Philipp J Vet Anim Sci 2024 50(1):33-44

# COMPARISON OF GASTRO-INTESTINAL TRACT MORPHOMETRY AND PROPORTIONS OF LEAN, FAT, AND BONE OF *DARAG* NATIVE CHICKEN AND SLOW-GROWING COMMERCIAL BROILER

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## ABSTRACT

**One hundred *Darag* Philippine native and 100 slow-growing commercial broiler day-old chicks were used to compare the gastro-intestinal tract (GIT) measurements, percent lean, fat, and bone, and their allometric growth up to 15 weeks of age. Using Completely Randomized Design, 10 replicates per group with 10 birds each were housed in a complete confinement system following standard management practice for slow-growing commercial broiler. Data were analyzed using t-test. Results showed that slow-growing commercial broiler had higher body weight and longer and heavier segments of GIT (*$P<0.05$*) all throughout the study. However, the normalized gizzard mass was higher in *Darag* (*$P<0.05$*). Normalized mass of the small intestine segments were also higher in *Darag* from 5 to 7 weeks and 15 weeks of age (*$P<0.05$*). Slow-growing commercial broiler had higher percentage lean, while *Darag* had higher proportion of bone particularly from 14 to 15 weeks of age (*$P<0.05$*). Both *Darag* native and slow-growing chicken have negative allometric GIT growth, while lean and bone growths have positive allometries (*$P<0.05$*). This study provides baseline information on the morphometry of GIT and proportions of lean, fat, and bone in *Darag* native chicken which provides valuable insights into their digestive capacity and nutrient utilization for growth.**

Keywords: allometric growth, Darag native chicken, GIT morphometry, lean-fat-bone, slow-growing broiler

## INTRODUCTION

Majority of chicken meat consumption in the world are from meat of fast growing broilers (Chodova *et al.*, 2021) while native/local chicken and slow-growing commercial broilers remain to have a niche specialty market. However, as consumer preferences nowadays shift toward healthier and naturally produced products and as they become more aware of bird welfare, native chicken and other slow-growing breeds are gaining considerable public interest (Fanatico *et al.*, 2007; Rayner *et al.*, 2020; Baxter *et al.*, 2021; Sarmiento-Garcia *et al.*, 2021). Native or local chicken is known for its disease resistance and outstanding meat flavor and savory taste, and is sold at premium prices (Choo *et al.*, 2014; Chumngoen and

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Tan, 2015). In 1985, the development of *Darag*, a Philippine native chicken, started in West Visayas State University (WVSU) in Iloilo province and is now a flagship native chicken breed in the country (DOST-PCAARRD, 2022). It can reach market weight of 800 g to 1.0 kg in 15 to 16 weeks of age. While there are already several commercial multiplier farms for this breed, its nutrient requirement and feeding management remain to be a major challenge. Slow-growing commercial broiler such as Hubbard Redbro is being raised for 8 to 10 weeks with a target market weight of 1.8 kg. It is the closest model for *Darag* native chicken in terms of production management standardization under alternative systems. Continuous breed development efforts for *Darag* native chicken is being carried out, however, its production system must also be established starting with the understanding of the development of its digestive system in relation to its growth potential. A study by Marchewka *et al.* (2021) on commercial and indigenous chicken breeds identified different correlations between the measurements of the gastrointestinal tract and its contents. These correlations resulted in varying growth rates, depending on the degree of genetic selection each strain had undergone. Therefore, it is hypothesized that the length, weight, and allometric growth of gastrointestinal tract, and weight of fat, lean, and bone of Darag and Redbro would be different from each other. This study will compare the GIT morphometry and proportions of lean, fat, and bone of *Darag* native chicken and slow-growing commercial broiler.

## MATERIALS AND METHODS

The study was conducted for 15 weeks at the University Animal Farm of College of Agriculture and Food Science, University of the Philippines Los Baños (14.145485903561903, 121.25209186479026) with protocol approved by the UPLB Institutional Animal Care and Use Committee (Approval Reference No.: UPLB-2023-036). One hundred (100) heads day-old *Darag* Philippine native chicks were produced at the University Native Animal Farm at UPLB. On the other hand, the 100 heads day-old Hubbard Redbro slow-growing commercial broiler chicks were obtained from Bounty Agro-Ventures Inc. (BAVI) hatchery in Bulacan province. Water with electrolytes were given upon arrival of the birds. All the chicks were given vaccine against Marek's disease and infectious bronchitis disease (IBD) one day after the arrival at the farm. The chicks were housed in a complete confinement system in an elevated cage with slatted flooring. Each cage has a dimension of 4 ft (L) x 3.0ft (W) x 2.5ft (H). The duration of light exposure was 24 hours for the first seven days, 18 hours until 21 days, and 12 hours thereafter until harvest. House temperature and relative humidity were monitored regularly. A crumble diet was fed on restricted basis for both groups and *ad libitum* water was given for the whole duration of the experiment. Commercial booster feed (CP 21.5%, C. Fat 3.0%, C. Fiber 3.5%, Ca 0.90-1.10%, P 0.55%) was given from 0 to 4 weeks of age. Commercial starter feed (CP 19.5%, C. Fat 3.0%, C. Fiber 6.0%, Ca 0.90-1.10%, P 0.55%) was fed from 5 to 8 weeks of age, and commercial grower feed (CP 15.5%, C. Fat 3.0%, C. Fiber 6.0%, Ca 0.90-1.10%, P 0.70%) from 9 weeks of age until harvest.

The experiment was laid out in a Completely Randomized Design (CRD) with breed of the chicken as the main factor with 10 replicates per group and 10 birds per replicate. Same housing, diet, and management were given to all birds. To attain the desired body weight for both *Darag* native and Redbro chicks, they were raised until 15 weeks of age.

Body weight was collected weekly from 0 to 15 weeks of age. For the intestinal morphometric traits and lean, fat, bone measurements, three birds per group were sacrificed on a weekly basis. The length of each intestinal segment as defined by de Verdal *et al.* (2010) was measured using a 45-cm aluminum ruler (00.0 cm). The weight of the glandular stomach, gizzard, duodenum, jejunum, ileum, cecum, weight of the fat/skin, lean, and bone were determined using an analytical balance (Shimadzu, Tokyo, Japan), contents of the intestinal segment were not removed during weighing. The following parameters were calculated to compare the length, weight, and allometric growth of gastrointestinal tract, fat, lean, and bone of *Darag* and Redbro: (1) normalized mass of the proventriculus, gizzard and intestinal segments were calculated as [mass (g)/total liveweight (g)] × 100.

All data were tested for normality and equality of variance and were subjected to t-test using SAS On Demand for Academics software (SAS Inc, Cary, USA). All statistical analyses were two-sided with significance defined at p-value < 0.05. To examine whether the relative changes of the proventriculus, gizzard, and intestinal segments masses were proportionate or disproportionate to overall body weight relative change, the allometric relationships were determined using the equation $ln\ y = k\ ln\ x + ln\ b$ where *ln* is natural logarithm, *y* is the mass of the proventriculus, gizzard, or intestinal segments, *x* is the weight of the bird, *b* is a constant reflecting the relationship between the mass of the GIT segment and the body weight of the bird. The symbol *k* is the slope of the regression line relating *y* and *x* and represents the rate of change of the GIT segment with changes in the body weight. If the value of *k* is equal to 1 (isometry), the rate of change is proportionate. If *k* departs significantly from a value of 1, then the relationship is allometric i.e. $k > 1$ = positive allometry and $k < 1$ = negative allometry (Alshamy *et al.*, 2018). The level of significance (a) used was also 0.05.

## RESULTS AND DISCUSSION

The average weekly body weight of *Darag* and slow-growing broiler chickens were significantly different from day-old up to 15 weeks old, with slow-growing broiler chickens being significantly higher at all ages (Table 1). *Darag* demonstrated an average daily weight gain (ADG) of 9 grams per day while slow-growing broiler chicken had an ADG of 29 g. Slow-growing broiler chicken was 3x heavier than *Darag* at 15 weeks of age. Since the birds were raised under similar conditions, the differences in their live weight can be attributed to their genetics which play a significant role in determining their growth potential. The genetic limitation for growth in local chicken under natural environment lead to low productivity in terms of the growth rate and egg production (Chomchuen *et al.*, 2022). Slow-growing broiler chickens, although bred to have less than 20 g ADG (Dal Bosco *et al.*, 2012) still possess genetic potential for growth that led to higher body weight compared to *Darag* native chicken in this study. *Darag* have a slower growth rate compared to slow-growing broiler chickens, therefore necessitating a longer period to reach its market weight. Obtained body weight of *Darag* in this study agrees with literature wherein there is average growth rate of 63.15 g/week (Bejar *et al.*, 2012). Meanwhile, body weights of Redbro slow-growing commercial broiler in this study were in agreement with the values reported by Sarmiento-García *et al.* (2021) under controlled housing. Optimal productivity of chicken genotypes can be achieved by balancing the nutritional requirement and growth rate (Chodova *et al.*, 2021).

Table 1. Mean body weight of Darag native and Redbro slow-growing commercial broiler from 0 to 15 weeks of age.

| Age (Week) | Darag | Redbro |
|---|---|---|
| BWT0, g** | 28.93 ± 0.76 | 42.60 ± 0.30 |
| BWT1, g** | 40.57 ± 0.90 | 89.00 ± 1.12 |
| BWT2, g** | 77.40 ± 0.80 | 232.90 ± 3.57 |
| BWT3, g** | 118.00 ± 1.90 | 425.30 ± 1.33 |
| BWT4, g** | 174.20 ± 9.87 | 642.50 ± 4.26 |
| BWT5, g** | 232.20 ± 7.46 | 831.50 ± 37.03 |
| BWT6, g** | 290.30 ± 20.84 | 1030.00 ± 10.00 |
| BWT7, g** | 363.50 ± 32.82 | 1275.00 ± 22.91 |
| BWT8, g** | 444.90 ± 11.50 | 1545.00 ± 20.00 |
| BWT9, g** | 513.10 ± 46.82 | 1733.30 ± 10.40 |
| BWT10, g** | 593.90 ± 57.65 | 2048.30 ± 23.62 |
| BWT11, g** | 653.40 ± 18.58 | 2178.30 ± 10.40 |
| BWT12, g** | 734.90 ± 5.10 | 2620.00 ± 121.30 |
| BWT13, g** | 791.60 ± 69.80 | 2831.70 ± 124.20 |
| BWT14, g** | 920.80 ± 31.14 | 2873.30 ± 95.04 |
| BWT15, g** | 966.70 ± 68.98 | 3066.70 ± 209.80 |

**(p<0.01)

The length of different sections of the small and large intestines were increasing from 0 to 15 weeks with slow-growing broiler chickens having significantly longer segments compared to *Darag* native chicken (Table 2). The length of the duodenum demonstrated significant differences between groups across all ages. At day-old, *Darag* displayed an average length of 6.5 cm, whereas slow-growing broiler chickens measured 1.6x longer (P=0.0210). Interestingly, as the chickens ages beyond 12 weeks old, the duodenum length showed no significant difference, except on the 14$^{th}$ week. The length of the jejunum was different (P<0.05) between the slow-growing broiler and *Darag* native chickens during majority of the periods. At day-old, no significant difference in jejunum length was detected between the two breeds. However, starting at week 1 to 5, and 7 to 10 weeks old, the jejunum length of slow-growing broiler chickens was consistently and significantly higher than *Darag*. The enhanced length of the jejunum in slow-growing broiler chickens chicken suggests a potentially higher surface area available for nutrient absorption compared to *Darag* chickens during this critical period of growth. However, from week 11 to 15, except for week 13, results showed no significant differences in jejunum length between the two breeds. This suggests that the development of jejunum in *Darag* chickens catches up with that of slow-growing broiler chickens, resulting in comparable lengths during the later stage of development. This also suggests that from 11 to 15 weeks of age, the surface area for nutrient absorption in *Darag* may be comparable with slow-growing broiler chickens and

Table 2. Length of the different segments of the intestines (duodenum, jejunum, ileum, cecum) of Darag native and slow-growing commercial broiler from 0 to 15 weeks of age.

| Age (Week) | LENGTH (cm)[1] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Duodenum | | Jejunum | | Ileum | | Cecum | |
| | Darag | Redbro | Darag | Redbro | Darag | Redbro | Darag | Redbro |
| 0 | 6.47[b] | 10.40[a] | 10.20 | 15.07 | 9.73[b] | 16.57[a] | 3.17[b] | 4.43[a] |
| 1 | 13.17 | 13.93 | 16.83[b] | 30.53[a] | 18.70[b] | 28.10[a] | 4.77[b] | 6.70[a] |
| 2 | 12.00[b] | 19.47[a] | 20.07[b] | 45.47[a] | 19.33[b] | 41.47[a] | 4.97[b] | 9.67[a] |
| 3 | 14.73[b] | 25.00[a] | 25.00[b] | 51.17[a] | 26.30[b] | 51.73[a] | 6.10[b] | 11.43[a] |
| 4 | 17.80[b] | 25.80[a] | 31.97[b] | 49.67[a] | 31.40[b] | 47.87[a] | 6.57[b] | 12.83[a] |
| 5 | 16.27[a] | 25.57[b] | 30.77[b] | 47.83[a] | 30.50[b] | 47.10[a] | 8.03[b] | 13.33[a] |
| 6 | 18.50 | 25.73 | 34.13 | 44.57 | 32.27[b] | 49.80[a] | 8.20[b] | 15.57[a] |
| 7 | 17.53[b] | 26.13[a] | 25.70[b] | 54.73[a] | 27.13[b] | 51.07[a] | 9.50[b] | 16.53[a] |
| 8 | 19.57[b] | 29.10[a] | 30.30[b] | 50.00[a] | 31.10[b] | 52.67[a] | 9.57[b] | 16.93[a] |
| 9 | 19.20[b] | 28.63[a] | 30.43[b] | 50.40[a] | 31.37[b] | 55.00[a] | 7.70[b] | 20.97[a] |
| 10 | 16.37[b] | 25.83[a] | 26.80[b] | 48.70[a] | 28.07[b] | 57.77[a] | 9.03[b] | 16.60[a] |
| 11 | 16.43[b] | 23.23[a] | 31.20 | 44.60 | 33.70[b] | 48.50[a] | 11.47[b] | 18.17[a] |
| 12 | 18.70 | 26.17 | 32.00 | 50.67 | 33.20[b] | 54.30[a] | 12.50[b] | 20.17[a] |
| 13 | 21.67 | 25.63 | 30.10[b] | 53.03[a] | 34.03[b] | 60.27[a] | 11.10[b] | 18.97[a] |
| 14 | 18.70[b] | 25.70[a] | 30.23 | 48.03 | 31.40[b] | 52.57[a] | 11.47[b] | 19.00[a] |
| 15 | 20.40 | 26.53 | 39.10 | 48.07 | 39.90 | 49.43 | 13.53[b] | 19.17[a] |

[1]Means of the variables in the same row with different superscript are significantly different ($p<0.05$).

that they may be offered with the same type of feed. The length of the ileum exhibited statistically significant differences between two breeds from day-old up to 14 weeks old. However, at 15 weeks old, no significant differences in ileum length were observed. This indicates that the growth rates or patterns of the ileum in *Darag* chickens catch up with slow-growing broiler chickens, resulting in comparable lengths by 15 weeks old. The average weekly increase in ileum length of both groups was 2.0 cm. The length of the cecum displayed consistent and statistically significant differences ($P<0.05$) from day-old to 15 weeks old. The cecum length of slow-growing broiler chickens was significantly greater than that of *Darag*. Understanding the variations in cecum length can provide valuable insights in digestive physiology and potential differences in microbial fermentation of the fibrous feed materials. Study of Ghayour-Najafabadi *et al.* (2017) in diet of birds using wheat or corn showed induced alterations in size (weight and length) of gut segments and digestive organs wherein increased caeca weight in the birds fed with wheat-based diets had superior growth performance compared to the birds fed with corn-based diets. Further studies by Lisnahan and Nahak (2020) on native Indonesian chickens demonstrated that supplementation with varying levels of L-Threonine and L-Tryptophan significantly improved the morphology of

Table 3. Weight of the different segments of the gastro-intestinal tract of Darag native and slow-growing commercial broiler from 0 to 15 weeks of age.

| Age (Week) | WEIGHT OF GI TRACT SEGMENTS (grams) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Proven | | Gizzard | | Duodenum | | Jejunum | | Ileum | | Cecum | |
| | Darag | Redbro | Darag | Redbro | Darag | Redbro | Darag | Redbro | Darag | Redbro | Darag | Redbro |
| 0 | 0.22$^{b}$ | 0.38$^{a}$ | 1.56$^{b}$ | 2.49$^{a}$ | 0.31$^{b}$ | 0.55$^{a}$ | 0.22 | 0.35 | 0.19$^{b}$ | 0.30$^{a}$ | 0.20 | 0.21 |
| 1 | 0.39$^{b}$ | 1.04$^{a}$ | 2.77$^{b}$ | 5.57$^{a}$ | 1.28$^{b}$ | 2.22$^{a}$ | 0.79$^{b}$ | 2.36$^{a}$ | 0.76$^{b}$ | 1.73$^{a}$ | 0.47$^{b}$ | 0.90$^{a}$ |
| 2 | 0.67$^{b}$ | 2.07$^{a}$ | 4.05$^{b}$ | 10.08$^{a}$ | 1.74$^{b}$ | 3.95$^{a}$ | 1.40$^{b}$ | 5.89$^{a}$ | 1.05$^{b}$ | 3.62$^{a}$ | 1.13$^{b}$ | 1.94$^{a}$ |
| 3 | 0.96$^{b}$ | 2.80$^{a}$ | 5.49$^{b}$ | 13.19$^{a}$ | 2.28$^{b}$ | 7.05$^{a}$ | 2.53$^{b}$ | 10.12$^{a}$ | 1.69$^{b}$ | 7.11$^{a}$ | 1.04$^{b}$ | 4.16$^{a}$ |
| 4 | 1.31$^{b}$ | 3.67$^{a}$ | 8.38$^{b}$ | 14.87$^{a}$ | 3.28$^{b}$ | 7.87$^{a}$ | 4.24$^{b}$ | 12.63$^{a}$ | 3.32$^{b}$ | 8.22$^{a}$ | 2.21$^{b}$ | 4.40$^{a}$ |
| 5 | 1.61$^{b}$ | 4.35$^{a}$ | 7.85$^{b}$ | 16.86$^{a}$ | 3.25$^{b}$ | 8.79$^{a}$ | 4.55$^{b}$ | 13.61$^{a}$ | 3.33$^{b}$ | 9.81$^{a}$ | 1.96$^{b}$ | 6.53$^{a}$ |
| 6 | 2.06$^{b}$ | 5.39$^{a}$ | 12.13$^{b}$ | 18.98$^{a}$ | 3.88$^{b}$ | 9.62$^{a}$ | 5.53$^{b}$ | 13.01$^{a}$ | 4.12$^{b}$ | 10.98$^{a}$ | 2.63$^{b}$ | 7.36$^{a}$ |
| 7 | 3.31$^{b}$ | 5.83$^{a}$ | 12.17$^{b}$ | 23.79$^{a}$ | 4.29$^{b}$ | 8.74$^{a}$ | 6.46$^{b}$ | 15.82$^{a}$ | 4.99$^{b}$ | 11.32$^{a}$ | 3.69$^{b}$ | 7.97$^{a}$ |
| 8 | 2.96$^{b}$ | 5.30$^{a}$ | 15.34$^{b}$ | 23.14$^{a}$ | 4.07$^{b}$ | 9.30$^{a}$ | 5.42$^{b}$ | 16.31$^{a}$ | 4.17$^{b}$ | 11.05$^{a}$ | 4.76$^{b}$ | 11.84$^{a}$ |
| 9 | 2.90$^{b}$ | 5.65$^{a}$ | 17.06$^{b}$ | 30.31$^{a}$ | 4.62$^{b}$ | 8.94$^{a}$ | 6.12$^{b}$ | 16.28$^{a}$ | 5.05$^{b}$ | 12.28$^{a}$ | 4.42$^{b}$ | 9.33$^{a}$ |
| 10 | 2.76$^{b}$ | 6.45$^{a}$ | 16.19$^{b}$ | 28.79$^{a}$ | 4.24$^{b}$ | 12.04$^{a}$ | 6.22$^{b}$ | 20.58$^{a}$ | 5.18$^{b}$ | 17.93$^{a}$ | 3.97$^{b}$ | 11.51$^{a}$ |
| 11 | 2.68$^{b}$ | 6.64$^{a}$ | 17.38$^{b}$ | 37.75$^{a}$ | 4.26$^{b}$ | 10.79$^{a}$ | 6.63$^{b}$ | 18.84$^{a}$ | 5.07$^{b}$ | 14.77$^{a}$ | 5.30$^{b}$ | 10.34$^{a}$ |
| 12 | 2.69$^{b}$ | 6.97$^{a}$ | 18.95$^{b}$ | 26.21$^{a}$ | 5.05$^{b}$ | 11.37$^{a}$ | 7.96$^{b}$ | 21.51$^{a}$ | 6.09$^{b}$ | 17.51$^{a}$ | 4.70$^{b}$ | 13.53$^{a}$ |
| 13 | 2.73$^{b}$ | 7.87$^{a}$ | 23.74 | 32.91 | 5.93$^{b}$ | 13.65$^{a}$ | 7.89$^{b}$ | 25.34$^{a}$ | 6.34$^{b}$ | 20.52$^{a}$ | 5.63$^{b}$ | 10.82$^{a}$ |
| 14 | 2.80$^{b}$ | 6.53$^{a}$ | 19.88$^{b}$ | 29.79$^{a}$ | 4.83$^{b}$ | 10.59$^{a}$ | 8.04$^{b}$ | 19.50$^{a}$ | 5.86$^{b}$ | 15.54$^{a}$ | 6.45$^{b}$ | 10.58$^{a}$ |
| 15 | 2.99$^{b}$ | 7.65$^{a}$ | 25.26 | 35.65 | 5.86$^{b}$ | 12.06$^{a}$ | 10.77$^{b}$ | 19.54$^{a}$ | 8.09$^{b}$ | 16.97$^{a}$ | 6.64$^{b}$ | 13.50$^{a}$ |

[1]Means of the variables in the same row with different superscript are significantly different ($p<0.05$).

Table 4. Relative weight of GIT to live weight (%) of Darag native and slow-growing commercial broiler from 0 to 15 weeks of age.

| Age (week) | PERCENT GI ORGAN WEIGHT RELATIVE TO THE LIVE WEIGHT | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Proven | | Gizzard | | Duodenum | | Jejunum | | Ileum | | Cecum | |
| | Darag | Redbro | Darag | Redbro | Darag | Redbro | Darag | Redbro | Darag | Redbro | Darag | Redbro |
| 0 | 0.77 | 0.90 | 5.41 | 5.84 | 1.07 | 1.30 | 0.76 | 0.82 | 0.67 | 0.70 | 0.69 | 0.50 |
| 1 | 0.95 | 1.16 | 6.82 | 6.26 | 3.16 | 2.49 | 1.93[a] | 2.65[b] | 1.87 | 1.95 | 1.14 | 1.01 |
| 2 | 0.86 | 0.89 | 5.22 | 4.32 | 2.24[a] | 1.70[b] | 1.81 | 2.52 | 1.36 | 1.55 | 1.45[a] | 0.83[b] |
| 3 | 0.82 | 0.66 | 4.65[a] | 3.10[b] | 1.93 | 1.66 | 2.15 | 2.38 | 1.43 | 1.67 | 0.88 | 0.98 |
| 4 | 0.76 | 0.57 | 4.83[a] | 2.31[b] | 1.88[a] | 1.22[b] | 2.45 | 1.97 | 1.91 | 1.28 | 1.27 | 0.68 |
| 5 | 0.69 | 0.52 | 3.38[a] | 2.03[b] | 1.39[a] | 1.06[b] | 1.96[a] | 1.64[b] | 1.43[a] | 1.18[b] | 0.84 | 0.79 |
| 6 | 0.71 | 0.52 | 4.20[a] | 1.84[b] | 1.35[a] | 0.93[b] | 1.92[a] | 1.26[b] | 1.43[a] | 1.07[b] | 0.92 | 0.71 |
| 7 | 0.92 | 0.46 | 3.34[a] | 1.86[b] | 1.19[a] | 0.69[b] | 1.79[a] | 1.24[b] | 1.39[a] | 0.89[b] | 1.00 | 0.63 |
| 8 | 0.67 | 0.34 | 3.45[a] | 1.50[b] | 0.92[a] | 0.60[b] | 1.22 | 1.05 | 0.94 | 0.72 | 1.07 | 0.77 |
| 9 | 0.57[a] | 0.33[b] | 3.34[a] | 1.75[b] | 0.91[a] | 0.52[b] | 1.20 | 0.94 | 0.99 | 0.71 | 0.88 | 0.54 |
| 10 | 0.47 | 0.31 | 2.73[a] | 1.40[b] | 0.72 | 0.59 | 1.05 | 1.01 | 0.87 | 0.88 | 0.67 | 0.56 |
| 11 | 0.41 | 0.30 | 2.66[a] | 1.73[b] | 0.65 | 0.50 | 1.02 | 0.87 | 0.78 | 0.68 | 0.81 | 0.47 |
| 12 | 0.37[a] | 0.27[b] | 2.58[a] | 1.00[b] | 0.69 | 0.43 | 1.08 | 0.82 | 0.83 | 0.67 | 0.64 | 0.52 |
| 13 | 0.35[a] | 0.28[b] | 3.01[a] | 1.16[b] | 0.75[a] | 0.48[b] | 1.00 | 0.89 | 0.80 | 0.73 | 0.72 | 0.38 |
| 14 | 0.30[a] | 0.23[b] | 2.16[a] | 1.03[b] | 0.52[a] | 0.37[b] | 0.87 | 0.68 | 0.64 | 0.54 | 0.70 | 0.37 |
| 15 | 0.31 | 0.25 | 2.63[a] | 1.15[b] | 0.60[a] | 0.40[b] | 1.11[a] | 0.64[b] | 0.83[a] | 0.55[b] | 0.69[a] | 0.44[b] |

[1]Means of variables in the same row with different superscript are significantly different ($p<0.05$).

the small intestine. Specifically, there were notable increases in the villi height and width, as well as the crypt depth of the duodenum, jejunum, and ileum. These enhancements led to a significant increase in the body weight of the birds.

The weight of the glandular stomach of slow-growing broiler chicken was higher (P<0.05) than *Darag* in most ages (Table 3). The proventriculus weight of Darag and slow-growing commercial broiler grew by 14x times and 20x, respectively, from 0 to 15 weeks of age. Values obtained were in agreement to the findings of Juanchich *et al.* (2021) on broilers divergently selected for digestive efficiency (D+/D-). These results indicate that slow-growing broiler chickens experienced a more substantial growth in glandular stomach mass compared to *Darag*. On the other hand, the normalized proventriculus mass between the two groups generally showed no significant differences across ages except on weeks 9, 12 to 14 (Table 4).

The gizzard weight of the slow-growing broiler was higher (P<0.05). Both groups displayed gradual growth of the gizzard over time. These results suggest that slow-growing broiler chickens experienced a relatively faster growth rate in gizzard weight compared to *Darag* of the same age. However, when the gizzard weight was normalized relative to its body weight, *Darag* had a higher values (P<0.05). Starting from week 3 up to week 15, *Darag* consistently showed a higher gizzard-to-live weight ratio which was in consonant with the findings of Alshamy *et al.* (2018) on slower growing genotypes. The differences in the normalized gizzard mass highlighted the potential variations in the mechanical digestion and processing capabilities between the two breeds. A larger gizzard relative to body weight may indicate a greater ability to effectively break down feed particles and enhance nutrient extraction suggesting potential use of whole-grains and other courser feed ingredients in *Darag* chicken. The weights of the duodenum, jejunum, and ileum of slow-growing commercial broiler chickens were all significantly higher at all ages compared to *Darag* (Table 3). The initial duodenum weight of *Darag* grew by 19x while it jejunum grew by 49x from 0 to 15 weeks of age. Lastly, the ileum of both groups grew substantially by 42x and 57x for *Darag* and slow-growing broiler chickens, respectively. These were in agreement with the findings of Alshamy *et al.* (2018). Juanchich *et al.* (2021) hypothesized that gizzard and jejunum development are the ones driving digestibility phenotypes between broilers divergently selected for digestive efficiency (i.e. D+ and D- broilers). These results emphasize the significant differences in the size and growth patterns of gizzard and different sections of small intestines between the two breeds providing valuable insights into the digestive functions and potential differences in feed utilization and nutrient absorption capabilities. Study of Khosravinia *et al.* (2015) in diet of broiler chicken wherein inclusion of 30 g/kg of citric acid showed increased proventriculus, gizzard, and ileum weight percentage resulted to improved Ileal digestibility of crude protein (CP), apparent metabolizable energy (AME), and total phosphorus (tP). Hence, there has been improvement in zootechnical indices as well as nutrient retention in the broiler chicken.

Table 5 shows the percentage of lean, bone, and fat-skin relative to carcass weight at different weeks of age. Generally, there were no significant differences observed except that percentage lean was higher while percentage bone was lower (p<0.05) in slow-growing commercial broiler. Higher proportion of lean was always observed in faster growing genotypes (Fanatico *et al.*, 2007; Chodova *et al.*, 2021). These findings suggest that *Darag* has a higher bone mass in proportion to its carcass weight indicating potentially stronger skeletal development. Percent fat-skin was higher (p<0.05) in slow-growing commercial broiler at 9, 11, and 14 weeks of age. Slow-growing broiler chicken has a tendency for greater fat accumulation during these particular stages.

For the results on allometric growth analysis, all *k* values were significantly different from 1.0 (Table 6) suggesting that growth proportions of the GIT, lean, fat/skin, and bone do not follow a simple linear relationship with body weight of the chickens. The GIT of the two breeds had negative allometry, while the lean and bone had positive allometry. These findings were in agreement with Alshamy *et al.* (2018). Negative allometry means that the growth of the gastro-intestinal tract is relatively slower compared to the increase in body weight. The negative allometry in the GIT suggests that there may be differences in the digestive capacities or nutrient requirements in relation to body size between the two breeds. On the other hand, both lean muscle and bone showed positive allometry in both breeds. Positive allometry means that the growth of lean muscle and bone is relatively faster compared to overall body weight. This suggests that as the body weight increases, the relative weight of lean muscle and bone increases at a faster rate.

Table 5. Proportion of lean, fat/skin, and bone of Darag native and slow-growing commercial broiler from 0 to 15 weeks of age.

| Age (Weeks) | Percent lean | | Percent bone | | Percent fat-skin | |
|---|---|---|---|---|---|---|
| | **Darag** | **Redbro** | **Darag** | **Redbro** | **Darag** | **Redbro** |
| 1 | 29.88 | 29.98 | 11.20 | 11.36 | 2.43 | 1.82 |
| 2 | 28.08$^{b}$ | 37.11$^{a}$ | 10.78$^{a}$ | 4.75$^{b}$ | 0.65$^{b}$ | 10.70$^{a}$ |
| 3 | 32.83$^{b}$ | 39.94$^{a}$ | 4.01$^{b}$ | 9.68$^{a}$ | 10.81$^{a}$ | 7.09$^{b}$ |
| 4 | 35.72$^{b}$ | 44.95$^{a}$ | 11.50 | 9.17 | 6.82$^{a}$ | 5.91$^{b}$ |
| 5 | 37.48$^{b}$ | 43.01$^{a}$ | 8.43 | 10.66 | 5.55$^{b}$ | 5.73$^{a}$ |
| 6 | 37.93 | 40.31 | 10.30 | 11.11 | 5.41 | 5.31 |
| 7 | 37.43$^{b}$ | 44.99$^{a}$ | 10.05 | 9.45 | 4.86 | 5.56 |
| 8 | 43.05 | 45.28 | 10.52$^{a}$ | 8.93$^{b}$ | 4.06 | 6.33 |
| 9 | 41.79$^{b}$ | 49.51$^{a}$ | 9.49 | 6.61 | 5.12$^{b}$ | 5.67$^{a}$ |
| 10 | 44.96 | 47.04 | 8.59 | 8.54 | 5.09 | 4.96 |
| 11 | 40.83$^{b}$ | 46.78$^{a}$ | 10.58$^{a}$ | 8.89$^{b}$ | 4.08$^{b}$ | 5.59$^{a}$ |
| 12 | 44.48 | 46.11 | 8.94 | 8.58 | 4.26 | 4.95 |
| 13 | 43.06$^{b}$ | 49.19$^{a}$ | 10.52 | 9.04 | 4.32 | 4.41 |
| 14 | 44.99$^{b}$ | 49.35$^{a}$ | 9.57$^{a}$ | 6.25$^{b}$ | 4.12$^{b}$ | 5.92$^{a}$ |
| 15 | 46.12$^{b}$ | 48.89$^{a}$ | 9.33$^{a}$ | 7.75$^{b}$ | 3.74 | 4.63 |

[1]Means of variables in the same row with different superscript are significantly different ($p<0.05$).

Table 6. Allometric growth of the GIT, lean, and bone of Darag native and slow-growing commercial broiler at different growth periods.

| Part | Breed | Period | Slope (k) Mean | Slope (k) Standard Error | CL95% | UL95% | $R^2$ |
|---|---|---|---|---|---|---|---|
| Crop | Darag | 0-7 | 0.90** | 0.05 | 0.7970 | 1.0089 | 0.93 |
| | | 0-10 | 0.84** | 0.04 | 0.7570 | 0.9332 | 0.92 |
| | | 0-15 | 0.86** | 0.03 | 0.8043 | 0.9281 | 0.94 |
| | Redbro | 0-7 | 0.88** | 0.05 | 0.7792 | 0.9882 | 0.94 |
| | | 0-10 | 0.87** | 0.03 | 0.7965 | 0.9469 | 0.94 |
| | | 0-15 | 0.82** | 0.02 | 0.7660 | 0.8750 | 0.95 |
| Proventriculus | Darag | 0-7 | 0.95** | 0.04 | 0.8511 | 1.0501 | 0.95 |
| | | 0-10 | 0.85** | 0.04 | 0.7632 | 0.944 | 0.94 |
| | | 0-15 | 0.70** | 0.03 | 0.7059 | 0.0382 | 0.88 |
| | Redbro | 0-7 | 0.75** | 0.03 | 0.6876 | 0.8211 | 0.96 |
| | | 0-10 | 0.68** | 0.02 | 0.6252 | 0.7411 | 0.95 |
| | | 0-15 | 0.62** | 0.02 | 0.58 | 0.67 | 0.94 |
| Gizzard | Darag | 0-7 | 0.77** | 0.03 | 0.69 | 0.84 | 0.95 |
| | | 0-10 | 0.75** | 0.02 | 0.69 | 0.81 | 0.96 |
| | | 0-15 | 0.72** | 0.02 | 0.68 | 0.76 | 0.96 |
| | Redbro | 0-7 | 0.59** | 0.03 | 0.52 | 0.66 | 0.93 |
| | | 0-10 | 0.58** | 0.02 | 0.53 | 0.64 | 0.94 |
| | | 0-15 | 0.56** | 0.02 | 0.51 | 0.60 | 0.93 |
| Small Intestine | Darag | 0-7 | 1.06** | 0.07 | 0.91 | 1.22 | 0.90 |
| | | 0-10 | 0.88** | 0.06 | 0.75 | 1.01 | 0.86 |
| | | 0-15 | 0.77** | 0.04 | 0.68 | 0.86 | 0.87 |
| | Redbro | 0-7 | 0.92** | 0.06 | 0.79 | 1.05 | 0.91 |
| | | 0-10 | 0.82** | 0.04 | 0.72 | 0.92 | 0.90 |
| | | 0-15 | 0.73** | 0.03 | 0.65 | 0.81 | 0.89 |
| Lean | Darag | 0-7 | 1.26** | 0.02 | 1.22 | 1.30 | 0.99 |
| | | 0-10 | 1.26** | 0.01 | 1.238 | 1.29 | 0.99 |
| | | 0-15 | 1.25** | 0.01 | 1.23 | 1.27 | 0.99 |
| | Redbro | 0-7 | 1.30** | 0.02 | 1.24 | 1.35 | 0.99 |
| | | 0-10 | 1.28** | 0.01 | 1.25 | 1.32 | 0.99 |
| | | 0-15 | 1.26** | 0.01 | 1.23 | 1.29 | 0.99 |
| Bone | Darag | 0-7 | 1.12** | 0.11 | 0.88 | 1.36 | 0.84 |
| | | 0-10 | 1.11** | 0.06 | 0.97 | 1.25 | 0.90 |
| | | 0-15 | 1.13** | 0.04 | 1.04 | 1.21 | 0.94 |
| | Redbro | 0-7 | 1.15** | 0.05 | 1.04 | 1.25 | 0.96 |
| | | 0-10 | 1.10** | 0.03 | 1.02 | 1.18 | 0.96 |
| | | 0-15 | 1.08** | 0.02 | 1.02 | 1.13 | 0.97 |

**k values significantly different from 1.0 ($p<0.01$); $k>1.0$ is positive allometry; $k<1.0$ is negative allometry; CL95 is 95% lower confidence limit; UP95 is 95% upper confidence limit.

## CONCLUSION

The observed differences in length, weight, and allometric growth between slow-growing commercial broiler and *Darag* native chickens may be influenced by a combination of genetic factors, environmental conditions, management, and care. In this study, wherein environment, feeding management and general practice and care given to chickens remained constant, the genetics of the two breeds gave the differences in gastrointestinal tract characteristics. The body weight, length of different sections of the small and large intestine, and weight of intestinal organs of slow-growing broiler chickens were significantly higher at all stages. However, the gizzard weight relative to live weight was significantly higher in *Darag*. In terms of percent lean, slow-growing broiler chickens was significantly higher than Darag. The GIT of both breeds has negative allometry, while the lean and bone of both have positive allometry. This study provides baseline information on the characteristics in terms of length, weight, and allometry of *Darag* native chicken that could aid in developing its management guide. Understanding the dynamics of GIT in Darag native chicken breed can provide valuable insights into their digestive physiology and nutrient absorption capacity. Further research is warranted to explore the underlying mechanisms driving these differences and to investigate potential implications for feed utilization and growth performance of *Darag* native chicken.

## ACKNOWLEDGMENTS

The authors would like to thank the Philippine Council for Agriculture, Aquatic, and Natural Resources Research and Development (PCAARRD) of the Department of Science and Technology (DOST) for the financial support through the project "Genome-wide association study for growth and egg production traits of *Darag* native chicken".

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