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Morphometry of digestive organs in creole hens (*Gallus domesticus*)

Morfometría de órganos digestivos en gallinas criollas (*Gallus domesticus*)

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Abstract

The objective of this research was to analize the morphometric characteristics of digestive organs in native hens (*Gallus domesticus*), considering variations related to age and rearing system. The study was conducted in the canton of Tosagua, located in the province of Manabí, Ecuador. Twenty Creole chickens were used, divided into two groups according to age: six months and one year, and raised under two types of rearing systems: pasture and semi-intensive rearing system (with four groups of five birds each). The birds were euthanized following a standardized methodology that included a 12-hour fasting period and uniform necropsy procedures to ensure comparability of measurements. The variables analyzed included absolute weight, relative weight, length, and diameter of digestive organs: esophagus, proventriculus, gizzard, liver, pancreas, small intestine, and large intestine. The data were organized and analyzed using the statistical software InfoStat, and averages and standard deviations were used to describe the variability between groups. The results indicated that age had a significant impact on most of the morphometric variables, with greater lengths and diameters observed in the esophagus, proventriculus, gizzard, liver, pancreas, and large intestine in one-year-old birds. The small intestine showed a greater relative weight in six-month-old birds, while differences due to the rearing system were less evident. These results suggest that age is the most influential factor in the morphometric development of digestive organs in Creole chickens.

Keywords: hens, morphometry, organs, rearing, age.

Resumen

El objetivo de la investigación fue analizar las características morfométricas de órganos digestivos en gallinas criollas (*Gallus domesticus*), según las variaciones relacionadas con la edad y el sistema de crianza. El estudio se llevó a cabo en el cantón de Tosagua, ubicado en la provincia de Manabí, Ecuador. Se trabajó con 20 gallinas criollas, divididas en dos grupos de acuerdo con su edad: seis meses y un año, y criadas bajo dos tipos de sistemas de crianza: pastoreo y semi pastoreo (con cuatro grupos de cinco aves cada uno). Las aves fueron sacrificadas siguiendo una metodología estándar que incluyó un periodo de ayuno de 12 horas y procedimientos de necropsia uniformes para asegurar que las mediciones fueran comparables. Las variables analizadas incluyeron el peso absoluto, el peso relativo, la longitud y el diámetro de órganos digestivos: esófago, proventrículo, molleja, hígado, páncreas, intestino delgado e intestino grueso. Los datos fueron organizados y analizados mediante el programa estadístico InfoStat, representados por promedios y desviaciones estándar para describir la variabilidad entre grupos. Los resultados indicaron que la edad tuvo impacto significativo en gran parte de las variables morfométricas, observándose longitudes y diámetros mayores en el esófago, proventrículo, molleja, hígado, páncreas e intestino grueso en las aves de un año. El intestino delgado mostró un mayor peso relativo en las aves de seis meses, mientras que las diferencias debido al sistema de crianza fueron menos evidentes. Estos resultados sugieren que la edad es el factor más influyente en el desarrollo morfométrico de los órganos digestivos en gallinas criollas.

Palabras clave: gallinas, morfometría, órganos, crianza, edad.

Introduction

Food production constitutes one of the main challenges on a global scale, and in Latin America, farmers stand out for their capacity to adapt to adverse economic, social, environmental, and cultural contexts (Hortúa and Cerón, 2021). In this scenario, backyard poultry farming has become established in rural areas as a strategic activity, based on the raising of Creole hens capable of developing under limiting conditions and with low-cost inputs. This system not only contributes to food security through the supply of protein of high biological value, but also represents a supplementary source of income for rural families (Toalombo et al., 2024).

Creole hens are exposed to marked genetic and environmental heterogeneity, which may translate into important differences in the anatomical and functional development of their organs, particularly those of the digestive system, with possible implications for nutrient utilization efficiency (Oñate et al., 2020). In Ecuador, the annual raising of approximately six million Creole hens is estimated, distributed mainly in the Coastal region (49.89%), followed by the Highlands (40.75%) and the Amazon region (9.33%) (Bailón, 2022). Nevertheless, despite their productive and sociocultural importance, the Food and Agriculture Organization of the United Nations has pointed to the limited availability of studies addressing the morphology of the digestive organs of these birds (FAO, 2013).

Creole birds are characterized by wide phenotypic variability, resulting from historical processes of domestication, uncontrolled crossbreeding, and adaptation to different production environments. This diversity is manifested in traits such as plumage, body conformation, and egg characteristics (Cuca et al., 2016; Illescas, 2023). In the Ecuadorian context, several studies have identified local biotypes through morphometric analyses based on qualitative and quantitative descriptors proposed by the FAO (2017), which include body structure, comb type, plumage color, tarsus length, and productive parameters (Villacís et al., 2016; Barzallo, 2019).

Morphometric analysis of the digestive organs constitutes a key tool for understanding the productive performance and digestive efficiency of Creole hens, as it allows the identification of structural alterations or anatomical variations that could negatively affect their productivity (Juárez et al., 2020). Likewise, this approach provides relevant information for the design of strategies aimed at optimizing management, feeding, and genetic selection, according to local production conditions, thereby contributing to the strengthening of sustainable poultry systems (Lázaro et al., 2012; Vera et al., 2021; Toalombo et al., 2024).

In this context, the objective of the study was to analyze the morphometric characteristics of the digestive organs in Creole hens (Gallus domesticus) and to compare these parameters as a function of age, considering the possible influence of the rearing system and of metabolic and environmental factors that could affect their development..

Materials and methods

The research was conducted in the canton of Tosagua, province of Manabí, Ecuador, located at coordinates 0.7859° S and 80.2346° W (Geodatos, 2025). The study had a quantitative approach, was non-experimental, with a descriptive scope and a field design, aimed at analyzing the morphometric characteristics of the digestive organs in Creole hens.

The study population consisted of 20 Creole hens acquired from rural farms in the canton of Tosagua, selected according to availability and previously established inclusion criteria. Birds in good sanitary condition, with no visible external lesions and no evidence of congenital malformations, within an age range of six months to one year, were considered. Birds that showed clinical signs of disease or evident anatomical alterations were excluded. The hens' age was provided by local producers, based on their management records. The birds' average body weight was approximately 2 kg.

The hens came from two rearing systems: free-range grazing and semi-grazing or a semi-intensive system. Based on this criterion, four experimental groups were formed: free-range grazing at six months, free-range grazing at one year of age, semi-grazing at six months, and semi-grazing at one year of age, with five birds per group. After acquisition, all hens were managed under homogeneous conditions of feeding, water supply, and health management, in order to minimize possible confounding effects on the morphometric variables evaluated.

Measurements were taken over a two-week period, according to the established schedule to ensure systematic data collection. Prior to slaughter, the birds were weighed using a digital scale (QP brand). The handling, slaughter, and processing of the birds were carried out in accordance with animal welfare principles and the ethical regulations in force for research involving animals, minimizing stress, pain, and suffering throughout the experimental process, in line with international recommendations for research in production animals and the guidelines of the World Organisation for Animal Health (WOAH, formerly OIE). Slaughter was performed by electrical stunning at 160 volts, followed by decapitation, ensuring rapid loss of consciousness and adequate bleeding. Subsequently, evisceration was carried out and the digestive organs were extracted for morphometric evaluation.

The variables analyzed included the bird's body weight and the morphometric measurements of the gastrointestinal tract, specifically the length, diameter, and weight of the digestive organs: esophagus, proventriculus, gizzard, liver, pancreas, small intestine, and large intestine. An analog micrometer (Trupper), a flexible measuring tape, and a digital scale with milligram precision (AWCNILACAV brand) were used for the measurements. In the case of organs with irregular morphology, the diameter was estimated by measuring the major and minor axes.

The length of the esophagus was measured from the pharynx to its junction with the proventriculus, and the diameter was recorded at three equidistant points. In the proventriculus, length was determined between the proximal and distal ends, while diameter was measured along the major transverse axis. In the gizzard, due to its muscular structure, the longitudinal and transverse axes were considered to describe its size. In the liver, the length of the main lobe was measured along its major axis and the diameter at its maximum width. The diameter of the pancreas was estimated by transverse measurement of its major functional axis. In the small intestine, length was measured along the entire course of each segment and diameter was recorded at three representative points. Finally, in the large intestine, length was measured from the ileocecal junction to the cloaca, and diameter was recorded at the level of the rectum.

For the determination of the morphometric index or relative organ weight, the relationship between organ weight and the bird's body weight was used, multiplied by 100, according to the following equation:

$$\text{Morphometric index} = \frac{\text{Organ Weight}}{\text{Chicken Weight}} \text{ X } 100$$

During the data collection process, the direct observation technique was used; an individual code was assigned to each bird and the evaluation date was recorded. The images obtained were digitally archived with detailed descriptions, and a record sheet was maintained in which the observations made and any incidents that occurred during the course of the study were documented.

The data obtained were organized in a statistical database and analyzed using InfoStat software. For each experimental group, the means and standard deviation of the variables evaluated were calculated, in order to adequately describe the internal variability of the morphometric measurements.

Results and discussion

Esophagus

One-year-old hens showed higher body weight than six-month-old hens (*P*<0.001), regardless of the rearing system (table 1). Accordingly, the absolute weight of the esophagus was significantly higher in adult birds (*P*= 0.0006), whereas relative weight showed no differences by age or by system (*P*= 0.979), indicating that esophageal growth was proportional to the increase in body weight, maintaining an allometric relationship close to isometry. This pattern has been previously described in domestic birds, in which organs of the digestive tract tended to retain stable proportions once physiological maturity was reached (Godoy, 2014; Ravindran, 2021).

Table 1. Morphometry of the esophagus in Creole hens of two ages from different rearing systems.

Rearing system	Age	Bird weight (g)	Absolute weight (g)	Relative weight (%)	Length (cm)	Diameter (mm)
Grazing	1 año	2196.20 ± 134.61	3.02 ± 0.15	0.138 ± 0.0068	13.64 ± 0.36	4.76 ± 0.11
Grazing	6 months	1752.80 ± 90.84	2.32 ± 0.47	0.133 ± 0.0268	11.52 ± 0.70	4.20 ± 0.16
Semi-grazing	1 año	2139.00 ± 107.49	3.02 ± 0.13	0.141 ± 0.0061	13.38 ± 0.26	4.64 ± 0.27
Semi-grazing	6 meses	1701.60 ± 48.89	2.50 ± 0.43	0.147 ± 0.0253	10.88 ± 0.47	4.28 ± 0.24
p-value (age)		<0.001	0.0006	0.979	<0.001	0.0001
p-value (rearing system)		0.230	0.545	0.218	0.049	0.831

Regarding dimensions, esophageal length was significantly greater in one-year-old birds (*P*<0.001) and also showed a slight but significant effect of the rearing system (*P*= 0.049), suggesting that access to grazing could influence the functional use of the anterior digestive tract, which could be related to differences in the consumption pattern (foraging vs. controlled provision) and in the filling dynamics of the anterior tract in birds with access to grazing.

By contrast, esophageal diameter was determined mainly by age (*P*= 0.0001), with no effect of the system (*P*= 0.831), and was greater in species that consumed large portions of whole food (Godoy, 2014). This was consistent with what was reported by Faria (2017) and Orosz (2020), who noted that esophageal diameter was more closely related to anatomical maturity than to production management. Studies in birds with outdoor access have shown variations associated with ranging behavior and the consumption of plant material, with implications for the development/functional use of the proximal digestive tract (Marchewka et al., 2021). Overall, these results support that anatomical maturity explains most of the morphometric variation, while the rearing system would have a more subtle and localized effect on length.

Proventriculus

The proventriculus showed a clear effect of age on its morphometric development, indicating that this organ reaches a stable functional state in adulthood. In one-year-old hens, the absolute weight of the proventriculus was significantly greater (*P*<0.001) and showed similar values between the grazing and semi-grazing systems, indicating that, at this age, the rearing system did not exert a relevant influence on its development (table 2). In contrast, six-month-old birds showed lower values,

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with slight variations between systems, suggesting that the proventriculus continued its growth process during this juvenile phase. Consistently, relative weight was significantly greater in adult birds (*P*= 0.0026), confirming the effect of physiological maturity on the proportional development of the organ. The length of the proventriculus followed this same trend, being greater in one-year-old birds (*P*<0.001), while diameter showed no significant differences associated with either age or the rearing system (*P*>0.05).

Table 2. Morphometry of the proventriculus in creole hens of two ages from different rearing systems.

Rearing system	Age	Bird weight (g)	Absolute weight (g)	Relative weight (%)	Length (cm)	Diameter (mm)
Grazing	1 year	2196.20 ± 134.61	6.94 ± 0.34	0.316 ± 0.016	4.78 ± 0.19	6.20 ± 0.16
Grazing	6 months	1752.80 ± 90.84	3.24 ± 0.39	0.185 ± 0.022	3.22 ± 0,18	5.42 ± 0.13
Semi-grazing	1 year	2139.00 ± 107.49	6.94 ± 0.28	0.325 ± 0.013	4.54 ± 0.18	5.84 ± 0.42
Semi-grazing	6 months	1701.60 ± 48.89	3.54 ± 0.54	0.208 ± 0.032	3.72 ± 0.68	5.34 ± 0.11
p-value (age)		<0.001	<0.001	0.0026	<0.001	<0.001
p-value (rearing system)		0.230	0.692	0.110	0.495	0.062

Overall, these results indicated that age was the main determinant factor of proventriculus morphometry, while the rearing system exerted a secondary influence under homogeneous feeding conditions. This pattern was consistent with what was described by Martínez et al. (2021), who reported progressive increases in the relative weight of the proventriculus during the early stages of development, and with Langlois (2003), who noted that the shape and size of this organ varied mainly as a function of the growth phase. More recent evidence supported that proventriculus maturation occurred early and stabilized as the rate of body growth decreased, in line with the ontogeny of the digestive system and the progressive increase in its secretory and functional capacity in domestic birds (Ravindran, 2021).

As noted, the rearing system showed no significant effects (*P*>0.05), which reinforces that proventriculus development is dominated by growth processes and physiological maturation rather than by management, at least under homogeneous post-acquisition feeding conditions. In turn, these results indicated that the morphometric development of the proventriculus is determined mainly by age and body growth, reaching a stable functional state in adulthood.

Gizzard

In one-year-old birds, the absolute weight of the gizzard was similar between rearing systems, which evidenced structural stability in adulthood (Table 3). In six-month-old birds, absolute weight was slightly higher under semi-grazing, while relative weight was higher in both systems, which could be interpreted as a physiological compensation typical of a stage of active growth.

Table 3. Morphometry of the gizzard in creole hens of two ages from different rearing systems.

Rearing system	Age	Bird weight (g)	Absolute weight (g)	Relative weight (%)	Length (cm)	Diameter (mm)
Grazing	1 year	2196.20 ± 134.61	7.12 ± 0.68	0.324 ± 0.031	8.64 ± 0.30	25.50 ± 1.12
Grazing	6 months	1752.80 ± 90.84	6.02 ± 1.06	0.344 ± 0.060	6.50 ± 0.96	23.06 ± 0.75
Semi-grazing	1 year	2139.00 ± 107.49	7.04 ± 0.35	0.329 ± 0.016	8.48 ± 0.26	25.86 ± 1.96
Semi-grazing	6 months	1701.60 ± 48.89	6.22 ± 0.7	0.366 ± 0.046	6.32 ± 0.30	23.70 ± 1.62
p-value (age)		<0.001	0.010	0.088	<0.001	0.001
p-value (rearing system)		0.230	0.859	0.353	0.479	0.407

The length and diameter of the gizzard were significantly greater in adult birds, regardless of the rearing system, confirming that body maturity influenced the development of this organ more than production management. Length and diameter were greater in one-year-old birds (8.48-8.64 cm and 25.50-25.86 mm) from both the grazing and semi-grazing systems (table 3). The gizzards of young birds were smaller, which was expected given that this organ continues to develop in response to the ingestion and grinding of feed.

Likewise, the absolute weight of the gizzard was similar in one-year-old birds (7.12 g), indicating structural stability at that age (table 3). In six-month-old birds, absolute weight was slightly higher under semi-grazing (6.22 g), and relative weight was higher in six-month-old birds on this occasion in both rearing systems (0.344 to 0.366%), possibly due to a physiological compensation associated with the stage of active growth.

These results were consistent with what was reported by Solís (2016) and Ruiz (2018), who indicated that gizzard size and musculature were closely related to feed particle size and to the bird's body growth. Likewise, Ravindran (2021) described a progressive decrease in relative gizzard weight with age, a pattern that coincided with what was observed in this study.

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When coarse particle size was used in the diet, a larger gizzard size was observed in the birds, and greater intestinal content in the gizzard was also observed (Solís, 2016). Gizzard volume depends on the size of the chicken. The larger the chicken, the lower the ratio; therefore, depending on the bird, the ideal is for it to be 1.5 to 2% of live body weight (Ruiz, 2018).

On the other hand, the gizzard does not allow anything longer than one millimeter to pass through. The larger the particle size, "the longer they remain retained inside the gizzard, increasing its musculature." This is why most intestinal health scientists regard the gizzard as a fully fundamental organ (Ruiz, 2018).

At the time of hatching, the gizzard is the largest organ associated with the gastrointestinal tract, even larger than the liver (52 versus 33 g·kg⁻¹ of body weight). However, the relative weight of the gizzard decreased steadily with age (Ravindran, 2021).

From a functional perspective, the gizzard is highly sensitive to the physical structure of the diet (particle size, structural fiber), which modulates its muscular hypertrophy and the dynamics of retention/grinding. Controlled trials have shown that diets with coarser particles can increase gizzard development and modify morphological parameters of the gastrointestinal tract (Novotný et al., 2023; Rueda et al., 2024).

Liver

One-year-old hens presented livers of greater weight and size compared to six-month-old birds, reflecting normal organ development with age (table 4). However, relative liver weight remained stable among groups, indicating that its proportion relative to body weight was not significantly affected by either age or the rearing system.

Differences between grazing and semi-grazing were minimal, suggesting that hepatic morphometry depended mainly on physiological maturity. This behavior was consistent with what was reported by Zaefarian et al. (2019), who described marked variations in relative liver weight during the early stages of life, followed by stabilization as body development progressed; in this regard, they found an increase in relative liver weight from 25 g·kg⁻¹ of body weight at hatch to 46 and 48 g·kg⁻¹ of body weight on day 8 in pullets for egg production and broiler chicks, respectively. Relative weights decreased thereafter, but the reductions were greater in egg-producing birds than in meat-type birds. By day 14, liver weight in meat-type chickens exceeded that of egg-type chickens.

The greater relative size of the liver at an early age presumably enables birds to metabolize nutrients more efficiently, due to lower feed intake and the secretion of endogenous enzymes. In a subsequent study, Nitsan et al. (1991) showed that the relative weights of the liver and pancreas reached their maximum at 6 and 9 days of age, respectively.

Table 4. Morphometry of the liver in creole hens of two ages from different rearing systems.

Rearing system	Age	Bird weight (g)	Absolute weight (g)	Relative weight (%)	Length (cm)	Diameter (mm)
Grazing	1 year	2196.20 ± 134.61	43.90 ± 2.70	2.00 ± 0.00	10.16 ± 0.27	13.50 ± 0.41
Grazing	6 months	1752.80 ± 90.84	34.40 ± 3.21	1.96 ± 0.13	8.18 ± 0.26	11.82 ± 0.29
Semi-grazing	1 year	2139.00 ± 107.49	42.34 ± 2.25	1.98 ± 0.02	9.94 ± 0.15	13.68 ± 0.35
Semi-grazing	6 months	1701.60 ± 48.89	33.86 ± 1.97	1.99 ± 0.07	8.04 ± 0.21	11.72 ± 0.30
p-value (age)		<0.0001	<0.0001	0.6647	<0.0001	<0.0001
p-value (rearing system)		0.2303	0.3638	0.9307	0.0865	0.7955

In this research, relative weight remained stable (~2%; P= 0.6647) and the rearing system showed no statistical effect (P>0.05). This pattern indicated proportional growth relative to live weight and greater anatomical development with maturity. In chickens, it has been described that metabolically active organs (including the liver) were especially dynamic during early phases and then tended to stabilize their proportional contribution as growth progressed (Ravindran, 2021; Gorenz et al., 2024).

Pancreas

The pancreas showed significant differences by age in all variables (table 5), with greater absolute weight, length, and diameter in one-year-old birds (P<0.0001). However, relative weight was higher in young birds (P<0.0001). As already indicated, absolute pancreas weight was higher in one-year-old birds, both under grazing and semi-grazing, evidencing a fully developed organ in adulthood (table 5). In contrast, six-month-old birds showed lower values, consistent with their growth status. The rearing system showed no significant effects (P>0.05), although the P-value for relative weight (0.0724) suggested a trend that could be explored with a larger sample size or with a finer characterization of the effective diet consumed in each system.

Tabla 5. Morphometry of the pancreas in creole hens of two ages from different rearing systems.

Rearing system	Age	Bird weight (g)	Absolute weight (g)	Relative weight (%)	Length (cm)	Diameter (mm)
Grazing	1 year	2196.20 ± 134.61	16.72 ± 1.07	0.76 ± 0.004	12.96 ± 0.34	1.28 ± 0.08
Grazing	6 months	1752.80 ± 90.84	14.16 ± 1.63	0.81 ± 0.09	10.52 ± 0.41	0.74 ± 0.17
Semi-grazing	1 year	2139.00 ± 107.49	16.24 ± 0.92	0.76 ± 0.004	12.78 ± 0.39	1.38 ± 0.08
Semi-grazing	6 months	1701.60 ± 48.89	14.12 ± 0.72	0.83 ± 0.02	9.96 ± 0.34	0.84 ± 0.11
p-value (age)		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
p-value (rearing system)		0.2416	0.3189	0.0724	0.0912	0.2847

With respect to relative weight, an opposite trend was evident: young birds showed higher percentages (0.81 to 0.83%) compared to adults (0.76%). This behavior suggested that, although the pancreas of six-month-old birds was smaller in absolute terms, it represented a greater proportion of body weight because the organism has not yet reached its adult size, something that is physiologically expected in digestive organs.

Regarding pancreas length, it was greater in one-year-old birds (approximately 12.78 to 12.96 cm), which again reflected the impact of age-related anatomical development. As for diameter, the measurements were higher in adult birds (1.28 to 1.38 mm), indicating that organ growth involved not only elongation but also an increase in thickness.

In relative terms, young birds showed higher percentages, indicating that, although the pancreas was smaller in absolute values, it represented a greater proportion of body weight during the early stages of development. Pancreas length and diameter were greater in adult birds, reflecting both longitudinal and transverse growth of the organ with age. This was consistent with allometric logic: during growth stages, an organ may represent a larger fraction of total body weight even when its absolute mass is lower. This dynamic has been documented in birds in relation to digestive and metabolic organs, particularly when proportions relative to live weight are evaluated (Ravindran, 2021; Gorenz et al., 2024).

Hooge (2020) indicated that liver and pancreas weight increased two- and fourfold, respectively, relative to total body weight during the first week of life. Nitsan et al. (2011) showed that relative pancreas weight increases at 8 days of age, at which point its allometric growth rate is approximately four times higher than body growth. After those 8 days, the rate began to decrease, and by day 23, allometric pancreas growth was 1.5 times greater compared to body weight.

Small intestine

For the small intestine, a trend was observed: six-month-old birds presented greater absolute weight and relative weight (P<0.0001), while length did not differ by age (P= 0.5490) or by system (P= 0.6595) (table 6). Intestinal length was comparable between ages and systems, whereas diameter was greater in adult birds, possibly as a result of greater functional capacity and digestive adaptation acquired with age. By contrast, diameter was higher in adult birds (P<0.0001). This result suggested that, at six months, the small intestine may be in a phase of greater tissue “prioritization” in terms of mass (possibly a greater relative investment in digestive tissue), whereas in adulthood a less proportionally heavy intestine is observed, but with a larger caliber, potentially associated with greater functional capacity/ luminal flow; which suggested a greater proportion of the organ during phases of active growth.

Tabla 6. Morphometry of the small intestine in creole hens of two ages from different rearing systems.

Rearing system	Age	Bird weight (g)	Absolute weight (g)	Relative weight (%)	Length (cm)	Diameter (mm)
Grazing	1 year	2196.20 ± 134.61	23.44 ± 1.41	1.07 ± 0.00	119.80 ± 5.40	8.26 ± 0.21
Grazing	6 months	1752.80 ± 90.84	33.60 ± 3.21	1.91 ± 0.12	113.00 ± 2.24	7.51 ± 0.14
Semi-grazing	1 year	2139.00 ± 107.49	22.78 ± 1.33	1.06 ± 0.01	115.60 ± 2.07	8.36 ± 0.18
Semi-grazing	6 months	1701.60 ± 48.89	31.62 ± 1.19	1.86 ± 0.07	119.40 ± 7.37	7.56 ± 0.18
p-value (age)		<0.0001	<0.0001	<0.0001	0.5490	<0.0001
p-value (rearing system)		0.2303	0.1470	0.3587	0.6595	0.3516

Six-month-old birds showed higher absolute and relative small intestine weight values (P<0.0001), while diameter was greater in adult birds (P<0.0001) (table 6). This trend suggested that, during the juvenile stage, the intestine prioritized tissue growth, whereas in adulthood its functional caliber increased.

In the small intestine, it was observed that six-month-old birds showed the highest values of both absolute and relative weight in the two rearing systems, with figures ranging between 31.62 and 33.60 g and between 1.86 and 1.91%. This suggested a higher proportion of the organ in relation to total body weight during phases of active growth (table 6).

Intestinal length was comparable among the different ages and rearing systems, with small variations that did not alter this trend, while diameter was greater in adult birds from both the grazing and semi-grazing systems, which could be the result of higher functional capacity and digestive adaptation acquired with age.

This trend indicated that, during juvenile stages, the small intestine underwent accelerated proportional growth to meet higher metabolic demands, whereas in adulthood it tended to stabilize its relative size and increase its thickness. Although these results differed partially from what was reported by Nitsan et al. (1991, 2011) and Nir et al. (2020), who observed maxima in relative weight in the first days post-hatch, they reflected adaptations typical of Creole birds in extensive and semi-extensive systems, where dietary diversity and growth rate differ from intensive systems (Gorenz et al., 2024).

From the literature, it is recognized that intestinal morphology responds to both ontogeny and diet and growth rate; for example, studies in broilers have shown relationships between body growth, relative weights of digestive organs, and intestinal lengths (Gorenz et al., 2024).

Large intestine

In the large intestine, age had a consistent effect: one-year-old birds showed greater weights (absolute and relative), as well as greater length (*P*= 0.0004) and diameter (*P*<0.0001) (table 7). Unlike other organs, an effect of the rearing system on length was also detected here (*P*= 0.0139), which should be explicitly reflected in the interpretation: although the system's impact is smaller than that of age, it is not negligible for that variable (table 7).

The large intestine showed greater absolute and relative weights in adult birds (*P*<0.001), as well as a significant effect of the rearing system on length (*P*= 0.0139) (table 7). This suggests that, although age is the dominant factor, the rearing system may modulate specific structural aspects of the colon.

Tabla 7. Morphometry of the large intestine in creole hens of two ages from different rearing systems.

Rearing system	Age	Bird weight (g)	Absolute weight (g)	Relative weight (%)	Length (cm)	Diameter (mm)
Grazing	1 year	2196.20 ± 134.61	8.28 ± 0.39	0.37 ± 0.00	7.70 ± 0.45	7.50 ± 0.08
Grazing	6 months	1752.80 ± 90.84	3.34 ± 0.38	0.19 ± 0.01	7.24 ± 0.21	6.78 ± 0.09
Semi-grazing	1 year	2139.00 ± 107.49	7.84 ± 0.39	0.37 ± 0.03	8.54 ± 0.17	7.56 ± 0.18
Semi-grazing	6 months	1701.60 ± 48.89	3.08 ± 0.25	0.18 ± 0.01	7.54 ± 0.58	6.74 ± 0.11
p-value (age)		<0.0001	<0.0001	0.0003	0.0004	<0.0001
p-value (rearing system)		0.2303	0.6203	0.4196	0.00139	0. 5925

One-year-old hens showed significantly higher absolute and relative large intestine weights than six-month-old birds, in both rearing systems. In contrast, length and diameter showed smaller variations, with slightly higher values in adult birds.

These results suggested that structural maturity of the large intestine was reached around the first year of life and that the rearing system had a limited impact on its morphometry. When comparing these values with those reported in other avian species (Mobini, 2011), Creole hens showed an intermediate large intestine length, consistent with a varied diet and a high capacity for digestive adaptation.

Overall, the results confirmed that age was the main determinant factor of morphometric development of the digestive tract in Creole hens, while the rearing system exerted a secondary effect, mainly during juvenile stages. This pattern reflected the functional plasticity of the digestive system of creole hens and its adaptation to different production systems.

In comparative terms, variation in the large intestine among birds may be related to diet and the degree of hindgut fermentation; however, under this design (and with homogeneous feeding after acquisition), maturity explained the main change and the system appears to subtly modulate length. Recent findings in Poultry Science highlight that the relative development of digestive organs and intestinal characteristics is associated with growth and metabolic profiles, even when there are no marked changes in histomorphology (Gorenz et al., 2024).

These findings suggest that full structural maturity of the colon is achieved around the first year of life, while the type of rearing has a minimal impact on these morphometric characteristics. For example, in animals of the same species with different production purposes, in broiler chickens the total length of the ceca and colon was found to be 14.64 to 39.84 cm and 2.22 to 10.83 cm, respectively, whereas these values in bronze turkey, adult chicken, penguin, and tinamou were 64.4 to 91.4 cm and 33.4 to 42 cm, 28 to 47 cm and 8 to 11 cm, 1.4 to 2.6 cm and 2.15 to 5.7 cm, and 2.5 to 6.2 cm and 2.8 to 5.8 cm, respectively. The total length of each cecum in broiler chickens was found to be 7.32 to 19.92 cm.

These sizes in some species, such as ducks, geese, and pigeons, ranged between 10 and 20 cm, 23 and 28 cm, and 1 and 3.5 cm, respectively. These variations indicated diversity in intestinal structure that was related to feeding type and digestive physiology (Mobini, 2011). In contrast, the Creole hens analyzed in this research showed an intermediate large intestine length, which is consistent with their varied diet and their ability to adapt during the digestive process. This reinforces the idea that large intestine development is strongly influenced by age and feeding type, and that Creole hens have a flexible and functional digestive system, adapted to both forage and concentrate.

Conclusion

Age was identified as the factor with the greatest influence on the morphometric characteristics of the digestive system in Creole hens, while the type of management (grazing or semi-grazing) generated marginal variations, without determining effects on the parameters evaluated. In general, one-year-old birds showed higher values of weight, length, and diameter in the digestive organs analyzed, which evidences a greater degree of anatomical development and structural stability.

In contrast, six-month-old hens showed organs of smaller size and absolute weight; however, in some cases they recorded higher relative values, consistent with the physiological processes associated with the phase of growth and organ maturation. Overall, these findings provide relevant information for the morphometric characterization of Creole hens in Ecuador and constitute a useful reference for future research, as well as for optimizing management, selection, and production strategies in rural poultry systems.

Conflict of interest

The authors declare that they have no conflicts of interest in the present publication at any of its stages.

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Declaration CRediT

María Teresa Cedeño Loor: formal analysis, writing—original draft of the article, and writing—review and editing of the article, funding acquisition. **Paula Leonela Macías Moreira:** investigation, methodology, visualization, writing—original draft of the article, funding acquisition. **Vicente Alejandro Intriago Muñoz:** conceptualization, formal analysis, visualization, writing—original draft of the article.