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Assessing the Relationship Between Pre-Laying Morphometrics and Productivity Traits in Magelang Ducks for Sustainable Breeding

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Abstract

Traditional selection of Magelang ducks relies on visual assessments despite a lack of scientific validation. This study evaluated the relationships among pre-laying morphometrics and productivity, an approach previously unexplored in this population. A total of 107 female ducks (70 days old) were recorded and monitored individually for 366 days under identical conditions. Data were analyzed using descriptive statistics, Spearman's correlation, and principal component analysis (PCA) to determine the independence of pre-laying morphometric and productivity traits. Productivity traits exhibited higher variability than pre-laying morphometrics, indicating that relatively uniform physical measurements do not reflect the wide range of production performance. Post-peak, extreme variability was driven by reproductive tract measurements, despite low variation in body weight, reflecting a physiological divergence that was hidden from external assessments. Spearman correlation revealed no significant relationship between pre-laying morphometrics and productivity. The mean age at molting was 398.65±29.31 days, occurring in 28.97% of ducks, and showed a weak positive correlation with production duration (235.25±39.27 days) and a significant, weak negative correlation with egg production (139.28±65.93 eggs). PCA identified 3 independent components: skeletal morphometrics (PC1), productivity (PC2), and body mass (PC3), which together accounted for 64.78% of the total variance. These findings confirm that visual selection for body size is ineffective for improving productivity. Researchers propose a two-stage selection strategy integrating skeletal screening with early performance recording and molecular markers. This framework enables farmers to identify elite layers and improve feed efficiency by culling unproductive, oversized ducks, thereby supporting sustainable breeding.

Keywords: breeding strategy; egg production; molting; PCA; variance

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INTRODUCTION

Ducks have been popular in the poultry industry for years, owing to their sensory attributes, distinctive nutritional characteristics, and high protein content (Chen et al., 2021; Quaresma et al., 2024). In Indonesia, duck breeding is integral to rural food security, as ducks account for approximately 1.5 to 1.6% of the total poultry population (Statistics Indonesia, 2024). The Magelang duck is one of the national genetic resources native to Central Java and is officially

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recognized under the Agriculture Ministerial Decree No. 701/Kpts/Pd.410/2/2013 (Maharani et al., 2019; Rahayu et al., 2020). While highly regarded for its adaptability and substantial production potential of 200 to 300 eggs annually (Ismoyowati and Purwantini, 2013), the lack of scientifically validated selection criteria remains a significant challenge for local farmers.

As economically important livestock and an affordable source of protein, Magelang ducks are important to smallholder farmers. However, the productivity of Magelang ducks is unstable, partly due to molting, which reduces egg production. Research on morphometric traits, age at first lay, age at molting, and egg production is crucial for optimizing management in duck farming. Phenotypic traits such as morphometric and egg production are influenced by genetic factors that can serve as selection criteria to improve targeted traits. In addition to morphometric traits, age at first lay is an important indicator in evaluating poultry productivity (Begli et al., 2018).

However, in smallholder farms, the selection of local duck breeds is often made visually based on exterior characteristics, such as body size and physical condition. Visual selection is considered simple and does not require recording individual data. Evidence from the field shows that the use of recording systems at the farmer level remains limited, so selection decisions are primarily based on intuition (FAO, 2012). Hence, farmers face significant economic challenges due to inefficient selection methods. Currently, traditional selection relies heavily on visual morphometric assessments, where larger body size is often misinterpreted as a sign of superior productivity. This misconception leads to the maintenance of oversized but unproductive ducks, thereby increasing feed costs without a commensurate increase in egg yield.

Phenotypic traits in ducks include external morphological characteristics such as body weight, shank length, bill length, and plumage color, and reproductive performance traits, such as age at first laying egg and egg number. These traits reflect the interplay between genetic and environmental factors, are essential for evaluating variation both within and among populations, and inform breeding strategies (Maharani et al., 2019; Sulaiman et al., 2023; Ma et al., 2024). Phenotypic variability is the fundamental basis for selective breeding, enabling productivity improvements, while preserving genetic diversity (Seddon et al., 2013; Hubbard et al., 2015). Phenotypic variability is commonly quantified using the coefficient of variation (CV), which reflects the relative degree of dispersion of a trait within a population. Duck phenotypes exhibiting moderate to high CVs may present substantial opportunities for genetic enhancement through selection programs (Hossein-Zadeh, 2024).

Morphometric analysis of ducks during the early developmental stages may predict adult performance (Gouda and Ali, 2017; Xi et al., 2023). However, the correlations with egg production remain inconsistent (Prayogi et al., 2024). Implementing early selection to remove low-performing ducks before the onset of laying can substantially reduce feed costs by preventing feed expenditure on individuals with poor production potential (Zhang et al., 2016; Zhu et al., 2017; Bai et al., 2022). Egg production is a critical performance indicator for layer poultry, including ducks. Molting, a physiological process characterized by feather renewal and reproductive regression, frequently disrupts laying cycles and is influenced by hormones, such as prolactin, and by energy reallocation (Kuenzel, 2003; Zhang et al., 2021).

Studies on other breeds, such as Alabio and Peking, have demonstrated that molting reduces egg output but aids recovery (Purba et al., 2005; Susanti et al., 2012). Genetic and phenotypic correlations reveal how one trait changes in response to selection on another trait, thereby highlighting the importance of mitigating potential adverse side effects (Wellmann, 2023). However, phenotypic relationships between pre-laying morphometric traits and productivity traits, mainly molting status and egg production in Magelang ducks, have not been well documented. Moreover, the use of principal component analysis (PCA) to integrate these traits for breeding-oriented interpretation in this local duck population remains unexplored. PCA effectively extracts multidimensional trait data and identifies key axes of variability for breeding (Ogah and Kabir, 2014; Sulaiman et al., 2023). In a previous study by Sulaiman et al. (2023) on Alabio ducks, PCA revealed medium-to-high communalities among body and egg traits, thereby facilitating selection.

This study aimed to (1) quantify phenotypic variance, (2) assess trait correlations, determine whether pre-laying morphometrics predict productivity traits, and (3) evaluate the principal component structure of phenotypic variation in the Magelang ducks. These findings will contribute to sustainable breeding practices for enhancing egg yield in Indonesia's poultry sector, particularly for Magelang ducks. Research on molting in Indonesian ducks is limited; thus, this study addresses this gap. This study is the first to comprehensively integrate PCA, molting, and production traits in Magelang ducks.

MATERIALS AND METHOD

Study site and animal management

The observational longitudinal study was conducted at Bina Mandiri Duck Breeding Farmer Group, located in Kalangan, Ambartawang, Mungkid, Magelang, Central Java, from February 2024 to February 2025. A total of 107 healthy Magelang ducks, aged 70 days and in the pre-laying phase, were housed individually in bamboo cages (40 cm × 50 cm × 40 cm). The ducks were fed twice a day (7:00 AM and 5:00 PM) using semi-commercial feed, with 50 g per duck during the pre-laying phase and 70 g per duck during the laying phase. The pre-laying phase feed contained ash (35.35%), crude protein (16.63%), crude fat (3.64%), crude fiber (4.07%), and nitrogen-free extract (NFE) (40.30%). The laying phase feed contained ash (30.75%), crude protein (17.28%), crude fat (4.81%), crude fiber (3.87%), and NFE (43.29%), with ad libitum water. Ethical approval was granted by the Institutional Review Board of the Faculty of Veterinary, Universitas Gadjah Mada (No. 148/EC-FKH/Int/2024).

Data collection

The observed variables were classified into 3 categories based on biological phase and trait type: pre-laying morphometric traits, productivity traits, and post-peak morphometric traits. Pre-laying morphometric traits were measured at 70 days of age during the pre-laying phase, following the FAO-2012 guidelines for measurement protocols (FAO, 2012). Body weight (g) was recorded using a Meilen portable digital scale (50 to 5,000 g), while linear measurements were taken using a measuring tape or caliper with 1 mm precision. Body length (cm) was measured from the breastbone (furcula) to the tail bone (pygostyle). Neck length (cm) was measured from the base of the neck to the point of attachment to the body, and neck circumference was measured at the base of the neck. Shank length (cm), representing the tarsometatarsal length, was measured from the knee joint to the base of the middle toe. Beak length (cm) was measured using a caliper from the tip to the base. All measurements were taken on the left side of the body, except for symmetrical traits such as neck circumference. The ducks were positioned upright during all measurements.

Productivity traits were recorded during the laying phase, from the onset of egg production until 436 days of age, including age at first egg, molting age, production duration, egg production, molting status, and survival status. Production duration was defined as the number of days from the onset of laying until permanent cessation or the end of the observation period. For ducks that did not cease laying, this value represents the observed production period. Post-peak morphometric traits were all measured at 436 days of age. At this age, 10 ducks, 5 molting and 5 non-molting, were randomly selected for dissection to assess body weight (g), ovary length (cm), oviduct length (cm), and reproductive tract weight (g). The sample size determined followed the resource equation approach by Arifin and Zahirudin (2017), with 5 individuals per group to ensure statistical validity and to adhere to the Replacement, Reduction, and Refinement (3Rs) ethical framework. All invasive procedures and measurements were conducted in accordance with the 2020 AVMA guidelines for animal welfare (Underwood and Anthony, 2020). Reproductive tract length was measured using a ruler with 1 mm precision. Tracts were weighed using a Lottol SF-400 portable scale with 1 g precision after removing connective tissue and blood.

Statistical analysis

Descriptive statistics were computed for all variables. Coefficients of variation (CV) were classified as low (≤ 5%), moderate (5 to 15%), or high (≥ 15%) (Rahmadhani et al., 2022). Data normality was assessed using the Kolmogorov-Smirnov and Shapiro-Wilk tests to determine the appropriate correlation method. Pearson's correlation was applied to normally distributed variables, while Spearman's rank correlation was used for non-normally distributed data. Correlation analyses evaluated associations among morphometric traits, reproductive performance, molting, and survival status. Statistical significance was determined using two-tailed tests at $p < 0.05$ and $p < 0.01$. PCA was used to summarize phenotypic variation and was performed on 8 standardized variables with complete data: body weight, body length, shank length, beak length, neck circumference, neck length, production duration, and egg production. Variables affected by missing values due to mortality or molting were excluded to avoid imputation-related bias, and components with eigenvalues greater than 1 were retained. Calculations were performed using SPSS 26 and R 4.5.1 for visualization.

RESULTS AND DISCUSSION

Variance of the pre-laying morphometric, productivity, and post-peak morphometric traits

The pre-laying morphometric data showed moderate variability, with a CV ranging from 7.19 to 12.41% (Table 1), classified as moderate variance, indicating sufficient variation for selection. Pre-laying morphometrics exhibited moderate CV, consistent with those of local duck breeds, such as Alabio in South Kalimantan (Sulaiman et al., 2023). In contrast, productivity traits, including production duration, egg production, and molting status, showed high variability (Table 1). Duck phenotypes with moderate-to-high CV have good potential for genetic improvement through selection programs (Hossein-Zadeh, 2024). This suggests that the observed pre-laying morphometric traits indicate their potential use as early phenotypic indicators for improving productive traits through selective breeding in Magelang ducks. Interestingly, the pronounced contrast in variability between pre-laying morphometric and productivity traits indicates that reliance on relatively uniform physical appearance alone is insufficient for identifying high-yielding individuals, as ducks with similar body size and shape may differ substantially in their productive capacity.

Body weight variability declined noticeably with age, indicating increased phenotypic homogeneity in adult ducks, as shown in the decrease of variance in body weight from pre-laying morphometric to live body weight at post-peak morphometric traits. This phenomenon reflects physiological stabilization as ducks reach optimal development, resulting in growth cessation and increased homogeneity (Ogah and Kabir, 2014; Xi et al., 2023). Consistent with this condition, morphometric variability in adult Magelang ducks has been reported to fall within the low-to-moderate range (Maharani et al., 2019). The high variability observed in productivity traits (CV > 157.30%) is consistent with previous research, including high variance in egg production over 36 weeks on Magelang ducks reported by Ulfah et al. (2025). The age at first egg indicates productivity heterogeneity comparable to that observed in Indian local populations, with

Table 1. Descriptive statistics of pre-laying morphometrics and productivity traits in Magelang ducks

Variable	N	Min	Max	Mean	SD	CV (%)	Class of CV*
Pre-laying morphometric traits (70 days of age)							
Body weight (g)	107	630	1,285	1,008.30	125.16	12.41	Moderate
Body length (cm)	107	18	25	21.06	1.71	8.12	Moderate
Shank length (cm)	107	5.50	8	7.39	0.69	9.33	Moderate
Beak length (cm)	107	4.50	7	5.74	0.59	10.27	Moderate
Neck circumference (cm)	107	6.50	9	7.65	0.55	7.19	Moderate
Neck length (cm)	107	14	19	16.62	1.83	11.01	Moderate
Productivity traits (70-436 days of age)							
Age at first egg (days)	105	156	255	196.27	22.08	11.25	Moderate
Molting age (days)	31	330	435	398.65	29.31	7.35	Moderate
Production duration (days)	107	0	280	235.25	39.27	16.69	High
Egg production (count)	107	0	252	139.28	65.93	47.34	High
Molting status (y/n)**	107	0	1	0.29	0.46	157.30	High
Survival status (d/a)**	107	0	1	0.92	0.28	7.36	Moderate
Post-peak morphometric traits (436 days of age)							
Live body weight (g)	10	1,725	1,825	1,774.70	42.62	2.40	Low
Reproductive organ morphometric:							
Ovary length (cm)	10	6	15	10.70	3.43	32.06	High
Oviduct length (cm)	10	14	42	30.20	10.61	35.13	High
Reproductive tract weight (g)	10	17	195	102.80	86.73	84.37	High

Note: N = Number of samples; Min = Minimum; Max = Maximum; SD = Standard deviation; CV = Coefficient of variation. *CV classes are categorized as low (≤ 5%), moderate (5 to 15%), and high (≥ 15%) according to Rahmadani et al. (2022). **Binary traits; mean values represent the proportion of the population a range of 145 to 223 days (Kamal et al., 2023). The occurrence of molting at more than 399 days suggests a later onset than in Alabio/Peking crossbred ducks (Susanti and Prasetyo, 2015).

The production of Magelang duck eggs, which ranged from 0 to 252, suggests potential traits that can be enhanced by selecting for maximum production and delayed molting at 436 days. Similar patterns of production variability influenced by management conditions have been reported by Henrik and Marhayani (2020). Moreover, both hormonal and genetic evidence support a correlation between molting timing and productivity, indicating that selection for delayed molting (approximately 436 days of age) may improve laying persistence (Susanti et al., 2012; Oyebanjo et al., 2023). The extremely high CV observed for molting status is attributable to the binary nature of the data, which results in a relatively large SD in relation to the mean. This pattern reflects a clear physiological separation between molting and non-molting ducks. These findings further suggest that productivity traits, including egg production and molting status, may serve as applicable selection criteria in Magelang duck breeding programs.

The average survival rate of ducks during the experimental period was 0.92 (92%), indicating an 8.00% mortality rate during observation. The CV classified this trait as moderately variable, suggesting generally stable survival among individuals. This finding is lower than that reported in previous research, which states that the mortality rate of poultry in the Mekong River Delta region raised under traditional management systems was 8.20% (Delabouglise et al., 2019). These results indicate a high survival capacity in Magelang ducks, highlighting their potential for further development and utilization in production systems.

The morphometric characteristics of the reproductive organs during the post-peak phase are detailed in Table 1. Although the live body weight was relatively homogeneous, the reproductive organs exhibited high variability. The anatomical evidence in Figure 1 corroborates the statistical findings in Table 1, which show that the reproductive tract weight exhibited a CV of 84.37%. This extreme variability, in contrast to the low CV of live body weight (2.40%), demonstrates that internal reproductive regression occurs independently of overall body mass stability. This variation implies that post-peak ducks represent a physiological continuum rather than a uniform stage, with some individuals potentially retaining partially functional ovaries and oviducts. Similar patterns have been observed in Muscovy ducks, where oviduct length and weight decrease significantly following the cessation of laying. This is consistent with the

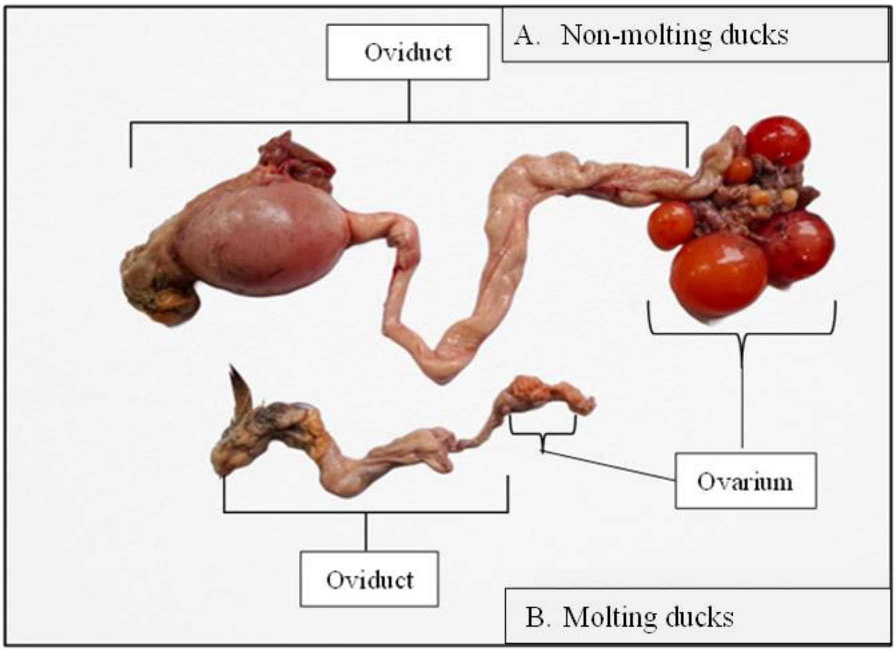

Figure 1. Representative variation in the reproductive tract of Magelang ducks at the post-peak production phase (436-day aged). (A) Non-molting ducks show a well-developed ovary with multiple follicles and an elongated oviduct. (B) Molting ducks exhibiting ovarian regression and reduced oviduct development

regression of glandular tissues (Linde et al., 2025). A comparative histomorphometry study by Mohammadpour et al. (2012) also demonstrated that the reproductive phase and hormonal status significantly influence the size of the reproductive tract in ducks.

The substantial CV in reproductive tract morphometrics signifies considerable heterogeneity in the extent of tissue regression among molting and non-molting ducks. This variation may be attributed to individual differences in endocrine responses, particularly in prolactin and estrogen levels, which are crucial for the transition from active laying to reproductive quiescence (Yang et al., 2024). Figure 1 demonstrates substantial variation in reproductive tract morphometrics. These findings collectively indicate that, although body weight remains relatively stable following egg-laying, the internal reproductive morphology exhibits significant dynamism and varies among individuals. This variability is indicative of differences in hormonal regulation, the timing of laying cessation, and the structural regression of the oviduct and ovary.

Correlation between pre-laying morphometric and productivity

Normality was assessed using the Kolmogorov-Smirnov and Shapiro-Wilk tests to guide the selection of appropriate correlation methods. Only body weight in pre-laying morphometrics showed a normal distribution across both tests ($p > 0.05$), while the other variables showed non-normal distributions ($p < 0.05$ in at least one test). Hence, Spearman's correlation was used rather than Pearson's correlation. The Spearman's correlation analysis (Figure 2) demonstrated significant positive correlations among pre-laying morphometrics traits, as indicated by the red cluster in the lower-right section of the heatmap, thereby suggesting proportional growth patterns.

Comparable results have been reported in Indian Runner ducks, in which body measurements, including beak length, neck

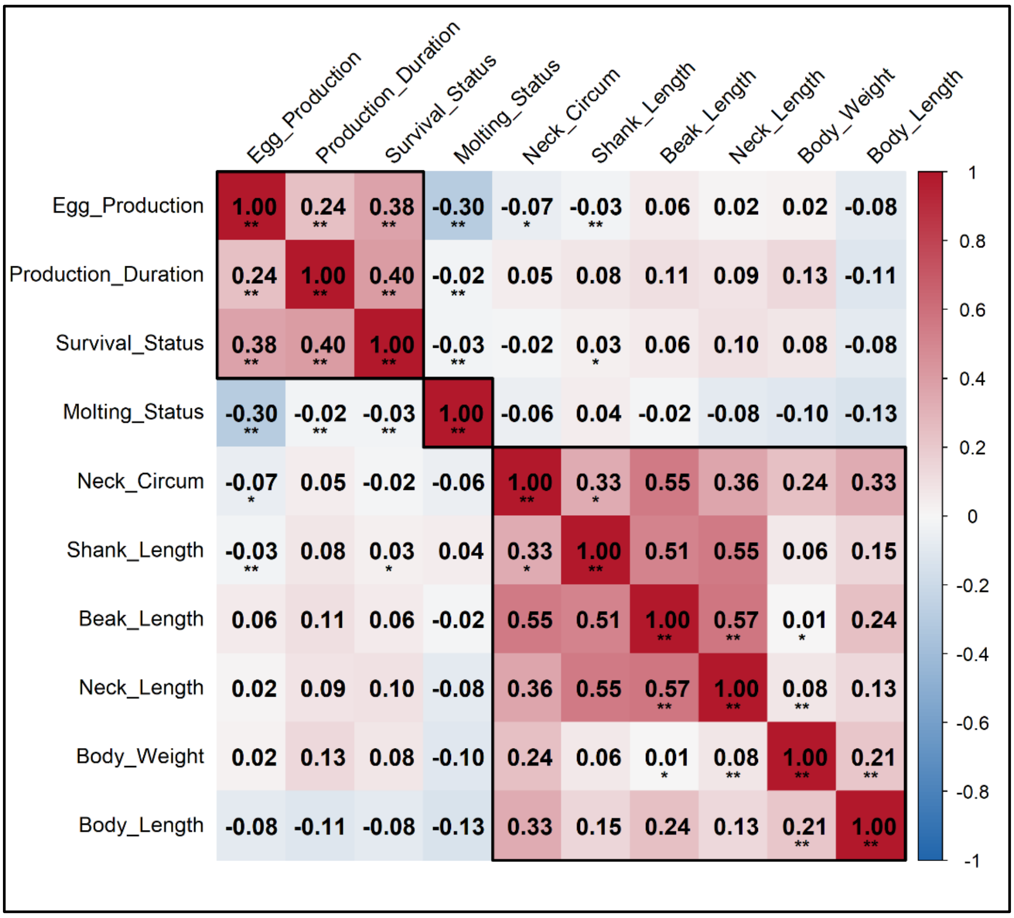

Figure 2. Spearman correlation-based clustered heatmaps of morphometric, reproductive, molting, and survival traits in Magelang ducks

Note: Red indicates positive correlations and blue indicates negative correlations (*$p < 0.05$ = Significant, **$p < 0.01$ = Highly significant) length, body length, and height, developed proportionally, conforming to an allometric growth pattern (Tamzil and Indarsih, 2024). Conversely, the correlation between pre-laying morphometrics and productivity traits was weak, as indicated by the pale blue color in the lower-left quadrant of the heatmap. The lack of significant correlations between morphometric traits and productivity indicates that early body size during the pre-laying phase is not a reliable predictor, aligning with findings in hens (Prayogi et al., 2024).

Hormonal and genetic factors may significantly impact egg production and molting patterns (Susanti et al., 2012). Contrary to the common practice among farmers who select breeding stock based on body size, Spearman's correlation analysis revealed no significant association between pre-laying morphometrics and productivity traits. Pre-laying morphometrics, such as body weight and body length, which are traditionally used as visual benchmarks, failed to predict egg production or production duration. This finding emphasizes that visual selection based on external body measurements is unreliable for improving egg yield in Magelang ducks.

The relationship among egg production, production duration, and survival status is significantly positive, as evidenced by coefficients of 0.24 and 0.31, highlighted in the red cluster at the top left of the heatmap. In contrast, molting status showed a significant negative correlation (-0.30), as illustrated in Figure 2. Although several correlations were statistically significant, their magnitudes were generally weak, indicating limited biological effect sizes. Such weak correlations are common in complex reproductive systems, where phenotypic traits are influenced by multiple interacting genetic and environmental factors rather than by a single morphometric predictor (Lynch and Walsh, 1998; Hill, 2013). These coefficients suggest that egg production is more closely associated with these factors than with physical characteristics such as body weight, body length, or beak length.

The observed negative correlation between egg production and molting status suggests that non-molting Magelang ducks demonstrate higher egg production compared to their molting counterparts. However, the correlation is relatively weak at -0.30. This finding suggests that ducks that do not molt tend to lay more eggs (Susanti et al., 2012). The inability of pre-laying morphometric traits to predict production performance is biologically plausible, as egg production and molting are complex traits regulated by endocrine mechanisms and energy allocation rather than early somatic size. Similar findings have been reported in ducks, where body size traits showed limited predictive value for egg production (Ulfah et al., 2025).

Molting imposes physiological stress on the organism, influencing both metabolic processes and hormonal balance, thereby inhibiting yolk formation and egg release. There is a positive correlation between survival status and egg production, as egg laying ceases upon death. The low correlation observed between molting and survival is consistent with existing research indicating that molting does not elevate the mortality risk in laying hens. Specifically, the mortality rate among laying hens subjected to induced molting was found to be comparable to that of non-molting hens, with rates ranging from 7 to 10% (Flock and Anderson, 2016).

The molting status exhibited a significantly weak negative correlation with both production duration (-0.02) and survival status (-0.03). Despite their statistical significance, these correlations are biologically negligible. This indicates that molting in Magelang ducks is mainly independent of the length of the laying period or survivability. This observation is consistent with the understanding that molting is primarily regulated by endocrine and genetic mechanisms rather than factors related to production. Previous studies on ducks have demonstrated that prolactin plays a central role in regulating the onset of molting and the temporary cessation of egg laying (Susanti et al., 2012). Variations in the prolactin (PRL) gene have been linked to reproductive outcomes and hormonal regulation in crossbred ducks, as demonstrated by Nguyen et al. (2023), affirming the genetic basis of molting variability. Although direct evidence in ducks is limited, molecular studies in poultry indicate that prolactin and thyroid hormones interact to regulate feather growth and replacement (Nozawa et al., 2025).

The slight negative correlation may reflect transient physiological adjustments during molt rather than a decline in productivity or survival. Environmental conditions, nutrition, and individual variation in hormonal responsiveness contribute to the weak relationship observed (Kuenzel, 2003). Among all internal morphometric relationships, the associations between morphometric variables are more robust than those with reproductive variables. Farmers often select ducks by body size, assuming that larger ducks lay more eggs. The results of this study show this is unreliable, emphasizing the need to record laying dates and egg numbers to identify truly productive ducks and improve flock performance.

Principal component structure of phenotypic variation

PCA, following Kaiser's criterion and the Elbow method (Table 2 and Figure 3), identified 3 components with eigenvalues exceeding 1.0, accounting for 64.78% of the total variance, effectively condensing the complex interplay of traits into independent structural and functional dimensions. According to commonly accepted guidelines, a cumulative variance of around 60 to 70% is typically regarded as adequate for exploratory PCA (Hair et al., 2010). These components reveal that Magelang duck phenotypic variation is not a singular trait but a composite of 3 separate biological factors.

The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was determined to be 0.674, indicating an acceptable level for factor extraction. According to Hair et al. (2010), KMO values below 0.50 are deemed unacceptable; values between 0.50 and 0.59 are considered marginal; those between 0.60 and 0.69 are adequate; values from 0.70 to 0.79 are moderate; 0.80 to 0.89 are good; and values of 0.90 or above are excellent. Therefore, the obtained KMO value supports the adequacy of the dataset for PCA. Bartlett's test of sphericity was significant (χ^2 (28) = 147.14, p < 0.001), confirming that the correlation matrix was suitable for factor extraction (Field, 2024).

Following standard guidelines for multivariate analysis, component loadings with absolute values ≥ 0.50 were considered practically meaningful for interpretation (Hair et al., 2010). Table 2 shows that the first component (PC1) had high loadings for beak, shank, and neck measurements, representing linear body dimensions. PC1 was identified as a skeletal morphometric component that indicates the structural size of ducks. The second component (PC2) correlated positively with production duration and egg duration, as evidenced by the high loadings on these variables relative to those of other components, indicating a productivity dimension related to duck reproductive performance. This component separates individuals based on their productivity capacity. The third principal component (PC3) was shaped by body weight, with a loading value higher than that of other variables, representing the weight/body mass dimension. This component captures specific variations in body weight that are relatively independent of skeletal morphometrics (PC1) and productivity (PC2).

These three dimensions are relatively independent of one another. These components suggest that skeletal morphometrics, productivity, and body mass contribute differently to phenotypic variation, and that productivity

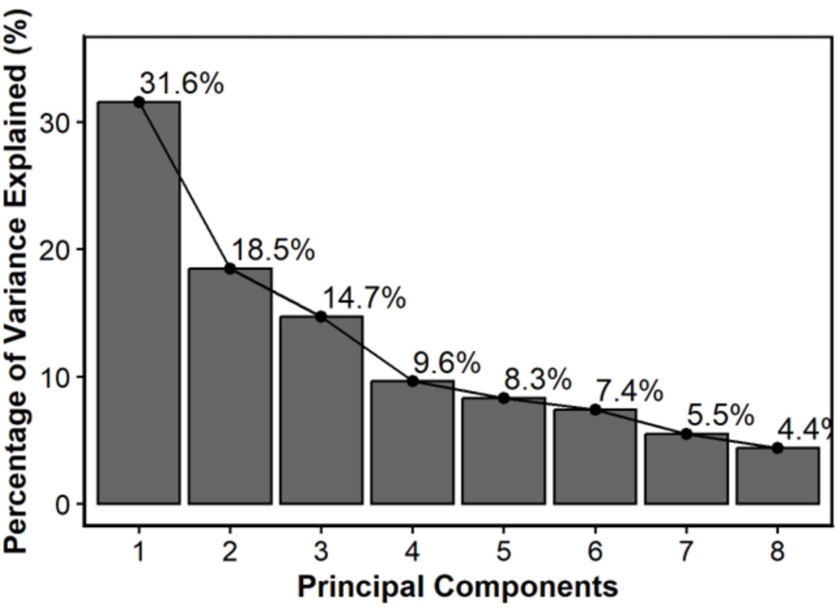

Figure 3. Scree plot of PCA

Table 2. PCA loadings and variance of morphometric and productivity traits in Magelang ducks

Variable	PC1	PC2	PC3	Communality
Body weight	0.27	-0.16	**0.75**	0.66
Body length	0.42	-0.47	0.44	0.59
Shank length	**0.72**	0.13	-0.25	0.59
Beak length	**0.82**	0.07	0.07	0.71
Neck circumference	**0.72**	-0.27	-0.27	0.60
Neck length	**0.73**	0.13	0.13	0.68
Production duration	0.20	**0.76**	0.26	0.69
Egg production	0.05	**0.73**	0.35	0.66
Eigenvalue	2.52	1.48	1.17	
% Variance	31.57	18.50	14.71	
Cumulative %	31.57	50.06	64.78	

Note: Bold values indicate high variable loadings (> 0.50) on the principal components

performance is not directly determined by pre-laying phase morphometrics in Magelang ducks. PCA loadings and variances of PC1, PC2, and PC3 are listed in Table 2. Variables with communalities exceeding 0.50 are considered robust indicators, and in this case, all variables exhibit communalities above this threshold. Communality values above 0.50 suggest that substantial variance from original variables has been captured by the principal components, ensuring dimensional reduction retains significant information (Hair et al., 2010).

Figure 4A shows that PC1 was primarily associated with skeletal morphometric traits, and PC2 was associated with productivity, indicating that overall skeletal morphometrics contributed more strongly to total phenotypic variation than productivity traits. Similar findings have been reported in other studies of local ducks, in which morphometric characteristics such as body length, chest girth, and shank length were identified as major contributors to total variance, whereas reproductive or production traits exhibited weaker discriminatory power (Maharani et al., 2019; Sulaiman et al., 2023). Although molting individuals tended to occupy the lower region of PC2, reflecting reduced egg production, there was substantial overlap between the 2 groups, suggesting that molting status was not a significant source of phenotypic variance within the population.

In the PC1 versus PC3 plot in Figure 4B, body weight exhibited significant loadings along PC3; however, the clustering pattern remained diffuse. This observation further proves that the variation in morphometrics within each group surpassed the differences observed between groups. The slight shift of non-molting ducks toward the positive side of PC1 to PC3 may indicate a marginal tendency toward larger body size among non-molting individuals. However, this difference was insufficient to produce clear group separation.

The PCA results further confirm that morphometric skeletal structure (PC1), productivity (PC2), and body mass (PC3) are independent dimensions of phenotypic variation. Because these traits do not overlap, selecting for a ‘larger’ duck (skeletal size) or ‘heavier’ duck (body mass) will not automatically result in a duck that lays more eggs (productivity). Productivity performance cannot be predicted solely from morphometric measurements but is instead a complex trait influenced by various factors. The PCA revealed that skeletal morphometric, productivity, and body mass traits collectively contributed to phenotypic variation. However, these dimensions were largely independent, and molting status did not clearly separate them within the population.

Implications for Magelang duck breeding

The lower variability of skeletal morphometric traits relative to egg productivity, reflected by PC1 and PC2, has important implications for breeding programs, highlighting the limited value of external morphology as a selection criterion for egg yield and molting occurrence. These findings necessitate a two-stage recording program and selection to improve productivity in Magelang ducks. In the first stage, pre-laying ducks should be screened for stable morphometric traits (PC1) to maintain the breed’s standard physical identity and adaptive fitness. However, because these traits do not predict yield, a second stage is required during the early production phase to record individual egg counts. Cumulative early period production is genetically correlated with later total production traits, indicating that early production records are informative for genetic selection (Han et al., 2025).

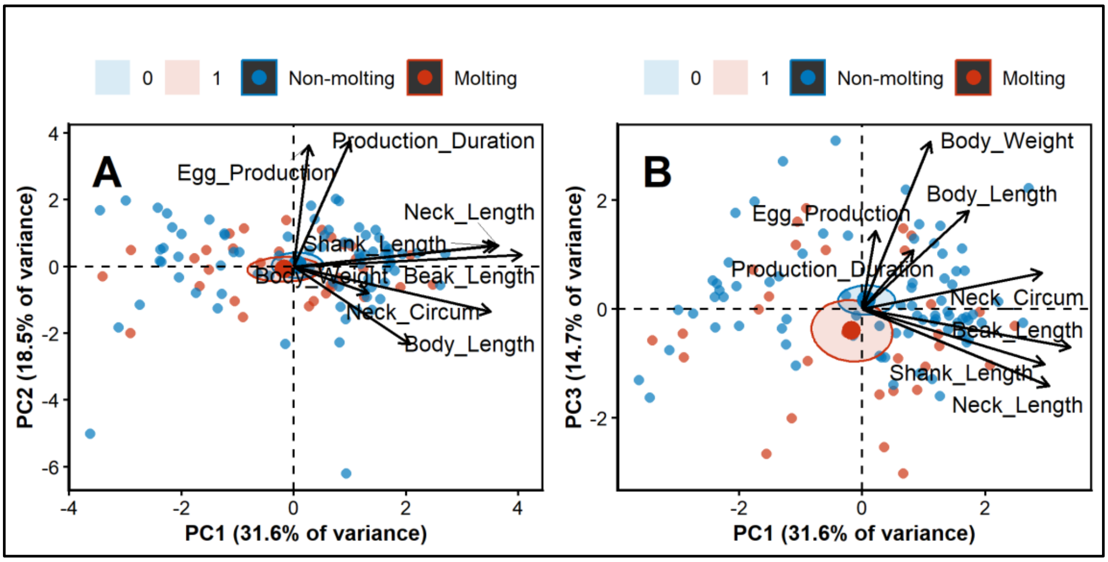

Figure 4. PCA biplots of morphometric and production traits in local Magelang ducks based on molting status. (A) PC1 vs PC2, (B) PC1 vs PC3

Note: Blue circles represent non-molting ducks (n = 76), red triangles represent molting ducks (n = 31), ellipses indicate 95% confidence intervals, and arrows represent variable loadings

This two-stage recording and selection program is ideally supported by molecular marker screening for reproductive genes, because although molting is linked to decreased productivity, the underlying variation is subtle and likely influenced by physiological or genetic mechanisms, such as the differential expression of prolactin-related genes, rather than by phenotypic characteristics (Kuenzel, 2003; Susanti et al., 2012). For smallholder farmers, these findings highlight the limitations of visual-based selection practices and underscore the importance of adopting data-driven selection criteria to objectively identify high-performing laying individuals that may not be phenotypically distinguishable from the general flock, thereby improving feed efficiency by minimizing the maintenance of unproductive, oversized ducks. Implementing this two-stage strategy allows for a more precise and sustainable breeding program that maximizes egg production while preserving the unique genetic heritage of the Magelang duck population. This strategy facilitates the development of a precise and sustainable breeding approach for local duck populations, especially for Magelang ducks.

CONCLUSIONS

Magelang ducks exhibited moderate morphometric variability and considerable reproductive diversity, indicating their potential for selective genetic improvement. Correlation and PCA analyses revealed 3 independent trait dimensions: morphometric skeletal structure, productivity, and body mass, indicating that morphometrics during the pre-laying phase do not predict productivity traits. However, phenotypic diversity in ducks is explained more by morphometric traits than by productivity traits. The findings underscore the significance of performance-based selection and targeted management through a two-stage recording program and selection to enhance productivity efficiency and support sustainable breeding strategies.

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AI Usage Statement

Declaration of AI Use: ChatGPT, Gemini, and Claude were used for coding assistance, while Grammarly and Paperpal were used for language editing.

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