessive alleles) for the genes *Frizzled feather*, *silky feather*, *ptilopody* and *polydactyly* (Po/po+) using the HardyWeinberg equilibrium. The observed allele frequencies were contrasted with their respective expected Mendelian allele frequencies using the X^2 test in the software GenAIEx version 6.5 (17)

The measurements body weight (BW) Body length (BL), thoracic perimeter (TP), leg length (LL) and wing length (WL), were subjected to

analysis of variance, to determine the effect of the genes *Frizzled feather*, *silky feather*, *ptilopody* and *polydactyly*, and sex. The statistical model used to analyze the fixed effect of sex and the gene effect was

$$Y_{ijk} = \mu + a_i + b_j + e_{ijk}$$

where: Y_{ijk} = phenotypically expressed trait taken in the *k-individual*, of the *j-th* sex, belonging to the *i-th* genotype; μ = is the effect of the mean, a_i = fixed effect of the *i-th* gene, b_j = fixed effect of the *j-th* sex (male, female), and e_{ijk} = is the effect of experimental error.

Phaneroptic variables were analyzed using absolute and relative frequency tables. A non-genetic relationship between farms was considered in all tests. All the analyzes of the zoometric and phaneroptic variables in females and males were carried out through the statistical package R ver. 4.0.5 (18).

RESULTS

The average results grouped by sex about the morphometric assessed recorded in creole's hens and roosters *Gallus domesticus L. Subspecies nudicollis* from Sincelejo and the Sabanas subregion in Sucre - Colombia are shown in table 1. Sex was a significant source of variation for all morphometric traits. Creole rooster showed a significantly higher body weight and body measurements in comparison with hens ($p<0.01$). Excluding body weight, the measurements with the greatest variation for hens was TailL, while for the roosters was WL.

All the quantitative traits studied in the hens varied significantly ($p<0.01$) among the 10 municipalities that make up the study subregion (Table 2). In general, hens from *San Pedro, Los Palmitos, and San Juan de Betulia*, are distinguished by presenting the highest morphometric measurements. Likewise, all the morphometric variables in the roosters varied significantly ($p<0.01$) between municipalities. In addition, the roosters from *Since, El Roble*, and *Los Palmitos* stand out as those that presented the highest measurements for most of the morphometric variables evaluated (Table 3).

The ANOVA for the variables weight and size of the tarsus was statistically significant ($p<0.01$). The above allowed to constitute two groups of hens and roosters, according to weight and were classified as heavy and light heavy. In relation to the tarsal size parameter, two clusters were established: large size and medium size (Table 4).

Table 1. Morphobiometric measurements for turken-naked neck hens and roosters *Gallus domesticus L. Subspecies nudicollis* from department of Sucre - Colombia.

Body measurements	Hens (n=480)			Roosters (n=170)		
	Mean	SD	CV	Mean	SD	CV
BW	2.1[a]	0.1	22.2	2.8[b]	0.6	18.9
BL	39.1[a]	3.6	10.6	43.6[b]	2.5	11.3
TP	34.8[a]	2.3	9.6	37.9[b]	2.0	8.9
TL	10.0[a]	1.2	11.2	12.5[b]	1.0	10.2
LL	10.4[a]	1.3	15.4	15.2[b]	1.3	11.7
TaL	9.4a	0.6	9.5	9.3[b]	1.0	14.6
WL	28.5[a]	2.0	8.2	36.8[b]	1.7	16.8
AL	2.0[a]	0.3	10.1	3.1[b]	0.5	17.2
LCL	1.6[a]	0.3	11.5	3.8[b]	0.4	11.8
TailL	17.2[a]	0.8	12.3	27.5[b]	0.9	9.8
WW	19.2[a]	2.2	9.8	27.4[b]	1.5	11.2
AW	1.7[a]	0.1	7.9	2.0[b]	0.8	10.9
CW	2.1[a]	0.2	11.9	4.2[b]	0.7	14.8
CH	2.1[a]	0.2	7.9	4.4[b]	0.4	9.7

SD: standard deviation, CV: coefficient of variation, BW: body weight (kg), BL: body length (cm), TP: thoracic perimeter (cm), TL: thigh length (cm), LL: leg length (cm), TaL: tarsal length (cm), WL: wing length (cm), WW: wing width (cm), CH: crest height (cm), AL: appendage length (cm), AW: appendage width (cm), LCL: length chin-length (cm), CW: chin width (cm), TailL: tail length (cm). [a, b]different letters in the same row indicate statistically significant differences $p<0.01$.

Overall, 196 zoometric (phenotypic) correlations were analyzed for hens and roosters (Table 5). There were 51 significant corrections ($p<0.05$), 26 (13.2%) for females and 25 (12.7%) for males. The above denotes a low body harmony. Among the zoometric variables evaluated, those that presented the greatest importance for males were: BL, TP, TL, TaL, WL and AW. Furthermore, these variables had a medium to high correlation with body weight (BW). While, in females, correlations were found between BW with BL, TP, TL, LL, TaL, CW and CH.

Table2. Morphometric means for turken-naked neck creole's biotypes in hens *(Gallus domesticus L. Subspecies nudicollis)* from department of Sucre - Colombia.

BodyM	Subpopulation									
	Sincelejo	Sincé	El Roble	San Pedro	Los Palmitos	Sampués	Corozal	Galeras	San Juan de Betulia	Buenavista
	n= 52	n= 50	n= 46	n= 47	n= 45	n= 47	n= 51	n= 45	n= 49	n= 48
BW	2.1±0.7^{a}	2.2±0.5^{a}	2.1±0.3^{a}	2.2±0.4^{a}	1.9±0.8^{b}	2.2±0.3^{a}	2.1±0.4^{a}	1.9±0.5^{b}	1.9±0.2^{b}	2.1±0.3^{a}
BL	42.2±2.1^{a}	35.7±3.6^{c}	42.9±1.0^{a}	44.7±3.7^{a}	42.7±0.41^{a}	37.7±2.7^{b}	38.4±0.8^{b}	34.3±2.9^{d}	36.6±1.5^{bc}	36.3±2.4^{c}
TP	31.3±2.2^{d}	34.5±2.1^{c}	32.5±2.8^{d}	33.8±2.8^{c}	35.1±1.8^{b}	38.7±2.5^{a}	35.4±2.6^{b}	33.2±2.5^{d}	38.2±1.3^{a}	35.2±3.1^{b}
TL	8.5±0.2^{d}	9.4±1.2^{c}	12.0±0.2^{a}	9.3±1.9^{c}	9.3±2.2^{c}	8.8±0.6^{c}	10.7±1.5^{b}	10.8±2.1^{b}	11.6±0.6^{a}	9.2±2.5^{c}
LL	12.1±2.2^{a}	8.1±1.7^{d}	8.9±1.3^{d}	9.8±2.9^{c}	10.6±1.8^{c}	11.2±1.7^{b}	11.2±1.8^{b}	11.9±1.5^{b}	11.2±1.4^{b}	9.4±1.2^{c}
TaL	9.4±2.6^{b}	8.9±1.4^{b}	9.8±0.7^{b}	9.3±1.8^{b}	8.9±1.9^{b}	8.6±2.7^{c}	10.3±1.2^{a}	9.2±1.9^{b}	10.5±2.6^{a}	8.9±2.5^{b}
WL	26.9±2.1^{c}	28.5±3.2^{b}	26±3.6^{c}	30.9±2.8^{a}	27.1±1.6^{c}	28.2±2.4^{b}	28.1±2.7^{b}	26.9±3.4^{c}	31.3±0.5^{a}	31.2±2.6^{a}
AL	2.3±0.5^{a}	1.8±1.2^{c}	1.9±0.9^{b}	1.7±0.7^{c}	1.8±0.3^{c}	1.9±0.6^{b}	2.4±0.5^{a}	1.8±0.2^{c}	1.9±0.8^{b}	2.3±0.4^{a}
LCL	1.2±0.18^{d}	1.6±1.5^{c}	1.3±0.4^{d}	1.8±1.7^{a}	1.8±0.4^{a}	1.6±0.5^{c}	1.2±0.6^{d}	1.7±0.8^{b}	1.9±0.9^{a}	1.7±0.6^{b}
TailL	17.6±1.5^{a}	17.5±1.2^{a}	16.7±2.5^{b}	17.2±2.7^{a}	18.5±1.2^{a}	16.7±2.6^{b}	17.6±0.7^{a}	16.5±1.9^{b}	15.5±2.3^{c}	17.9±2.1^{a}
WW	21.3±1.6^{a}	21.5±0.9^{a}	16.2±3.9^{c}	22.1±1.9^{a}	19.5±0.7^{b}	19.7±1.8^{b}	19.5±2.7^{b}	16.2±2.8^{c}	19.6±1.8^{b}	16.5±1.8^{c}
AW	1.5±0.2^{d}	1.6±0.3^{c}	1.8±0.8^{a}	1.7±0.9^{b}	1.9±0.6^{a}	1.9±1.2^{a}	1.8±1.6^{a}	1.6±2.9^{c}	1.8±0.2^{a}	1.6±2.1^{c}
CW	2.2±0.6^{b}	2.3±0.6^{a}	1.9±0.5^{c}	2.3±0.8^{a}	2.3±0.3^{a}	2.4±1.3^{a}	1.9±0.6^{c}	1.7±1.4^{d}	2.2±0.5^{b}	2.2±0.7^{b}
CH	1.9±1.2^{d}	1.9±0.7^{d}	1.9±0.4^{d}	2.1±0.4^{c}	2.3±0.2^{a}	2.2±0.6^{b}	2.3±1.2^{a}	2.2±0.6^{b}	2.1±0.4^{c}	2.0±0.3^{c}

BodyM: Body measurements; BW: body weight (kg), BL: body length (cm), TP: thoracic perimeter (cm), TL: thigh length (cm), LL: leg length (cm), TaL: tarsal length (cm), WL: wing length (cm), WW: wing width (cm), CH: crest height (cm), AL: appendage length (cm), AW: appendage width (cm), LCL: length chin-length (cm), CW: chin width (cm), TailL: tail length (cm).$^{a, b,}$ different letters in the same row indicate statistically significant differences p< 0.01.

Table 3. Morphometric means for turken-naked neck creole's biotypes in roosters *(Gallus domesticus L. Subspecies nudicollis)* from department of Sucre - Colombia.

BodyM	Subpoblación									
	Sincelejo	Sincé	El Roble	San Pedro	Los Palmitos	Sampués	Corozal	Galeras	San Juan de Betulia	Buenavista
	n= 19	n= 17	n= 14	n= 18	n= 15	n= 16	n= 18	n= 19	n= 16	n= 18
BW	2.7±1.5^{c}	2.8±1.3^{b}	3.0±0.2^{a}	2.7±1.3^{c}	2.9±1.1^{a}	2.8±0.7^{b}	2.9±1.6^{a}	2.8±1.6^{b}	2.9±1.5^{a}	2.8±0.9^{b}
BL	42.2±1.6^{b}	48.6±1.9^{a}	46.2±2.5^{a}	38.4±1.4^{d}	40.2±2.6^{c}	44.1±2.2^{b}	41.3±2.1^{c}	37.8±2.5^{d}	38.2±1.1^{d}	39.5± 1.3^{c}
TP	37.3±1.7^{c}	34.9±2.2^{d}	35.1±2.2^{d}	39.7±2.5^{b}	38.5±2.1^{b}	42.2±2.1^{a}	40.2±1.9^{b}	36.1±2.3^{d}	37.7±1.6^{c}	37.8±1.9^{c}
TL	11.8±1.9^{c}	11.9±1.5^{c}	11.4±1.9^{c}	11.2±1.7^{c}	12.5±1.1^{b}	15.3±0.9^{a}	13.6±1.1^{b}	13.1±2.1^{b}	12.4±1.8^{b}	11.9±1.7^{c}
LL	13.9±1.2^{b}	13.2±2.1^{b}	14.6±2.1^{b}	16.2±1.2^{a}	16.5±1.2^{a}	16.1±1.1^{a}	15.1±2.2^{a}	15.2±2.5^{a}	14.6±1.7^{b}	15.5±1.2^{a}
TaL	9.9±1.9^{a}	9.6±2.2^{a}	8.8±2.2^{b}	10.1±1.4^{a}	8.1±2.1^{b}	9.1.2±1.6^{a}	9.8±2.1^{a}	9.2±1.6^{a}	9.2±0.6^{a}	9.6±2.1^{a}
WL	32.8±2.1^{c}	32.5±2.5^{c}	34.1±2.1^{c}	36.3±2.2^{b}	39.2±1.4^{a}	38.3±2.1^{a}	36.2±1.8^{b}	38.7±1.5^{a}	37.3±1.4^{b}	38.3±1.3^{a}
AL	2.7±0.6^{c}	3.1±1.5^{b}	3.2±0.7^{a}	3.13±1.2^{b}	2.94±1.9^{b}	3.4±1.3^{a}	3.1±0.3^{b}	2.8±2.3^{c}	3.0±1.5^{b}	2.8±1.5^{c}
LCL	3.4±0.2^{d}	4.3±1.3^{a}	3.5±1.3^{d}	3.90±2.1^{b}	4.10±0.8^{b}	3.6±0.9^{c}	3.8±0.9^{c}	3.7±1.6^{c}	3.6±1.2^{c}	3.4±1.7^{d}
TailL	26.5±1.6^{c}	25.2±2.9^{d}	27.2±3.3^{b}	28.4±1.1^{a}	29.0±1.5^{a}	27.4±2.3^{b}	26.8±1.9^{c}	28.2±1.9^{a}	27.5±1.9^{b}	27.5±1.3^{b}
WW	27.2±1.7^{b}	26.9±0.3^{c}	29.1±1.9^{a}	27.2±1.6^{b}	28.5±1.8^{a}	26.6±2.1^{c}	28.8±1.5^{a}	27.5±1.8^{b}	26.2±2.2^{c}	28.2±1.6^{a}
AW	1.9±1.6^{b}	2.3±0.7^{a}	1.8±1.9^{c}	1.9±1.6^{b}	2.1±1.9^{a}	2.2±1.6^{a}	2.2±1.1^{a}	1.9±1.6^{b}	1.7±0.9^{d}	1.8±1.7^{c}
CW	4.3±1.5^{a}	4.1±2.7^{c}	4.4±1.2^{a}	4.1±0.32^{c}	4.3±0.7^{a}	4.3±3.1^{a}	4.2±0.9^{b}	4.2±1.3^{b}	4.3±0.8^{a}	4.13±0.7^{c}
CH	4.3±1.4^{c}	4.9±0.8^{a}	4.7±0.9^{b}	4.4±1.1^{c}	3.9±0.9^{d}	4.4±1.5^{b}	4.1±0.8^{d}	4.3±0.2^{c}	4.6±0.3^{b}	4.8±0.2^{a}

BodyM: Body measurements; BW: body weight (kg), BL: body length (cm), TP: thoracic perimeter (cm), TL: thigh length (cm), LL: leg length (cm), TaL: tarsal length (cm), WL: wing length (cm), WW: wing width (cm), CH: crest height (cm), AL: appendage length (cm), AW: appendage width (cm), LCL: length chin-length (cm), CW: chin width (cm), TailL: tail length (cm).$^{a, b,}$ different letters in the same row indicate statistically significant differences p<0.01.

Table 4. Variables of morphological differentiation for turken-naked neck creole's biotypes in males and females *(Gallus domesticus L. Subspecies nudicollis)* from department of Sucre - Colombia.

Variable	Grupo	Hens	Roosters
BW means (kg)	Heavy	2.650[a]	3.120[a]
	Semi-heavy	1.880[b]	2.701[b]
TaL means (cm)	Big TaL	10.2[a]	11.89[a]
	Medium TaL	8.50[b]	9.71[b]

[a, b] different letters in the same column, within the group indicate significant statistical differences p<0.01. BW: body weight (Kg), TaL: tarsal length (cm).

The frequencies of the carriers of dominant genes *Frizzled feather* (F/f), *Ptilopody* (Pti/pti), and *Polydactyly* (Po/po), in the study population were between 2.2% and 6.5%, while the frequency of the carrier of the recessive *Silky feather* (h) gene presented the lowest frequency (0.02%), and the *Polydactyly* (Po) gene the highest (12%). The allelic frequencies of each of the genes varied between 0.002 and 0.12 for the h and Po alleles, respectively (Table 6). The gene frequencies F and Pti were 3% and 1.1%, respectively. Moreover, all genotype frequencies presented statistical differences (p<0.01) from the expected Mendelian proportions.

Table 5. Pearson correlations between zoometric variables for turken-naked neck creole's biotypes in roosters (top) and hens (bottom), *Gallus domesticus L. Subspecies nudicollis* from department of Sucre - Colombia.

	BW	BL	TP	TL	LL	TaL	WL	AL	LCL	TailL	WW	AW	CW	AC
BW		0.7*	0.6*	0.4*	0.3	0.4*	0.5*	0.3	0.2	0.3	0.4	0.4*	0.3	0.2
BL	0.5*		0.7*	0.3	0.2	0.4*	0.2	0.2	0.3	0.2	0.3	0.2	0.3*	0.5*
TP	0.6*	0.4*		0.5*	0.4*	0.3*	0.5*	0.3*	0.4*	0.4*	0.3*	0.4*	0.3*	0.4*
TL	0.4*	0.1	0.0		0.5*	0.0	0.1	0.1	-0.3	0.2	-0.1	-0.1	0.1	0.4*
LL	0.5*	0.1	0.1	0.3		0.1	0.5*	0.0	0.0	0.2	-0.1	0.0	0.2	0.3
TaL	0.3*	0.2	0.0	0.7*	0.2		0.3	0.0	0.1	0.1	-0.3	0.2	0.3	0.0
WL	0.1	0.2	0.5*	0.1	0.2	0.1		-0.3	0.2	-0.1	-0.1	-0.3	0.2	0.3
AL	0.1	0.1	0.1	0.1	0.3	0.3	0.0		0.0	0.1	0.3	0.0	0.1	0.1
LCL	0.4*	0.2	0.5*	0.0	-0.1	0.2	0.6*	-0.6*		0.2	0.1	0.4*	0.1	0.2
TailL	0.2	0.3	0.3	0.6*	-0.2	-0.5*	0.2	0.3	-0.2		-0.3	0.2	-0.1	-0.1
WW	0.2	-0.1	-0.1	0.5*	0.0	0.0	0.2	-0.1	0.0	0.2		0.2	0.1	1.0
AW	0.2	0.2	0.6*	0.3	0.0	0.1	0.1	-0.3	0.2	-0.1	-0.1		0.3	0.2
CW	0.4*	0.2	0.4*	0.7*	-0.2	0.4*	0.4*	-0.2	0.4*	0.2	0.7*	0.2		0.2
CH	0.4*	0.1	0.5*	0.2	0.5*	0.1	0.0	-0.1	0.3	0.1	0.0	0.6*	-0.1	

BW: body weight (kg), BL: body length (cm), TP: thoracic perimeter (cm), TL: thigh length (cm), LL: leg length (cm), TaL: tarsal length (cm), WL: wing length (cm), WW: wing width (cm), CH: crest height (cm), AL: appendage length (cm), AW: appendage width (cm), LCL: length chin-length (cm), CW: chin width (cm), TailL: tail length (cm).[a, b,] different letters in the same row indicate statistically significant differences p < 0.05.

Table 6. Proportion of major gene carriers and their gene frequency for turken-naked neck creole's biotypes *Gallus domesticus L. Subspecies nudicollis* from department of Sucre - Colombia.

Gene	Allele	Number			Allele frequency		
		Expected	Observed	Proportion (%)	Observed	Expected	p
Frizzled feather	F	488	42	6.5	0.03	0.75	<0.01
Normal	f+	163	608	93.5	0.97	0.25	<0.01
Silky feather	h	488	2	0.2	0.002	0.75	<0.01
Normal	H+	162	648	99.8	0.998	0.25	<0.01
Ptilopody	Pti	488	14	2.2	0.011	0.75	<0.01
Normal	pti+	162	636	97.8	0.999	0.25	<0.01
Polydactyly	Po	488	15	2.3	0.12	0.75	<0.01
Normal	po+	162	635	97.7	0.98	0.25	<0.01

The main body parameters of the birds carrying the *Normal*, *Frizzled feather*, *Polydactyly*, *Silky feather*, *Ptilopody* y *Polydactyly* in *Gallus domesticus L. Subespecies nudicollis* from Sincelejo and Sabanas subregion in Sucre deparment were BW, BL, TP, LL, and WL (Table 7). The allele for polydactyly (Po) had a greater positive effect. Additionally, birds with polydactyly presented higher values for BW, BL, TP, LL and WL, with respect to others. On the other hand, the birds of the *Frizzled feather* genotype had the lowest body measurements and the lowest effects.

Table 7. Main body parameters of carriers of the Normal, *Silky feather, Frizzle, Polydactyly* and *Ptylopody* genotypes for turken-naked neck creole's biotypes *Gallus domesticus L. Subspecies nudicollis* from department of Sucre - Colombia.

Variable	Normal	SF	*Frizzle*	Poly	Ptylo
BW	2.1	1.9	2.0	2.3	2.1
BL	39.0	38.2	40.1	42.1	39.8
TP	34.5	31.9	32.8	35.1	34.8
LL	9.2	9.1	9.3	9.7	9.0
WL	28.3	28.4	28.2	29.1	28.7
			Genotype effectt		
BW	-0.02	0.02	0.01	0.04	0.02
BL	-0.89	0.11	0.12	0.15	0.15
TP	-0.15	0.09	0.10	0.36	0.15
LL	-0.04	0.01	0.02	0.09	0.08
WL	-0.08	0.06	0.02	0.12	-0.15

SF: *Silky feather*; Poly: *Polydactyly*; Ptylo: Ptylopody; BW: body weight (kg), BL: body length (cm), TP: thoracic perimeter (cm), LL: leg length (cm), WL: wing length (cm).

Regarding the phaneroptic characteristics (Table 8), a standard was evidenced in the male and female, with the dominance of the normal plumage type (94.1%), as well as with a normal plumage pattern (99.7%). The brown plumage color predominated (40%) over the others. In the tarsus, the most frequent color was yellow (81.3%). 68.1% of the birds had red earlobes and 84.5% had red-orange eyes. Regarding the size of the crest, in hens, the small ridges predominated (58.5%), and in the roosters, the large ridges (76.1%), although in both cases, the simple form of the crest was the most frequent (79.2%).

Table 8. Absolute and relative frequencies of phaneroptic characteristics for turken-naked neck creole's biotypes *Gallus domesticus L* biotype *Subespecie nudicollis*, from department of Sucre - Colombia.

Qualitative variables	Hens		Roosters		Both genders
	AF	RF	AF	RF	RF
Plumage type					
Normal	446	0.929	162	0.953	0.941
Frizzy	34	0.071	8	0.047	0.059
Total	480	1.000	170	1.000	1
Plumage pattern					
Silky	2	0.004	0	0.000	0.003
Normal	478	0.996	170	1.000	0.997
Total	480	1.000	170	1	1
Plumage color					
White	83	0.17	25	0.140	0.156
Black	72	0.150	46	0.270	0.210
Ash (bluish)	55	0.115	30	0.180	0.147
Brown	221	0.460	58	0.340	0.400
Others	49	0.102	11	0.070	0.086
Total	480	1	170	1	1
Tarsus color					
Greenish	32	0.067	12	0.071	0.069
White	21	0.044	5	0.029	0.037
Yellow	363	0.756	148	0.871	0.813
Blue	0	0.000	0	0.000	0.000
Black	52	0.108	3	0.018	0.063
Brown	12	0.025	2	0.012	0.018
Total	480	1	170	1	1
Earlobe color					
Unpigmented (White)	5	0.01	1	0.006	0.008
Red	312	0.650	121	0.712	0.681
Red White	163	0.340	48	0.282	0.311
Total	480	1	170	1	1
Eye color					
Black	25	0.052	8	0.047	0.050
Orange Red	402	0.838	145	0.853	0.845
Pearl	15	0.031	17	0.100	0.066
Brown	38	0.079	0	0.000	0.040
Total	480	1	170	1	1
Ridge size					
Small	281	0.585	2	0.011	0.298
Median	190	0.396	41	0.228	0.312
Big	9	0.019	137	0.761	0.390
Total	480	1	180	1	1
Ridge shape					
Pea	19	0.040	1	0.006	0.023
Nut	28	0.058	10	0.059	0.059
Rose	31	0.065	32	0.188	0.126
Simple	402	0.838	127	0.747	0.792
Total	480	1	170	1	1

AF: absolute frequency, RF: relative frequency.

DISCUSSION

The morphometric variables measured in hens and roosters in the present work differ from similar studies reported in the literature (6,12,16,19), being able to affirm that the differences between morphometric measures established between the groups of birds studied can be attributable to selection processes, and adaptability of individuals to environmental conditions, age and physiological state (8,9-22).

Zoometric differences between sexes are widely documented, attributing the divergence to sexual dimorphism, exerted by the control of some hormones over these characters, which condition growth (16,21-25). Some CV values are similar (Table 1) to those reported in different hen populations (8,21,22,26). Likewise, the variability found in the study population could allow the selection of animals with desirable productive characteristics in defined agro-ecologies, contributing to the conservation and improvement of alternative traditional and socially sustainable production systems for rural inhabitants (12).

In addtion, Intra-sex variation, between communities, could be attributed to the different management of BAS in each of the municipalities that make up the Sabanas subregion and Sincelejo, to the ethnic groups that manage these resources, as well as to migratory processes that are produced by the transhumance of livestock in the area (8,24). Some research has associated a larger crest and chin size in roosters with gonadal development and secretion of sex hormones (8,10,19), this suggests that the roosters used in this research they may have a similar reproductive performance.

Hens classified as heavy (Table 4), were characterized by presenting large limbs (LL and TaL). In particular, it has been shown that this biotype of animals is selected and kept in the productive units by the producers, with the purpose of obtaining eggs and meat at the end of the productive cycle (12,15). The second group identified as medium-sized; these hens show good posture (6,12,15,27).

On the other hand, most of the genes that influence the structural conformation are not of local action, but of general action. The foregoing denotes the importance of estimating the harmony of the morphostructural model, which is made from the amount of significant positive correlations between the measurements. Thus, the higher the percentage, the more structurally harmonic the animal is (28). However, in this work, morphostructural harmony in females and males was low suggesting a great variability in terms of external morphological characteristics, which means a great biological richness for the study area. The above coincides with there are no genetic improvement plans in the zone, aimed at increasing the productivity in the BAS. Previous works denote the correlation of the BW variable as the most studied in relation to other body measurements, concluding that the association between BW with BL and TP measurements may be appropriate to infer BW in hens and roosters (4,6,24).

The expected Mendelian ratios, allele frequencies, and deviations reported here, in the genes *Frizzled feather*, *Polydactyly*, *Silky feather*, *Ptilopody* and *Polydactyly* were similar to those reported by Fayeye et al. (29); Dahloum et al. (30); Brown et al. (20); and Hassan et al. (24). However, the expected phenotypic relationship and gene frequencies for the gene *Frizzled feather*, was calculated with the assumption that the number of dominant homozygous individuals (FF) is equal to zero. This is because the dominant allele is lethal in the homozygous state (24). The low genotype and allelic frequencies found may be due according to Fayeye et al. (29) to that, the appearance of these phenotypes, grant cultural prejudices, which have led to the elimination of the birds.

The effect of the genotype on the body measurements estimated here are similar to those reported by other authors (20,29,31,32). Additionally, studies conducted by Ogunshola et al. (33) in chickens in Southwestern Nigeria, indicated that the birds that had the genotype Po/po (polydactyly), presented higher value of the least squares means in live weight, gutted weight, breast weight, proventriculus weight, liver weight, spleen weight, pancreas weight, wing weight, when with males and females without polydactyly.

The type, pattern and color of the plumage reported are widely disseminated in the literature (4,6,8,12,20,25). The plumage colors found, presented a predominance of dark tones, these seem to prevail evolutionarily, as they provide advantages by hiding from predators (25). The yellow color found in the tarsus can be determined by several effects, among them, the homozygous recessive genotype ww, which

causes yellow pigmentation in the skin, while the dominant W gene gives rise to white-skinned hens, with effects on beak and tarsi (6). Also, the yellowish hue can be a product of the food supplied, which is based mainly on grazing and agricultural by-products (8). Finally, the presence of animals with light and barred plumage suggest, as well as yellow tarsi, are indicative of the influence of commercial or specialized breeds through their introgression (4,34).

The size and shape of the head are directly related to the sexual dimorphism of the bird, in males, they are developed and showy, on the contrary in females, they are small (35). The foregoing agrees with our results regarding the size of the crest, in hens, it ranged between small and medium with three to four well-defined teeth, while in roosters it ranged between medium and large. Similar results are reported by Toalombo et al. (8), Montes et al. (12) and Andrade-Yucailla et al. (34).

In conclusion, the different morphobiometric and/or phaneroptic parameters measured show that *Gallus domesticus L. Subspecies nudicollis*, from Sincelejo and the Sabanas subregion in the department of Sucre - Colombia, maintains a natural character, which allows exploring a future productive and conservation potential of strains. A heterogeneous population with great phaneroptic variability was found, which would favor the conservation of genetic resources. However, the presence of animals with barred and clear plumage, as well as yellow tarsi, are indications of introgression between specialized breeds. Gene frequencies for *Frizzled feather, Polydactyly, Silky feather* and *Ptilopody* indicating that these genes could soon disappear from the studied population. This work confirmed, higher performance for the characteristics TP, BL, and LL in birds with polydactyly genotype. The controlled management of genotypes can help to demonstrate the superiority of these birds and stop their negative selection. Finally, the morphobiometric and/or phaneroptic diversity of the population of hens and roosters studied, constitutes the starting point for the implementation of promotion and conservation programs, potentiating the qualities of adaptability to different Agro-ecological systems such as BAS, and improve the efficiency in the productivity and use in socio-cultural activities.

Conflict of interest

No conflict of interest has arisen during the preparation of this paper by the authors.

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