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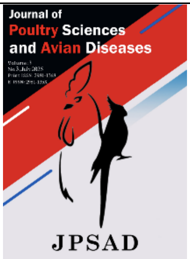

Effect of Broiler Strain, Sex, and Age on the Live Body Weight and Relative Weights of the Visceral Organs in Broiler Chickens

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A B S T R A C T

The study investigated the effects of age, strain, and gender on body weight, carcass yield, and the relative weights of selected visceral organs in broiler chickens. A total of 224-day-old chickens from two broiler strains (Arian and Ross 308) were randomly allocated into 56 wire cages. Each cage contained four broilers (two males and two females), resulting in 28 replicate cages for each strain. On four specific days of the rearing period (days 10, 24, 32, and 42), 12±2 male and 12±2 female chickens from each broiler strain were randomly selected, weighed, and slaughtered. The carcass yield, visceral organ weights, and the weight of different segments of the alimentary tract were determined on each slaughter day after evisceration. The findings indicated that Ross 308 broilers were significantly heavier than Arian chickens at 32 and 42 days. The gizzard and jejunum relative weights in the Arian strain were significantly higher than in Ross 308 ($p<0.05$). Females in both strains had a higher relative liver weight compared with males. The bursa in the Ross 308 was found to be significantly heavier compared to Arian only in 32-day-old broiler chickens. Additionally, in 24-day-old chickens of the Ross strain, the weight of the bursa was heavier than that in 10-day-old chickens from the same strain ($p<0.05$). Therefore, due to enhanced bursa growth (10–24 days) and higher relative bursa weight in Ross 308 compared with Arian, it is postulated that the Ross 308 strain underwent more intensive breeding programs for improved immune competence.

Keywords: *Arian, breeding, carcass, Ross 308, small intestine.*

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1 Introduction

The issues that arise following selection from different genetic backgrounds of broiler chickens stem from the resource allocation theory. According to this theory, animals prioritize certain traits over others based on their genetic makeup. For instance, in a certain broiler strain (Arian), nutrients may be redirected from the normal development of essential organs toward muscle growth. This can hinder the optimal development of vital organs, ideally occurring early in life (1). To sustain a rapid metabolic rate, chickens must properly develop their cardiovascular and respiratory systems. However, studies have indicated that rapidly growing broilers struggle to adequately develop their respiratory and renal systems to support muscle growth in line with their overall body growth rate (2). To address these issues, breeding programs assess strain characteristics by periodically comparing them. Moreover, the poultry industry now classifies breeds by their advantages throughout the production chain, from breeding to processing (3). Consequently, leading breeding companies meticulously evaluate the slaughter weight of chickens at different ages to optimize the yield of marketable products obtained from each bird (4). Gender also plays a pivotal role in determining the final body weight of birds and the distribution of weight among different visceral organs and carcass parts (5). For example, it was reported that females had a higher relative weight of neck, liver, and visceral fat than males, while males had a higher percentage of head, legs, heart, and thighs than females (4). Another study revealed that males had significantly heavier carcasses, livers, and gizzards than females, whereas females had more visceral fat (5). Therefore, in this context, large poultry companies aim to enhance their profitability by expanding the range of slaughter weights in single-sex and mixed flocks of various strains. Moreover, by analyzing visceral organ weights after evisceration and calculating proper regression equations, they sought to determine how much the growth processes of these organs are affected by slaughter age or gender (6). Poultry body composition data have also been the subject of interest for animal nutrition researchers to develop nutritional system approaches (7). Previous studies have indicated that male broiler chickens have higher maintenance requirements than female Leghorn chickens of the same weight, which can be attributed to the varying amount of feathers (7). Consequently, assessing the relative weight of consumable and non-consumable body parts in different broiler breeds and genders becomes crucial, aiming to enhance the accuracy of predicting energy demands for bird growth. In addition, understanding the growth rate of the intestines at different ages can be used to predict the overall growth rate of the body. The Gallus species exhibits a rapid rate of growth, which is influenced by intestinal growth (8). Consequently, studying the macroscopic anatomy of the digestive system will prove beneficial in the context of breeding programs.

Furthermore, determining the visceral organs' relative weight can also be used to assess the broiler's health status in nutritional investigations where various feed treatments, deficiencies, and pharmaceuticals are administered to the birds. In these contexts, analyzing the alterations in the absolute and relative weight of internal organs, which occur due to the natural growth in male and female birds from different genetic backgrounds, will aid in interpreting the findings from these nutritional studies. Therefore, our research aimed to determine the effect of gender and age on the visceral organ weights in two strains of broiler chickens.

2 Materials and Methods

The study was conducted in a spacious room measuring 15 meters in length, 8 meters in width, and 3 meters in height. Within the room, 224 individual cages were arranged in five rows. Each cage had approximate dimensions of 27 ×21 × 13 cm. All day-old chickens (112 Arian and 112 Ross 308) were purchased from two corresponding broiler breeder flocks of the same age. Chicks were distributed into a completely randomized design in a factorial scheme 2 × 2 × 4, with 28 replications for each strain. Each replicate comprised two males and two females housed in four adjacent cages. Two broiler strains (Arian and Ross 308), two sexes (males and females), and four slaughter ages (10, 24, 32, and 42 days) were considered in the study. Feed and water were supplied *ad libitum* throughout the experimental period. The diets were described according to the Arian company recommendations based on corn and soybean meal (Appendix Table).

During the initial week of the chickens' arrival, the temperature within the room was maintained at approximately 33°C. Subsequently, the temperature was gradually decreased by three degrees each week until it reached the desired range of 23-24°C, which was then sustained throughout the remainder of the experimental period. At specific intervals (days 10, 24, 32, and 42), a random selection of broiler chickens (12±2 males and 12±2 females) from each broiler strain were chosen, weighed, and slaughtered for further analysis after six hours of fasting. There was a slight difference in the ratio of slaughtered birds of both sexes due to the definitive diagnosis of gender after slaughter. Subsequently, various internal organs, such as the liver, pancreas, gizzard, bursa of Fabricius, spleen, intestines, and different segments of the small intestine, were carefully dissected and weighed using a laboratory scale with an accuracy of 0.01 g. These weights were analyzed as a percentage of the live weight. The carcass weight was measured after skinning and removing all the visceral organs and internal fat. The carcass yield was reported as a percentage of the bird's live weight. The collected data were subjected to statistical analysis using the SAS software's GLM, REG, and CORR procedures (version 9.1)—the analysis aimed to investigate the interaction between strain, sex, and age. The F test was employed to assess the impact of gender and strain, while regression analysis was used to evaluate the influence of age on slaughter. Adjusted regression coefficients were extracted to estimate the maximum and minimum points of the quadratic and cubic models. Tukey's multiple range test was applied at the 5% level for all statistical procedures to compare the average of treatments.

3 Results

The effects of age, gender, broiler strain, and combined effects on the relative weight of some visceral organs and different digestive tract segments were presented in Tables and 2, respectively. Additionally, considering the strong correlation between the relative weight of different organs and body weight (Table 6), regression equations were formulated to enable the estimation of visceral organ weight based on age:

1. Live Body weight for Arian = $0.6119x^2 + 31.9735x-138.9633$;

Live Body weight for Ross 308 = $0.0734x^3-5.2149x^2+171.8629x-1025.4873$

2. Carcass percentage for Arian = $0.0036x^3-0.2705x^2+6.4179x+11.0771$;

Carcass percentage for Ross 308 = $0.0123x^2-0.0266x+51.4463$

3. Liver (%) = $0.526x^2+38.146x-187.72$

4. Duodenum (%) = $-0.0005x^3+0.0444x^2-1.4794x+18.5472$;

5. Jejunum for Arian (%) = $0.0009x^3+0.893x^2-3.1548x+42.4913$;

Jejunum for Ross 308 (%) $=0.0013x^3+0.1265x^2-3.9637x +46.4071$

6. Ilium (%) = $0.0003x^3+0.0635x^2-5.204x+146.956$

7. Small intestines (%) $=-.0025x^3+0.2458x^2-8.2312x +105.067$

8. Gizzard for Arian (%) = $0.0004x^3-0.0258x^2 + 03202x+5.3114$;

Gizzard for Ross 308 (%) = $0.0002x^3-0.0140x^2+0.0429x+6.755$

9. Proventriculous = $0.0001x^3-0.0046x^2+0.0752x + 0.6398$

10. Heart $=0.82x+15.81$

The statistical analysis revealed a significant effect of strain on the live weight of broilers (Table 1). Specifically, the Ross 308 strain exhibited a higher final body weight than the Arian strain ($p<0.05$). Additionally, gender influenced the live weight of chickens ($p<0.05$), with males weighing more than females, regardless of the broiler strain (Table 1). The interaction between age and gender on the live body weight of birds was statistically significant ($p<0.05$; Table 1). Further analysis of this interaction in Table 3 demonstrated that the effect of gender on body weight became evident after 24 days of age. In other words, at the slaughter ages of 32 and 42 days, males had a higher live weight than female chickens ($p<0.05$). Additionally, there was a significant strain*age effect on the live body weight ($p<0.05$). Further unfolding of this interaction (Table 4) revealed that there was no significant difference in the body weight of the two strains until the age of 24 d; However, the weight difference (i.e., higher weights in the Ross 308 compared to Arian) became apparent at subsequent slaughter ages (Table 4).

The results indicated that the strain influenced the carcass yield ($p<0.05$). Specifically, the carcass yield was higher in Ross 308 compared with Arian at 32 and 42 days of age (Table 4). Moreover, findings showed that the interaction between age and strain influenced the carcass yield (Table 1). Upon unfolding this interaction (Table 4), it was evident that the carcass yield of the Ross 308 strain surpassed that of the Arian strain only at 32 and 42 days of age. The peak carcass yield for both strains was observed at 42 days of age. As indicated in Table 2, the gizzard and jejunum relative weights were notably higher in the Arian than in Ross 308 ($p<0.05$). The age*gender effect was significant for gizzard relative weight (Table 2). Further unfolding of this interaction (Table 3) reveals that genders had no significant difference in the gizzard's relative weight at any slaughter age. However, at a young age, the relative weight of the gizzard was considerably higher, and it reached a relatively stable level with increasing age (after 32 days). This highlights the potential role of the gizzard in enhancing nutrient digestion and promoting the growth of chickens during early life. The results (Table 1) indicate a significant effect of gender on relative liver weight, with females exhibiting higher values than males across broiler strains. Gender did not significantly affect the relative weight of other visceral organs. The age*gender interaction on the relative weight of the liver was also found to be statistically significant ($p<0.01$; Table 1). Upon unfolding this in Table 3, it was observed that the difference in the relative liver weight between males and females was only significant at the slaughter ages of 10 and 24 days ($p<0.05$). The impact of slaughter age on the relative weight of Bursa Fabricius did not yield statistically significant results (Table 1). The broiler strain approached significance ($p=0.051$), with Ross 308 exhibiting a higher mean bursa relative weight than Arian. The bursa's relative weight was also affected by strain*age interaction (Table 1; $p<0.05$). Upon unfolding this interaction in Table 4, it was revealed that the higher values of bursa weight for the Ross 308 strain compared to Arian was statistically significant only at the 32-day slaughter ($p<0.05$), with no significant differences at other slaughter days. Moreover, the Ross strain's bursa weight significantly increased from 10 to 24 days, which may indicate the development of the immune system within this period in the Ross 308 broilers.

Gender, strain, and age did not significantly affect relative duodenal weight (Table 2). However, a significant Strain*Gender*Age interaction was observed for the relative weight of this intestinal segment ($p<0.05$). Unfolding of this interaction in Table 5 revealed that, irrespective of gender, the most substantial increase in the relative weight of the duodenum occurred in young birds (up to 10 days of age). Nevertheless, between 10 and 24 days of age, the rate of total body growth exceeded that of the duodenum. The Arian broiler strain had a significantly higher relative jejunum weight than the Ross 308 strain ($p<0.05$; Table 2). While gender had a notable effect on liver weight (females in both strains exhibited higher relative liver weight than males), it did not significantly impact the relative weight of other visceral organs.

Table 6 displays the correlation between the relative weight of various internal organs and body weight. Small intestine and liver weights correlated strongly with body weight (Table 6). Moreover, the correlation between the small intestine and the bursa's relative weight in the Ross 308 strain was positive and significant (Table 5).

Table 1. Live weight (grams) and relationship (%) between live weight and some abdominal organ weight from different broiler strains

	Live W (g)	Carcass (%)	Heart (%)	Bursa (%)	Spleen (%)	Liver (%)
Age (d)						
10	242.06±27.8	51.82±3.52	0.75±0.09	0.20±0.04	0.12±0.06	3.93±0.61
24	1052.86±86.8	59.99±2.17	0.69±0.10	0.22±0.05	0.10±0.02	3.02±0.38
32	1518.82±169.7	59.19±2.20	0.57±0.08	0.21±0.04	0.26±0.08	2.47±0.24
42	2359.01±175.2	71.66±2.64	0.53±0.08	0.20±0.05	0.10±0.02	2.26±0.23
Gender						

Male	1488.84±816.0^{a}	62.04±8.2	0.63±0.12	0.21±0.05	0.14±0.30	2.68±0.59^{b}
Female	1289.44±743.3^{b}	60.66±7.3	0.62±0.12	0.20±0.04	0.22±0.7	2.99±0.0.83^{a}
Strain						
Arian	1337.26±763^{b}	60.28±7.25^{b}	0.62±0.14	0.19±0.04	0.10±0.04	2.87±0.74
Ross	1428.43±802^{a}	62.35±8.08^{a}	0.63±0.11	0.21±0.05	0.26±0.78	2.82±0.74
ANOVA						
Strain	<0.01	<0.01	0.78	0.051	0.17	0.32
Gender	<0.01	0.32	0.20	0.28	0.76	<0.01
Age	Quadratic[1]	Cubic[2]	Linear[10]	NS	NS	Quadratic[3]
Strain*Gender	0.15	0.52	0.14	0.10	0.76	0.87
Strain*Age	0.03	0.04	0.77	<0.01	0.08	0.75
Age*Gender	<0.01	0.53	0.61	0.11	0.94	<0.01
Strain*Gender Gender*Age	0.31	0.80	0.39	0.28	0.96	0.34

^{ab}: Within columns, mean values with homogenous letter(s) are not statistically significant (*p*>0.05)

Table 2. Effects of age, gender, broiler strain, and their interactions on the relative weights of different parts of the digestive tract in broiler chickens

	Prov (%)	Gizzard	Sint (g/100gBW)	Ilium (g/100gBW)	Jejunum (g/100gBW)	Duodenum (g/100gBW)
Age (d)						
10	0.99±0.09	6.17±0.77	44.91±5.74	18.61±2.66	18.56±2.31	7.73±1.18
24	0.68±0.09	3.22±0.63	14.62±1.90	6.07±0.67	5.98±0.80	2.40±0.25
32	0.41±0.05	1.64±0.17	12.06±1.41	5.07±0.66	5.04±0.68	1.95±0.18
42	0.35±0.05	1.55±0.22	8.50±0.72	3.93±0.31	3.89±0.33	1.40±0.08
Gender						
Male	0.57±0.26	2.84±1.85	17.70±13.66	7.46±5.52	7.43±5.56	2.97±2.44
Female	0.59±0.26	3.02±1.95	19.83±15.06	8.37±6.23	8.30±6.14	3.33±2.60
Strain						
Arian	0.59±0.25	3.09±1.91^{a}	19.18±14.95	8.12±6.08	8.16±6.08^{a}	3.24±2.53
Ross	0.57±0.26	2.79±1.89^{b}	18.49±13.93	7.77±5.76	7.63±5.69^{b}	3.09±2.54
ANOVA						
Strain	0.18	<0.01	0.22	0.162	0.02	0.33
Gender	0.98	0.39	0.80	0.59	0.67	0.88
Age	Cubic	Cubic	Cubic	Cubic	Cubic	Cubic
Strain*Gender	0.33	0.13	0.29	0.39	0.27	0.04
Strain*Age	0.94	0.55	0.09	0.27	0.29	0.49
Age*Gender	0.34	0.02	0.77	0.772	0.89	0.98
Strain*Gender*Age	0.33	0.43	0.34	0.704	0.28	0.03

^{ab}: Within columns, mean values with heterogenous letter(s) are not statistically significant (*p*>0.05)

Table 3. Unfolding of interaction gender*age for body weight, liver, and gizzard relative weights

	10 d		24 d		32 d		42 day	
	Male	Female	Male	Female	Male	Female	Male	Female
Body weight (g)	242.4±30^{f}	241. 4±20^{f}	1043.5±80^{e}	1064.7±30^{e}	1633.2±180^{c}	1456.1±120^{d}	2403.8±150^{a}	2301.5±140^{b}
Liver (% BW)	3.57±0.54^{e}	4.17±0.55^{d}	2.81±0.28^{c}	3.28±0.33^{b}	2.45±0.25^{a}	2.49±0.22^{a}	2.24±0.23^{a}	2.28±0.19^{a}
Gizzard (% BW)	6.28±0.80^{a}	6.10±0.62^{a}	3.02±0.54^{b}	3.47±0.54^{b}	1.59±0.15^{c}	1.66±0.16^{c}	1.59±0.20^{c}	1.49±0.16^{c}

^{abcdef}: Within rows, mean values with heterogenous letter(s) are not statistically significant (*p*>0.05)

Table 4. Unfolding of the interaction strain*slaughter age for the significant parameters for these interactions

	Arian				Ross308			
	10 d	24 d	32 d	42 d	10 d	24 d	32 d	42 d
Body weight(g)	239±20^{e}	996±40^{d}	1499±150^{c}	2287±160^{b}	245±30^{e}	1110±80^{d}	1539±170^{b}	2431±60^{a}
Carcass (%)	51.81±2.91^{e}	59.12±1.43^{cd}	57.56±1.14^{d}	70.53±1.81^{b}	51.84±4.15^{e}	60.81±2.45^{c}	60.87±1.77^{c}	72.81±2.87^{a}
Bursa (%)	0.21±0.03^{abc}	0.21±0.02^{abc}	0.17±0.02^{c}	0.20±0.06^{bc}	0.18±0.05^{c}	0.23±0.06^{ab}	0.24±0.03^{a}	0.20±0.04^{bc}

^{abcde}: Within rows, mean values with heterogenous letter(s) are not statistically significant (*p*>0.05)

Table 5. Unfolding of interaction strain*sex*age for duodenum relative weight (g/100g body weight)

E	Male	10 d	7.39±0.68^{a}

		24 d	2.51 ± 0.19^{bc}
		32 d	1.96 ± 0.21^{bcd}
		42 d	1.40 ± 0.09^{d}
	Female	10 d	8.02 ± 0.18^{a}
		24 d	2.64 ± 0.21^{b}
		32 d	1.96 ± 0.15^{bcd}
		42 d	1.42 ± 0.06^{bc}
Ross 308	Male	10 d	8.12 ± 0.85^{a}
		24 d	2.33 ± 0.18^{bc}
		32 d	1.84 ± 0.18^{bcd}
		42 d	1.37 ± 0.08^{d}
	Female	10 d	7.45 ± 0.92^{a}
		24 d	2.14 ± 0.16^{bcd}
		32 d	1.99 ± 0.20^{bcd}
		42 d	1.37 ± 0.07^{d}

[abcd]: Within column, mean values with heterogenous letter(s) are not statistically significant ($p>0.05$)

Table 6. Correlation coefficients between the body weight, carcass yield, and relative weight of some internal organs in two strains of broiler chickens[1]

	Ross 308	Arian
Body weight & Carcass yield	0.90**	0.88**
Body Weight & Liver	-0.79**	-0.83**
Body Weight & Spleen	0.06	-0.30**
Body weight & Small intestine	-0.84**	-0.87**
Liver & Carcass yield	-0.70**	-0.70**
Liver & Spleen	0.03	0.39**
Liver & Small Intestine	0.80**	0.84**
Spleen & Bursa	0.15	0.27*
Spleen & Small Intestine	0.09	0.40**
Bursa & Small intestine	0.28**	0.14
Carcass yield & Small intestine	-0.77**	-0.71**

[1] Only significant correlation coefficients are shown
*$p<0.05$; **$p<0.01$

4 Discussion

The findings confirm the results of a previous study in which males consistently had a higher body weight than females (9). Body weight was found to be dependent on the slaughter age, but the predictive equation of live body weight in Arian (quadratic) was different from that in Ross 308 (cubic). It has been reported that the age at which chickens are slaughtered has a quadratic effect on their body weight and carcass yield, regardless of their gender or breed (10).

The carcass percentage of Ross 308 broilers was greater than that of Arians. This contradicts the findings of a previous study in which the genotype (Ross308 and Cobb strain) had no significant effect on carcass yield (5). Additionally, it was reported that when comparing the Ross 308, Cobb, Hubbard, and Arbor Acres strains, there were no significant differences between the strains regarding carcass yield or breast percentage (10). Considering the carcass percentage, no significant interaction was found between gender and broiler strain, which is inconsistent with the findings of Benyi *et al.* (5). These researchers reported that the carcass weight of males was significantly higher than that of females only in the Cobb (and not in Ross 308) strain (5).

In line with this study's results, a previous study has shown that when chickens selected from two lines (Lohman Dual and Ross 308) had the same body weight, the gizzard weight was greater in the Lohman Dual (slow growth) than in the Ross 308 (fast growth) (11). Additionally, it has been reported that the gizzard and large intestine weights (g) in a lightweight breed (Venda) were statistically greater compared to those in the Ross 308, when birds were slaughtered at the age of 70 days (12). The relative weight of the gizzard in male birds did not significantly differ from that of females in the current study. Santos et al. (2005) found no significant difference in the relative weight of the gizzard between broiler sexes (13).

Having a larger liver early in life may play a vital role in the metabolism of feed for the accelerated growth of birds (14). However, the impact of strain, strain*gender, and strain*age on the liver's relative weight was not found to be significant. This is in contrast to the findings of a previous study in which the genotype (Ross and Cobb strains) had a significant effect on liver weight (5). Another study found no significant differences in visceral weights, including liver weight, among Ross, Cobb, Hubbard, and Arbor Acres broiler strains (10). In our current experiment, the liver and gizzard relative weights were unaffected by the interaction between strain and gender. This finding contrasts with a previous study that reported a significant effect of the strain-by-gender interaction on liver and gizzard weights (15). It has also been indicated that liver weight in male chickens exceeded that of females in the Cobb strain. However, the disparity in liver weight between the genders was not deemed significant in Ross 308 broilers (5).

Allometric changes in the bursa reflect the broiler's immunological status, with bursa growth directly proportional to immunological activity (16). A larger size of the bursa of Fabricius may indicate better bird health, as smaller sizes have been linked to organ atrophy (17). In the current experiment, the impact of gender on the relative weight of the bursa was not statistically significant. It has been shown that female chickens only tend to have lower relative bursa weight compared to males, especially at younger ages (2). Various factors, such as flock density, influence the weight of the bursa of Fabricius (18). Hence, the higher density of chickens in the cage system during the current experiment may explain why the bursa's relative weight in 32-day-old chickens was larger compared to the report in a previous study (19).

The small intestine of chickens comprises the duodenum, jejunum, and ileum, which are relatively simple and short but highly efficient (20). The morphology of the alimentary canal could play a significant role in the growth patterns of bird species (21). In addition, according to morphometric measurements, a strong dependence of intestinal growth on carcass weight has been shown in previous reports (22). The gastrointestinal tract exhibits significant morphological and functional variations within and between species (23). According to the results, strain and gender did not significantly affect the relative weight of the small intestine. On the contrary, it was indicated that the relative and absolute weight of the digestive tract was greater in males than in females, regardless of the broiler strain (24).

Only male birds from both strains exhibited a decrease in the relative weight of the duodenum at 42 compared to 24 days of age. This may be attributed to the more pronounced muscle growth during this rearing period in male broilers compared to females. In the current investigation, the duodenum's relative weight at 42-day-old broilers was higher in the Arian strain than in the Ross 308. It has been demonstrated in a previous study that the relative weight and length of the digestive tract segments were elevated in Lohmann-laying male chickens (with a slow growth rate) when compared to Ross 308 male broilers (with a fast growth rate) across all age groups (11). Moreover, it was reported that the chickens' genetic lineage had a notable impact on the relative length of the jejunum-ileum and colorectum segments; therefore, the jejunum-ileum was 6.2% longer in Ross broilers than in Lohmann's chickens at the equivalent body weight (25). It is worth noting that the ratio of organ weight to body weight varies across different breeds (26), and this ratio is influenced by the bird's growth rate (27). Birds with faster growth rates exhibit a lower organ weight-to-body weight ratio (11), indicating differential growth rates between the visceral organs and overall body mass. Moreover, it is important to highlight that the birds' digestive systems' anatomical, functional, and histological characteristics play a crucial role in their feed conversion efficiency (25).

In agreement with Mobini (21), there was a significant correlation between the weights of all intestinal segments and body weight. In another study, a linear function with a strong correlation was obtained for White Rock and Leghorn breeds when plotting the percentage of body weight gain against the weight of the intestines (7). Additionally, Al-Dabagh and Abdulla (1963) also conducted a study on Rhode Island Red chickens and found a consistent correlation between body weight and the weight of the liver and spleen (28). The increase in the growth rate during compensatory growth in broiler chickens has also been associated with an increase in the relative intestinal weight (29). Additionally, chickens under feed restriction showed a reduction in the weight of their intestines, suggesting that the relative size of the intestines may limit bird growth (9). Hence, the size of the intestine changes to adapt to the growth rate of the birds (27). Therefore, it can be concluded that the Arian strain has no limitations in terms of intestinal morphometric characteristics that may affect the growth of the broiler chickens.

The research found a strong link between the relative weight of the liver and the small intestine. Martínez et al. (2021) further highlighted the importance of this correlation, specifically focusing on the relationship between small intestine weight and liver weight (30). It has been proposed that a strong correlation exists between the weight of the small intestine and the liver due to the heightened hepatic metabolism resulting from increased feed intake (31). Notably, the correlation between the relative weight of the liver and spleen was only significant in the Arian strain. A study by Martínez et al. (2021) also discovered a relationship between the spleen, liver, and heart sizes in chicken specimens (30). These organs are interconnected through the portal vein, facilitating detoxification and arterial blood exchange (31). Additionally, the venous blood leaving the spleen and intestines contains nutrients absorbed from the digestive system, which can impact liver growth (32).

A positive correlation has been reported between the weight of the small intestine and the weight of the lymphatic organs, including the spleen and bursa (33). However, in the experiment, the weight of the bursa was only significantly correlated with the small intestine weight in the Ross 308 strain.

The higher intestinal activity ensures the production of more B and T lymphocytes, which increases the relative weight of these organs in young chickens (33). It should be noted that the intestines have a unique nervous system and house 70% of the body's immune cells, which means that increasing the absorption of nutrients, especially at early ages, is essential for the growth and development of organs involved in the immune system (34). This study also discovered a positive relationship between spleen and bursa size, although this association was only statistically relevant in the Arian strain. Prior research also indicated a positive correlation between spleen and bursa weight in broiler chickens (35). A well-developed spleen indicates a strong immune system in birds (16). As a hematopoietic organ, the spleen also plays a crucial role in both humoral and cellular immune responses. The research found a notable inverse relationship between body weight and the relative size of the spleen in Arian strain subjects. Consequently, this negative correlation in Arian broilers may indicate a lack of hematopoiesis commensurate with growth in this strain compared with Ross 308.

In contrast to this discovery, it has been noted that the dimensions and mass of the spleen expand alongside the weight gain in birds (26), and body weight has a greater impact on spleen development in ducks (36). Certain bacterial and viral diseases can also impact the function, morphology, and absolute weight of the spleen in broilers (16). The dimensions of the spleen can differ considerably based on various factors, including breed, body mass, health condition, and the bird's habitat (36). It has been observed that the genetic background of hybrid broiler chickens greatly influences the functional activity of this immune organ, resulting in variations in size and function among different broiler chicken lineages (37). Another study failed to confirm commercial strain as a source of variation in relative bursa and spleen weight (38). It has been reported that Ross chickens had reduced T-helper cells but increased cytotoxic cells and antibody titers under controlled rearing conditions compared with Arin chickens (39).

5 Conclusion

Due to the positive correlation observed between bursa size and body mass, coupled with the elevated relative bursa weight characteristic of the Ross strain, it is plausible that Ross 308 chicks possess a higher proportion of immune-related visceral tissue per kilogram of body weight in comparison to Arian chicks. Consequently, heavier Ross chicks are anticipated to demonstrate more robust immune responses when contrasted with Arian chicks of equivalent weight.

Appendix

Appendix Table. Composition and nutrient content of the basal diet

	1-14 days of age	15-24 days of age	25-35 days of age	35-42 days of age
Ingredient (% of as fed)				
Maize	54.58	62.72	66.60	68.55
Soybean meal (44% crude protein)	38.80	31.69	27.80	22.16
Autoclaved wheat bran	0.15	0.15	0.15	0.15
Corn gluten	1.00	0.00	0.00	0.00
Soybean oil	1.00	1.00	1.30	1.00
Limestone	1.16	1.07	1.00	1.01
Calcium phosphate	1.88	1.71	1.44	1.49
Vitamin premix	0.25	0.25	0.25	0.25
Mineral premix	0.25	0.25	0.25	0.25
DL-methionine	0.30	0.31	0.27	0.26
L-lysine	0.19	0.26	0.26	0.23
L-threonine	0.07	0.13	0.13	0.10
NaCl	0.33	0.21	0.21	0.21
Sodium bicarbonate	0.04	0.25	0.34	0.34
Sum	100	100	100.	100
Calculated composition				
Metabolizable energy (kcal/kg)	2871	2950	3025	3025
Crude protein (%)	22.50	19.50	18.06	17.44
Lysin (%)	1.33	1.20	1.10	1.04
Methionine (%)	0.67	0.63	0.57	0.55
Methionine+cysteine (%)	1.00	0.92	0.85	0.82
Threonine (%)	0.89	0.82	0.76	0.72
Calcium (%)	0.96	0.87	0.78	0.78
Available phosphorus (%)	0.48	0.44	0.39	0.39
Na (%)	0.17	0.18	0.20	0.20
Anion-cation balance (mEq/kg)	240	230	225	220

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Conflict of Interest

The authors declare no competing interests.

Author Contributions

F.S. designed and directed the project; J.H. conceived and planned the experiments; R.A., and A.E. carried out the experiments; M.M.D. analyzed the data; F.S. took the lead in writing the manuscript with input from all authors. All authors discussed the results and commented on the manuscript.

Data Availability Statement

Data are available from the corresponding author upon reasonable request.

Ethical Considerations

The authors confirm that this study was conducted following the animal welfare and ethical guidelines established by the Animal Science Department's Ethical Committee at Yasouj University. Research proposals approved by the committee are assigned an ethical code linked to their proposal identification number; for this study, the ethical code was 64528. Additionally, the authors voluntarily adhered to the European Union standards for the protection of animals used for scientific purposes, as well as relevant feed legislation.

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