EFFECTS OF STRAIN AND SEX ON HAEMATOLOGICAL AND SERUM BIOCHEMICAL PARAMETERS OF BROILER CHICKENS AT DIFFERENT AGES

AKINYEMI, Omolola Felicia, ADU, Olufemi Adesanya and CHINEKE, Clifford Adinma
Department of Animal Production and Health, The Federal University of Technology, Akure, PMB 704, Ondo State, Nigeria.

Corresponding Author: Akinyemi, O. F. Department of Animal Production and Health, The Federal University of Technology, Akure, PMB 704, Ondo State, Nigeria. **Email:** akinyemiof@futa.edu.ng **Phone:** +234 7030170237

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ABSTRACT

Blood is a diagnostic tool for assessing an individual's or flock's health status. This study aimed to characterise 2-broiler strains based on haematological and serum indices as influenced by strain and sex at 6 and 8 weeks of age. Arbor-Acre and Cobb-500 chicks (n = 192) were divided into four groups comprising males and females for each strain with three replicates. They were raised for 56 days at the Poultry Unit of the Teaching and Research Farm, The Federal University of Technology Akure. Blood samples were collected from a total of 24 birds at two birds per replicate at six and eight weeks of age for laboratory analysis. A 2 x 2 factorial design in a completely randomized arrangement was used to analyze the data collected from the samples. Results showed that the Cobb-500 strain had significantly higher ($p<0.05$) values for packed cell volume (31.63 ± 0.83%), erythrocyte counts ($300.17 \pm 7.60 \times 10^4/mm^3$) and haemoglobin concentration (10.73 ± 0.19g/100ml) compared to the Arbor-Acre strain. The Arbor-Acre strain however had a significantly higher ($p<0.05$) erythrocyte sedimentation rate value (3.71 ± 0.18%). The study concluded that the differences in haematological and serum biochemical parameters among broiler strains and sexes at six and eight weeks were attributed to genetic factors. These factors underscore their importance when developing health improvement programmes in poultry birds at specific ages. The result of this study could be used by breeders to generate baseline data for health and welfare improvement programmes in poultry birds.

Keywords: Sexual dimorphism, Poultry birds, Improvement, Welfare, Health status

INTRODUCTION

Blood values in chickens are influenced by various factors such as age, sex, breed, climate, geographical location, day length, time of day, season, nutritional status, species' life habitat and the current physiological state of the individual (Islam *et al.,* 2004). According to Amao and Oyewumi (2017), significant differences in erythrocytic values and serum biochemical components among broiler strains are largely influenced by age.

Investigating normal blood indices in chickens is crucial for diagnosing various pathological and metabolic disorders. Blood serves as a diagnostic tool to assess the health status of individuals or flocks. Although research on haematological and serum biochemical values of broiler chickens in Nigeria and other West African countries have been ongoing for some three decades now, the information obtainable from these studies is still not sufficient enough to bring about any tangible improvement in the health, welfare and physiological performances of both indigenous and imported poultry species in Nigeria (Ojedapo *et al.,* 2008; Atansuyi *et al.,* 2019; Sam *et al.,* 2023). Moreover, different strains of commercial broiler chickens are often imported into Nigeria alongside some improved indigenous chickens with extensive studies on their haematological and biochemical profiles to determine their health status and adaptation to different climatic and agro-ecological zones in the country which could ultimately enhance their productive performances (Amao and Oyewumi, 2017; Atansuyi *et al.,* 2019; Iyaode *et al.,* 2020; Bah *et al.,* 2022).

Blood profiles of broiler strains at various ages during natural husbandry periods are essential for accurately interpreting haematological tests (Talebi *et al.,* 2005). Therefore, understanding the normal blood values of broiler chickens under local conditions is desirable. Haematological and serum biochemical indices have been reported to provide critical information for breeding purposes and the immune status of animals (Kral and Suchý, 2000; Ladokun *et al.*, 2008). Therefore, the present study aimed to characterise the haematological and serum indices of two broiler strains, taking into account the factors of strain and sex at different ages of the birds.

MATERIALS AND METHODS

The experiment was carried out at the Poultry Unit of the Teaching and Research Farm. The laboratory analysis to determine the haematology and serum biochemical parameters was carried out at the Haematological Laboratory of the Department of Animal Production and Health, The Federal University of Technology Akure, Nigeria, located between latitude 07°16^1 and 07°18^1 N and longitude 05°09^1 and 05°11^1 E. There is a bimodal rainfall patterns which start from February to July and September to October with an average rainfall of 1,556 mm per annum. The ambient temperature range is about 30 – 32°C with a relative humidity of 80% (NCEI, 2018).

Management of the Experimental Animals: A total of 192-day-old chicks, consisting of 96 Arbor-Acre and 96 Cobb-500 broiler strains, were purchased from reputable farms in Ibadan, Oyo State, Nigeria. The chicks were randomly allocated to pre-tagged pens according to their strains and sexes, creating four groups with three replicates per group. They were raised intensively on a deep litter system, and the field experiment lasted for eight weeks (56 days). Throughout the study period, routine and occasional health management practices were strictly followed, with all necessary vaccinations and medications administered as needed. The experimental diet (crude protein = 22 and 20%; ME = 2,900 and 3,000 kcal/kg for starter and finisher feeds respectively) was formulated at the Feed Mill of the Federal University of Technology Akure (FUTA) Teaching and Research Farm, Ondo State, Nigeria, and the birds were fed *ad libitum* during the experiment.

Data Collection

Haematological analysis: At six and eight weeks of age, two birds per replicate from each strain were randomly selected for the experiment. Approximately 2 mL of blood was collected from the jugular vein of each bird into well-labelled bijou bottles containing a speck of ethylenediamine tetraacetic acid (EDTA) for haematological analysis. The EDTA bottles were gently rocked to prevent coagulation, and the blood samples were immediately analyzed using the method described by Varley *et al.* (2006). The haematological parameters studied included packed cell volume (PCV), erythrocyte sedimentation rate (ESR), haemoglobin concentration (HBC), white blood cell (WBC) count and red blood cell (RBC) count. The differential counts of WBC, including lymphocytes (LYM), heterophils (HET), eosinophils (EOS), monocytes (MON) and basophils (BAS) were assayed as described by Tagesu (2018).

Serum analysis: Similarly, 10 mL of blood was collected from the birds and transferred into a set of sample bottles without EDTA. These samples were allowed to stand in a slanting position for about 12 hours until they clotted. The clear, straw-coloured liquid that gathered on top of the dark red clot was carefully decanted into cryo-preservative containers and stored in a freezer at -4ºC. Before analysis, the serum was separated by centrifuging the samples in a microcentrifuge. The serum was then analyzed using Randox test kits, Randox Laboratories Limited, United Kingdom. The serum parameters studied included Alanine Aminotransferase (ALT), Aspartate Aminotransferase (AST), creatinine (CREAT), glucose and cholesterol.

Statistical Analysis: The data obtained for the combined interactions of strain and sex were subjected to analysis of variance (ANOVA) using SAS (2013). A completely randomized design with a 2 x 2 factorial arrangement was used to analyze chicken strains and sexes. Duncan's Multiple Range Test (DMRT) of the same statistical package was employed to separate the differences among the means at $p<0.05$ level of significance. The statistical model used for the combined interactions of strain and sex was as follows: $Y_{ijk} = \mu + S_i + X_j + (SX)_{ij} + \varepsilon_{ijk}$ Where: Y_{ijk} = Observation of a bird for i^{th} strain in the j^{th} sex (n = 1 - 192); μ = General mean for specific population; S_i = Effect of the i^{th} strain (i = 1-2) X_j = Effect of the j^{th} sex (j = 1-2); SX_{ijk} = Interaction effect of i^{th} strain and j^{th} sex on the experimental chickens; and ε_{ijk} = Experimental Error. Separate data on sex (male vs. female) and strains (Arbor-Acre vs. Cobb-500) were analysed using Student's t-test.

RESULTS AND DISCUSSION

Effects of strain and sex on haematological parameters of experimental birds at six weeks: The results presented in Table 1 demonstrate significant effects of strain on the ESR, PCV, RBC count and HBC in the experimental birds at six weeks of age. The Cobb-500 strain exhibited higher values for PCV, RBC and HBC compared to the Arbor-Acre strain, while the Arbor-Acre strain showed a higher ESR value. These findings align with previous research indicating that genetic factors contribute to differences in haematological parameters among chicken strains (Olanrewaju *et al.,* 2014; Adewole *et al.,* 2021). The study also revealed that sex had no significant impact on any of the haematological parameters, although males exhibited slightly higher numerical values for ESR, LYM, MON, and EOS, while females had higher values for PCV, RBC, HBC, HET and BAS. These results are consistent with other studies reporting minimal or no significant differences in haematological parameters between male and female broiler chickens (Muneer *et al.,* 2021; Kareem-Ibrahim *et al.,* 2022). The Cobb-500 strain also demonstrated a significantly higher HBC (10.73 ± 0.19 g/dL) compared to the Arbor-Acre strain (8.95 ± 0.22 g/dL) at six weeks of age. However, the strain did not significantly affect LYM, HET, MON and BAS between the two strains at this age. A significant effect of strain was observed on EOS, with the Cobb-500 strain showing higher values than the Arbor-Acre strain. Furthermore, the interaction between strain and sex did not result in significant differences in any of the haematological parameters at six weeks. These findings are in line with other studies that have reported minimal or no significant differences in haematological parameters between sexes in broiler chickens (Bah *et al.,* 2022).

Effects of strain and sex on haematological parameters of experimental birds at eight weeks: Table 2 presents the effects of strain and sex on the haematological parameters of the experimental birds at eight weeks of age. The results indicated no significant differences ($p>0.05$) between strains in ESR, PCV, RBC count, Hb concentration, LYM and MON. However, significant differences ($p<0.05$) were observed between strains in HET, BAS and EOS. Specifically, the Arbor-Acre strain exhibited higher HET counts, while the Cobb-500 strain showed lower HET counts. Conversely, the Cobb-500 strain had higher BAS and EOS counts compared to the Arbor-Acre strain. Additionally, a significant sex effect occurred in the BAS counts, with males displaying higher values than females. Other haematological parameters did not show significant differences between sexes. These findings are consistent with previous research that has documented the influence of strain and sex on haematological parameters in birds (Iyaode *et al.,* 2020; Adewole *et al.,* 2021). For example, Adewole *et al.* (2021) reported significant effects of strain and sex on the haematological and serum biochemical indices of tropical indigenous chickens.

Table 1: Effects of strain and sex on haematological parameters of experimental birds at six weeks

Phenotypic traits	**Parameter**								
	ESR (mm/hr)	**PCV (%)**	**RBC (10^4/mm^3)**	**HBC (g/100ml)**	**LYM (%)**	**HET (%)**	**MON (%)**	**BAS (%)**	**EOS (%)**
Strain									
AA	3.71 ± 0.18*	26.9 ± 0.93	240.29 ± 8.50	8.95 ± 0.22	58.75 ± 0.39	25.46 ± 0.65	11.21± 0.35	3.42 ± 0.10	0.96 ± 0.12
Cobb-500	3.13 ± 0.16	31.63 ± 0.83*	300.17 ± 7.60*	10.73 ± 0.19*	59.00 ± 0.35	25.13 ± 0.58	11.10 ± 0.31	3.37 ± 0.09	1.40 ± 0.10*
Sex									
Male	3.61±0.17	28.99 ± 0.88	264.80 ± 8.06	9.64 ± 0.21	59.05 ± 0.37	25.17 ± 0.62	11.17 ± 0.33	3.38 ± 0.10	1.24 ± 0.11
Female	3.23 ± 0.17	29.60 ± 0.88	275.66 ± 8.06	10.05 ± 0.21	58.70 ± 0.37	25.43 ± 0.62	11.14 ± 0.33	3.41 ± 0.10	1.12 ± 0.11
Strain x Sex									
AA Male	4.08± 0.26	26.25 ± 1.31	232.00 ± 12.02	8.73 ± 0.31	59.17 ± 0.56	25.00 ± 0.92	11.33 ± 0.50	3.42 ± 0.15	1.08 ± 0.16
AA Female	3.33 ± 0.26	27.67 ± 1.31	248.58 ± 12.02	9.18 ± 0.31	58.33 ± 0.56	25.92 ± 0.92	11.08 ± 0.50	3.42 ± 0.15	0.83 ± 0.16
Cobb-500 Male	3.13 ± 0.23	31.73 ± 1.17	297.60 ± 10.75	10.55 ± 0.27	58.93 ± 0.50	25.33 ± 0.82	11.00 ± 0.44	3.33 ± 0.13	1.40 ± 0.15
Cobb-500 Female	3.13 ± 0.23	31.53 ± 1.17	302.73 ± 10.75	10.92 ± 0.27	59.07 ± 0.50	24.93 ± 0.82	11.20 ± 0.44	3.40 ± 0.13	1.40 ± 0.15

*AA = Arbor-Acre, ESR = Erythrocyte sedimentation, PCV = Packed cell volume, RBC = Red blood cell, HBC = Haemoglobin concentration, LYM = Lymphocytes, HET = Heterophils, MON = Monocytes, BAS = Basophils, EOS = Eosinophils, * = values with an asterisk are significantly different ($p<0.05$) using student t-test pairwise comparison*

Table 2: Effects of strain and sex on haematological parameters of experimental birds at eight weeks

Phenotypic traits	Parameter								
	ESR (mm/hr)	PCV (%)	RBC (10^4/mm^3)	HBC (g/100ml)	LYM (%)	HET (%)	MON (%)	BAS (%)	EOS (%)
Strain									
AA	3.63 ± 1.80	26.50 ± 0.93	239.17 ± 8.50	8.80 ± 0.22	58.79 ± 0.39	26.00 ± 0.65*	11.50 ± 0.35	3.13 ± 0.10	0.58 ± 0.12
Cobb-500	4.83 ± 1.61	25.49 ± 0.83	227.70 ± 7.60	9.92 ± 0.19	57.07 ± 0.35	22.83 ± 0.58	10.37 ± 0.31	3.50 ± 0.09*	1.00 ± 0.10*
Sex									
Male	4.06 ± 0.17	26.21 ± 0.88	237.17 ± 8.16	9.43 ± 0.21	57.54 ± 0.37	24.91 ± 0.62	10.82 ±0.33	3.46 ± 0.10*	0.71 ± 0.10
Female	4.40 ± 0.17	25.78 ± 0.88	229.70 ± 8.16	9.30 ± 0.21	58.32 ± 0.37	23.93 ± 0.62	11.05 ± 0.33	3.17 ± 0.10	0.88 ± 0.10
Strain x Sex									
AA Male	3.58 ± 0.26	26.67 ± 1.31	242.00 ± 12.02	8.86 ± 0.31	58.42± 0.56	26.42 ± 0.92	11.50 ± 0.50	3.25 ± 0.15	0.42 ± 0.16
AA Female	3.67 ± 0.26	26.33 ± 1.31	236.33 ± 12.02	8.75 ± 0.31	59.17 ± 0.56	25.58 ± 0.92	11.50 ± 0.50	3.00 ± 0.15	0.75 ± 0.16
Cobb-500 Male	4.53 ± 0.23	25.75 ± 1.17	232.33 ± 10.75	9.99 ± 0.27	56.67 ± 0.50	23.40 ± 0.82	10.13 ± 0.44	3.67 ± 0.13	1.00 ± 0.15
Cobb-500 Female	5.13 ± 0.23	25.22 ± 1.17	223.07 ± 10.75	9.84 ± 0.27	57.47 ± 0.50	22.27 ± 0.82	10.60 ± 0.44	3.33 ± 0.13	1.00 ± 0.15

*AA = Arbor-Acre, ESR = Erythrocyte sedimentation, PCV = Packed cell volume, RBC = Red blood cell, HBC = Haemoglobin concentration, LYM = Lymphocytes, HET = Heterophils, MON = Monocytes, BAS = Basophils, EOS = Eosinophils, * = values with an asterisk are significantly different (p<0.05) using student t-test pairwise comparison*

Similarly, Iyaode *et al.* (2020) found that both sex and strain significantly impacted the haematological parameters of broiler chickens fed a ginger-based diet in the early phase. These results also support the notion that different bird strains may exhibit distinct physiological responses to various factors, including nutrition and environmental conditions. This understanding is crucial for assessing bird health and performance in different settings and for developing strategies to enhance their welfare and productivity.

Effects of strain and sex on serum parameters of experimental birds at six weeks: The study presented in Table 3 on the effects of strain and sex on the serum parameters of experimental birds at six weeks of age, reveals significant strain effects across all serum parameters. Specifically, there was a highly significant effect on AST, with the Arbor-Acre strain showing higher AST levels compared to the Cobb-500 strain. Additionally, significant differences (p<0.05) were observed between the strains for ALT, with the Arbor-Acre strain exhibiting higher values than the Cobb-500 strain. Conversely, the Cobb-500 strain demonstrated significantly higher (p<0.05) CREAT levels compared to the Arbor-Acre strain. Furthermore, a significant difference (p<0.05) was found in cholesterol levels, with the Arbor-Acre strain showing higher values than the Cobb-500 strain. Regarding glucose levels, the Arbor-Acre strain again displayed significantly higher (p<0.05) values compared to the Cobb-500 strain. These findings align with previous studies that have reported strain-related differences in serum parameters in broiler chickens, emphasizing the importance of considering strain when analyzing serum parameters in experimental birds (Amao and Oyewumi, 2017; Adewole *et al.,* 2021; Bah *et al.,* 2022). This study also investigated the effects of sex on the serum parameters at six weeks and significant sex effects were found for both AST and ALT levels. Specifically, female birds exhibited higher AST levels, whereas male birds showed higher ALT levels. These differences in AST and ALT levels in birds can be attributed to factors such as hormonal differences, metabolic rates and physiological variations between the sexes (Kasarinaite *et al.*, 2023). However, no significant differences (p>0.05) were observed between the sexes for CREAT, cholesterol and glucose levels, indicating similar values for both male and female birds in these parameters. A significant interaction (p<0.05) between strain and sex was observed for AST, with female birds of the Arbor-Acre strain recording the highest value (163.66 ± 5.65 U/L) compared to Cobb-500 males and females, which had similar, lower values. No significant interactions (p>0.05) were found for other serum parameters at six weeks, underscoring the independent effects of sex on these specific blood parameters. These findings are consistent with previous research highlighting the influence of sex on serum parameters in broiler chickens (Livingston *et al.,* 2020; Kasperek *et al.,* 2021; Bah *et al.,* 2022). The observed differences in AST and ALT levels between the sexes underscore the importance of considering sex when analysing serum parameters in experimental birds.

Effects of strain and sex on serum parameters of experimental birds at eight weeks: The study presented in Table 4 on the effects of strain and sex on serum parameters of experimental birds at eight weeks of age, reveals significant differences (p<0.05) between strains in various serum parameters. Notably, AST levels were significantly higher (p<0.05) in the Arbor-Acre strain compared to the Cobb-500 strain. Conversely, the Cobb-500 strain exhibited significantly higher (p<0.05) ALT levels than the Arbor-Acre strain. The Cobb-500 strain also showed significantly higher (p<0.05) CREAT levels compared to Arbor-Acre. In terms of cholesterol, the Arbor-Acre strain had significantly higher (p<0.05) levels than the Cobb-500 strain. Additionally, glucose levels were significantly higher (p<0.05) in the Arbor-Acre strain compared to the Cobb-500 strain. Interestingly, the study found no significant differences (p>0.05) in serum parameters based on sex alone. However, significant interactions (p<0.05) between strain and sex were observed for some serum parameters, indicating a combined effect of these factors on specific blood parameters.

Table 3: Effects of strain and sex on serum parameters of experimental birds at six weeks

Phenotypic traits	Parameter				
	AST (U/L)	ALT (U/L)	CREAT (µmol/L)	CHOLE (mmol/L)	GLU (mg/dL)
Strain					
AA	151.52 ±3.99*	28.10 ± 0.43*	31.40 ± 374.39	2.42 ± 0.07*	126.28 ± 11.48*
Cobb-500	3.24 ± 3.65	1.7± 0.39	5105.25 ± 341.77*	0.08 ± 0.06	60.31 ± 10.48
Sex					
Male	71.55 ± 3.65	15.90 ± 0.39*	2566.27 ± 341.77	1.23 ± 0.06	102.16 ± 10.48
Female	83.21± 3.99*	13.97 ± 0.43	2570.38 ± 374.39	1.27 ± 0.70	84.43 ± 11.48
Strain x Sex					
AA Male	139.38 ± 5.65^{b}	29.57 ± 0.61	36.80 ± 529.47	2.38 ± 0.10	132.82 ± 16.23
AA Female	163.66 ± 5.65^{c}	26.62 ± 0.61	26.00 ± 529.47	2.46 ± 0.10	119.75 ± 16.23
Cobb-500 Male	3.72 ± 4.61^{a}	2.22 ± 0.50	5095.74 ± 432.31	0.08 ± 0.08	71.51 ± 13.25
Cobb-500 Female	2.75 ± 5.65^{a}	1.32 ± 0.61	5114.76 ± 529.47	0.08 ± 0.10	49.11 ± 16.23

*AA = Arbor-Acre, AST = Aspartate Aminotransferase, ALT = Alanine Aminotransferase, CREAT = Creatinine, CHOLE = Cholesterol, GLU = Glucose, * = values with an asterisk are significantly different ($p<0.05$) using student t-test pairwise comparison, $^{a, b, c}$ = means in the same column bearing different letter superscripts are significantly different ($p<0.05$)*

Table 4: Effects of strain and sex on serum parameters of experimental birds at eight weeks

Phenotypic traits	Parameter				
	AST (U/L)	**ALT (U/L)**	**CREAT (µmol/L)**	**CHOLE (mmol/L)**	**GLU (mg/dL)**
Strain					
AA	176.46 ± 2.46*	27.48 ± 0.45	28.15 ± 3.45	2.13 ± 0.43*	137.82 ± 3.68*
Cobb-500	101.47 ± 2.20	33.00 ± 0.41*	55.89 ± 3.09*	1.98 ± 0.39	117.74 ± 3.29
Sex					
Male	137.28 ± 2.34	30.10 ± 0.43	42.56 ± 3.27	1.99 ± 0.04	127.16 ± 3.49
Female	140.65 ± 2.34	30.38 ± 0.43	41.49 ± 3.27	2.11 ± 0.04	128.40 ± 3.49
Strain x Sex					
AA Male	171.83 ± 3.45	26.58 ± 0.64^{a}	27.46 ± 4.88	2.01 ± 0.06^{ab}	138.50 ± 5.19
AA Female	181.10 ± 3.45	28.37 ± 0.64^{a}	28.84 ± 4.88	2.26 ± 0.06^{b}	137.13 ± 5.19
Cobb-500 Male	102.74 ± 3.12	33.61 ± 0.57^{b}	57.65 ± 4.36	1.99 ± 0.06^{a}	115.82 ± 4.65
Cobb-500 Female	100.21 ± 3.12	32.40 ± 0.57^{b}	54.14 ± 4.36	1.96 ± 0.06^{a}	119.66 ± 4.65

*AA = Arbor-Acre, AST = Aspartate Aminotransferase, ALT = Alanine Aminotransferase, CREAT = Creatinine, CHOLE = Cholesterol, GLU = Glucose, * = values with an asterisk are significantly different ($p<0.05$) using student t-test pairwise comparison, $^{a, b}$ = means in the same column bearing different letter superscripts are significantly different ($p<0.05$)*

These findings align with previous research on the impact of strain and sex on serum parameters in poultry, underscoring the importance of considering these factors when evaluating physiological traits in birds (Amao and Oyewumi, 2017; Adewole *et al.,* 2021; Bah *et al.,* 2022). One particularly noteworthy finding was the significant interaction (p<0.05) between strain and sex on ALT levels in the experimental birds. The results indicated that both male and female Cobb-500 birds had the highest ALT values, which were similar to each other. In contrast, both male and female Arbor-Acre (AA) birds recorded the lowest ALT values, also similar to each other but significantly different (p<0.05) from the Cobb-500 strain. This suggests that the effect of sex on ALT levels varies across different strains. While the Cobb-500 strain, with the highest ALT levels, showed no significant difference between males and females, the AA strain exhibited a significant sex difference, with females having higher ALT levels than males.

This study highlights the importance of considering both strain and sex when analyzing the effects of these factors on serum parameters like ALT in birds. Such insights are particularly relevant in poultry production, where understanding the interactions between genetic and environmental factors can inform breeding and management strategies aimed at optimizing bird health and productivity (Adewole *et al.,* 2021).

Conclusion: The study showed that genetic factors were responsible for the haematological parameter variations among broiler strains at six weeks, with no significant differences observed between sexes. Additionally, sex did not have a significant effect on any haematological parameters measured at this age. However, the differences observed between the sexes in AST and ALT levels underscore the importance of considering sex when analysing serum parameters in experimental birds at six weeks. These differences are likely due to hormonal, metabolic and physiological factors. At eight weeks, the effect of strain was also significantly higher in Cobb-500 compared to Arbor-Acre. Specifically, the Arbor-Acre strain exhibited significantly higher cholesterol levels than the Cobb-500 strain. This suggests that Arbor-Acre birds might have distinct immune responses or health statuses compared to Cobb-500, which could affect their cholesterol levels. Factors such as stress, disease challenges and differences in immune function can impact lipid metabolism. Although no significant differences in serum parameters were found based on sex, it remains important to consider strain and sex when assessing physiological traits in birds. The study emphasizes the importance of considering both strain and sex when analyzing the effects of these factors on ALT levels in birds. This is particularly relevant in poultry production, where understanding the interactions between genetic and environmental factors can inform breeding and management strategies aimed at optimizing bird health and productivity.

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