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Phenotypic Features and Serum Protein (SDS–PAGE) Characteristics of Muscovy Cairina moschata and Mallard Anas platyrhynchos Ducks in Nigeria

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Running Head: Genetic diversity in the Head features of Ducks

Abstract

Muscovy (*Cairina moschata*) and Mallard (*Anas platyrhynchos*) ducks are the most available breeds being raised as alternative to chickens in Nigeria. Thus, this study compared head and neck morphometric characteristics, plumage patterns and serum protein of these two ducks. A total of 84 Mallards and 62 Muscovies, were measured for head length, head-to-nostril distance, head width, neck length, bill dimensions, and neck ring height. The head plumage coloration and neck ring expression were documented across sexes. Sodium Dodecyl Sulphate - Polyacylamide Gel Electrophoresis (SDS-PAGE) were carried out on the serum protein from the blood samples. Mallards, drakes exhibited higher significant ($p<0.05$) values for head length (9.22 ±0.30 cm), head width (2.70 ±0.21 cm), neck length (15.0 ±1.05cm), and bill length (5.52 ±0.23 cm) compared with hens. Muscovy drakes similarly displayed significantly ($p<0.05$) larger head length (9.02 ±0.41 cm vs. 7.77 ±0.44 cm) and bill length (4.66 ± 0.49 cm vs. 4.19 ±0.21 cm) than hen. Between species, Muscovies were generally characterized by significantly ($p<0.05$) longer necks compared with Mallards. Bill width was more variable, with Mallard hens averaging 2.54 ±0.12 cm versus 2.03 ±0.48 cm in Muscovy hens. A distinct neck ring (3.68 ±2.35 cm) and bright-green head (100%) was observed in Mallard drakes, while hens showed either dark grey (43.3%) or light grey (66.7%) head plumage. In contrast, Muscovies displayed greater variability across sexes, with predominantly black heads (59.3%), followed by black-and-white (34.9%) and white (5.8%) patterns. Neck rings were recorded only in Mallard drakes, either perfect (66.7%) or diffuse (33.3%). The clustering pattern in the dendrogram for each breed reflects a complementary approach to morphological measurements for assessing breed differentiation, genetic diversity, and possibly even health or adaptive traits. These findings provide insight into breed identification, sexual dimorphism, and adaptive morphological divergence between the two duck species.

Keywords: Genetic diversity, SDS-PAGE, morphometrics, plumage, sexual dimorphism, neck ring

خلاصة

يُعدّ بط المسكوفي (*Cairina moschata*) والبط البري (*Anas platyrhynchos*) من أكثر السلالات شيوعًا في نيجيريا كبديل للدجاج. لذلك، قارنت هذه الدراسة الخصائص المورفومترية للرأس والرقبة، وأنماط الريش، وبروتين مصل الدم لهذين البطّين. تم قياس طول الرأس، والمسافة بين الرأس وفتحات الأنف، وعرض الرأس، وطول الرقبة، وأبعاد المنقار، وارتفاع حلقة العنق لدى 84 بطة برية و62 بطة مسكوفي. وُثّق لون ريش الرأس وتعبير حلقة العنق لدى الجنسين. أُجريت عملية الرحلان الكهربائي للهلام بولي أسيل أميد - كبريتات دوديسيل الصوديوم (SDS-PAGE) على بروتين مصل الدم من عينات الدم. أظهرت البطة البرية والذكور قيمًا أعلى معنويًا ($p<0.05$) لطول الرأس (9.22 ± 0.30 سم)، وعرض الرأس (2.70 ± 0.21 سم)، وطول الرقبة (15.0 ± 1.05 سم)، وطول المنقار (5.52 ± 0.23 سم) مقارنةً بالدجاج. وبالمثل، أظهرت البطة المسكوفية طول رأس أكبر معنويًا ($p<0.05$) (9.02 ± 0.41 سم مقابل 7.77 ± 0.44 سم) وطول منقار (4.66 ± 0.49 سم مقابل 4.19 ± 0.21 سم) مقارنةً بالدجاجة. وتميزت البطة المسكوفية عمومًا برقاب أطول معنويًا ($p<0.05$) مقارنةً بالبط البري. كان عرض المنقار أكثر تنوعًا، حيث بلغ متوسط عرض المنقار لدى دجاجات البط البري 2.54 ± 0.12 سم مقابل 2.03 ± 0.48 سم لدى دجاجات المسكوفي. لوحظ وجود حلقة رقبة مميزة (3.68 ± 2.35 سم) ورأس أخضر فاتح (100%) لدى بط البط البري، بينما أظهرت الدجاجات ريش رأس إما رمادي غامق (43.3%) أو رمادي فاتح (66.7%). في المقابل، أظهرت بطات المسكوفي تباينًا أكبر بين الجنسين، حيث غلب اللون الأسود على الرؤوس (59.3%)، يليه الأسود والأبيض (34.9%) والأبيض (5.8%). سُجلت حلقات الرقبة فقط لدى بط البط البري، إما كاملة (66.7%) أو منتشرة (33.3%). يعكس نمط التجمع في مخطط الشجرة لكل سلالة نهجًا متكاملًا للقياسات المورفولوجية لتقييم تمايز السلالات والتنوع الجيني، وربما حتى السمات الصحية أو التكيفية. توفر هذه النتائج نظرة ثاقبة حول تحديد السلالات، والازدواج الشكلي الجنسي، والتباعد المورفولوجي التكيفي بين نوعي البط.

الكلمات الرئيسية: تنوع الجيني، SDS-PAGE، القياسات المورفولوجية، الريش، التباين الجنسي، حلقة العنق

Introduction

Ducks represent an important avian supply contributing to food security and livelihood in many parts of the world, including Nigeria. Among the domesticated ducks, the Muscovy (*Cairina moschata*) and the Mallard (*Anas platyrhynchos*) are the most widely distributed and utilized species (Ajayi, 2010; Yakubu, 2013). Globally, indigenous or local population of ducks forms a major production of duck species in comparison to exotics ones. Previous studies (Dynowska et al., 2013; Veeramani et al., 2014; Oguntuji et al., 2020) revealed significant contributions of indigenous breeds of duck to its large population, economy and food (meat and egg) production. China is the main producer in Asia with enhanced genetic improvement of her local Pekin duck (Zeng et al., 2016; Fouad et al., 2018). India recorded its common duck breeds as Indian Runner, Nageswari, Sythetmete, Kuttanad, and Arni among others; while Arni, Sanyasi and Keeri at northern districts of Tamil Nadu as indigenous varieties (Gajendran and Karthickeyan 2009; Murugan et al., 2009; Veeramani et al., 2009). In Nigeria, two breeds of duck are found, viz: Muscovy, *Cairina moschata* that is referred to as local duck, and Mallard, *Anas platyrhynchos* known as exotic duck (Oguntunji and Ayorinde 2014). However, Muscovy duck is more prevalent compared to *A. platyrhynchos* in all agro-ecological zones (Nwanta et al., 2006; Adeyemi et al., 2008; Oguntunji and Ayorinde 2015), perhaps due to its prolificacy, resistance to harsh weather conditions and common poultry diseases, as well as the ability to utilize feed of low quality (Yakubu et al., 2011). Muscovy ducks differ in size, plumage and other features (Adesope and Nodu 2002), they are hardy less susceptible to diseases than chicken and quite promising among indigenous poultry breeds because of their rapid growth rate and carcass of their drakes (Duru et al., 2006).

However, these two breeds exhibit considerable phenotypic diversity, particularly in head and neck morphology, bill structure, plumage coloration, and sexual dimorphism, which serve as distinguishing features useful for classification, breeding, and productivity assessments (Adeola et al., 2019). Outside external morphology, serum protein characterization provides insight into genetic diversity, adaptive responses, and physiological status of poultry breeds. Sodium dodecyl sulfate–polyacrylamide gel electrophoresis (SDS–PAGE) has been widely applied in avian studies for separating and comparing protein fractions, serving as biochemical markers for breed differentiation and genetic relationships (Okomoda et al., 2017; Okeudo et al., 2020). Such protein-based approaches complement phenotypic characterization and are valuable for conservation and improvement programs.

In Nigeria, limited studies have combined morphological traits with serum protein profiling of indigenous and exotic ducks, despite the potential benefits for genetic resource management and sustainable utilization. Understanding the phenotypic features alongside SDS–PAGE serum protein patterns of Muscovy and

Mallard ducks will provide baseline information on their genetic diversity, adaptive traits, and breed differentiation, thereby aiding selection strategies and biodiversity conservation efforts. This study was designed to investigate distinct head features, phenotype, morphology and serum protein using SDS-PAGE on Muscovy (*C. moschata*) and Mallard *(A. platyrhynchos)* ducks.

Materials and Methods

Samples and location

Muscovy and Mallard ducks used for the study were obtained from farms within the southwestern part of Nigeria. A total number of 149 samples each of Muscovy and Mallard ducks were used for the phenotypic traits. Female (hen) to male (drake) ratio for Muscovy was 45:41 and Mallard was 33:30.

Husbandry of samples

The criteria for ducks used for the study were the rearing methods and up to date record keeping. The samples were reared in local pens made of fibres, and a water tank was provided for swimming. The ducks were monitored on the farm for 28 days during which commercial feeds (18% crude protein, 2900kcal/kg ME) and clean water was given daily. They were also allowed to scavenge after the early morning feed. The records were obtained for age and medication history for similarities across the farms.

Data Collection

After the 28 days, data on qualitative traits of plumage head and bill, and quantitative traits on the following head morphological features were recorded: head length, head to nostril, head width, neck length, bill length and width and neck ring height. The morphological traits of the ducks were measured according to the breed descriptors of the Food and Agriculture Organization (FAO, 1986). Standard measuring tape and ruler were used to take the following measurements to the nearest 0.1 centimetre (cm): the head length was measured as the distance between rear end of bill and occipital condyle ; the bill length was measured as the distance between the tip of the bill and rear end of the beak; head and bill widths were measured at end to end of side; neck length was measured as the distance between the location of first and last cervical vertebrae; neck ring height was measured as the distance between onset of the ring to the end.

Electrophoretic procedure

Samples of blood were drawn from the veins under the wings of the ducks using sterile hypodermic syringes. Physiological saline water (0.9% NaCl) was added to 3:2 blood samples and left at room temperature for 1 h. Thereafter, the solution was centrifuged at 3,000 rpm for 10 min. The supernatant (containing serum protein) was extracted and stored at $4C^0$ before undergoing electrophoretic analysis (Avtalion, 1984; Olaniyi et al., 2018). The electrophoretic procedure on gel preparation, sample preparation, staining, and de-staining of gel was carried out following Olaniyi et al. (2018). Data analysis on each gel was scored both visually and by observation of its scanned image for the presence (1) or absence (0) of protein bands. The data were log transformed and analysed with PAlaeontological STatistics (PAST) software to generate dendrograms (Hammer et al., 2008). The mean value of each species was employed to generate distance indices data for comparative genetic distance evaluation, choosing the Euclidean option.

Statistical Analysis

Data obtained were subjected to independent sample t-test analysis using analytical procedure of Statistical Analysis System (SAS Institute, 2002), with degree of freedom to determine the critical t-value for significance determination. The model is given below:

$Y_{ik} = \mu + \alpha_i + \varepsilon_{ik}$

Where,

Y_{ik} = the observed response of the k^{th} parameter (e.g. head length of the ith replicate or of the treatment (e.g. drake of Muscovy duck)

μ = overall mean

α_i = effect of ith treatment (e. drake of Muscovy duck)

ε_{ik} = random error

t-test was also carried out between the drake and hen of each breed

Results and Discussion

Table 1 shows the head and neck measurements of Mallard and Muscovy ducks. The t-test indicates a statistically significant difference in the length of the head between the drake and hen for Mallard at t=3.69, df=84 (9.22±0.03 and 8.57±0.51 respectively) and Muscovy at t=7.48, df=84 (9.02±0.41; 7.77±0.44 respectively) (⟩<0.05). The head to nostril was significantly (t=3.26, df=84) different in Mallard drake and hen (4.39±0.30 and 4.07±0.16, respectively) (⟩<0.05) but not statistically different (t=3.08, df=84) in Muscovy (⟩>0.05). The head width showed a significant difference between the drake and hen of Mallard (t=3.41, df=84) and Muscovy (t=2.69, df=61). Also, neck length was significant (t=3.08, df=84) between the sexes of both breeds with hen and drake of Mallard measuring 15.00±1.50 and 11.58±1.72 respectively (⟩<0.05), while Muscovy did not show any significant difference (t=1.34, df=61) (⟩<0.05). The bill width showed no significant difference (t=0.78, df=84) between the drake and hen of Mallard ducks (⟩>0.05), while Muscovy drake and hen recorded significant difference (t=5.03, df=61) between the drake (2.41±0.27) and the hen (2.03±0.48) (<0.05). The neck ring was not present in Muscovy, but only the drakes of Mallard showed the presence of the ring.

The results of the head and neck measurements revealed that the drake had superior measurement than the hen in both the Mallard and Muscovy, and this could have been a natural ability endowed to them by nature to dominate the hen during mating. This showed the expression of sexual dimorphism in all the traits measured, a distinctive feature of these ducks as reported by Pratama et al. (2023), where the male exhibits significantly greater size compared to the female. (Yakubu et al., 2011; Foluke Eunice et al., 2020), and also that male often perform better than females (Maynard et al., 2023). Though, performance could be affected by factors of genetics such as strain, breed, sex and age and importantly the environmental factors such as nutrition, space or stocking density and housing, and the interactions between different factors (Young et al., 2001; Mehaffey et al., 2006; Abdullah et al., 2010; Lopez et al., 2011, Maynard et al., 2023). Sexual dimorphism is a genetic factor that cannot be misplaced in growth and development (Abe, 2022). The usefulness of these quantitative traits is due to their important input to farmers' profit margins, especially on farms where market weight or meat for sale is the primary objective (Oguntunji, 2017). The Muscovy and Mallard ducks, categorized as native avian species in Nigeria, stand out as the predominant waterfowl species in the country (Pratama et al., 2023). Morphometric measurements and associated indices play a pivotal role in characterizing, selecting, and genetically enhancing farm animals (Oguntunji and Makram, 2019).

Table 2 below shows the effect of sex on head plumage and neck ring height of Mallard and Muscovy ducks. 33.33% of Mallard drake showed white spotted plumage at part of the bright-green, then such drakes of Mallard revealed non-perfect neck ring height (usually diffused), while the completely bright-green head had perfect circumference neck ring height (Table 2). This could be genetically inclined. Neck ring height was absent in the Muscovy ducks, representing a major phenotypic variation between Muscovy and Mallard ducks. The phenotype showed a bright-green head (100%) in the drakes of Mallard in Fig. 1. a & b below in comparison to its hen which was grey but of different intensity (Fig. 1. b & c) has also shown below. This indicated that the trait of bright-green phenotypic head is sex dependent and a good marker of drake of Mallard ducks. However, Oguntuji et al. (2020) reported localization of tiny (non-conspicuous) green sheen in the frontal part of the hen's head and also expression of iconic glossy head as a major identifier. Essentially, the expression of bright-green phenotypic head could be genetically sex-influenced by male hormone (Oguntuji et al., 2020) in the drakes of Mallard, which totally varied to the Muscovy. Moreover, the drake and hen of Muscovy showed a combination of plumage (Fig. 2. a-c).

The colour of the bill for drake of Mallard ducks is mostly light-green or olive, but with a few yellow or pink, especially for the drake with perfect neck ring height (Fig. 1a), while the drakes with non-perfect (diffused) neck ring height (Fig. 1b) had more phenotypic yellow or pink bills. Mallard hens depicted grey-coloured bills. The colour of the bill in Muscovy ranged from pink, black and their combinations, however mostly with a yellowish bill edge (Fig. 2a-c). Muscovy with pure white plumage usually have pink (15%) bill colour while those with a combination of the plumage colours had grey bills (33%).

Table 1. Head and neck measurements of Mallard and Muscovy duck

Parameters	Sex	Mallard			Muscovy		
		Mean (cm) ± SD	df	t-test	Mean (cm) ± SD	df	t-test
Head length	Drake	9.22 ± 0.30	84	3.69	9.02 ± 0.41	61	7.48
	Hen	8.57 ± 0.51			7.77 ± 0.44		
Head to nostril	Drake	4.39 ± 0.30	84	3.26	4.91 ± 0.51	61	0.54
	Hen	4.07 ± 0.16			4.10 ± 0.10		
Head width	Drake	2.70 ± 0.21	84	3.41	2.61 ± 0.16	61	2.69
	Hen	2.49 ± 0.05			2.49 ± 0.04		
Neck length	Drake	15.0 ± 1.05	84	3.08	16.1 ± 1.89	61	1.34
	Hen	11.6 ± 1.72			16.1 ± 0.56		
Bill length	Drake	5.52 ± 0.23	84	4.73	4.66 ± 0.49	61	3.18
	Hen	4.84 ± 0.42			4.19 ± 0.21		
Bill width	Drake	2.59 ± 0.19	84	0.78	2.41 ± 0.27	61	5.03
	Hen	2.54± 0.12			2.03 ± 0.48		
Neck ring height	Drake	3.68 ± 2.35	32	NA	0.00 ± 0.00	NA	NA
	Hen	0.00± 0.00			0.00± 0.00		

SD=Standard Deviation, df=degree of freedom, NA=Not Applicable

The clustered algorithm analysis for association between the samples was shown in Fig 5. The genetic difference between the two breeds of ducks revealed 0.4% that indicated a high level of proximity of the two breeds.

Table 2. Effect of sex on head plumage and neck ring of Mallard and Muscovy ducks

Parameter	Breed	Sex	Description	Number observed	Percent (%)
Head plumage	Mallard	Drake	Bright-green	30	100
		Hen	Dark grey	13	43.3
			Light grey	20	66.7
			Black	51	59.3
	Muscovy	Both sexes	White	5	5.81
			Black and white	30	34.9
Neck ring height	Mallard	Drake	Perfect	20	66.7
			Diffuse	10	33.33
		Hen	Nil	0	0
	Muscovy	Drake	Nil	0	0
		Hen	Nil	0	0

Fig. 1 (a – d). Mallard duck. a = Drake showing perfect neck ring height and bright-green head; b=Drake showing non-perfect (diffused) neck ring height; c & d=Hen showing grey head features with of different intensity

Fig. 2 (a – c). Muscovy duck. a=Hen with pure white plumage head features; b = Hen with combined plumage; c=Drake

Figures 3 and 4 respectively, showed representative SDS-PAGE gels from samples of both breed serum protein in all their lanes for *A. platyrhynchos* and *C. moschata*. SDS–PAGE resolved serum proteins into 9 bands in Mallards (Fig 3) and 7 bands in Muscovies (Fig 4). In Mallards, the most intense fractions occurred at ~66 kDa (albumin) and ~90 kDa, with moderate bands at 40–45 kDa. Faint but distinct higher molecular weight bands at ~120–150 kDa were also detected. Muscovies showed strong, thick bands at ~66 kDa and ~45 kDa, representing dominant serum fractions. Compared to Mallards, Band intensity analysis revealed greater heterogeneity in Mallards, with variable thickness across lanes. Muscovy lanes, however, exhibited more uniform and concentrated protein expression. On average, Mallards expressed two more fractions than Muscovies, indicating higher polymorphism. The presence/absence of high-molecular-weight bands was the key distinguishing feature. These observations are consistent with Ogbu et al. (2019), who reported higher protein diversity in more ecologically distributed species compared to more conserved domestic strains. Similarly, Adeola and Akinyemi (2018) found that Muscovies possessed stronger, dominant protein fractions, while other duck species expressed more polymorphic bands. The observed protein polymorphism may reflect evolutionary and ecological distinctions. Mallards, being widely distributed and

prone to hybridization, show broader genetic variation (Cherry & Morris, 2008). Muscovies, by contrast, are characterized by slower growth, higher carcass yield, and disease resistance, which may explain their more uniform protein architecture (Ayorinde, 2004). The consistency of dominant bands in Muscovies suggests that selective breeding may have stabilized key serum proteins, whereas Mallards retain greater heterogeneity.

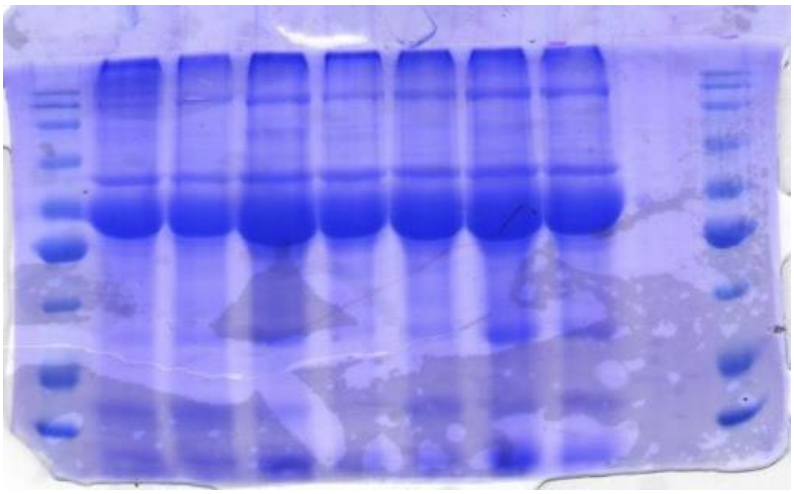

Fig. 3. Representative gels of the samples from *A. platyrhynchos*

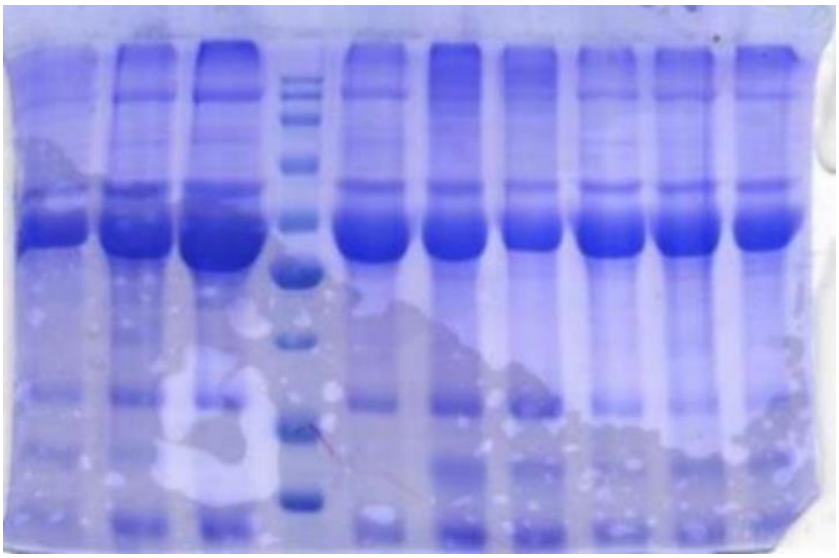

Fig. 4. Representative gels of the samples from *C. moschata*

The SDS–PAGE profiles of serum proteins from Mallard (*Anas platyrhynchos*) and Muscovy (*Cairina moschata*) ducks, as shown in Fig 5 revealed distinct banding patterns. Mallard ducks exhibited between 7 and 10 discrete bands across the lanes, with prominent fractions at approximately 25 kDa, 45 kDa, and 66 kDa. The band intensities varied among individuals, suggesting higher polymorphism within the Mallard group. In contrast, Muscovy ducks consistently displayed 5–7 bands with fewer variations in band intensity, dominated by strong bands around 30 kDa and 60 kDa. This indicates relative homogeneity in serum protein expression in Muscovy ducks compared to Mallards. These electrophoretic differences were corroborated by the dendrogram analysis. The hierarchical cluster separated the samples into two main clusters corresponding to the two duck species. The Mallard samples were distributed into two sub-clusters, reflecting considerable intra-breed variability, while the Muscovy samples formed a tight cluster above 80% similarity, indicating less within-breed variability. The two species only converged at a low similarity coefficient, demonstrating their genetic distinctiveness.

The variability observed in Mallards aligns with reports that *Anas platyrhynchos* populations exhibit broad genetic diversity due to their wide geographical distribution and frequent hybridization with other duck breeds (Cherry and Morris, 2008; Kulikova et al., 2005). Conversely, the reduced polymorphism in Muscovy ducks corresponds with earlier findings that *Cairina moschata* populations are more genetically conserved, likely due to domestication bottlenecks and reduced gene flow (Ayorinde, 2004; Adeola and Akinyemi, 2018). Previous studies on poultry serum proteins using SDS–PAGE have shown similar discriminatory power in distinguishing between breeds and species (Ogbu et al., 2019).

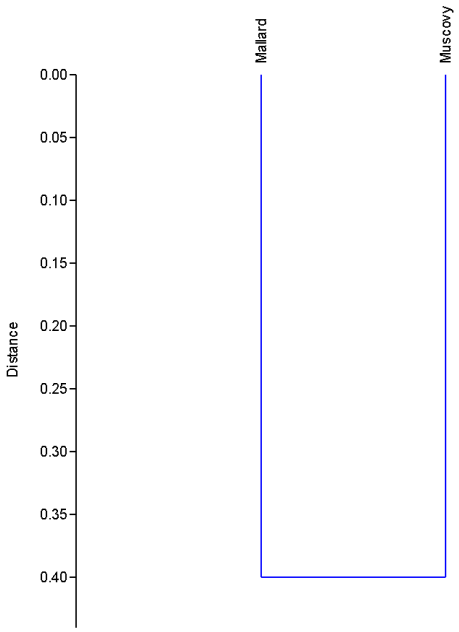

Fig. 5. Dendrogram for Mallard duck, *A. platyrhynchos* and Muscovy duck, *C. moschata*

Conclusion

This research showed that both duck breeds, Muscovy (*C. moschata*) and Marllad *(A. platyrhynchos),* expressed significant differences between the drake and hen in all the parameters of the head and neck features. The sexual dimorphism recorded was in favour of drakes with higher measurements over the hens. Moreover, both breeds showed close genetic relationships but were significantly different in phenotype. The combination of SDS–PAGE and dendrogram clustering further confirms the genetic distinctiveness of Mallard and Muscovy ducks while revealing higher polymorphism within Mallards. These findings validate the utility of serum protein profiling as a cost-effective molecular tool for breed characterization and conservation planning in ducks. Additionally, it also shows that they may be close substitutes for each other, especially in breeding programs such as hybridization. However, further molecular studies are necessary to know more about the similarities and genetic diversity they shared.

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Author contributions

Conceptualization: Wasiu Adekunle OLANIYI ; Methodology, Wasiu Adekunle OLANIYI, Kolawole Segun IKUPOLUYI, Abdulrasaq Adeyemi IBRAHIM, Adewale Isaac OLUTUMISE; Investigation: Kolawole Segun IKUPOLUYI, Abdulrasaq Adeyemi IBRAHIM ; Data curation: Adewale Isaac OLUTUMISE, Olugbenga Samson ABE ; Writing, Wasiu Adekunle OLANIYI , Olugbenga Samson ABE;

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All authors have read and agreed to the published version of the manuscript.

Ethics

All procedures for this study were approved by the Ethical committee of Department of Animal Science, Adekunle Ajasin University, Akungba-Akoko, Ondo State, Nigeria.

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