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RESEARCH ARTICLE

Principal Component Analysis of the Female Pengging Soloan Duck Based on Morphometric Traits

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Abstract: The Pengging Soloan duck is an emerging indigenous genetic resource from Central Java, Indonesia, recognized for its adaptability and egg-laying potential. However, its phenotypic characterization remains limited compared with established Indonesian duck breeds such as Mojosari, Tegal, and Magelang ducks. This study aimed to characterize 70 adult female Pengging Soloan ducks aged 5 6.5 months using Principal Component Analysis (PCA) based on 13 morphometric traits. Descriptive statistics, Pearson's correlation, and PCA with Varimax rotation were applied. Most morphometric traits showed low variability (CV<10%), indicating a relatively homogeneous population, although moderate variation was observed in neck length (10.74%), pubic width (12.26%), and shank length (10.20%). Significant positive correlations were identified among cranial traits, particularly between Beak Length (BeL) and Beak Width (BeW) ($r = 0.563$). PCA extracted six principal components explaining 72.10% of the total variance, with the first component primarily associated with cranial morphology, while subsequent components reflected body conformation, limb dimensions, and pelvic traits. The separation between cranial and post-cranial components suggests distinct patterns of morphological organization and developmental modularity. In addition, the pubic width emerged as an important contributor to phenotypic variation, although its relationship with reproductive performance was not directly evaluated. The findings provide preliminary baseline information on the morphometric structure of Pengging Soloan ducks. However, the results should be interpreted cautiously due to the relatively small sample size ($n = 70$), single-location sampling, exclusion of male individuals, and the absence of productivity data. Future studies involving large populations, multiple locations, both sexes, and the integration of production and molecular data are required to achieve more comprehensive breed characterization.

Keywords: Indonesian Local Duck, Morphometric, Multivariate Analysis, Pengging Soloan Duck, PCA

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Introduction

Duck farming is an economically significant component of the poultry sector in Indonesia, particularly in wetland ecosystems where they are frequently reared in traditional and semi-intensive systems [1]. Duck farming produces meat and eggs and benefits rural economies through both subsistence and commercial activities. While well-known local duck breeds, such as Tegal, Magelang, and Mojosari have received extensive research, an undescribed local duck breed known for its adaptability and promising productive traits has emerged from Central Java, Indonesia. The Pengging Soloan duck remains poorly documented despite its increasing population. The lack of systematic morphometric and genetic characterization limits the potential of this species to be integrated into breeding and conservation programs. Although this has not been confirmed, many people refer to this duck as the "Soloan" duck because its population has recently increased significantly in the Solo area. These local ducks are valued for their relatively high egg-laying ability, meat quality, and tolerance to harsh local environmental conditions, making them a viable candidate for sustainable poultry production in low-resource environments. Therefore, their population has spread across many locations in Central Java, Indonesia. Despite increasing recognition among farmers and researchers, scientific documentation of its biological and morphological characteristics is limited.

Documenting morphometric traits is critical for breed identification, characterization, and selection. Morphometric traits such as linear body measurements and weights are important indicators of genetic diversity, growth potential, and overall fitness [2]. These characteristics are also associated with important productivity metrics such as meat yield, egg production, and feed efficiency [3-5] . Understanding the variation in morphometric traits within and between local duck populations can provide important insights into genetic structure, adaptive capacity, and opportunities for genetic improvement. Breed characterization using morphometrics is especially important in countries such as Indonesia, where crossbreeding, habitat loss, and commercial hybrids threaten local breeds. Characterization enables the identification of distinctive traits that can be preserved or improved through selective breeding. Furthermore, it contributes to policymaking and conservation efforts by providing the baseline data required to establish conservation priorities and develop breeding programs that maintain genetic diversity.

Compared to well-characterized Indonesian duck breeds such as Mojosari, Tegal, and Magelang, which have been extensively studied with respect to morphometric structure, genetic diversity, and production performance, the Pengging Soloan duck remains entirely undocumented in the peer-reviewed scientific literature. No published study has yet characterized the morphometric traits of this breed, nor has PCA been applied to examine the dimensional structure or developmental modularity of its phenotypic variation. Previous morphometric studies on Indonesian local ducks have predominantly relied on univariate descriptive statistics or bivariate correlation analyses. Recent studies have shown that Mojosari ducks exhibit relatively strong body size uniformity and more stable laying performance compared with several local duck populations and reciprocal crosses [6]. Furthermore, morphometric investigations revealed that Mojosari ducks tend to exhibit more consistent body conformation than other Indonesian local ducks, suggesting a relatively stable selection history. In contrast, Tegal and Magelang ducks reportedly show greater variation in reproductive-related morphometric traits, particularly pubic width and body conformation, which may reflect differences in reproductive capacity and adaptive diversity. The Pengging Soloan duck in the present study exhibited relatively homogeneous morphometric characteristics, although moderate variation remained evident in traits associated with reproductive morphology, such as pubic width. These findings suggest that the Pengging Soloan duck may possess a distinct morphological profile compared with other Indonesian local duck populations and therefore warrants further comparative and multi-location validation studies.

Advanced statistical methods, such as PCA, are effective tools for understanding the complexities of morphometric data. PCA reduces the dataset's dimensionality by identifying key trait combinations that account for most of the variability, simplifying trait evaluation [7]. These tools help decipher complex trait relationships and enable more precise phenotypic characterization of animal populations. Although morphometric characterization has been conducted for several Indonesian duck breeds, including Mojosari, Tegal, Magelang, and Alabio, information on the morphometric structure of the Pengging Soloan duck remains limited. Previous studies on Indonesian local ducks have primarily focused on production performance, phenotypic descriptions, genetic diversity, or univariate morphometric analyses. However, the underlying multivariate structure of morphometric variation in Pengging Soloan ducks has not been systematically investigated. To the best of our knowledge, no previous study has applied Principal Component Analysis (PCA) to identify the major dimensions of phenotypic variation and trait interrelationships in this newly recognized population. Compared with Mojosari ducks, which generally exhibit more uniform body conformation and stable laying performance, and Tegal and Magelang ducks, which often display greater variation in reproductive-related morphometric traits, the morphological characteristics of Pengging Soloan ducks remain

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poorly documented. Therefore, a comprehensive multivariate morphometric assessment is necessary to establish baseline phenotypic information, identify the principal sources of morphological variation, and provide a foundation for future breeding, conservation, and comparative studies. Therefore, this study aimed to characterize female Pengging Soloan ducks using morphometric trait-based PCA. This study, therefore, represents the first systematic, multivariate morphometric characterization of the Pengging Soloan duck, filling a critical knowledge gap and providing baseline phenotypic data for future breeding improvement and genetic conservation programs. The findings of this study are expected to help improve understanding and sustainably develop local duck genetic resources, ultimately benefiting food security, rural development, and biodiversity conservation.

Materials and Methods

Study Location and Sampling

This study was conducted from April to October 2024 at the Banyubiru Duck Livestock Park (Taman Itik Banyubiru) breeding station in Semarang Regency, Central Java, Indonesia. The ducks were kept semi-intensively in flock cages under the same management. The ducks were fed commercial feed and water ad libitum. A total of 70 adult female ducks were randomly sampled. To ensure morphological maturity, all sampled ducks were healthy and actively laying, aged approximately 5–6.5 months. To standardize morphometric measurements to a reference age (5.5 months), allometric scaling was applied as described by [8]. Each trait (*Y*) was adjusted using the Equation:

$$Y_{adj} = Y_i \left(\frac{\bar{\mathrm{A}}}{\mathrm{A}i}\right)^b$$

Where Y_{adj} is the adjusted trait value, Y_i is the observed value, $\mathrm{A}i$ is the age of the individual, A is the mean age of the population, and b is the allometric coefficient estimated from the regression of log-transformed trait values on log-transformed age. This adjustment minimizes size-related variation due to age differences and improves comparability across individuals.

The phenotypic characteristics of female Pengging Soloan ducks are shown in Fig. 1.

As illustrated in Fig. 1, the Pengging Soloan duck exhibits a slender body structure with elongated neck characteristics, which may explain the moderate variation observed in neck length. The sampled ducks represented a managed breeding population maintained under relatively uniform environmental and management conditions at the Banyubiru Duck Livestock Park. Although the sample size (n = 70) was limited, it satisfied the minimum requirements commonly adopted in exploratory morphometric PCA studies and provided preliminary information regarding population structure.

Fig. 1: Phenotypic characteristics of the female Pengging Soloan ducks

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Morphometric Measurement

Thirteen morphometric traits were measured for each duck, comprising both linear and circumferential dimensions, i.e. Body Weight (BW), Body Length (BL), Chest Girth (CG), Chest Width (CW), Wing Length (WL), Neck Length (NL), Head Length (HL), Head Width (HW), Beak Length (BeL), Beak Width (BeW), Pubic Width (PW), Tibia Length (TL), and Shank Length (SL). Digital scales with a 2 kg capacity and 10 g precision for weight, as well as a measuring tape, ruler, and vernier calipers for linear dimensions, were used for all measurements. The following were used: Measurement was conducted in accordance with the method of [9-11] procedures as visualized in Fig. 2. To reduce observer bias, the average value was recorded, and each measurement was made three times.

Fig. 2 provides detailed anatomical landmarks used for morphometric measurements, ensuring repeatability and methodological consistency.

Data Analysis

All morphometric traits were adjusted using allometric scaling to a standard age of 5.5 months. The gathered data were first examined using descriptive statistics to determine the measures of central tendency (mean) and dispersion (standard deviation and coefficient of variation) for each feature. The degree and direction of linear relationships between pairs of morphometric variables were then determined by computing Pearson's correlation coefficients. Highly intercorrelated traits were identified as possible candidates for dimension reduction. PCA was used to identify underlying trait clusters and reduce data dimensionality. The Kaiser-Meyer-Olkin (KMO) measure and Bartlett's sphericity test were used before PCA to assess the suitability of the correlation matrix and sample adequacy. Prior to PCA, all 13 morphometric variables were standardized using z-score normalization to eliminate the effect of measurement scale differences between traits. Variables were included in the final PCA solution based on two criteria: communality values ≥ 0.5 after extraction, and factor loadings ≥0.5 on at least one principal component. No variables were excluded from the present dataset based on these criteria. A loading threshold of |0.5| was applied to identify the dominant traits contributing to each component, following the recommendation of [12]. Varimax rotation was used to improve interpretability, and PCA extraction was based on the Kaiser criterion (eigenvalues >1). Varimax rotation was selected because it produces a simpler and more interpretable factor structure by maximizing the variance of squared loadings within each component, thereby reducing ambiguity in the assignment of variables to specific components. This orthogonal rotation approach is appropriate under the assumption that the principal components reflect independent morphological modules, which is consistent with the biological expectation of distinct cranial, axial, and appendicular developmental regions in the Pengging Soloan duck. IBM SPSS Statistics version 25 was used for all statistical analyses.

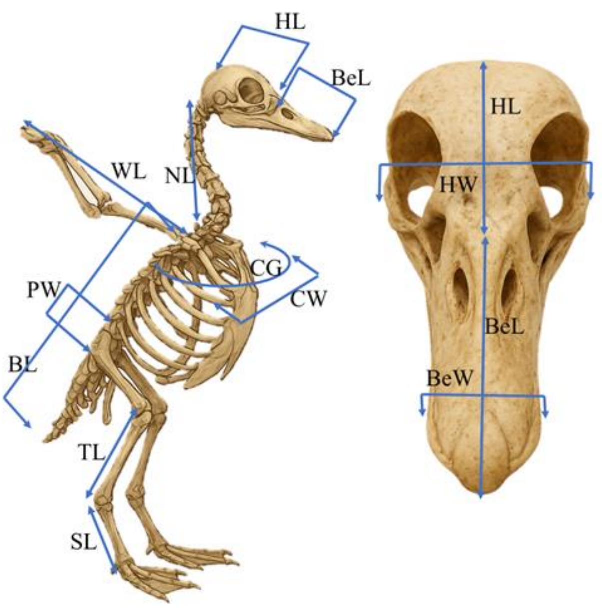

Fig. 2: Morphometric measurement points in the Pengging Soloan duck

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Results

Morphometric Traits

The morphometric characteristics of the 70 female Pengging Soloan ducks were presented in Table 1. The morphometric traits of female Pengging Soloan ducks were relatively uniform, with a low Coefficient of Variation (CV) of <10%, except for NL (10.74%), PW (12.26%), and SL (10.20%), which were categorized as moderate CV (10%<CV<20%). The lowest CV was for BeL (5.55%), and the highest was for PW (12.26%).

Phenotypic Correlation

The Pearson's correlation coefficient (r) for all morphometric traits of female Pengging Soloan ducks is presented in Table 2. Phenotypic correlations revealed substantial positive associations between multiple characteristics.

Table 1: Descriptive statistics of morphometric traits in the female Pengging Soloan duck

Morphometric Traits	Minimum	Maximum	Mean	Standard Deviation	Coefficient of Variation (%)
Body weight (g)	1,123.39	1,830.00	1,459.91	137.49	9.42
Body length (cm)	18.25	26.20	21.59	1.91	8.85
Chest girth (cm)	20.18	30.34	25.88	1.92	7.42
Chest width (cm)	5.89	8.85	7.75	0.53	6.64
Wing length (cm)	20.00	27.75	23.76	1.99	8.38
Neck length (cm)	13.65	23.86	18.72	2.01	10.74
Head length (cm)	5.38	8.37	6.10	0.46	7.54
Head width (cm)	2.56	3.85	2.95	0.21	7.12
Beak length (cm)	4.96	7.18	5.59	0.31	5.55
Beak width (cm)	2.42	3.75	2.69	0.16	5.95
Pubic width (cm)	4.97	8.98	6.36	0.78	12.26
Tibia length (cm)	8.13	12.65	10.77	0.86	7.99
Shank length (cm)	5.13	8.96	6.87	0.70	10.20

Table 2: Phenotypic correlation among morphometric traits in female Pengging Soloan duck

Variables[1]	BW	BL	CG	CW	WL	NL	HL	HW	BeL	BeW	PW	TL	SL
BW	1.000												
BL	-0.187	1.000											
CG	0.100	0.330	1.000										
CW	-0.062	0.483	0.105	1.000									
WL	0.028	0.265	0.342	0.043	1.000								
NL	0.005	-0.030	-0.085	0.038	0.015	1.000							
HL	0.140	-0.247	-0.087	-0.169	0.168	0.167	1.000						
HW	0.099	-0.059	-0.068	0.025	-0.165	0.143	0.061	1.000					
BeL	0.346	-0.212	-0.083	-0.056	-0.016	0.104	0.184	0.429	1.000				
BeW	0.258	-0.033	-0.013	-0.035	0.093	0.120	0.098	0.458	0.563	1.000			
PW	0.175	-0.100	-0.056	0.258	-0.160	0.151	0.111	-0.019	0.215	0.219	1.000		
TL	-0.069	-0.112	-0.074	0.087	0.063	0.008	0.181	0.036	0.044	0.050	0.047	1.000	
SL	-0.001	-0.111	-0.160	0.022	-0.148	-0.128	0.075	0.134	0.196	0.031	-0.016	0.371	1.000

[1]BW = Body Weight, BL = Body Length, CG = Chest Girth, CW = Chest Width, WL = Wing Length, NL = Neck Length, HL = Head Length, HW = Head Width, BeL = Beak Length, BeW = Beak Width, PW = Pubic Width, TL = Tibia Length, SL = Shank Length

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Substantially associated between BeL and BeW (r = 0.563), BeL and HW (r = 0.429), and BeW and HW (r = 0.458), indicating possible cranial morphology modularity. However, body weight showed modest associations with most linear measurements (BeW, BeL, PW, HL), suggesting that factors beyond skeletal dimensions, such as fat and muscle distribution, may influence total mass. The other positive correlation was found between BL and CW (r = 0.483).

Principal Component Analysis

The KMO measure of sampling adequacy in this study was 0.555, and the Bartlett's test was significant (p<0.001), indicating that the PCA results were accurate. The PCA identified six principal components with eigenvalues greater than one (the Kaiser criterion) (Fig. 3), accounting for a total variance of 72.10% (Table 3). The PCA projection of factors and associations between morphometric measurements (PC1, PC2, PC3) is illustrated in Fig. 4. PC1 explained the largest variation and was dominated by head-related features (HW, BeL, and BeW), whereas PC2 focused on CW and BL. Moreover, PC3 consists of WL and CG; PC4 consists of TL and SL; PC5 consists of PW and BW, and PC6 focuses on NL. These data indicate that cranial and post-cranial measures are separate axes of morphological variation. All features had communality values of more than 0.500, indicating that they significantly contributed to the overall morphometric structure.

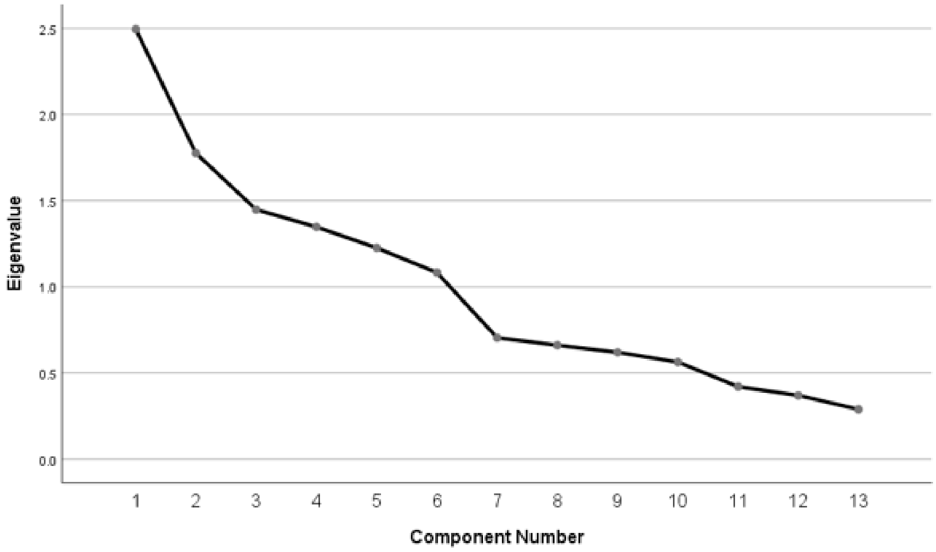

Fig. 3: The scree plot of morphometric measurement in female Pengging Soloan duck

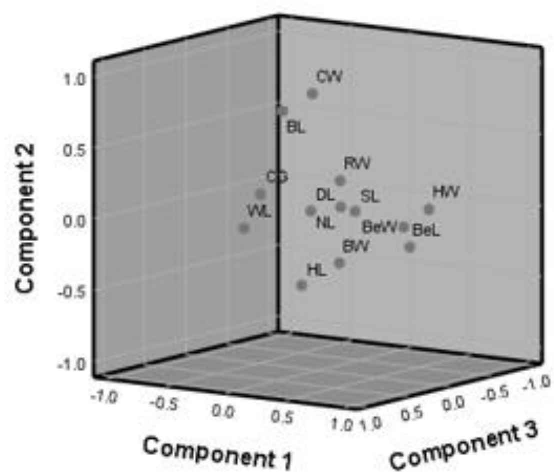

Fig. 4: Projection plot on principal component analysis (PCA) of the factors and associations between morphometric measurements in female Pengging Soloan duck based on the rotated component matrix (PC1, PC2, PC3)

Table 3: Eigenvalue, percentage of total variance, and communalities in female Pengging Soloan ducks using the varimax rational component matrix

Variables[1]	PC1	PC2	PC3	PC4	PC5	PC6	Communality
BW	0.329	-0.293	0.211	-0.126	0.591	-0.247	0.664
BL	-0.042	0.759	0.365	-0.114	-0.194	-0.029	0.762
CG	-0.006	0.225	0.683	-0.174	0.044	-0.228	0.602
CW	-0.030	0.834	0.024	0.143	0.261	0.066	0.790
WL	-0.026	0.007	0.852	0.066	-0.099	0.151	0.764
NL	0.148	0.043	-0.064	-0.117	0.034	0.836	0.741
HL	0.045	-0.471	0.260	0.337	0.205	0.462	0.660
HW	0.806	0.075	-0.186	0.041	-0.215	0.096	0.747
BeL	0.770	-0.167	-0.006	0.117	0.278	-0.001	0.712
BeW	0.804	-0.006	0.115	-0.001	0.164	0.094	0.695
PW	0.049	0.198	-0.199	0.038	0.827	0.210	0.810
TL	-0.018	0.016	0.059	0.836	0.013	0.109	0.715
SL	0.168	-0.006	-0.208	0.748	-0.048	-0.279	0.711
Eigenvalue	2.055	1.705	1.576	1.485	1.346	1.205	
% Variance	15.807	13.118	12.123	11.426	10.356	9.269	
Cumulative	15.807	28.925	41.049	52.474	62.830	72.100	

[1] BW = Body Weight, BL = Body Length, CG = Chest Girth, CW = Chest Width, WL = Wing Length, NL = Neck Length, HL = Head Length, HW = Head Width, BeL = Beak Length, BeW = Beak Width, PW = Pubic Width, TL = Tibia Length, SL = Shank Length

Discussion

Indonesian local ducks are noted for their high morphometric and genetic diversity, making them a valuable livestock resource that must be maintained [13, 14]. Pengging Soloan ducks were raised on commercial feed with ad libitum access. Feeding ducks with comprehensive and regularly available nourishment allows them to use energy more efficiently, which has an impact on the process of sustaining tissue biomass, particularly bone, muscle, and fat tissue [15, 16]. The protein composition (17.22 to 20.08%), calcium content (1.82–3.04%), and metabolic energy (2,630.50–2,880.45 kcal/kg) of Pengging ducks meet the requirements and are appropriate. Meanwhile, differences in body size due to the genes possessed by the ducks in this study are supported by [17, who argue that genetic diversity in livestock can be caused by additive genes, the majority of genes, and epistatic genes. According to [18], variances in livestock body size are caused by genes. Although the sample size (n = 70) is relatively limited for multivariate analysis, it meets the minimum threshold commonly used in exploratory PCA studies of livestock morphometrics.

It is important to acknowledge that the KMO value of 0.555, while technically acceptable, falls at the lower boundary of adequacy and is classified as mediocre according to Kaiser's conventional scale [19]. This value indicates that inter-variable partial correlations are relatively modest on average, which may partly reflect the genuine multidimensionality of duck morphometrics, where anatomically distinct body regions (cranial, axial, pelvic, and limb structures) tend to vary semi-independently. Consequently, the PCA components extracted in the present study should be interpreted as exploratory in nature rather than as a confirmed latent structure. The Bartlett's test of sphericity ($p<0.001$) nonetheless confirms that the correlation matrix differs significantly from an identity matrix, validating the application of PCA to this dataset. The borderline KMO value further underscores the need for future studies with larger sample sizes (n>150) and multi-location sampling to obtain more robust PCA solutions with higher sampling adequacy scores.

The significant relationships among cranial features indicate that coordinated development is most likely mediated by shared genetic or developmental processes. This modularity enables the use of composite trait indices in selection procedures. The weak relationship between body weight and other morphometric features suggests the presence of non-linear factors such as muscle composition, fat deposition, and metabolic efficiency, all of which warrant further physiological examination. The dominance of cranial traits in PC1 suggests that head morphology represents a primary axis of phenotypic variation in the Pengging Soloan duck. This may reflect strong developmental integration among cranial structures, which are often regulated by tightly coordinated genetic pathways. Cranial traits tend to exhibit lower environmental plasticity compared to body traits, making them more stable indicators of genetic differentiation. Cranial structures are generally characterized by strong developmental integration and relatively high genetic stability. In contrast, the separation between cranial and post-cranial traits indicates morphological modularity, whereby different anatomical regions may vary relatively independently and potentially respond to distinct selective pressures. The separation between cranial (PC1) and post-cranial components (PC2–PC6) indicates morphological modularity. This implies that different body regions may evolve or respond to selection pressures independently. Such modularity is advantageous in breeding programs, as it allows targeted selection on specific functional traits without affecting overall body conformation.

Compared with Mojosari, Tegal, and Magelang ducks, the Pengging Soloan duck exhibited relatively homogeneous morphometric characteristics, as indicated by the low coefficients of variation (<10%) observed for most traits. Nevertheless, pubic width showed moderate variation (12.26%), suggesting the presence of phenotypic diversity in reproductive-related morphology within the population. This finding may indicate that, despite the overall morphological uniformity, certain traits remain variable and could be useful for future selection studies. However, additional comparative investigations involving multiple populations and geographic locations are needed to determine whether these characteristics are unique to Pengging Soloan ducks or reflect population-specific management and environmental conditions.

According to [20], the body size of healthy local ducks is characterized by bones that expand continuously but at a modest rate as they age. The duck's body size can be used as a selection reference, including chest width, chest length, beak length, head circumference, head height, neck length, wing length, back length, shank length, shank circumference, tibia length, tibia circumference, longest toe length, pubic bone distance, and back height [21]. A duck's body size can be employed in selection because it is related to its output, particularly egg production. Furthermore, [22] found that pubic width in Tegal ducks, as a morphometric characteristic, had a correlation coefficient of 0.693 with egg production. [23] found that pubic width has a very high positive link with hen day production, whereas body weight, chest circumference, body length, wing length, neck length, and shank length had a negative correlation. [5] showed that the expression of specific genes associated with the PI3K-Akt signaling pathway is critical for follicular development and, ultimately, egg production in Gaoyou ducks. The observed associations reported in previous studies suggest that certain morphometric traits may have potential relevance to reproductive performance; however, this relationship was not directly evaluated in the present study.

The PCA successfully classified essential traits into six functionally coherent components, explaining 72.10% of the total variance. Cumulative variance ≥70% is generally considered an adequate representation [24]. Head-related characteristics, namely Head Width (HW), Beak Length (BeL), and Beak Width (BeW) had the largest loadings in PC1 (with the highest eigenvalue), implying that these measurements are the first predictors of overall body size variance in the Pengging Soloan duck. However, because the difference in percentage variation between each PC (PC1 to PC6) is small, each feature of interest in each PC can be used sequentially to rank the animal in the selection process. This multivariate approach provides a more concise assessment of breed variability than univariate methods, thereby facilitating the establishment of consistent selection criteria. Morphometric evaluation remains a highly practical, low-cost tool for breed characterization, especially in resource-constrained environments where sophisticated molecular equipment may be unavailable.

Despite the valuable baseline data, this study has certain limitations. The research was localized to a single breeding station, which may not fully capture the extent of phenotypic plasticity across different geographic regions or management systems. Additionally, the sample was limited to female ducks, leaving the morphometric characteristics and sexual dimorphism of males undocumented. Furthermore, while correlations were drawn from existing literature, this study did not directly measure real-time egg production or molecular markers in the sampled population.

Longitudinal studies should be conducted to monitor morphometric changes throughout the duck's entire life cycle. Expanding the scope to include genotype-environmental interaction studies will clarify how different management techniques affect phenotypic expression. Unlike molecular approaches, which may require sophisticated equipment and funding, morphometric analysis relies on simple field observations and can be conducted on a broad scale. These methodologies can provide a thorough understanding of breed structure and variety when combined with molecular data. This study also lays the foundation for future research. Longitudinal studies of morphometric changes in the Pengging Soloan duck throughout its life cycle could help optimize selection windows to maximize productivity [25, 26]. Integrating morphometric features with data on reproductive performance, feed conversion, and disease resistance will increase the breed's improvement potential.

Incorporating multivariate analysis into breed characterization efforts improves our understanding of indigenous animal varieties and facilitates evidence-based decision-making in livestock production [25, 27]. This study provides critical insights into the preservation and genetic enhancement of Indonesia's important poultry resources by examining the morphometric structure of the Pengging Soloan duck. Finally, integrating these morphometric findings with high-throughput molecular data and direct reproductive performance metrics will be crucial for long-term genetic enhancement, selection breeding program, and pursuing GI certification for the Pengging Soloan duck.

Several limitations of this study must be explicitly acknowledged. First, the sample comprised exclusively adult female ducks, which precludes any assessment of sexual dimorphism or the morphometric characteristics of male Pengging Soloan ducks. Inclusion of males in future studies would allow a more complete and comparative phenotypic description of the breed. Second, all sampled individuals were sourced from a single breeding station, which may not capture the full range of phenotypic variation distributed across the broader Pengging Soloan duck population in Central Java. Multi-location sampling across multiple farms or regencies is strongly recommended to validate and expand the morphometric baseline established here. Third, no production performance data (egg production, egg weight, or feed conversion ratio) were collected alongside the morphometric measurements, preventing direct assessment of morphology productivity relationships. Fourth, the sample size (n = 70), while meeting the minimum threshold commonly applied for exploratory PCA in livestock morphometrics, limits the statistical robustness of the extracted component structure, particularly in the context of the borderline KMO value (0.555). Future studies with n >150 and multi-location designs would substantially improve the reliability and generalizability of the PCA solution. These limitations should be carefully considered when extrapolating the findings to other duck populations or applying them in practical breeding program design.

Conclusion

This study provides a preliminary multivariate characterization of the female Pengging Soloan duck based on morphometric traits. The population exhibited relatively low morphological variability, although moderate variation was observed in neck length, pubic width, and shank length. PCA reduced 13 morphometric variables into six principal components, explaining 72.10% of the total variance and highlighting cranial morphology and body conformation as the primary axes of phenotypic variation. Significant positive correlations between beak dimensions and head width indicate coordinated developmental modularity. In contrast, the inclusion of pubic width as a key component may suggest a potential association with reproductive performance, as reported in previous studies. However, this relationship was not directly evaluated in the present study. The separation between cranial and post-cranial traits suggests morphological modularity, indicating that different body regions may vary relatively independently. These findings may provide useful baseline information for future breeding and conservation studies. However, the results should be interpreted cautiously due to limitations including the relatively small sample size, single-location sampling, exclusion of male individuals, and the absence of population performance data. Future studies should incorporate larger and multi-location populations, include both sexes, and integrate morphometric, production, and molecular data to enable more comprehensive characterization of the Pengging Soloan duck population.

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Author's Contributions

Rini Nur Hayati: Contributed to conceptualization, supervision, funding acquisition, methodology, data curation, and write original draft.
Subiharta: Contributed to data curation and write original draft.
Yudi Adinata: Contributed to data curation, investigation, methodology, and write original draft.
Franciscus Rudi Prasetyo Hantoro: Contributed to data curation, investigation, project administration, and writing original draft.
Agung Prabowo: Contributed to data curation, validation, visualization, and write original draft.
Dwi Rohmadi: Contributed to data curation, investigation.
Heri Kurnianto: Contributed to data curation, investigation, and write original draft.
Ivan Mambaul Muni: Contributed to investigation and validation.
Zubir: Contributed to validation and write original draft.
Jhon Firison: Contributed to data curation and validation.
Ade Syahrul Mubarak: Contributed to validation and write original draft.
Pita Sudrajad: Contributed to validation, write original draft, and write review and edited.
Agus Tri Sudaryanto and Alam Surya Wijaya: Contributed to resources, data curation, and investigation.
Alek Ibrahim: Contributed to conceptualization, data curation, methodology, validation, formal analysis, software, resources, write original draft, and write review and edited.

Ethics

The use of experimental animals in this study was approved by the ethics committee of the Animal Welfare Commission of the National Research and Innovation Agency, No: 115/KE.02/SK/05/2024. No clinical disorders were observed during the experimental period.

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