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Morphometric and phenotypic variation of muscovy ducks (*Cairina moschata*) in Central Java, Indonesia

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Abstract. *Sutopo, Ramandhani MI, Sianturi FK, Setiaji A. 2025. Morphometric and phenotypic variation of muscovy ducks (*Cairina moschata*) in Central Java, Indonesia. Biodiversitas 26: 4267-4273.* The muscovy duck (*Cairina moschata*) is an important part of traditional poultry systems in Central Java, Indonesia. However, the genetic and phenotypic diversity among local varieties remains poorly characterized, limiting efforts in sustainable breeding and conservation. This study aimed to characterize the morphometric and phenotypic variability of three local muscovy duck types (Local, Rambon, and Jumbo) through quantitative and qualitative assessments. A total of 96 adult female ducks were sampled, comprising 36 Local (Demak), 30 Rambon (Kendal), and 30 Jumbo (Temanggung). Morphometric traits measured included maxilla length, neck length, chest circumference, and wing length, among others. Qualitative traits examined included plumage color and body conformation (e.g., caruncle, breast, shank, and abdomen). Data were analyzed using descriptive statistics, discriminant analysis, cluster analysis, and canonical discriminant functions. Jumbo ducks exhibited significantly larger body dimensions compared to the Local and Rambon groups, with an average chest circumference of 34.6±1.8 cm and neck length of 20.4±1.2 cm. Jumbo ducks also showed predominantly white plumage (80%) and pink bills, contrasting with the darker and more variable coloration in Local ducks. Discriminant analysis revealed chest circumference, neck length, and femur length as key variables for group differentiation, achieving 86.67% classification accuracy for Jumbo ducks. Cluster and canonical analyses confirmed the morphological divergence, positioning Rambon ducks as an intermediate group. Substantial morphometric and phenotypic diversity exists among muscovy duck populations in Central Java. Jumbo ducks are morphologically distinct and likely subjected to selection for meat traits. These findings emphasize the importance of conserving local duck genetic resources for future breeding and sustainable production strategies.

Keywords: Discriminant analysis, genetic resource conservation, morphometric traits, muscovy duck, phenotypic diversity

INTRODUCTION

Indonesia is a country rich in biodiversity, including a wide range of local poultry genetic resources. Among these, the muscovy duck (*Cairina moschata* Linnaeus, 1758), known locally as "entok," holds a prominent place in rural poultry farming systems, particularly in Central Java (Ismoyowati et al. 2020). It is favored by smallholder farmers for its adaptability to diverse environmental conditions, low feed requirements, disease resistance, and ability to thrive in low-input systems (Sutopo et al. 2021; Widianingrum et al. 2023). In addition to supporting household food security, muscovy ducks provide a source of income and contribute to traditional and cultural practices. Despite their value, scientific information on the genetic diversity of muscovy ducks in Central Java remains limited. As global food systems face challenges such as climate change, disease outbreaks, and rising demand for animal-based protein, the conservation and sustainable use of local genetic resources are increasingly important (Wijerathna-Yapa and Pathirana 2022). Local breeds like the muscovy duck serve as vital genetic reservoirs for future breeding and conservation efforts. Assessing their genetic and phenotypic diversity is essential for developing effective management strategies and improving traits such as growth performance, adaptability, and meat quality in response to changing environmental and market demands (Maharani et al. 2019; Mishra and Naim 2022; Ussyarif et al. 2024).

One practical method for evaluating genetic diversity in duck populations is through the analysis of morphometric and phenotypic traits. Morphometric parameters such as body weight, body length, shank length, chest circumference, and wingspan serve as indicators of growth performance, productivity, and adaptability (Habimana et al. 2021). Phenotypic traits like plumage color, beak shape, eye color, and skin pigmentation reflect observable genetic differences and adaptation to local environments (Liu and Churchil 2022). In Indonesia, research on poultry biodiversity has primarily focused on native chickens (Mustofa et al. 2021; Sophian et al. 2021; Nurgiartiningsih et al. 2024), with limited studies on muscovy ducks, particularly in Central Java. This lack of documentation, combined with uncontrolled crossbreeding and the absence of structured breeding programs, risks the loss of valuable genetic traits. Preserving indigenous duck genetic diversity is essential for ensuring long-term sustainability, resilience to diseases, and adaptability to environmental changes. The FAO's Animal Genetic Resources (FAO 2012) emphasizes the importance of conserving local breeds through proper identification, documentation, and both in situ and ex situ strategies. Likewise, Indonesia's national approach highlights the need to protect native genetic resources to bolster food security and rural livelihoods. Therefore, documenting the diversity of muscovy ducks is an essential step toward effective conservation and sustainable use of this genetic resource.

Central Java in Indonesia, with its diverse topography, agro-ecological zones, and farming practices, provides an ideal case study for examining phenotypic and morphometric variation in muscovy ducks. Local farming systems vary widely across regions-from backyard free-range systems to semi-intensive production-each potentially exerting different selective pressures that influence the physical and genetic characteristics of the ducks (Ismoyowati et al. 2020; Susanti et al. 2020). These differences can be captured through systematic sampling and measurement, providing insights into the structure and diversity of muscovy duck populations across the province. This study aims to evaluate the morphometric and phenotypic diversity of muscovy ducks from several districts in Central Java.

MATERIALS AND METHODS

Animal and data collection

The observation was conducted in accordance with the relevant standards and guidelines for animal welfare, as outlined in Indonesian Law No. 41 of 2014. The selection of experimental samples was conducted using purposive sampling, with consideration given to the population density of muscovy ducks in administrative border areas. The study involved a total of 96 female muscovy ducks, consisting of 36 Local, 30 Rambon, and 30 Jumbo ducks (Figure 1). Samples were collected from three districts in Central Java, Indonesia: Demak (Local). Kendal (Rambon), and Temanggung (Jumbo). The locations used for sampling collection are shown in Figure 2. All female ducks selected for the study were aged seven months or older. A comprehensive evaluation was carried out on ten qualitative characteristics: bill color, caruncle color, head color, neck color, back color, breast color, primary wings and secondary wings, abdomen color, and shank color. In addition, eleven morphometric traits were measured following the guidelines for the phenotypic characterization of muscovy ducks as described by FAO (2012). The morphometric traits included: maxilla length, neck length, chest length, chest circumference, body length, wing length, femur length, tibia length, tarsometatarsus length, tarsometatarsus circumference, and length of the third toe (Osaiyuwu et al. 2023). The measurements were standardized according to the Phenotypic Characterization of Animal Genetic Resources (FAO 2012). Measurements were recorded in centimeters (cm) using a calibrated ruler, measuring tape, and calipers. To minimize measurement error and ensure consistency, all measurements were taken by the same trained technician.

Statistical analysis

Descriptive statistics were employed to summarize and compare the qualitative traits, which were presented in percentage form. For the morphometric data, a General Linear Model (GLM) was applied to assess differences among the three muscovy duck populations. To further distinguish between the duck populations, discriminant analysis was conducted. This analysis aimed to identify key variables that most effectively differentiate the three breeds. The methodological framework included an analysis of the canonical structure, cross-validation to evaluate the accuracy of group classification, and visual mapping of population distribution based on discriminant scores. The canonical discriminant function analysis played a central role by highlighting the primary sources of variation among the populations. This thereby clarifying the morphological traits that contributed most significantly to group separation. The model used in the Canonical Discriminant Analysis (CDA) was as follows:

$$C = \mu + \mu_1 y_1 + \mu_2 y_2 + \mu_3 y_3$$

Where, μ_1, μ_2, μ_3 are the estimates of canonical coefficients and y_1, y_2, y_3 indicated ducks' populations (Local, Rambon, and Jumbo, respectively). The discriminant analysis was performed using the Statistical Analysis System (SAS) On Demand for Academics (SAS 2021). The results of the Canonical Discriminant Analysis (CDA) were subsequently transformed and analyzed using the MEGA 11 software to determine genetic distances and construct a phylogenetic tree employing the Unweighted Pair Group Method with Arithmetic Mean (UPGMA).

Figure 1. The female muscovy ducks used in the study: A. Local, B. Rambon, C. Jumbo

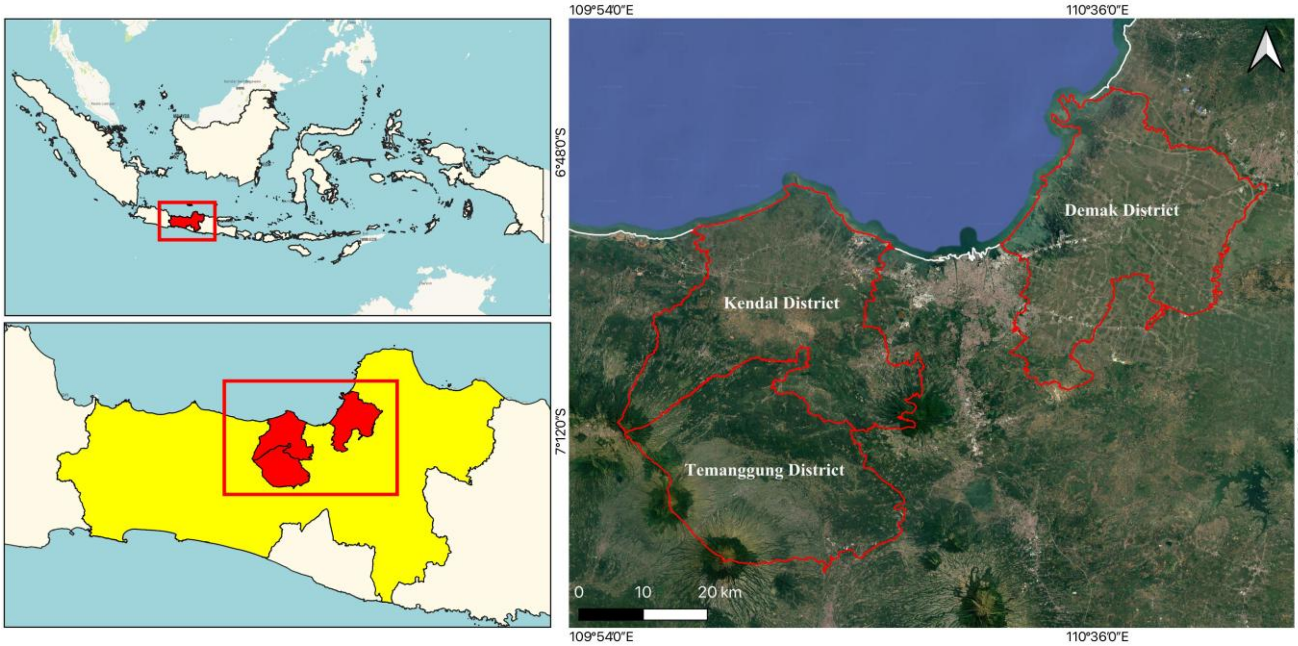

Figure 2. The location used for collecting the sample of muscovy ducks

RESULTS AND DISCUSSION

The details of the phenotypic characteristics of three breeds are presented in Table 1. The observed variations in external color traits among Local, Rambon, and Jumbo duck ecotypes reveal not only the phenotypic diversity within Indonesian duck populations but also offer insights into genetic differentiation, environmental adaptation, and selection preferences. For instance, bill color in Jumbo ducks is predominantly pink (66.6%), followed by Rambon (43.2%), while Local ducks are mostly pink with black spots (73.2%). These differences suggest variations in pigmentation pathways, potentially influenced by genetic factors such as the melanocortin 1 receptor gene, known to regulate melanin production (Ren et al. 2024). Caruncle color, another sexually dimorphic trait, is almost exclusively red in Jumbo (96.6%) and Rambon (93.3%), possibly reflecting uniform selection for sexually mature or dominant individuals, as red caruncles have been associated with higher reproductive performance in ducks. Such traits are important for breeders and farmers in low-input systems as they serve as visible indicators of maturity, health, and even genetic purity within ecotypes (Oguntunji and Ayorinde 2015).

Feather color traits across various body parts, head, neck, back, breast, and wings, demonstrate clear distinctions between the ecotypes. Local ducks exhibit a high frequency of dark or mixed colors, such as black (46.6% on the head, 46.6% on the back) and black-white patterns, indicating a more variable genetic pool. This diversity is likely a result of minimal artificial selection and a high degree of natural selection, favoring traits such as camouflage or heat absorption, which are beneficial in open or traditional rearing systems (Zhou et al. 2018). Conversely, Jumbo ducks show a dominance of white plumage across most body parts (e.g., 93.3% white breast, 90.0% white back, 93.3% white neck), consistent with selection for meat production. White plumage is economically advantageous as it results in a cleaner appearance post-slaughter, which is preferred in commercial markets. Rambon ducks present a more intermediate profile with both light (e.g., white and light brown) and dark (e.g., brown) feather colors, suggesting either hybridization or transitional selection for dual-purpose use. These distinctions also reflect historical and regional breeding preferences, highlighting how phenotypic traits can evolve under varying socio-economic and ecological contexts (Liu and Churchil 2022; Ma et al. 2024).

The shank color further supports the pattern of differentiation among the ecotypes. Yellow shanks, a trait associated with carotenoid deposition, are highly prevalent in Rambon (90.0%) and Jumbo (80.0%) ducks, suggesting uniform selection likely due to aesthetic or cultural preferences. In contrast, Local ducks show greater variation, including yellow (43.3%), yellow with black spots (43.3%), black (10.0%), and black with yellow spots (3.4%), indicative of a broader gene pool and less directed selection. This diversity may be advantageous from a conservation and sustainability perspective, as it implies higher adaptability to environmental stressors. The phenotypic data as a whole can be used not only for breed characterization but also to inform breeding strategies aimed at improving production traits without compromising genetic diversity. Studies like those by Zhang et al. (2020), which detail the genetic basis of feather pigmentation, and Sun et al. (2024), which focus on bill color genetics in ducks, underline the importance of integrating phenotypic and genotypic data in the development of resilient and productive indigenous duck lines suitable for diverse farming systems in Indonesia.

Table 1. Variation of qualitative traits among muscovy ducks in Central Java, Indonesia

Trait	Color (%)	Local	Rambon	Jumbo
Bill color	Pink	26.8	43.2	66.6
	Pink with a black spot	73.2	56.8	33.4
Caruncle color	Red	70.0	93.3	96.6
	Red with a black spot	30.0	6.7	3.4
Head color	Black	46.6	6.7	0
	Black and white	43.3	23.3	26.6
	Dark brown	3.4	0	0
	White	6.7	50.0	66.6
	Light brown	0	6.7	3.4
	Brown	0	13.3	3.4
Neck color	Black	0	3.4	0
	Black and white	23.4	3.4	0
	White	76.6	43.3	93.3
	Light brown	0	33.3	0
	Brown	0	16.6	6.7
Back color	Black	46.6	0	0
	Black and white	3.4	0	0
	Dark brown	6.7	10	0
	White	43.3	16.7	90.0
	Light brown	0	10.0	0
	Brown	0	33.3	6.7
	Light brown	0	13.3	0
	Ash	0	10.0	0
	Ash white	0	6.7	0
	Ash brown	0	0	3.3
Breast color	Black	3.4	3.4	0
	Black and white	16.6	0	0
	White	76.6	33.3	93.3
	Light brown	3.4	10.0	6.7
	Brown	0	46.6	0
	Ash	0	6.7	0
Primary wings	Black	16.6	0	0
	Black and white	3.4	0	0
	white	76.6	43.3	86.6
	Light brown	0	16.6	10.0
	Brown	0	23.3	0
	Dark brown	3.4	3.4	0
	Ash black	0	3.4	0
	Ash brown	0	3.4	0
	Ash	0	6.6	3.4
Secondary wings ‘	Black	13.3	3.4	0
	Black and white	13.3	3.4	0
	Dark brown	3.4	0	0
	White	70.0	23.3	86.6
	Light brown	0	30.0	3.4
	Ash white	0	6.6	6.6
	Brown	0	26.5	0
	Ash brown	0	3.4	3.4
	Ash black	0	3.4	0
Abdomen color	Black	26.7	10.0	0
	Black and white	20.0	3.4	0
	Dark brown	0	3.4	0
	White	53.3	13.4	83.3
	Light brown	0	16.6	0
	Brown	0	40.0	6.7
	Ash	0	6.6	3.3
	Ash white	0	0	6.7
	Ash brown	0	6.6	0
Shank color	Yellow	43.3	90.0	80.0
	Yellow with a black spot	43.3	10.0	20.0
	Black	10.0	0	0
	Black with yellow spot	3.4	0	0

The morphometric traits measured among Local, Rambon, and Jumbo muscovy duck populations exhibit significant differences, reflecting their diverse genetic backgrounds and potential selection histories. In general, Jumbo ducks showed superior body dimensions compared to Local and Rambon populations. For instance, Jumbo ducks had significantly longer maxilla lengths (5.03±0.10 cm) compared to Local (4.56±0.10 cm) and Rambon (4.71±0.08 cm), indicating a possibly larger skull size which may correlate with feeding efficiency or sexual dimorphism (Basso et al. 2014; Pecsics et al. 2017). Neck length also followed this trend, with Jumbo ducks reaching an average of 11.26±0.36 cm, significantly exceeding both Local and Rambon ducks (8.75±0.31 cm and 8.40±0.23 cm, respectively). These measurements suggest that Jumbo ducks may have undergone more intensive selection for growth-related traits, especially those contributing to larger frame size and muscle mass. Similar trends were observed in other body dimensions. Jumbo ducks had the highest chest circumference (44.32±0.71 cm), followed by Rambon (38.95±0.77 cm) and Local (36.55±0.53 cm), suggesting better development of the pectoral region, which may be advantageous for meat yield (Ismail and Joo 2017). Additionally, body length, wing length, femur length, and the length of the third toe were significantly higher in Jumbo ducks, reinforcing their superior physical size and structural robustness. The wing length of Jumbo ducks (25.37±0.65 cm) was notably greater than that of Rambon (19.33±1.18 cm) and Local (21.19±1.01 cm), which could reflect either genetic influence or environmental adaptation. Interestingly, tibia length did not differ significantly among groups, indicating that some limb traits may be under less selective pressure or exhibit lower heritability.

The Rambon ecotype often displayed intermediate morphometric values, such as in chest length (21.64±0.57 cm) and tarsometatarsus length (5.65±0.12 cm) (Table 2), which may suggest a hybrid or transitional form between Local and Jumbo ducks. The Local population generally presented the smallest measurements across most traits, potentially reflecting limited selection intensity or adaptation to traditional rearing systems. These morphometric differences can be essential for developing selective breeding programs aimed at enhancing the productivity and adaptability of local muscovy duck populations. Previous studies have highlighted the relevance of morphometric traits as predictors of body weight and carcass yield (Yakubu et al. 2015; Kokoszyński et al. 2019). Incorporating such data into selection indices may help optimize genetic improvement programs tailored to local production goals and environments. Moreover, morphometric variation often reflects underlying genetic diversity, providing valuable insight into population structure. Preserving this variation is crucial for conserving local breeds, as it supports long-term adaptability and resilience through targeted conservation breeding strategies.

The canonical structure analysis based on morphometric variables reveals the relative contribution of each trait to the discrimination among muscovy duck populations across the three canonical functions. Canonical variate 1 (CAN 1) accounted for the largest proportion of variation, with chest circumference (0.727), neck length (0.722), femur length (0.658), and length of the third toe (0.617) contributing most strongly. These traits appear to be critical in distinguishing populations, likely reflecting differences in skeletal and muscular development that are influenced by genetics and environmental adaptation. Table 3 on the canonical variate 2 (CAN 2) was dominated by tarsometatarsus length (0.492) and Tibia length (0.328) instead of chest length (0.326), suggesting these measurements play a secondary role in separating duck types, possibly linked to differences in locomotion and body shape. CAN 3, though accounting for less variation, showed the highest loading for tarsometatarsus circumference (0.418) and neck length (0.328), indicating these traits may further fine-tune the classification among populations (Table 3). The findings support the use of multivariate morphometric analysis as a powerful tool for breed characterization, as previously demonstrated in studies by González et al. (2021), Osaiyuwu et al. 2023 and Chebo et al. (2024), emphasizing the importance of integrating multiple body traits for accurate phenotypic differentiation in local poultry populations.

Table 2. Means±standard errors of morphometric traits measured among muscovy duck populations

Traits (cm)	Local	Rambon	Jumbo
Maxilla length	4.56±0.10^{b}	4.71±0.08^{b}	5.03±0.10^{a}
Neck length	8.75±0.31^{b}	8.40±0.23^{b}	11.26±0.36^{a}
Chest length	20.15±0.72^{b}	21.64±0.57^{ab}	22.77±0.59^{a}
Chest circumference	36.55±0.53^{c}	38.95±0.77^{b}	44.32±0.71^{a}
Body length	23.94±0.59^{b}	24.22±0.45^{b}	27.08±0.65^{a}
Wing length	21.19±1.01^{b}	19.33±1.18^{b}	25.37±0.65^{a}
Femur length	7.81±0.35^{b}	8.34±0.40^{b}	11.03±0.34^{a}
Tibia length	8.06±0.25^{a}	8.65±0.30^{a}	8.72±0.18^{a}
Tarsometatarsus length	5.20±0.11^{b}	5.65±0.12^{a}	5.85±0.13^{a}
Tarsometatarsus circumference	4.33±0.14^{b}	4.62±0.12^{b}	4.95±0.08^{a}
Length of third toe	5.85±0.14^{b}	6.12±0.14^{b}	6.93±0.09^{a}

Note: ^{ab}differents superscripts in the same row indicate statistical different, P<0.05

Table 3. Total canonical structure based on morphometric variables

Traits	CAN 1	CAN 2	CAN 3
Maxilla length	0.395	0.205	0.047
Neck length	0.722	-0.191	0.328
Chest length	0.283	0.326	-0.032
Chest circumference	0.727	0.357	-0.255
Body length	0.489	0.037	0.171
Wing length	0.459	-0.279	0.031
Femur length	0.658	0.139	0.053
Tibia length	0.137	0.328	0.218
Tarsometatarsus length	0.316	0.492	0.016
Tarsometatarsus circumference	0.381	0.324	0.418
Length of the third toe	0.617	0.231	-0.395

The classification results based on morphometric traits indicate a moderate to high level of accuracy in distinguishing among the muscovy duck populations. As shown in Table 4, 66.67% of Local ducks, 58.33% of Rambon ducks, and 86.67% of Jumbo ducks were correctly classified into their respective groups. The highest classification success was observed in the Jumbo population, reflecting its distinct morphometric profile, likely due to intensive selection for growth and size traits. Conversely, the Rambon group showed the highest level of misclassification, with 36.11% of individuals incorrectly assigned to the Local group, suggesting morphological overlap or a shared genetic background between these two populations. The Mahalanobis distance matrix (Table 5) supports these observations, showing a large distance between Jumbo and the other two groups (13.174 with Local and 13.235 with Rambon), indicating strong morphological divergence. In contrast, the distance between Local and Rambon (2.411) was much smaller, further supporting their closer phenotypic relationship. These findings highlight the effectiveness of morphometric traits in breed differentiation and suggest that discriminant function analysis is a valuable tool for phenotypic characterization and conservation of indigenous duck populations. This is consistent with the findings of Muluneh et al. (2023) and Markos et al. (2024), who reported the usefulness of Mahalanobis distances and classification functions in distinguishing among local poultry ecotypes.

The dendrogram highlights clear phenotypic distinctions among three muscovy duck populations based on morphometric traits (Figure 3). Local and Rambon ducks cluster closely (distance 1.206), suggesting strong similarity, likely due to shared ancestry or similar environments. In contrast, Jumbo ducks are distinctly separated (distance 6.602), reflecting their larger size and probable selective breeding. These results underscore the value of morphometric analysis in breed characterization and conservation, with Rambon ducks potentially representing an intermediate form.

Table 4. Percent of individual ducks classified into their respective breed and cross-validation of classification based on morphometric traits (values in brackets are the number of ducks)

Breeds	Local	Rambon	Jumbo	Total
Local	66.67 (20)	26.67 (8)	6.67 (2)	100 (30)
Rambon	36.11 (13)	58.33 (21)	5.56 (2)	100 (36)
Jumbo	0.00 (0)	13.33 (4)	86.67 (26)	100 (30)
Total	34.38 (33)	34.38 (33)	34.38 (30)	100 (96)

Table 5. Distance of Mahalanobis, based on morphometric traits between duck populations

Breeds	Local	Rambon	Jumbo
Local	**1**		
Rambon	2.411	**1**	
Jumbo	13.174	13.235	**1**

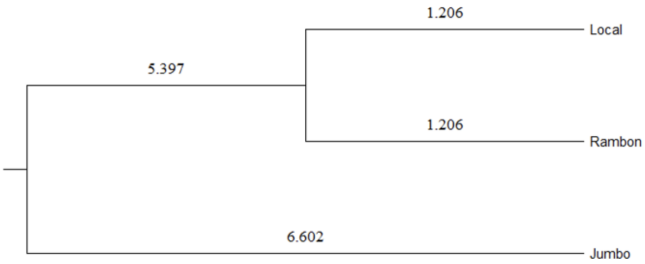

Figure 3. Phylogenetic tree between duck populations based on morphometric traits

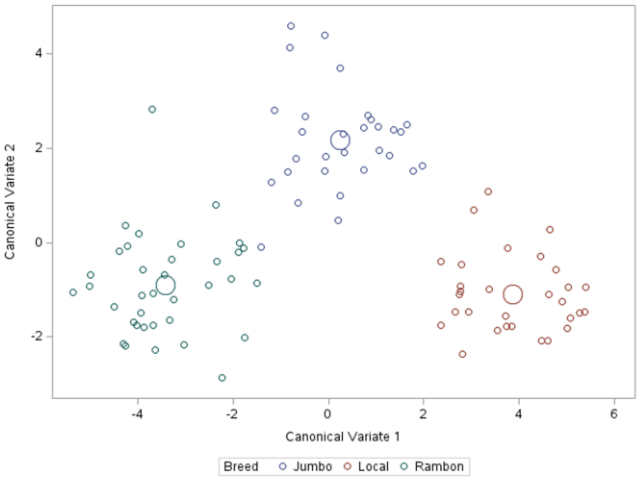

Figure 4. Display the plot constructed using the three canonical variables to highlight the differences between the duck populations

The scatter plot presents the Canonical Discriminant Analysis (CDA) results for the three muscovy duck populations, Jumbo, Local, and Rambon, based on their morphometric traits (Figure 4). Each point represents an individual duck, plotted according to their scores on Canonical value, which are linear combinations of the original morphometric variables that best distinguish the groups. Similar to the finding of Chebo et al. (2024), the plot shows clear separation among the three groups, indicating that the morphometric traits used are effective for differentiating between populations. The Jumbo ducks cluster distinctly on the left side, the Local ducks are in the center, and the Rambon ducks are grouped on the right side. The minimal overlap between clusters confirms the validity of CDA in identifying population structure based on physical characteristics.

In conclusion, the phenotypic diversity among muscovy duck ecotypes has significant implications for local poultry development and genetic resource management. Jumbo ducks show strong potential for meat production, while the broader variation in Local and Rambon ducks highlights valuable genetic diversity for breeding and conservation. This diversity supports region-specific breeding strategies, helps preserve adaptive traits, and strengthens sustainable poultry systems that improve rural livelihoods and food security. These ducks represent important local genetic resources with traits suited to different environmental conditions and production needs. To ensure their long-term sustainability, integrated conservation approaches are recommended—combining in-situ conservation through support of traditional farming systems with ex-situ strategies such as gene banks and controlled breeding programs. Sustainable use through community-based breeding initiatives can further promote both conservation and productivity.

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