Brazilian Journal of Poultry Science
Revista Brasileira de Ciência Avícola

e-ISSN: 1806-9061 2025 / v.27 / n.4 / 001-009

http://dx.doi.org/10.1590/1806-9061-2024-2033

Original Article

Native vs. Exotic Chickens: A Comparative Study on Leukocyte Profiles and Serum Biochemical Characteristics in Bangladesh

■Author(s)

Haque MI[I] https://orcid.org/0000-0002-8415-2794
Rahman MM[I] https://orcid.org/0009-0006-7475-523X
Mustari A[I] https://orcid.org/0000-0002-7651-5487
Miah MA[I] https://orcid.org/0000-0003-2778-9614

[I] Bangladesh Agricultural University, Faculty of Veterinary Science, Department of Physiology, Mymensingh, 2202, Bangladesh.

■Mail Address

Corresponding author e-mail address
Mohammad Alam Miah
Bangladesh Agricultural University, Faculty of Veterinary Science, Department of Physiology, Mymensingh, 2202, Bangladesh.
Phone: +880 176 638 3494
Email: mam74@bau.edu.bd

■Keywords

Leucocyte profile, lipid profile, Deshi chicken, broilers and serum proteins.

Section Editor: Ramon Malheiros

Submitted: 28/November/2024
Approved: 23/November/2025

ABSTRACT

This study was conducted to assess and compare leukocyte and biochemical parameters in Deshi (local), Sonali crossbred, and broiler chickens. 90 chickens were included in the experiment, with 30 each from the commercial broiler, Deshi, and Sonali (RIR cock × Fayoumi hen) groups. Blood samples were collected to measure total leukocyte counts (TLC) and differential leukocyte counts (DLC). The serum biochemical parameters assessed were triglycerides, high-density lipoprotein (HDL), low-density lipoprotein (LDL), serum total protein, glucose, alanine transaminase (ALT), aspartate transaminase (AST), alkaline phosphatase (ALP), uric acid, and creatinine. Deshi chickens exhibited significantly higher TLC, characterized by elevated heterophil counts and lower lymphocyte counts ($p<0.05$). Both Deshi and Sonali chickens displayed a higher heterophil-to-lymphocyte (H/L) ratio than broilers. Broilers showed the highest serum total cholesterol, triglyceride, and LDL-c levels, while Deshi chickens had the lowest. Deshi and Sonali chickens also had significantly higher serum total protein and albumin levels, with stable glucose concentrations. Liver function showed no significant differences among breeds. Additionally, Deshi and Sonali chickens demonstrated better kidney health. In conclusion, Deshi and Sonali chickens demonstrated a more favourable leukocyte and lipid profile, as well as better kidney health compared to broilers, highlighting their potential for healthy and productive poultry farming.

INTRODUCTION

Blood parameters offer a window into the internal physiological dynamics of animals, serving as essential indicators of health, stress, and nutritional status. In poultry, hematological and biochemical profiles are widely employed to assess the impact of environmental factors, disease exposure, and dietary interventions on bird performance and well-being (Olorode & Longe, 2000; Herdt & Hoff, 2011). Among these parameters, leukocytes—or white blood cells (WBCs)—play a crucial role in mediating the immune response, and are often regarded as sensitive biomarkers of both infectious and non-infectious stressors (Zhou *et al.*, 1999; Nelson *et al.*, 2020). Monitoring changes in total leukocyte count (TLC), differential leukocyte count (DLC), and heterophil-to-lymphocyte (H:L) ratios has thus become a well-established approach for evaluating immunological resilience in avian species (Dhabhar *et al.*, 1996).

While commercial broiler chickens have been extensively studied in terms of their hematobiochemical responses to various physiological and nutritional interventions (Alikwe *et al.*, 2010; El-Gendy *et al.*, 2011), there remains a significant gap in the literature regarding the immune and biochemical profiles of indigenous or regionally adapted chicken breeds, particularly under alternative rearing systems such

as free-range or semi-scavenging conditions. This is especially pertinent to the context of Bangladesh, where poultry production contributes significantly to food security, rural employment, and income generation. In recent years, interest has been growing in sustainable, low-input production systems that leverage the natural hardiness of native chicken breeds, offering an alternative to the highly input-dependent, confinement-based broiler production models.

In this regard, Deshi chickens, the most widely distributed indigenous poultry breed in Bangladesh, hold immense agricultural and socio-economic value. These birds are raised predominantly by rural households under extensive or scavenging systems, often with minimal feed supplementation or veterinary care. Their inherent resilience, adaptability to harsh climatic conditions, and resistance to common poultry diseases make them particularly suited to backyard production and smallholder farming systems (Perumal & Pisupati, 2013; Haque *et al.*, 2017). Despite their slower growth rates compared to commercial breeds, Deshi chickens are often preferred in local markets for their superior meat and egg quality, commanding premium prices due to consumer perceptions of taste and safety.

Similarly, the Sonali chicken, a synthetic cross between a Rhode Island Red cock and a Fayoumi hen, has emerged as a widely adopted dual-purpose breed in Bangladesh. Combining the egg-laying capacity of layer breeds with the moderate growth traits of broilers, Sonali chickens are particularly suitable for semi-intensive production models. Their growing popularity stems from their intermediate performance traits—offering improved productivity over Deshi chickens while maintaining a degree of disease tolerance and lower input requirements compared to commercial broilers. Their prevalence in Bangladesh's northern and central districts reflects a shift towards rearing breeds that align with the resource constraints and environmental realities of rural farming communities (Islam *et al.*, 2004; Adegoke *et al.*, 2018).

Despite these breeds' critical role in local poultry systems, comprehensive studies investigating their leukocyte and biochemical profiles under outdoor or low-input rearing conditions are lacking. Most existing research has either focused on commercial strains or been conducted under highly controlled laboratory or confinement settings, which may not accurately represent field conditions in resource-limited environments. This absence of data impedes breed-specific health management and limits efforts to design tailored nutritional and veterinary interventions to improve productivity and welfare.

Moreover, comparative studies comparing the physiological performance of these breeds to commercial broilers are virtually non-existent. Such comparisons are essential, as they can elucidate potential advantages of local or crossbred genotypes in terms of disease resistance, stress adaptability, and metabolic efficiency—traits that are increasingly valuable in the context of climate change, fluctuating input costs, and consumer demand for ethically and sustainably-produced poultry.

In light of these gaps, the present study aims to generate novel data by systematically evaluating and comparing the leukocyte profiles and serum biochemical parameters of Deshi, Sonali, and commercial broiler chickens raised in outdoor rearing systems in Bangladesh. By investigating total leukocyte counts, differential leukocyte distributions, and key serum biomarkers, this research seeks to uncover meaningful physiological distinctions across genotypes. The findings are expected to advance our understanding of how breed and rearing environment interact to shape immune responses and metabolic profiles, with practical implications for breed selection, management practices, and sustainable poultry development strategies in low-resource settings.

MATERIALS AND METHODS

A total of 90 chickens were used in this study, comprising three genotype groups: Deshi (indigenous), Sonali (Rhode Island Red × Fayoumi), and commercial broilers (Cobb 500). All selected birds were males of similar physiological age (approximately 6 weeks old at the time of slaughter). The uniformity in sex and age was deliberately maintained to reduce physiological variability associated with sex hormones, which are known to significantly influence leukocyte profiles and serum biochemical parameters. The age of each bird was confirmed using purchase and farm records. Birds were sourced directly from typical rearing environments representative of their respective production systems. Deshi and Sonali chickens were obtained from smallholder farms practicing a semi-scavenging system, while broilers were selected from commercial farms employing intensive rearing protocols. All farms maintained basic veterinary oversight and biosecurity measures, and birds were confirmed to be free from overt clinical illness, injury, or signs of infection at the time of selection. Importantly, the birds were not subjected

to any laboratory holding period before slaughter. To minimize stress-induced alterations in physiological parameters, they were transported directly from their farms to the department's designated slaughter area early in the morning, under humane and low-stress handling protocols. Upon arrival, a resting period of 30–45 minutes was observed in a shaded, quiet holding area to allow for partial recovery from transport stress. This minimal holding time was provided to preserve the physiological status of the birds as close as possible to their on-farm conditions. Slaughter was performed by trained personnel following ethical and humane procedures in compliance with institutional animal welfare guidelines.

Ethical Approval

The research was conducted in compliance with the guidelines of the Animal Welfare and Experimentation Ethics Committee (AWEEC) of Bangladesh Agricultural University, Mymensingh, Bangladesh [AWEEC/BAU/2020-22].

Blood Sample Collection

Blood samples were collected immediately after slaughter by cervical dislocation. Pre-slaughter fasting for 6 hours before slaughter was implemented for all birds. This fasting period was chosen to reduce postprandial variation in biochemical markers, while also avoiding undue physiological stress or metabolic disturbance due to prolonged food deprivation. Two types of blood samples were obtained: one collected in tubes containing anticoagulant for total and differential leukocyte counts (TLC and DLC), and the other in plain tubes for serum separation. Serum samples were centrifuged within two hours of collection to ensure sample quality. All specimens were carefully labeled and stored in ice boxes during transport to maintain their integrity. Subsequently, the samples were transported to the haematology laboratory of the Department of Physiology at Bangladesh Agricultural University (BAU) for further analysis.

Staining Procedure and Cell Counting for DLC and TLC

In this study, Total Leucocyte Count (TLC) and Differential Leucocyte Count (DLC) were conducted following staining procedures outlined by Welberg (2001) and Carisch (2019), with slight modifications. Wright-Giemsa staining was applied to thin blood films. After air-drying, smears were saturated with filtered Wright-Giemsa stain for 5 minutes, diluted with distilled water for another 5 minutes, and washed. Specimens were observed under an oil immersion objective (×100) of a microscope, and WBC counts were reported as percentages. For TLC, stained WBCs were counted from 10 objective fields, averaged, and multiplied by 2000 (Figure 1).

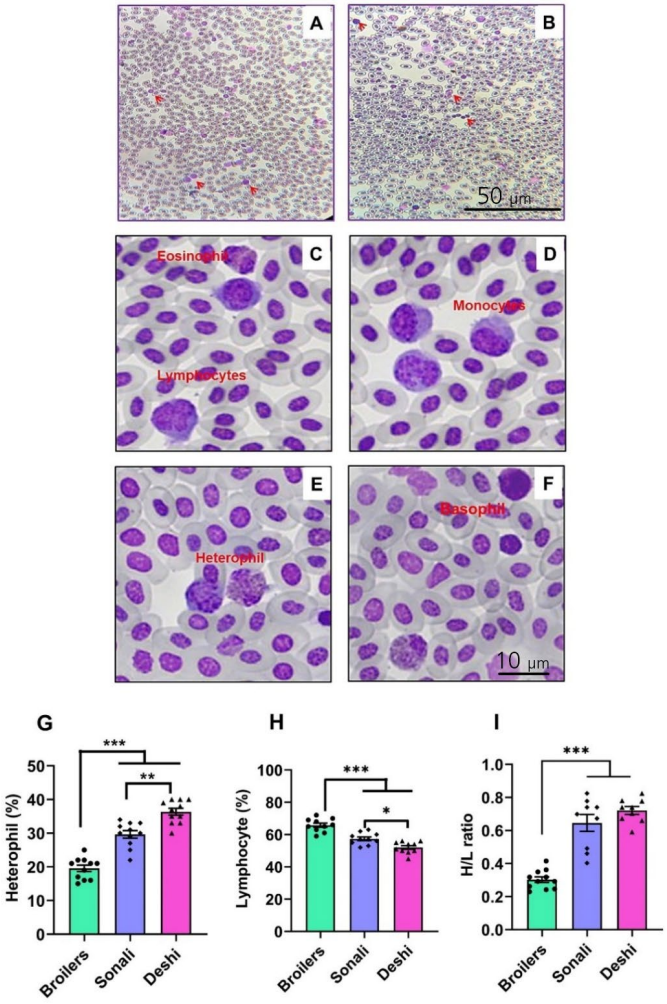

Figure 1 – Leukocyte profile of Broiler, Sonali, and Deshi chickens. Representative Wright-Giemsa-stained leukocytes from different groups. (A, B) TLC images at 40X magnification with a scale bar of 50 µm; (C-F) DLC images at 100X magnification with a scale bar of 10 µm (G-I) Percentage of Heterophils, Lymphocytes, and H/L ratio across different groups, *p<0.05, **p<0.01, ***p<0.001.

Preparation of Serum for Biochemical Analysis

Approximately 10 mL of blood was collected in a sterile test tube and placed in a slanting orientation at room temperature. Subsequently, the collected samples were refrigerated overnight at 4°C. The separation of serum from the coagulated blood was accomplished through centrifugation at 1500 rpm for 10 minutes. The resulting cell-free serum samples were then stored at –20°C for subsequent biochemical analysis.

Serum Biochemical Parameters

The analysis of the separated serum included the examination of total cholesterol, triglycerides, high-density lipoprotein cholesterol (HDL-c), low-density lipoprotein cholesterol (LDL-c), and creatinine. This was conducted using a UV spectrophotometer from PG Instruments, Great Britain, following the methodology described by Haque *et al.* (2017), and employing reagents from High Technology Incorporation (HTI), USA. Total protein was determined using the biuret method. In addition, alanine aminotransferase (ALT), aspartate aminotransferase (AST), and alkaline phosphatase (ALP) were conducted using a spectrophotometer (Khalil *et al.*, 2020).

Statistical Analysis

The data collected in the laboratory were first recorded and organized using Microsoft Excel 2010, after which they were imported into GraphPad Prism 8 for comprehensive statistical analysis. Descriptive statistical methods were employed to determine the mean values, standard error (SE), and *p*-values for each parameter under investigation. To compare the parameters across the three experimental groups, a one-way Analysis of Variance (ANOVA) was utilized. Given the involvement of multiple comparisons, Bonferroni's correction was applied to adjust the *p*-values to minimize the risk of type I errors. A significance level of $p<0.05$ was established as the threshold for statistical significance.

RESULTS

Leukocyte Profile of Deshi, Sonali and Broiler Chickens

Blood samples from different groups were analyzed using DLC and TLC. A significantly higher total leukocyte count ($p<0.05$) was observed in Deshi chickens compared to Sonali and broilers (Table 1).

Table 1 – Total and Differential Leukocyte Count (Mean ± SE) of Deshi, Sonali & Broiler Chickens.

Groups	Lymphocytes (%)	Heterophil (%)	Eosinophil (%)	Basophil (%)	Monocyte (%)	TLC (x10³/µL)
Deshi	52.26 ± 5.25^{c}	36.72 ± 4.33^{c}	5.43 ± 2.6^{c}	0.75 ± 0.05^{c}	7.9 ± 3.95^{b}	17.6 ± 3.80^{c}
Sonali	58.22 ± 4.20^{b}	28.6 ± 5.12^{b}	6.10 ± 1.15^{b}	1.75 ± 0.15^{b}	7.25 ± 3.5^{b}	14.8 ± 1.60^{b}
Broiler	66.5 ± 6.21^{a}	19.35 ± 3.54^{a}	5.24 ± 2.75^{a}	1.25 ± 0.45^{a}	9.3 ± 2.25^{a}	13.0 ± 0.89^{a}

*Values with dissimilar letters (superscript) in a column differ significantly

Deshi chickens also exhibited a significantly higher percentage of heterophils ($p<0.01$) compared to Sonali and broilers (Fig. 1G). Interestingly, lymphocyte numbers were significantly lower ($p<0.05$) in Deshi and Sonali chickens compared to broilers (Fig. 1H). Monocyte, basophil, and eosinophil percentages were consistent across all groups. The H/L ratio was significantly higher ($p<0.001$) in both Deshi and Sonali chickens compared to broilers (Fig. 1).

Lipid Profile of Deshi, Sonali and Broiler Chickens

The lipid profiles of Deshi, Sonali, and Broiler chickens are illustrated in Fig. 2. Broilers exhibited significantly higher ($p<0.001$) serum cholesterol (Fig. 2A) and triglyceride (Fig. 2B) levels compared to Deshi and Sonali chickens. While no significant differences were observed in HDL-c levels across the groups (Fig. 2D), both Sonali and Deshi chickens demonstrated a notable decrease ($p<0.01$) in LDL-c compared to the broilers (Fig. 2C).

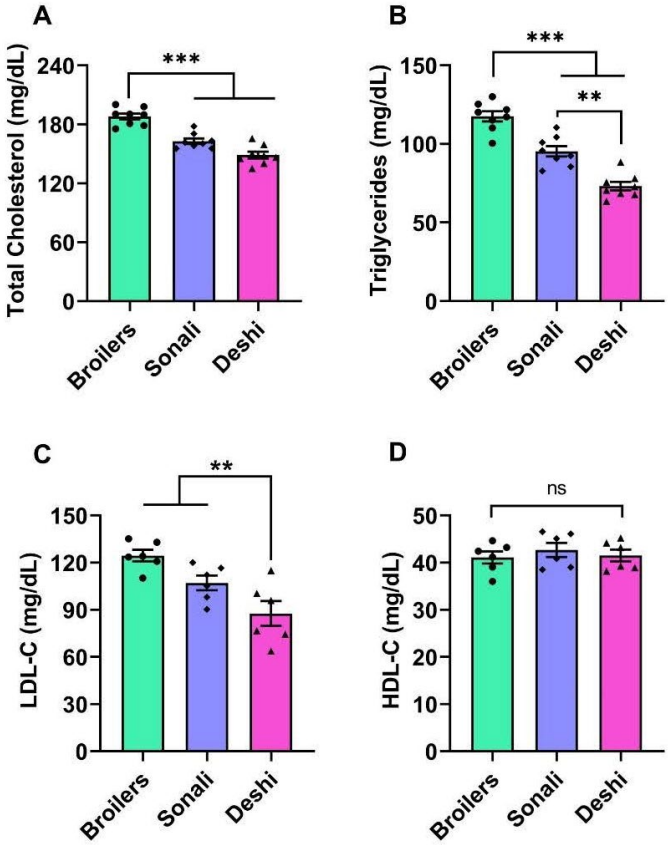

Figure 2 – Lipid profile of Deshi, Sonali and Broiler chickens, $^{**}p<0.01$, $^{***}p<0.001$.

Serum Glucose and Protein Levels of Deshi, Sonali and Broiler Chickens

The serum glucose and protein levels for Deshi, Sonali, and Broiler chickens are presented in Figure 3.

No statistically significant differences in serum glucose levels were observed among the groups (Figure 3A). However, the total serum protein concentration was significantly elevated (p<0.05) in both Deshi and Sonali chickens compared to the broilers (Figure 3B). Further analysis of albumin and globulin levels revealed that albumin concentrations were significantly higher (p<0.01) in Deshi and Sonali chickens than in Broilers (Figure 3C), while the globulin concentrations remained consistent across all groups (Figure 3D). Additionally, the albumin-to-globulin (A/G) ratio was significantly greater in Deshi and Sonali chickens compared to Broilers (Figure 3E).

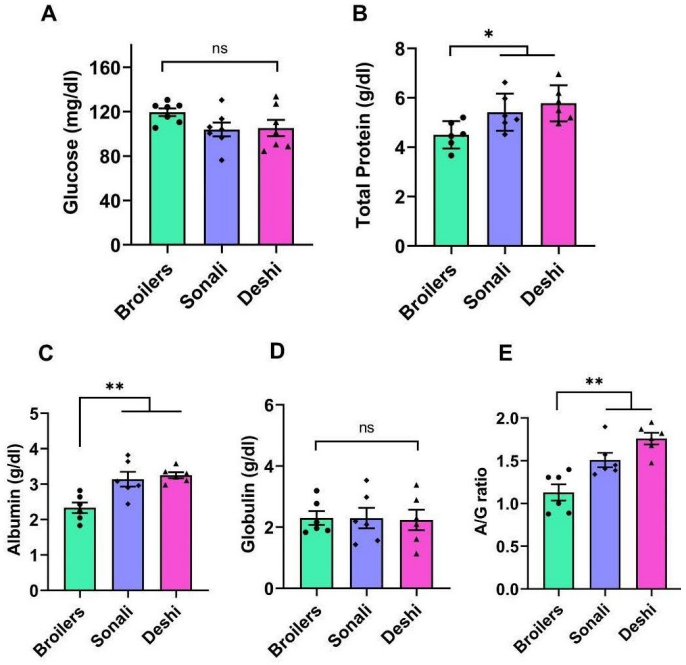

Figure 3 – Serum glucose and protein levels across the different groups, *p<0.05, **p<0.01.

Liver and Kidney Function Tests of Deshi, Sonali and Broiler Chickens

Fig. 4 presents the liver and kidney function test results for Deshi, Sonali, and Broiler chickens, specifically examining ALT, ALP, AST, uric acid, and creatinine levels. The slight variations in ALT and AST levels among the groups were not statistically significant (Fig. 4A and 4C). In contrast, Sonali chickens exhibited a significantly elevated ALP level (p<0.05) compared to Deshi and Broiler chickens (Fig. 4B). Uric acid levels remained consistent across all groups (Fig. 4D). However, both Deshi and Sonali chickens displayed significantly lower creatinine levels (p<0.05) compared to Broilers (Fig. 4E).

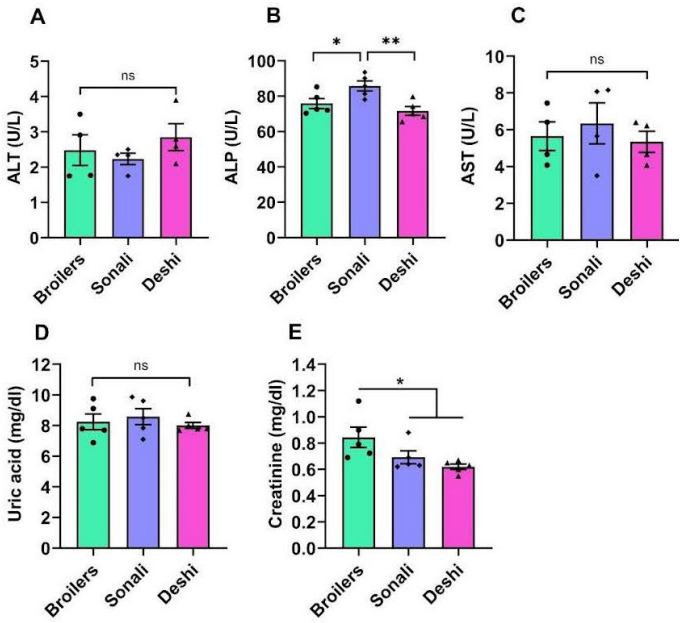

Figure 4 – Liver (A-C) and kidney function (D, E) assessment of Deshi, Sonali and Broiler chickens, *p<0.05, **p<0.01.

DISCUSSION

The blood leukocyte profiles varied significantly among broiler, Deshi, and Sonali chickens, reflecting notable differences in immune strategies and adaptations. One of the most striking findings was the significantly higher TLC in Deshi chickens compared to Sonali and Broilers. Elevated leukocyte counts in Deshi chickens may reflect a heightened immune response or stress adaptation, as leukocytosis is commonly associated with infections or stress-induced immune stimulation (Tvedten & Raskin, 2012). Similar observations of breed-specific variation in leukocyte numbers have been reported in other poultry species, with indigenous breeds often showing higher leukocyte counts due to exposure to a wider range of environmental pathogens and the resulting adaptive immune capacity (Orawan & Aengwanich, 2007; Subhadarsini *et al.*, 2020). The significantly higher percentage of heterophils observed in Deshi chickens further supports this hypothesis. Heterophils, the avian equivalent of mammalian neutrophils, are key components of the innate immune system, responsible for responding to infections and stressors. The elevated heterophil count in Deshi chickens suggests a more robust innate immune defense, likely an adaptation to their more pathogen-rich environment (Thiam *et al.*, 2022). This finding aligns with reports from studies on other indigenous breeds such as Thai chickens, among which similar elevations in heterophil counts were observed (Orawan & Aengwanich, 2007). Elevated

heterophil counts in indigenous breeds could indicate enhanced abilities to respond to immune challenges (Thiam *et al.*, 2021).

In contrast, broiler chickens exhibited a higher percentage of lymphocytes, which are crucial for adaptive immunity (Wlazlak *et al.*, 2023). The dominance of lymphocytes in broilers could be attributed to their selective breeding for rapid growth and high commercial productivity. This selection may have altered their immune profile, favoring adaptive immunity to cope with potential stressors associated with their fast growth rate (Zhang *et al.*, 2023). Broilers' higher energy demand for growth and metabolic processes might necessitate a greater lymphocyte proportion to maintain immune balance (Maharjan *et al.*, 2021). The comparatively lower lymphocyte counts in both Deshi and Sonali chickens suggest a different immune regulation strategy, where these breeds may rely more on innate immunity (via heterophils) rather than adaptive immunity (via lymphocytes). This approach may be evolutionarily advantageous in environments where rapid response to infections is more critical. Deshi chickens, in particular, are likely to encounter a wider array of pathogens in free-range or semi-intensive systems, leading to a robust first-line defense via heterophils.

The H/L ratio was also higher in both Deshi and Sonali chickens. An increased H/L ratio is often indicative of stress or enhanced immune activity (Thiam *et al.*, 2021), further supporting the notion that these chickens are capable of adapting to more challenging environments. Our findings suggest that Deshi and Sonali chickens might possess immune adaptations that allow them to cope with the environmental stressors they face. Future studies should focus on whether these leukocyte profiles translate into tangible differences in disease resistance and survival rates across different environmental conditions. Understanding the genetic and environmental factors that contribute to these immune differences will provide valuable insights into breeding strategies aimed at enhancing disease resistance in poultry.

The lipid profile analysis revealed significant differences in serum total cholesterol and triglyceride levels among the three chicken breeds, with Broilers exhibiting substantially higher levels than both Deshi and Sonali chickens. These elevated lipid levels in Broilers are likely attributable to genetic predispositions and the intensive feeding and management practices commonly employed in commercial broiler farming. Broilers are selectively bred for rapid growth and enhanced muscle development, which increases their energy and nutrient demands, particularly in terms of lipid metabolism (Buzala & Janicki, 2016). This metabolic demand is reflected in the higher serum cholesterol and triglyceride concentrations observed in broilers, as their bodies prioritize fat deposition and energy storage to sustain rapid weight gain. These findings align with previous research. Kalita *et al.* (2018) reported significant differences in cholesterol levels between indigenous and broiler chickens, similar to the disparities observed in our study. Furthermore, Sirri *et al.* (2010) found that slow-growing birds, typically indigenous breeds, had lower lipid contents in their meat compared to fast-growing birds like Broilers, supporting the association between growth rate and lipid metabolism. Alam *et al.* (2020) also observed significantly elevated serum lipid profiles in Broiler chickens, attributing these differences to variations in dietary habits, genetic selection, and rearing practices between commercial and indigenous breeds.

No significant differences in serum glucose levels were observed among the groups, indicating that glucose regulation mechanisms may be relatively similar across the three chicken breeds. In contrast, significant differences were observed in serum protein profiles, with Deshi and Sonali chickens exhibiting higher total serum protein, albumin levels, and an elevated albumin-to-globulin (A/G) ratio compared to Broilers. These results are consistent with previous research, where indigenous breeds such as Sudani chickens have demonstrated higher total protein values (Elagib *et al.*, 2011; Khawaja *et al.*, 2012). Similarly, Kalita *et al.* (2018) identified significant differences in total protein concentrations between native Assamese chickens and Broilers, further demonstrating that native or dual-purpose breeds tend to exhibit superior protein profiles relative to commercial Broilers. Elevated serum protein, particularly albumin, in Deshi and Sonali chickens may indicate enhanced liver function or more efficient protein synthesis. As a key plasma protein, albumin maintains osmotic pressure, transports biomolecules, and reflects nutritional and liver health. The higher levels observed in these breeds likely reflect adaptation to nutrient-limited environments.

Liver function tests, including ALT and AST, did not reveal any significant differences among the three groups, indicating that liver damage or dysfunction was not a concern in any of the groups. However, ALP levels were significantly more elevated in Sonali chickens as compared to the other groups, potentially reflecting differences in bone metabolism or liver

function. Elevated ALP levels are commonly associated with bone growth or turnover; thus, further studies are warranted to elucidate the specific factors contributing to this increase in Sonali chickens.

In this study, uric acid levels remained consistent across the groups, slightly exceeding the range observed by Bhatti *et al.* (2001) among Desi and Naked Neck hens, but in line with the values reported by Elagib *et al.* (2011) for Sudanese rural chickens. Notably, both Deshi and Sonali chickens exhibited significantly lower creatinine levels compared to Broilers. Since creatinine serves as an indicator of kidney function, the lower levels in Deshi and Sonali chickens may suggest superior renal health or reduced muscle mass. Given that broilers are selectively bred for rapid growth and larger muscle mass, their higher creatinine levels likely reflect increased muscle turnover rather than compromised kidney function. Additionally, commercial feed, which includes growth promoters, additives, and trace elements - as suggested by Liu *et al.* (2012) - may induce heightened liver and kidney activity in broilers, potentially contributing to the observed differences.

While this study reveals notable differences in leukocyte, lipid, and protein profiles among broiler, Deshi, and Sonali chickens, we caution against overgeneralizing these findings as purely breed-specific without supporting mechanistic evidence. The birds used were sourced directly from their typical production environments rather than being reared under standardized experimental conditions, which introduced natural variation associated with management, nutrition, and environmental factors. Additionally, some hematological parameters, particularly in the Deshi group, showed relatively high within-group variability—reflecting the inherent genetic and physiological heterogeneity of indigenous chickens. Although individual birds were treated as biological replicates and random sampling was applied to minimize bias, pen-level replication was not feasible under field conditions. Despite these constraints, this design was intentionally chosen to preserve the ecological validity of the data and to represent the true physiological status of these genotypes as they exist in Bangladesh's production systems in smallholder farms. Our findings provide practically relevant baseline hematobiochemical reference values for Deshi, Sonali, and commercial broiler chickens, contributing valuable region-specific data for poultry health assessment, disease diagnosis, and future comparative physiological or genetic studies in tropical environments. Leukocyte profiles and H/L ratios could serve as accessible, non-invasive biomarkers for monitoring stress and immune health in field settings. From a breeding perspective, the integration of immune and protein profile traits into genetic improvement programs may boost disease resilience and productivity, particularly under variable environmental conditions. Lastly, the superior biochemical and immunological profiles of Deshi and Sonali chickens could be leveraged to develop branding strategies that emphasize animal welfare, ecological adaptability, and meat quality attributes, all of which are increasingly valued in sustainable poultry markets. Future research should aim to clarify the mechanistic details of the physiological differences observed in our study. Longitudinal studies involving controlled environmental and dietary conditions are essential to determine whether the elevated heterophil and total leukocyte counts in Deshi chickens indeed translate to improved disease resistance and survival under pathogen-rich or stress-prone environments. Additionally, functional immune assays and molecular profiling should be employed to validate the innate and adaptive immune capacities of different breeds.

CONCLUSION

In conclusion, our comparative study revealed that Deshi and Sonali chickens exhibited higher total leukocyte counts and H/L ratios, indicating stronger innate immunity compared to broilers. These breeds also had a more favorable lipid profile, with lower total cholesterol, triglycerides, and LDL-c levels. Additionally, Deshi and Sonali chickens showed higher total protein and albumin levels. While AST and ALT levels were similar across breeds, broilers had significantly higher creatinine levels, suggesting potential differences in kidney function. Future research should investigate the genetic, environmental, and management factors contributing to such variations within these chicken breeds to introduce targeted breeding and health management strategies in the poultry industry.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the Bangladesh Agricultural University Research System (BAURES), for funding the project (Project No. 2019/757 (24)/BAU).

AUTHOR CONTRIBUTIONS

MIH and MAM conceived and designed the study. MIH and MMR conducted the experiment

and collected the data, performed data analysis and drafted the original manuscript. AM critically revised the manuscript for significant intellectual content. MAM supervised the project, secured funding, and approved the final version.

FUNDING

The project was funded by Bangladesh Agricultural University Research System (BAURES), (Project No. 2019/757 (24)/BAU).

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

CONFLICT OF INTEREST

The authors reported no potential conflicts of interest.

REFERENCES

Adegoke AV, Abimbola MA, Sanwo KA, *et al.* Performance and blood biochemistry profile of broiler chickens fed dietary turmeric (Curcuma longa) powder and cayenne pepper (Capsicum frutescens) powders as antioxidants. Veterinary and Animal Science 2018;6:95–102. https://doi.org/10.1016/j.vas.2018.07.005

Alam M, Ohidullah M, Malik SUF, Islam MS. Broiler and indigenous chickens: a comparison through biochemical parameters. International Journal of Sustainable Agricultural Research 2020;7(4):228–33. https://doi.org/10.18488/journal.70.2020.74.228.233

Alikwe PCN, Faremi AY, Egwaikhide PA. Biochemical evaluation of serum metabolites, enzymes and haematological indices of broiler-chicks fed with varying levels of rumen epithelial scraps in place of fish meal proteins. International Journal of Poultry Science 2010;3(2):27–31. https://doi.org/10.3923/ijps.2010.27.31

Bhatti BM, Talat T, Sardar R. Estimation of serum alkaline phosphatase, cholesterol, calcium and phosphorus during pre-laying and laying conditions in different strains of chickens. Pakistan Veterinary Journal 2002;22(2):94–6.

Buzala M, Janicki B. Review: Effects of different growth rates in broiler breeder and layer hens on some productive traits. Poultry Science 2016;95(9):2151–9. https://doi.org/10.3382/ps/pew173

Carisch L, Stirn M, Hatt JM, *et al.* White blood cell count in birds: evaluation of a commercially available method. BMC Veterinary Research 2019;15:93. https://doi.org/10.1186/s12917-019-1834-8

Dhabhar FS, Miller AH, McEwen BS, *et al.* Stress-induced changes in blood leukocyte distribution: role of adrenal steroid hormones. Journal of Immunology 1996;157(4):1638–44.

El-gendy EA, El-komy EM, El-far AA, *et al.* Developmental stability in chickens local to warm climatic region 2: Variation in blood metabolites due to genetic selection and crossing. International Journal of Poultry Science 2011;10(5):358–64. https://doi.org/10.3923/ijps.2011.358.364

Elagib HAA, Ahmed ADA. Comparative study on haematological values of blood of indigenous chickens in Sudan. Asian Journal of Poultry Science 2011;5:41–45. https://doi.org/10.3923/ajpsaj.2011.41.45

Haque MI, Ahamad N, Miah MA. Comparative analysis of body weight and serum biochemistry in broilers supplemented with some selected probiotics and antibiotic growth promoters. Journal of Advanced Veterinary and Animal Research 2017;3(4):288–94. https://doi.org/10.5455/javar.2017.d226

Herdt TH, Hoff B. The use of blood analysis to evaluate trace mineral status in ruminant livestock. Veterinary Clinics of North America: Food Animal Practice 2011;27(2):255–83. https://doi.org/10.1016/j.cvfa.2011.02.004

Islam MS, Lucky NS, Islam MR, *et al.* Haematological parameters of Fayoumi, Assil and local chickens reared in Sylhet region in Bangladesh. International Journal of Poultry Science 2004;3(2):144–7. https://doi.org/10.3923/ijps.2004.144.147

Kalita DJ, Sultana R, Roy MN, *et al.* Comparative study of certain biochemical profile of broiler and indigenous chicken of Assam. Approaches in Poultry, Dairy, and Veterinary Sciences 2018;2(4):1–5. https://doi.org/10.31031/APDV.2018.02.000544

Khalil KKI, Islam MA, Sujan KM, *et al.* Dietary acidifier and lysozyme improve growth performances and hemato-biochemical profile in broiler chicken. Journal of Advanced Biotechnology and Experimental Therapeutics 2020;3(3):241–7. https://doi.org/10.5455/jabet.2020.d130

Khawaja T, Khan SH, Mukhtar N, *et al.* Comparative study of growth performance, egg production, egg characteristics and haemato-biochemical parameters of Desi, Fayoumi and Rhode Island Red chicken. Journal of Applied Animal Research 2012;40(4):273–83. https://doi.org/10.1080/09712119.2012.672310

Liu J, Cui H, Liu X. Dietary high vanadium causes oxidative damage-induced renal and hepatic toxicity in broilers. Biological Trace Element Research 2012;145:189–200. https://doi.org/10.1007/s12011-011-9185-8

Maharjan P, Martinez DA, Weil J, *et al.* Review: Physiological growth trend of current meat broilers and dietary protein and energy management approaches for sustainable broiler production. Animal 2021;15(1). https://doi.org/10.1016/j.animal.2021.100284

Subhadarsini M, Silpa M, Gayatri A. Comparative hematology and biochemical parameters of indigenous and broiler chicken. International Journal of Scientific & Technology Research 2020;9(4):972–9.

Nelson JR, Sobotik EB, Athrey G, *et al.* Effects of supplementing yeast fermentate in the feed or drinking water on stress susceptibility, plasma chemistry, cytokine levels, antioxidant status, and stress- and immune-related gene expression of broiler chickens. Poultry Science 2020;99(7):3312–8. https://doi.org/10.1016/j.psj.2020.03.037

Olorode BR, Longe OG. Effect of replacing palm kernel cake with shear butter cake on quality characteristics, haematology and serum chemistry of laying hens. Nigerian Journal of Animal Production 2000;27:19–23. https://doi.org/10.51791/njap.v27i.1853

Orawan C, Aengwanich W. Blood cell characteristics, hematological values and average daily gained weight of Thai indigenous, Thai indigenous crossbred and broiler chickens. Pakistan Journal of Biological Sciences 2007;10(2):302–9. https://doi.org/10.3923/pjbs.2007.302.309

Perumal T, Pisupati B. Biodiversity and livelihood, experiences from India: agro-biodiversity. Chennai: National Biodiversity Authority; 2013.

Sirri F, Castellini C, Roncarati A, *et al.* Effect of feeding and genotype on the lipid profile of organic chicken meat. European Journal of Lipid Science and Technology 2010;112:994–1002. https://doi.org/10.1002/ejlt.200900204

Thiam M, Barreto Sánchez AL, Zhang J, *et al.* Association of heterophil/lymphocyte ratio with intestinal barrier function and immune response to Salmonella enteritidis infection in chicken. Animals (Basel) 2021;11(12):3498. https://doi.org/10.3390/ani11123498

Thiam M, Wang Q, Barreto Sánchez AL, *et al.* Heterophil/lymphocyte ratio level modulates Salmonella resistance, cecal microbiota composition and functional capacity in infected chicken. Frontiers in Immunology 2022;13:816689. https://doi.org/10.3389/fimmu.2022.816689

Tvedten H, Raskin RE. Leukocyte disorders. In: Weiss DJ, Wardrop KJ, editors. Schalm's veterinary hematology. 6th ed. Hoboken: Wiley-Blackwell; 2012. p.63–91. https://doi.org/10.1016/B978-1-4377-0657-4.00004-1

Walberg J. White blood cell counting techniques in birds. Seminars in Avian and Exotic Pet Medicine 2001;10(2):72–6. https://doi.org/10.1053/saep.2001.22051

Wlaźlak S, Pietrzak E, Biesek J, *et al.* Modulation of the immune system of chickens: a key factor in maintaining poultry production—a review. Poultry Science 2023;102:102785. https://doi.org/10.1016/j.psj.2023.102785

Zhang J, Wang J, Wang Q, *et al.* Immunogenetic basis of chicken's heterophil to lymphocyte ratio revealed by genome-wide indel variants analysis. Journal of Integrative Agriculture 2023;22:2810–23. https://doi.org/10.1016/j.jia.2022.12.012

Zhou WT, Fujita M, Tamamoto S. Thermoregulatory responses and blood viscosity in dehydrated heat-exposed broilers (*Gallus domesticus*). Journal of Thermal Biology 1999;24(3):185–92. https://doi.org/10.1016/S0306-4565(99)00010-8

DISCLAIMER/PUBLISHER'S NOTE