Pakistan J. Zool., pp 1-6, 2026. DOI: https://dx.doi.org/10.17582/journal.pjz/20250621053215

Comparative Study of Hematological and Biochemical Parameters in Muscovy Ducks Raised on Slatted Flooring and Free-Range Systems

Nguyen Thi Chuc, Trinh Thi Hong Mo, Nguyen Minh Tri, Nguyen Thi My Phuong, Phan Nhan*

Faculty of Applied Biology, Tay Do University, 68 Tran Chien Street, Cai Rang Ward, Can Tho 900000, Vietnam

Article Information
Received 21 June 2025
Revised 25 July 2025
Accepted 17 August 2025
Available online 28 January 2026 (early access)

Authors' Contribution
NTC: Writing-review and editing; TTHM: Validation and formal analysis; NMT: Writing-original draft and Investigation; NTMP: Methodology and formal analysis; PN: Conceptualization, methodology, writing-review and editing.
All authors have read and agreed to the final version of the manuscript.

Key words
Muscovy duck, Hematological parameters, Biochemical profile, Slatted flooring, Free-range system, Poultry physiology

ABSTRACT

This study aimed to evaluate the effects of housing systems and sex on the hematological and biochemical parameters of Muscovy ducks. Forty clinically healthy ducks, approximately 8 weeks of age, were randomly assigned to slatted flooring or free-range systems, with equal numbers of males and females in each group. Blood samples were collected every 14 days over a two-month period. Results showed no significant differences in RBC, hemoglobin, hematocrit, or erythrocyte indices between housing systems. However, WBC was significantly higher in free-range ducks ($24.18 \pm 2.98 \times 10^3/mm^3$) compared to slatted flooring ducks ($23.01 \pm 3.11 \times 10^3/mm^3$) ($p < 0.05$), suggesting increased immune response in outdoor conditions. Urea levels were also higher in free-range ducks (1.49±0.21 mmol/L), while slatted flooring ducks had significantly higher levels of total protein (36.24±17.21 g/L), albumin (21.51±2.47 g/L), and globulin (17.73±3.01 g/L) ($p<0.05$), indicating improved protein metabolism under confined rearing. Sex-related differences were more prominent than those from housing systems. Male ducks exhibited significantly higher RBC (up to $3,71 \pm 0,26 \times 10^6/mm^3$), WBC ($27.95 \pm 5.12 \times 10^3/mm^3$), and higher serum concentrations of albumin (23.93±0.85 g/L) and globulin (18.89±2.26 g/L) than females, indicating greater metabolic and immunological activity. In conclusion, housing systems influenced certain blood parameters, but sex showed a more consistent impact on both hematological and biochemical profiles. These findings offer useful insights for improving Muscovy duck health and productivity through environment and sex-specific management strategies.

INTRODUCTION

Poultry production systems play a pivotal role in determining animal health, welfare, and productivity. Among avian species, the Muscovy duck has gained attention for its robustness, adaptability to various environments, and economic value in meat production. Moreover, ducks possess inherent resistance to many common infectious diseases (Oluyemi and Roberts, 1979), a trait that significantly contributes to their resilience and long-term survivability, particularly under challenging conditions associated with ongoing global climate change. As global demands for sustainable and welfare-friendly livestock practices increase, there is a growing interest in evaluating how different rearing systems affect physiological and metabolic responses in poultry. Ducks exhibit superior adaptability and survivability compared to many other livestock species, even under challenging environmental conditions such as heavy rainfall, high ambient temperatures, elevated humidity, and suboptimal housing (Ola, 2000).

Housing systems such as slatted flooring and free-range environments represent two contrasting models of management. Slatted flooring, often used for its hygiene and space efficiency, limits natural behaviors but reduces contact with waste and pathogens. In contrast, free-range systems allow ducks to express natural behaviors, potentially improving welfare but increasing exposure to environmental stressors and parasites. These environmental differences may significantly influence internal physiological markers, particularly hematological and biochemical parameters, which serve as essential indicators of animal health, immune function, and metabolic state. Poultry blood, a by-product of slaughtering operations, is often discarded as waste, contributing to environmental pollution and the underutilization of a valuable protein source. Nonetheless, this material is rich

* Corresponding author: pnhan@tdu.edu.vn
0030-9923/2026/0001-0001 $ 9.00/0

in essential amino acids, bioactive peptides, and functional components, exhibiting promising functional properties for incorporation into food systems. These characteristics highlight its potential as a sustainable and high-value food ingredient (Zheng *et al*., 2023). Hematological parameters such as red and white blood cell counts, hemoglobin concentration, hematocrit, and erythrocyte indices (MCV, MCH, MCHC) reflect the oxygen-carrying capacity and immune status of the animal. White blood cells serve as the primary cellular components of the immune system, playing a critical role in host defense mechanisms and influencing the animal's capacity to respond to infections (Schalm *et al*., 1975). Simultaneously, serum biochemical indices like creatinine, urea, total protein, albumin, and globulin offer insights into renal function, protein metabolism, and overall homeostasis. Variations in these indicators under different husbandry conditions can reveal subclinical health changes not apparent through external observation. These biochemical variations may be influenced by intrinsic factors such as hormonal fluctuations, differences in metabolic rate, behavioral stress, courtship activity, and reproductive stages. Such parameters are essential indicators for evaluating the physiological status and health profile of ducks, as highlighted by Acharya *et al*. (2020).

Despite the increasing number of studies on rearing systems in commercial poultry, limited data are available for Muscovy ducks, especially in tropical or subtropical regions. Understanding how blood profiles respond to housing conditions can support optimized management strategies that align with both productivity and animal welfare standards. Therefore, this study aimed to compare the hematological and biochemical profiles of Muscovy ducks raised on slatted flooring and those reared in free-range systems. The findings are expected to contribute valuable data to poultry science and support evidence-based recommendations for duck farming practices.

MATERIALS AND METHODS

Location and time

The study was conducted at Hai Suong farm, located in Dai Thanh commune, Nga Bay City, Hau Giang province, Vietnam. Blood sample collection and experimental procedures were carried out on-site. Laboratory analyses of hematological and biochemical parameters were performed at the Veterinary Laboratory, Tay Do University, Can Tho City. The research was conducted over a period of five months, from August to December 2024.

Animals and experimental design

A total of 40 clinically healthy Muscovy ducks, approximately 8 weeks of age, were used in this study. The ducks were randomly assigned to two rearing systems: slatted flooring and free-range, with each system comprising 10 males and 10 females housed separately by sex. All animals were acclimatized to their respective environments for two weeks prior to the initiation of sampling. Blood samples were then collected at 14-day intervals over a two-month period, resulting in four sampling points. All the blood samples were taken in the morning before the ducks were fed.

Ducks were provided a commercial pelleted diet twice daily (morning and afternoon), formulated from broken rice, rice bran, maize, fish meal, and soybean meal. The diet supplied a metabolizable energy of 3000 kcal/kg, crude protein ≥17%, calcium 0.8–1.2%, and available phosphorus ≥0.62%. Clean drinking water was available ad libitum throughout the trial.

All animal handling procedures adhered to international guidelines for the humane treatment of animals in scientific research. Efforts were made to minimize handling stress. Blood collection was conducted aseptically by trained personnel, and animal health and welfare were closely monitored throughout the experimental period.

Hematological analysis

Red blood cell (RBC) were counted using a Neubauer hemocytometer after dilution with Marcano's solution (5 g sodium sulfate, 1 drop 40% formalin in 200 mL distilled water) at a 1:200 ratio. White blood cells (WBCs) were determined via blood smear stained with Giemsa stain and counted under a light microscope at 40× magnification. Hemoglobin (Hb) concentration was estimated using the Sahli method, in which blood reacts with 0.1N HCl to form brown acid hematin. The color intensity was matched against a standard comparator tube, and the value was read in g/100 mL. Hematocrit (HCT) values were determined by the microhematocrit method using capillary tubes centrifuged at 10,000 rpm for 4 min. The percentage of packed red blood cells was read using a standard hematocrit reader.

Erythrocyte indices (Wintrobe indices) were calculated based on formulas described by Swenson (1970)

MCV (mean corpuscular volume) = (HCT×10)/RBC

MCH (mean corpuscular hemoglobin) = (Hb × 10) /RBC

MCHC (mean corpuscular hemoglobin concentration) = (Hb × 100) / HCT

Serum biochemical analysis

Biochemical parameters including urea, creatinine, total protein, albumin, and globulin were measured using a semi-automated biochemistry analyzer (Model: Chem-7). Globulin was calculated as the difference between total protein and albumin:

Globulin = total protein – albumin

Statistical analysis

Statistical analyses were conducted using SPSS version 26.0. All data were expressed as mean ± standard deviation (SD). An independent samples t-test was applied to compare means between housing systems and sexes. Statistical significance was considered at $p < 0.05$.

RESULTS AND DISCUSSION

Hematological and biochemical components of serum

Table I shows analysis of hematological and biochemical parameters in Muscovy ducks raised under slatted flooring and free-range systems. Red blood cell (RBC) count showed no significant difference between systems, with values of 3.22±0.63 and 3.21±0.82 $\times10^6$/mm^3, respectively. Tajali and Habibabadi (1996) reported that native Iranian ducks exhibit an average RBC count of approximately 2.66$\times10^6$/µl, highlighting potential inter-breed variation in erythrocyte profiles. Kocan (1972) reported species-specific variations in RBC counts among several wild duck species, with canvasbacks, lesser scaups, ring-necked ducks, and buffleheads exhibiting mean RBC values of 2.56$\times10^6$/mm^3, 2.45$\times10^6$/mm^3, 2.50$\times10^6$/mm^3, and 2.64 $\times$ 10^6/mm^3, respectively. Hb concentration was also similar between groups, recorded at 13.65±1.74 and 13.48±1.69 g/100 mL. Healthy ducks have an average RBC count of 3.31 million/mm^3, with hemoglobin levels at 10.3 g% and packed cell volume (PCV) at 33% (Soliman *et al.*, 2010). The white blood cell (WBC) counts observed in this study were within the reference range of 10,2 to 30,0$\times10^3$/mm^3 as reported by Jain (1993), suggesting that the ducks maintained normal leukocyte profiles under both rearing systems. According to Hatipoglu and Bağcı (1996), healthy Peking ducks exhibit an average RBC count of 3.84$\times10^6$/mm^3 and a WBC count of approximately 15.95$\times10^3$/mm^3, values that serve as important reference points for hematological evaluation in waterfowl. Hemoglobin is an iron-containing metalloprotein responsible for binding and transporting oxygen in the bloodstream of all vertebrates (Sidell and O'Brien, 2006). It is a key component of red blood cells and plays a crucial role in maintaining efficient respiratory and metabolic functions (Etim *et al.*, 2014). HCT values followed the same pattern, being 36.27±4.32 and 36.09±4.18%. HCT indicates the proportion of RBC within the total blood volume, and is commonly used as a measure of oxygen-carrying capacity in animals (Galvez *et al.*, 2009). It plays an essential role in the transport of oxygen and absorbed nutrients throughout the body (Isaac *et al.*, 2013). These findings indicate that the erythropoietic activity and oxygen transport capacity of ducks were not influenced by the housing condition. Similarly, erythrocyte indices including MCV, MCH, and MCHC showed no statistically significant differences between the groups. MCV values were 112.64±12.83 and 112.43±13.01 m3, MCH values were 42.39±5.17 and 41.99±5.29 pg, and MCHC values were 37.63±3.46 and 37.35±3.26 percent in slatted flooring and free-range systems, respectively. In contrast, WBC was significantly higher in ducks raised in the free-range system, at 24.18±2.98 $\times10^3$/mm^3 compared to 23.01±3.11 $\times10^3$/mm^3 in slatted flooring birds, with a p-value less than 0.05. This elevated leukocyte count suggests a stronger immunological activation likely due to greater exposure to environmental antigens in open-field conditions. Studies on Dom and Co Lung duck breeds have reported notably high white blood cell counts, with values reaching 43.12 $\times$ 10^3/mm^3 (Hoa, 2015) and ranging from 38.55 $\times$ 10^3/mm^3 in males to 40.98 $\times$ 10^3/mm^3 in females (Mui *et al.*, 2018), indicating possible breed-related hematological variation.

Table I. Hematological and blood biochemical parameters of Muscovy ducks raised in slatted flooring and free-range systems.

Parameters	Slatted flooring (n= 20)	Free-range systems (n= 20)
Hematological parameters		
Red blood cell count (10^6/mm^3)	3.22±0.63	3.21±0.82
White blood cell count (10^3/mm^3)	23.01 ± 3.11^{b}	24.18 ± 2.98^{a}
Hemoglobin (g/100mL)	13.65±1.74	13.48±1.69
Hematocrit (%)	36.27±4.32	36.09±4.18
Wintrobe index		
MCV (m^3)	112.64±12.83	112.43±13.01
MCH (pg)	42.39±5.17	41.99±5.29
MCHC (%)	37.63±3.46	37.35±3.26
Blood biochemical parameters		
Creatinine (mmol/L)	33.27±5.87	33.86±6.23
Urea (mmol/L)	1.32 ± 0.15^{b}	1.49 ± 0.21^{a}
Protein (g/L)	36.24 ± 17.21^{a}	34.08 ± 16.65^{b}
Albumin (g/lL)	21.51 ± 2.47^{a}	19.62 ± 2.52^{b}
Globulin (g/L)	17.73 ± 3.01^{a}	14.46 ± 2.86^{b}

^{ab} Mean values within rows with different superscripts are different at p<0.05

Data are presented as mean ± SD. Values were summarized across four sampling points (every 14 days over two months)

MCV, mean corpuscular volume; MCV, mean corpuscular hemoglobin; MCHC, mean corpuscular hemoglobin concentration; n, number of animals.

Regarding biochemical parameters in Table I, creatinine levels showed no significant variation between systems, measured at 33.27±5.87 and 33.86±6.23 mmol/L. However, urea levels were significantly higher in free-range ducks (1.49±0.21 mmol/L) compared to slatted flooring ducks (1.32±0.15 mmol/L), reflecting increased protein catabolism and possibly higher muscular activity. Total protein, albumin, and globulin levels were all significantly higher in the slatted flooring group, with values of 36.24±17.21, 21.51±2.47, and 17.73±3.01 g/L respectively, compared to 34.08±16.65, 19.62±2.52, and 14.46±2.86 g/L in the free-range group. Normal levels of blood chlorides, sugar, creatine, creatinine, urea, and iron are 370 mg%, 250.6 mg%, 1.1 mg%, 0.59 mg%, 7.2 mg%, and 34.6 mg%, respectively (Soliman *et al*., 2010). Duck blood hemolysate can synthesize porphyrins, primarily protoporphyrin IX and hemin, with storage conditions affecting the accumulation of different porphyrins (Frydman *et al*., 1977). These differences suggest that confined ducks may have better nutrient assimilation and hepatic protein synthesis, possibly due to lower physical stress and antigenic challenge.

Sex-based biochemical and hematological analysis

Table II shows **s**ex-based physiological differences than rearing system alone. Male ducks exhibited significantly higher red blood cell counts than females across both systems. In slatted flooring birds, males had 3.71±0.26×10⁶/mm³ while females had 3.05±0.83×10⁶/mm³. Similarly, in free-range conditions, males reached 3.65 ± 0.15 while females recorded 3.09±0.47 ×10⁶/mm³. White blood cell counts were also higher in males, at 27.95±5.12 and 26.89±5.43 ×10³/mm³, compared to 20.14±4,86 and 22.27±5.21 ×10³/mm³ in females. The average WBC count is 20.700/mm³, with lymphocytes being the most prevalent at 66.2% (Soliman *et al*., 2010). The current results regarding WBC differentials are consistent with earlier reports indicating that lymphocytes and neutrophils constitute the predominant leukocyte populations in domestic ducks (Olayemi and Arewwolo, 2009; Gladbach *et al*., 2010). Although hemoglobin and hematocrit values were not statistically different, males showed consistently higher means. Erythrocyte indices revealed that females had higher MCV values, suggesting larger RBC volume, with slatted flooring females at 112.16±9.13m³ versus 93.13±15.81m³ in males. Comparative studies across avian species have demonstrated notable variability in erythrocyte indices. Elarabany (2018) reported MCV values of 88.07fl and 91.52fl, MCH of 28.75pg and 29.38pg, and MCHC of 335g/l and 326.6g/l in Northern shovelers and Eurasian teals, respectively. In Indonesian ducks, Pranoto and Nugrahalia (2020) observed marked sex-related differences, with MCV and MCH reaching 94.62fl and 30.68pg in males, and 146.24fl and 45.67pg in females. Muneer *et al*. (2021) noted MCV values between 118.76 and 126.75 fl, and MCH values from 31.71 to 32.29 pg in broilers and native chickens. Additionally, Durai *et al*. (2012) documented wide-ranging values of MCV (84.81–142.04 fl), MCH (34.63–50.24 pg), and MCHC (312.3–345.58 g/l) across multiple poultry breeds.

Table II. Comparative hematological and serum biochemical parameters of male and female muscovy ducks raised in slatted flooring and free-range systems.

Parameters	Female		Male	
	Slatted flooring (n= 10)	Free-range systems (n= 10)	Slatted flooring (n= 10)	Free-range systems (n= 10)
Hematological parameters				
Red blood cell count (10⁶/mm³)	3.05±0.83[d]	3.09±0.47[c]	3.71±0.26[a]	3.65±0.15[b]
White blood cell count (10³/mm³)	20.14±4.86[d]	22.27±5.21[c]	27.95±5.12[a]	26.89±5.43[b]
Hemoglobin (g/100mL)	11.09±0.95	11.64±1.08	15.97±1.96	15.83±2.09
Hematocrit (%)	34.21±3.11	34.55±3.09	38.67±3.17	38.09±3.25
Wintrobe index				
MCV (m³)	112.16±9.13[a]	110.71±16.45[b]	93.13±15.81[d]	105.95±19.36[c]
MCH (pg)	36.36±2.43	37.67±3.58	43.05±6.54	43.37±6.63
MCHC (%)	32.42±3.17	33.69±4.96	41.30±3.71	41.56±4.08
Serum biochemical parameters				
Creatinine (mmol/L)	31.89±4.71	31.75±5.15	32.21±4.93	35.49±5.07
Urea (mmol/L)	1.14±0.02[c]	0.98±0.19[d]	1.48±0.25[b]	1.52±0.08[a]
Protein (g/L)	30.87±2.09	31.19±1.96	39.61±1.81	41.85±2.54
Albumin (g/L)	17.69±0.61[c]	15.25±0.73[d]	23.93±0.85[a]	22.96±0.99[b]
Globulin (g/L)	13.18±1.84[d]	15.94±2.17[b]	15.68±1.93[c]	18.89±2.26[a]

[abcd] Mean values within rows with different superscripts are different at $p<0.05$
For abbreviations, see Table I.
Data are presented as mean ± SD. Values were summarized across four sampling points (every 14 days over two months). n, number of animals.

The present study's erythrocyte indices fall within these previously reported ranges, suggesting consistency in physiological patterns across both domestic and wild avian species. This may indicate sex-related differences in erythrocyte morphology and hydration status. Several previous studies have indicated that female poultry tend to exhibit elevated levels of key biochemical parameters compared to their male counterparts (Okeudo *et al*., 2003; Mui *et al*., 2018; Ologbose and Dick, 2021). Sex-related variation in hematological and biochemical traits of ducks has been previously attributed to physiological and hormonal differences. According to Acharya *et al*. (2020), significant differences in erythrocyte morphology, plasma chemistry (including glucose, cholesterol, total plasma protein, albumin, and globulin), and leukocyte subpopulations were observed between male and female ducks. While parameters such as PCV, RBC, and leukocyte count exhibited statistical differences ($p < 0.05$ to $p < 0.01$), erythrocyte indices like MCV, MCH, and MCHC did not vary significantly. The observed disparities were associated with metabolic rate, stress, reproductive activity, and immune responses, further reinforcing the findings of the present study, where males consistently showed higher RBC and WBC counts, along with elevated albumin and globulin levels. Biochemical differences by sex were also clear. Urea levels in males were significantly higher, particularly under free-range conditions, with 1.52±0.08 mmol/L compared to 0.98±0.19 mmol/L in females. Albumin levels were markedly greater in males, with slatted flooring males reaching 23.93±0.85 g/L, while free-range females recorded only 15.25±0.73 g/L. Globulin levels followed a similar trend, with free-range males having the highest value of 18.89±2.26 g/L and slatted flooring females the lowest at 13.18±1.84 g/L. These findings reflect higher metabolic and protein synthesis activity in males, along with potentially stronger humoral immune responses. While creatinine levels did not show significant sex-based differences, males tended to have higher means, which may correlate with greater muscle mass and mobility.

In summary, while housing system had a moderate effect on some hematological and biochemical traits, particularly in immune and protein metabolism markers, biological sex exerted a more consistent and substantial influence. These results emphasize the importance of considering sex as a key variable in physiological studies on poultry and provide valuable data for optimizing rearing strategies in Muscovy duck production systems.

CONCLUSION

Ducks raised under free-range conditions exhibited significantly higher white blood cell counts (24.18±2.98 $\times 10^3$/mm^3) and urea levels (1.49±0.21 mmol/L), suggesting heightened immune activation and metabolic demand. In contrast, birds in slatted flooring systems showed superior values in total protein (36.24±17.21 g/L), albumin (21.51±2.47 g/L), and globulin (17.73±3.01 g/L), indicating enhanced protein synthesis and possibly reduced antigenic exposure. Males consistently outperformed females across red blood cell counts (up to 3.71±0.26 $\times 10^6$/mm^3), albumin (23.93±0.85 g/L), and globulin (18.89±2.26 g/L), underscoring the physiological impact of sex on hematological and metabolic traits.

DECLARATIONS

Acknowledgement

We acknowledge the support of time and facilities from Tay Do University (TDU) for this study.

IRB approval

IRB approval was not required for this study as it involved routine animal handling and blood sampling performed in accordance with the Vietnamese national standard QCVN 01-83:2011/BNNPTNT (General requirements for collection of animal specimens).

Ethical statement

All procedures involving animals were carried out in compliance with ethical standards for animal welfare. Efforts were made to minimize stress and discomfort to the animals during sample collection.

Generative AI and AI-assisted technology statement

The authors confirm that the manuscript was prepared under the authors' responsibility, and any generative AI or AI-assisted tools, if used, were only for language improvement. The authors take full responsibility for the content.

Statement of conflict of interest

The authors have declared no conflict of interest.

REFERENCES

Acharya, G., Rout, S., Das, S. and Sahoo, A., 2020. Effect of sex on biochemical, cytomorphometrical and haematological parameters of mallard duck, *Anas platyrhynchos* (Linnaeus, 1758). *Compar. Haematol. Int.*, **29**: 201–211. https://doi.org/10.1007/s00580-019-03026-6

Durai, P.C., Maruthai, T.P.T., Arumugam, S.S. and Venugopal, O.A., 2012. Haematological profile and erythrocyte indices in different breeds of poultry. *Int. J. Livest. Res.*, **2**: 89-92. https://doi.

org/10.5455/ijlr.20120824083537

Elarabany, N., 2018. A comparative study of some haematological and biochemical parameters between two species from the Anatidae family within migration season. *J. Basic Appl. Zool.*, **79**: 31. https://doi.org/10.1186/s41936-018-0044-4

Etim, N., Williams, M.E., Akpabio, U. and Offiong, E.E., 2014. Haematological parameters and factors affecting their values. *Agric. Sci.*, **2**: 37-47. https://doi.org/10.12735/as.v2i1p37

Frydman, R.B., Frydman, B. and Feinstein, G., 1977. Porphyrin biosynthesis from prophobilinogen by duck blood hemolysate. *Mol. Cell. Biochem.*, **16**: 187–192. https://doi.org/10.1007/BF01732060

Galvez, C., Ramírez, G. and Henry, J., 2009. El-laboratorio clínico en hematología de aves exóticas. *Biosalud*, **8**: 178-188. http://www.scielo.org.co/pdf/biosa/ v8n1/v8n1a20.pdf.

Gladbach, A., Gladbach, D.J. and Quillfeldt, P., 2010. Variation in leucocyte profiles and plasma biochemistry are related to different aspects of parental investment in male and female upland geese *Chloephaga picta leucoptera*. *Comp. Biochem. Physiol. A: Mol. Integr. Physiol.*, **1562**: 269-277. https://doi.org/10.1016/j.cbpa.2010.02.012

Hatipoglu, S. and Bağcı, C., 1996. Some hematologic values of Peking ducks. *Berl. Munch. Tierarzt. Wochensch.*, **109**: 172. https://www.ncbi.nlm.nih.gov/pubmed/8694745

Hoa, D.V., 2015. *Biological characteristics, productive performance of Dom duck (Pat Lai) and the cross between Dom duck and T14 duck (CV. Super M3).* Doctoral thesis in Agriculture, National Institue of Animal Science.

Isaac, L., Abah, G., Akpan, B. and Ekaette, I., 2013. *Haematological properties of different breeds and sexes of rabbits*. Proceedings of the 18th Annual Conference of Animal Science Association of Nigeria, pp. 24-27.

Jain, N.C., 1993. *Essentials of veterinary hematology*. Lea and Febiger, Philadelphia. pp. 76-250.

Kocan, R.M., 1972. Some physiologic blood values of wild diving ducks. *J. Wildl. Dis.*, **8**: 115–118. https://doi.org/10.7589/0090-3558-8.2.115

Mui, N.B., Ha, D.N. and Duy, N.V., 2018. Blood haematological and biological parameters of Co Lung duck. *Vietnam J. agric. Sci.*, **16**: 585–590.

Muneer, M., Bilal, M. and Ditta, A., 2021. A comparative study of some hematological parameters of broiler and indigenous breeds of poultry. *SVU Int. J. agric. Sci.*, **3**: 203-213. https://doi.org/10.21608/svuijas.2021.99388.1146

Okeudo, N.J., Okoli, I.C. and Igwe, G.O.F., 2003. Hematological characteristics of ducks *(Cairina moschata)* of Southeastern Nigeria. *Tropicultura*, **2**: 61-65.

Ola, S.I., 2000. Growth and carcass characteristics of the Nigerian muscovy duck. In: *The Proceedings Of The Xxi World's Poultry Congress*, *August 20-24 2000, Montreal, Canada*.

Olayemi, F.O. and Arewwolo, R.O.A., 2009. Seasonal variations in the haematological values of the Nigerian duck (*Anas platyrhynchos*). *Int. J. Poult. Sci.*, **8**: 813-815. https://doi.org/10.3923/ijps.2009.813.815

Ologbose, F. and Dick, S., 2021. Breeds, age and sex effect on haematological and biochemical parameters of ducks in rivers State, Nigeria. *Black Sea J. Agric.*, **4**: 52-57. https://doi.org/10.47115/bsagriculture.809820

Oluyemi, J.A. and Roberts, F.A., 1979. *Poultry production in warm wet climates*, Macmillian Press Ltd., London. pp. 197.

Pranoto, H. and Nugrahalia, M., 2020. A study on sex based hematology and biochemistry of lesser whistling duck (*Dendrocygna javanica*). *Int. J. Poult. Sci.*, **19**: 124-129. https://doi.org/10.3923/ijps.2020.124.129

Schalm, O.W., Jain, N.C. and Carroll, E.J., 1975. *Veterinary hematology*. Lea and Febiger, Philadelphia.

Sidell, B.D. and O' Brien, K.M., 2006. When bad things happen to good fish: The loss of haemoglobin and myoglobin expression in Antarctic icefishes. *J. exp. Biol.*, **209**: 1791-1802. https://doi.org/10.1242/jeb.02091

Soliman, M.K., El-Amrousi, S. and Ahmed, A.A.S., 2010. Cytological and biochemical studies on the blood of normal and spirochaete-infected ducks. *J. Vet. Med. Ser. B Infect. Dis. Vet. Publ. Hlth.*, **13**: 82–86. https://doi.org/10.1111/j.1439-0450.1966.tb00880.x

Tajali, M. and Habibabadi, S.N., 1996. Hematological values of healthy native Iranian ducks. *J. appl. Anim. Res.*, **10**: 207–210. https://doi.org/10.1080/09712119.1996.9706151

Zheng, H., Zhao, S., Lu, Y., Zhang, N., Soladoye, O.P., Zhang, Y. and Fu, Y., 2023. Toward the high-efficient utilization of poultry blood: Insights into functionality, bioactivity and functional components. *Crit. Rev. Fd. Sci. Nutr.*, pp. 1–20.