Black Sea Journal of Agriculture
doi: 10.47115/bsagriculture.1032032

Open Access Journal
e-ISSN: 2618 – 6578

Research Article
Volume 5 - Issue 2: 167-171 / April 2022

COMPARATIVE STUDIES ON BLOOD SERUM PROFILES OF LIVER ENZYMES, PROTEINS, TOTAL BILIRUBIN AND LIVER ORGAN MORPHOMETRY OF MUSCOVY DUCKS

Shima Samuel CHIA[1]*, Jethro Myom ADAGI[2], Mamfe Elizabeth ATE[1], Kumawuese Samuel UMA[1]

[1]*Department of Animal Breeding and Physiology, Joseph Sarwuan Tarka University, Makurdi, Benue State, Nigeria*
[2]*Department of Animal Nutrition, Joseph Sarwuan Tarka University, Makurdi, Benue State, Nigeria*

Abstract: Twenty adult apparently healthy Muscovy ducks *Cairina moschata* (10 males, 10 females) were used in a study to compare between sexes blood serum alanine aminotransferase (ALT), aspartate aminotransferase (ALT), alkaline phosphatase (ALP), total protein, albumin, and total bilirubin profiles using jugular venous blood. Comparative biometric measurements (weight, length, width and thickness) of their liver organs were also done. Total protein and albumin were significantly ($P<0.05$) higher in female ducks than in males while ALT, AST ALP and total bilirubin were unaffected ($P > 0.05$) by sex. The biometric measurements of the liver of Muscovy ducks according to sex were significantly ($P < 0.05$) higher in males than females. Liver biometric measurements according to lobation were significantly ($P < 0.05$) higher in the right lobe than in the left lobe, particularly, in terms of liver lobe weight and length of both sexes of ducks while liver lobe width and thickness were statistically similar ($P > 0.05$) in both sexes. Therefore, sex had a significant influence on serum total protein and albumin, as well as the biometric measurements of the liver of Muscovy ducks studied.

Keywords: Muscovy ducks, Serum biochemistry, Liver organ, Biometry

***Corresponding author:** Department of Animal Breeding and Physiology, Joseph Sarwuan Tarka University, Makurdi, Benue State, Nigeria
E mail: chia.shima@uam.edu.ng (S. S. CHIA)
Shima Samuel CHIA https://orcid.org/0000-0002-3160-3854
Jethro Myom ADAGI https://orcid.org/0000-0001-8585-0626
Mamfe Elizabeth ATE https://orcid.org/0000-0001-9361-616X
Kumawuese Samuel UMA https://orcid.org/0000-0002-8126-8273

Received: December 15, 2021
Accepted: March 22, 2022
Published: April 01, 2022

Cite as: Chia SS, Adagi JM, Ate ME, Uma KS. 2022. Comparative studies on blood serum profiles of liver enzymes, proteins, total bilirubin and liver organ morphometry of Muscovy ducks. BSJ Agri, 5(2): 167-171.

1. Introduction

The liver is the largest gland of the body and it is dark red or red brown in colour, bilobated into right and left lobes with the right usually larger than the left (Dyce et al., 2010). The bulk of the liver lies to the right in all species (Dyce et al., 2010). The right and left liver lobes are joined cranially at the midline and the lobes are with specific shapes and sizes (Iqbal et al., 2014). The liver plays a crucial role in numerous physiological processes such as synthesis of blood proteins, production and secretion of bile, detoxification, nutrients absorption, metabolism of several substances, and storage of metabolites (Odokuma and Omokara, 2015).

Abnormal weights of internal organs such as the liver and kidney arise because of the increase in metabolic rate of these organs in an attempt to reduce toxic elements or anti-nutritional factors into non-toxic metabolites (Bone, 1979). Toxins such as mycotoxins, heavy metals and some poisonous plants can have serious effect on the physiological performance of the avian liver, thus leading to elevations in serum liver enzymes and other blood metabolites. Some of the enzymes used for assessing liver functions include alanine transaminase (ALT), aspartate transaminase (AST), alkaline phosphatase (ALP), and gamma-glutamyl transpeptidase (GGT). Other metabolites like proteins (total protein and albumin) and total bilirubin are also associated with liver function.

ALT and AST are the most specific markers of hepatic injury (Vernon et al., 2011; Music et al., 2015) but they lack specificity as they are also present in muscle (cardiac and skeletal), kidney and red blood cells (Clementine and Tar Choon, 2010). ALP is found in the liver, bone, kidney, intestine and placenta and is helpful in detecting liver damage due to bile duct obstruction (Clementine and Tar Choon, 2010). Gamma glutamyltransferase (GGT) is present in liver, kidney, pancreas and intestines and considered to be a sensitive indicator of liver damage but it is not specific (Penn and Worthington, 1983). Nearly all proteins are synthesized in the liver, hence, total protein is used to assess the synthesis and maintenance of proteins in circulation, although, it is not a sensitive measure of hepatic failure (Bertholf, 2014). Albumin helps maintain osmotic balance and also acts as a transport protein for calcium, unconjugated bilirubin and thyroid hormones (Bertholf, 2014). Bilirubin is the end product derived from liver breakdown of heme in hemoglobin of red blood cells (Fevery, 2008). It is transported in the blood bound to albumin and secreted in bile juices which is stored in the gall bladder

(Clementine and Tar Choon, 2010). Bilirubin serves as a diagnostic marker of liver disorder due to jaundice.

Literature on serum metabolites as well as biometric studies of the internal organs of indigenous ducks in Nigeria, particularly, the Muscovy duck *Cairina moschata* is generally lacking. Therefore, this study sought to contribute to the pool of existing data on ducks through comparative evaluations of some blood serum liver enzymes, proteins, total bilirubin, and gross morphometric measurements of the liver organs between male and female Nigerian Muscovy ducks.

2. Material and Methods

2.1 Experimental Birds and Procedure

Twenty apparently healthy extensively managed adult Muscovy ducks *Cairina moschata* (10 males, 10 females) were sourced from rural household farmers in three (3) villages near Joseph Sarwuan Tarka University, Makurdi and used for the study. Makurdi falls within the southern guinea savanna vegetative zone and is geographically located between latitude 6° 5" N and 8° 5" N and between longitude 7° 47" E and 10° E. The ducks were typically bred under makeshift structures with little or no water bath provided. Common feed resources that formed the bulk of the birds feeding include kitchen wastes, grain supplements, scavenging for insects, worms, grasses etc. and their availability depended on cropping activities and season of year. The sampling of ducks was on the basis of their breeding potential using visual appraisal of body size and caruncle development while determined body weights of at least 1.8 kg (males) and 1.3 kg (females) was ensured. The ducks were sacrificed by neck slaughter while jugular venous blood was collected into a set of test tubes without an anticoagulant and plasma was obtained using standard procedures. The sera were analysed for alanine aminotransferase (ALT), asparte aminotransferase (AST), alkaline phosphatase (ALP), total protein, albumin, and total bilirubin. After slaughter, the carcasses were scalded, eviscerated, and the liver organs excised. The biometric measurements such as weight, length, width and thickness of liver organs were carried out using methods described by Iqbal et al. (2014).

2.2 Statistical Analysis

Statistical analysis of data was performed using IBM SPSS version 21.0 software. The mean concentrations of serum liver enzymes, proteins, and total bilirubin were compared between male and female using t-test analysis at 95% confidence interval. The means of the biometric measurements of the liver were compared between male and female as well as between liver lobation locations using t-test analysis at 95% confidence interval.

3. Results and Discussion

There is paucity of literature on serum biochemical characteristics partitioned according to sex for indigenous ducks, especially, Muscovy ducks in Nigeria. The blood components of indigenous and exotic duck breeds found in different regions of the world have been steadily reported upon (Chen et al., 2014; Gerzilov and Petrov, 2015; Rath et al., 2019), although, to a large extent not in the context of sex. The serum profiles of liver enzymes, proteins and total bilirubin of Muscovy ducks is presented in Table 1. Serum alanine aminotransferase (ALT), aspartate aminotransferase (AST), alkaline phosphatase (ALP) and total bilirubin did not show significant (P>0.05) variation between male and female ducks. ALT and AST are the most specific markers of hepatic injury (Music et al., 2015) while ALP is also useful in detecting biliary related liver damage (Clementine and Tar Choon, 2010). The findings on serum ALT, AST and ALP in this study were in line with Mulley (1979) for black ducks. Jerabek et al. (2018) also found similar result for serum ALT and ALP of fattened Mallard ducks but observed a significant effect of sex on AST which contrasted from the present investigation. In contrast, Rath et al. (2019) also observed significant ALT and AST concentrations in different breeds of female ducks. These observed significant differences from previous studies cited in comparison to the results of this study may have been due to differences in reproductive stages. The influence of sex and different reproductive stages on serum liver enzymes of ducks have been reported (Fairbrother et al., 1990).

The concentrations of serum ALT, AST and ALP obtained in this study were lower than the findings of Fairbrother et al. (1990) for adult Mallard ducks and this could be attributed to differences in age, breed and reproductive stages.

Table 1. Serum profiles of liver enzymes, proteins and total bilirubin of Muscovy ducks (Mean ±SEM)

Organ measurement	Sex		P-value
	Male	Female	
ALT (IU/L)	16.14±2.36	13.91±1.37	0.427^{ns}
AST (IU/L)	51.85±5.23	53.60±5.29	0.817^{ns}
ALP (IU/L)	291.10±37.69	282.30±60.56	0.903^{ns}
Total protein (g/dL)	2.82±0.13^{b}	3.48±0.16^{a}	0.005
Albumin (g/dL)	1.08±0.04^{b}	1.27±0.05^{a}	0.006
Total bilirubin (mg/dL)	0.078±0.003	0.074±0.004	0.372^{ns}

^{a,b}Means in the same row with different superscripts differ significantly (P<0.05), SEM= standard error mean, ns= not significant (P>0.05).

In addition, age-related decreases have been observed in ALP levels of ducks (Fairbrother et al., 1990), turkeys (Franchini et al., 1990a; Franchini et al., 1990b) and broiler chickens (Meluzzi et al., 1992). This has been attributed to decreased osteoblastic activity (Protais et al., 1982; Franchini et al., 1988a; Franchini et al., 1988b).

Total bilirubin concentrations from the present investigation recorded non-significant (P>0.05) differences between the male and female ducks which were also corroborated by Mulley (1979). This study recorded lower total bilirubin concentrations compared to the findings of Mulley (1979) and Fairbrother (1990) for black and Mallard ducks respectively. This may have been due to reductions in haemolytic activity of the liver, thus, suggestive of normal liver function. Female ducks recorded significantly (P<0.05) higher serum total protein and albumin values than the male ducks. Serum total proteins are considered important blood parameters because these estimates are indicative of immune status of the species due to antibody fractions contained in them (Rath et al., 2019). The significantly higher total protein concentration observed in female ducks from this study agreed with the findings of Ologbose and Dick (2021) and Okeudo et al. (2003) for Muscovy ducks. Orji et al. (1986) and Verma et al. (1975) also corroborated this observation in adult guinea fowls and domestic chickens respectively. This phenomenon according to Swathi and Sudhamayee (2005) was the result of increased levels of estrogens during the laying period thereby inducing protein synthesis. Total protein concentrations from this study were lower than the findings of the previous works of Okeudo et al. (2003) and Mulley (1979) for ducks. This is probably due to variations in the plane of nutrition as influenced by the management system of the birds. The influence of age, sex, diet and sampling time on serum total protein has been reported (Gattani et al., 2016).

Albumin is the most abundant circulating protein found in the plasma (Moman and Varacallo, 2018) and it is useful in assessing liver function or its ability to synthesize proteins and factors vital to overall homeostasis (Chang and Holcomb, 2016). According to Rath et al. (2019) and Santos et al. (2019), female ducks recorded significantly higher albumin values than the males which may be attributed to reproductive physiological processes. This is in conformity with the results of this study, however, Ologbose and Dick (2021) did not observe any significant sex effect on albumin concentration of Muscovy ducks. These authors posited that differences in age, blood collection procedures, animal housing and nutrition may account for differences in blood albumin values.

Literature on comprehensive morphometric studies of duck organs, especially the liver, irrespective of partitioning according to sex is very limited. However, available reports on morphometric studies of the chicken liver are few (Iqbal et al., 2014; Ripa et al., 2020; Ishi et al., 2000). Table 2 shows the biometric measurements of the liver of Muscovy ducks. The male ducks recorded significantly (P<0.05) higher values than the females in all the biometric measurements considered. The paired liver weight, right lobe weight and left lobe weight were significantly higher in the male ducks. Ishi et al. (2000), Iqbal et al. (2014) and Rani et al. (2020) observed significant differences in intact liver weights of broiler chickens at different ages. However, Etuk et al. (2006) observed non-significant (P>0.05) differences in intact liver weights of Muscovy ducks reared under different management systems. This may have been due to differences in the managements systems the birds were exposed to which impacted their plane of nutrition.

The mean liver weight of Muscovy ducks from the present study was comparable to the report of Ishi et al. (2000) but however contrasted with the higher values observed by Iqbal et al. (2014) for intact liver weights of broiler chickens. The male ducks recorded significantly (P<0.05) higher biometric measurements (i.e. paired, right lobe and left lobe) for liver length, liver width and liver thickness than the female ducks.

Table 2. Biometric measurements of liver organ of Muscovy ducks (Mean ± SEM)

Organ measurement	Sex			
	Male	Female	Mean±SE	P-value
Paired liver weight (g)	50.38±4.11[a]	27.66±0.95[b]	39.02±3.32	0.000
Right lobe weight (g)	33.14±2.81[a]	17.92±0.65[b]	25.53±2.24	0.000
Left lobe weight (g)	17.25±1.38[a]	9.74±0.42[b]	13.49±1.11	0.000
Paired liver length (cm)	17.10±0.48[a]	13.84±0.42[b]	15.47±0.46	0.000
Right lobe length (cm)	10.33±0.32[a]	8.29±0.24[b]	9.31±0.30	0.000
Left lobe length (cm)	6.77±0.23[a]	5.55±0.08[b]	6.16±0.18	0.000
Paired liver width (cm)	7.63±0.34[a]	6.38±0.23[b]	7.01±0.25	0.008
Right lobe width (cm)	3.80±0.15[a]	3.26±0.14[b]	3.53±0.12	0.019
Left lobe width (cm)	3.83±0.22[a]	3.12±0.12[b]	3.48±0.15	0.013
Paired liver thickness (cm)	3.06±0.09[a]	2.65±0.09[b]	2.86±0.08	0.004
Right lobe thickness (cm)	1.51±0.06[a]	1.33±0.04[b]	1.42±0.04	0.021
Left lobe thickness (cm)	1.55±0.05[a]	1.32±0.07[b]	1.44±0.05	0.017

[a,b]Means in the same row with different superscripts differ significantly (P<0.05), SEM= standard error mean, SE= standard error.

The significant differences in these measurements observed in this study were in conformity with the report of Ishi et al. (2000) and Iqbal et al. (2014) for different age groups of broiler chickens. Similarly, Rani et al. (2020) observed highly significant (P<0.01) differences between the right lobe and left lobe measurements for liver length and liver width of broiler chickens. However, the non-significant (P>0.05) findings for liver thickness measurements (right lobe and left lobe) observed by these authors were at variance with the result of this study. This can be attributed to the young age groups (2 weeks and 4 weeks) of birds used by these authors that could not meaningfully influence this part of the liver biometry. The mean values for liver length, width and thickness measurements recorded in this present investigation were similar to the findings of Rani et al. (2020) and comparable to the previous studies of Iqbal et al. (2014). The distinctively higher liver biometrical measurements (weight, length, width and thickness) observed in male Muscovy ducks suggest a dominant effect of sex which was corroborated by Nwachukwu (1998). In addition, Siregar et al. (1982) and Duong (1994) suggested that there may be nutritional related influences on internal organs due to increased consumption of fibrous substances associated with extensively reared poultry.

The biometric measurements of the liver of Muscovy ducks according to liver lobation is presented in Table 3. The right liver lobe produced significantly (P<0.05) higher liver weights and lengths than the left liver lobe in both male and female ducks. However, lobation did not significantly (P>0.05) alter the liver width and thickness measurements in both male and female ducks. It is worthy of note that the values of these measurements according to liver lobation (right and left liver lobes) recorded in this study have not been previously reported upon in literature for any poultry species and therefore limiting comparisons that would have validated this result.

Table 3. Biometric measurements of liver organ of Muscovy ducks according to lobation (Mean ± SEM)

Organ measurement	Lobation		P-value
	Right	Left	
Male:			
liver lobe weight (g)	33.14±2.81^{a}	17.25±1.38^{b}	0.000
liver lobe length (cm)	10.33±0.32^{a}	6.77±0.23^{b}	0.000
liver lobe width (cm)	3.80±0.15	3.83±0.22	0.913^{ns}
liver lobe thickness (cm)	1.51±0.06	1.55±0.05	0.616^{ns}
Female:			
liver lobe weight (g)	17.92±0.65^{a}	9.74±0.42^{b}	0.000^{ns}
liver lobe length (cm)	8.29±0.24^{a}	5.55±0.08^{b}	0.000^{ns}
liver lobe width (cm)	3.26±0.14	3.12±0.12	0.458^{ns}
liver lobe thickness (cm)	1.33±0.04	1.32±0.07	0.902^{ns}

^{a,b}Means in the same row with different superscripts differ significantly (P<0.05), SEM= standard error mean, ns= not significant (P>0.05).

4. Conclusion

Among the blood serum biochemical characteristics investigated, total protein and albumin concentrations were significantly (P<0.05) higher in female ducks. However, ALT, AST, ALP and total bilirubin concentrations did not vary significantly (P>0.05) between male and female ducks. The male ducks recorded significantly (P<0.05) higher biometric measurements for liver weights, lengths, widths and thickness. The right liver lobe was observed to be significantly (P<0.05) higher for liver weights and lengths in both male and female ducks. The liver width and thickness measurements in both male and female ducks were not significantly (P>0.05) affected by lobation. In conclusion, sex had a significant influence on specific serum metabolites as well as liver biometric measurements of Muscovy ducks. Liver lobation effect was significantly pronounced on right liver lobe with emphasis on liver weight and length measurements. Therefore, the liver organ of Muscovy ducks reared extensively in the given local tropical environment, are well adapted and capable of normal functions.

Author Contributions

S.S.C: conceptualized the research idea, developed, supervised the research, structured the paper and wrote the manuscript. J.M.A.: co-supervised the research, organized the data, analyzed and interpreted the data statistics. M.E.A.: co-supervised the research, suggested the research methods and revised the manuscript. S.K.U.: collected the data and proofread the manuscript.

Conflict of Interest

All authors declared that there is no conflict of interest.

Ethical Consideration

The authors confirm that the ethical policies of the journal, as noted on the journal's author guidelines page, have been adhered to. Ethical approval was obtained from the Animal Ethical Review Committee of Joseph Sarwuan Tarka University (2021-2; 05-02-2021).

References

Bertholf L. 2014. Proteins and albumin (Review). Lab Medic, 45(1): 25-41.

Bone FJ. 1979. Evaluation of two herbal spices as feed additives for finisher broilers. Biotechnol Anim Husb, 26(5-6): 383-392.

Chang R, Holcomb JB. 2016. Choice of fluid therapy in the initial management of sepsis, severe sepsis, and septic shock. Shock, 46(1): 17–26. DOI: 10.1097/SHK.0000000000000577.

Chen X, Horn N, Cotter PF, Applegate TJ. 2014. Growth, serum biochemistry, complement activity, and liver gene expression responses of Pekin ducklings to graded levels of cultured aflatoxin B1. Poult Sci, 93: 2028-2036.

Clementine YF, Tar Choon AW. 2010. Liver function tests. Proc Singapore Healthcare, 19(1): 80-82.

Duong TV. 1994. Growth performance of Muscovy ducks. Graduate Thesis, Can Tho University, Faculty of Animal Husbandry and Veterinary Medicine, Can Tho city, Viet Nam.

Dyce KM, Sack WO, Wensing CJG. 2010. Text book of veterinary anatomy (4th ed.) Sunders, Elsevier, new York, US, pp: 848.

Etuk IF, Abasiekong SF, Ojewola GS, Akomas SC. 2006. Carcass and organ characteristics of Muscovy ducks reared under three management systems in south eastern Nigeria. Int J Poult Sci, 5(6): 534-537.

Fairbrother A, Craig MA, Walker K, O'Loughlin D. 1990. Changes in Mallard (Anasplatyrhynchos) serum chemistry due to age, sex, and reproductive condition. J Wildl Dis, 26(1): 67-77.

Fevery J. 2008. Bilirubin in clinical Practice: A Review. Liver Int, 2008: 592–605. DOI: 10.1111/j.1478-3231.2008.01716.x.

Franchini A, Meluzzi A, Bertuzzi S, Giordani G. 1988b. High doses of vitamin E in broiler diets. Arch Gefltigelkd, 52:12-16.

Franchini A, Meluzzi A, Garella E, Montemaggi E. 1988a. Parametri ematochimici della pollastra in rapporto alia tecnica di allevamento. Avicoltura, 57(6): 53-57.

Franchini A, Meluzzi A, Manfreda G, Bertuzzi S. 1990b. Blood constituents of turkeys fed high doses of dietary vitamin E. In: Proceedings VIII European Poultry Conference, Barcelona, Spain, pp: 236-239.

Franchini A, Meluzzi A, Montemaggi E, Manfreda G. 1990a. Andamento di taluni parametri ematochimici di tacchini in accrescimento. Zootec Nutr Anim, 16:145-151.

Gattani A, Pathak A, Kumar A, Mishra V, Bhatia JS. 2016. Influence of season and sex on hematobiochemical traits in adult turkeys under arid tropical environment. Vet World, 9(5): 530-534.

Gerzilov V, Petrov P. 2015. Relationship between some blood biochemical parameters and fatty liver weight in force feeding of mule ducks. Bulgarian J Agric Sci, 21:1039-1043.

Iqbal J, Bhutto AL, Shah MG, Lochi, GM, Hayat S, Ali N, Khan T, Khan AM, Khan SA. 2014. Gross anatomical and histological studies on the liver of broiler. J Appl Environ Biol Sci, 4(12): 284-295.

Ishi PV, Dhande, DP, Kumar MA, Jagadale RB. (2000). Macroanatomical studies of the liver in broilers. J Bombay Vet Coll, 11(5/6): 97-100.

Jerabek M, Suchy, P, Strakova E, Kudelkova L, Simek V, Jakesova P, Machacek M, Zapletal D. 2018. Selected blood biochemical indicators of Cherry valley ducks undergoing fattening in relation to their diet and sex. Veterinarni Medicina, 63(09): 420-432. DOI: 10.17221/81/2018-VETMED.

Meluzzi A, Primiceri G, Giordani, R, Fabris G. 1992. Determination of blood constituents reference values in broilers. Poult Sci, 71: 337-345.

Moman, RN, Varacallo M. 2018. Physiology, albumin. StatPearls URL: https://www.ncbi.nlm.nih.gov/books/NBK45 9198/ (access date: October 14, 2021).

Mulley RC. 1979. Haematology and blood chemistry of the black duck Anas superciliosa. J Wildl Dis, 15(3): 437-441.

Music M, Dervisevic A, Pepic E, Lepara O, Fajkic A, Ascic-Buturovic B. 2015. Metabolic syndrome and serum liver enzymes level at patients with type 2 diabetes mellitus. Med Arch, 69(4): 251.

Nwachukwu EN. 1998. Sexual dimorphism of some conformation traits and carcass composition of Muscovy ducklings raised intensively. In: Proceedings of Silver Anniversary Conference of NSAP/WASP, Inaugural Conference, pp: 298-299.

Odokuma EI, Omokaro EI. 2015. Comparative histologic anatomy of vertebrate liver. Ann Bioanthropol, 3: 1-5.

Okeudo NJ, Okoli IC, Igwe GOF. 2003. Hematological characteristics of ducks (Cairina moschata) of south eastern Nigeria. Tropicultura, 21(2): 61-65.

Ologbose F, Dick S. 2021. Breeds, age and sex effect on haematological and biochemical parameters of ducks in rivers state, Nigeria. BSJ Agri, 4(2): 52-57.

Orji BI, Okeke, GC, Ojo, OO. 1986. Hematological studies on the guinea fowl (Numida meleagris Pallas): II. Effect of age, sex and time of bleeding on protein and electrolyte levels in blood serum of guinea fowls. Nig J Anim Prod, 13: 100-106.

Penn R, Worthington DJ. 1983. Is serum gamma-glutamyltransferase a misleading test? Br Med J, 286: 531-535. DOI: 10.1136/bmj.286.6364.531.

Protais I, Bougon, M, L'Hospitalier R, Lecuyer T, Quemeneur P, Menec ML. 1982. Evoluzione comparata dell'eti dei pol U, del contenuto di sostanze minerali, di calcio e di fosforo delleossa e nel contenuto di calcio, di fosforo e difosfatasi alcalina nel siero. Zootecnica, 22(23): 2-8.

Rath R, Panigrahi B, Mishral SK, Pradhan CR, Maity A, Tewari H. 2019. Comparative serum biochemical profile for different breeds of ducks versus White Leghorn chickens in peak laying period. Indian J Anim Res, 53 (3): 327-331.

Santos ANA, Cruz FGG, Oliveira Filho PA, Farias TM, Rufino, JPF, Viana Filho GB. 2019. Serum biochemical profile of the muscovy ducks (Cairina moschata domesticus) fed diets with different levels of sodium. Rev Cient Avic Suin, 5(1): 015-026.

Siregar AP, Cumming RB, Farell DJ. 1982. The nutrition of meat-type ducks. I. The effects of dietary proteinin is energetic diets on biological performance. Aust J Agri Res, 33: 857- 864.

Verma PN, Rawat, JS, Pandey, MD. 1975. Effect of age and sex on the serum proteins of the white leghorn birds. Indian Vet J, 52(7): 544-546.

Vernon G, Baranova A, Younossi Z. 2011. Systematic review: the epidemiology and natural history of non-alcoholic fatty liver disease and non-alcoholic steato-hepatitis in adults. Aliment Pharmacol Ther, 34(3): 274–285.