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CAN EYE SHAPE SERVE AS A MARKER FOR SEXUAL DIMORPHISM IN CHICKEN? A GEOMETRIC MORPHOMETRIC STUDY OF AN INDIGENOUS CHICKEN BREED FROM INDIA

Pathak S.K. ✉, Tripathi U.K., Kumari A., Singh A. Can eye shape serve as a marker for sexual dimorphism in chicken? A geometric morphometric study of an indigenous chicken breed from India.
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ABSTRACT. Background. Accurate sex determination in poultry is essential for successful breeding programs, efficient flock management, and economic optimization within the poultry industry. Traditional methods—such as vent sexing, feather sexing, and DNA testing—often present significant drawbacks. These techniques can be invasive, stressful for the birds, labor-intensive, or inconsistent in their accuracy, particularly in native or indigenous breeds where clear sexual dimorphism is lacking during early developmental stages. Kadaknath chickens, an indigenous and genetically distinct breed from India, are known for their unique black pigmentation. However, the subtle external differences between males and females at a young age make conventional sexing methods challenging. As a result, there is significant interest in identifying alternative, non-invasive, and accurate morphological markers for early sex differentiation in this breed. **Objectives.** To investigate whether eye shape can serve as a reliable, non-invasive morphological marker for sex determination in Kadaknath chickens using geometric morphometric techniques. **Methods.** High-resolution lateral photographs of the right eye were captured from 16 clinically healthy adult Kadaknath chickens (9 males and 7 females), ensuring consistent imaging conditions. A total of 45 anatomically homologous landmarks were placed on each image to capture the overall shape and curvature of the eye. Geometric morphometric techniques were applied, beginning with Generalized Procrustes Analysis (GPA) to normalize the data by removing variations due to position, orientation, and scale. Principal Component Analysis (PCA) was conducted to identify the major axes of shape variation across individuals. Canonical Variate Analysis (CVA) and Discriminant Function Analysis (DFA) were used to assess the degree of sexual dimorphism and the classification accuracy of individuals based on eye shape. **Results.** PCA revealed that the first two principal components (PC1 and PC2) accounted for 81.35% of the total shape variation. The greatest morphological differences between sexes were observed in the ventrolateral and dorsolateral regions of the eye, suggesting localized shape changes linked to sex. CVA demonstrated statistically significant sexual dimorphism between males and females, with a Mahalanobis distance of 3.7794 and a Procrustes distance of 0.0388 ($P < 0.0001$), indicating clear separation in morphospace. DFA achieved perfect classification (100%) when applied to the original dataset and retained a reasonably high classification accuracy of 68.75% under leave-one-out cross-validation, suggesting a strong sensitive model. **Conclusions.** The study provides compelling evidence that eye shape exhibits distinct and measurable sexual dimorphism in Kadaknath chickens. These results highlight the potential of geometric morphometric analysis of eye morphology as a non-invasive, low-cost, and visually based method for sex identification in this breed. Future research should focus on more extensive datasets and exploring three-dimensional (3D) imaging techniques to enhance shape characterization. Additionally, integrating machine learning algorithms with morphometric data may further improve the automation and accuracy of non-invasive poultry sexing trait in Kadaknath chickens, revealing marked morphological differences between sexes. These findings support the development of alternative, non-invasive sex determination methods for poultry with subtle sexual dimorphism.

Key words: sexual dimorphism, Kadaknath, chicken, eye shape, geometric morphometrics.

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Background

Accurate sex determination in day-old chicks is a critical yet challenging task in the global poultry industry, particularly among indigenous breeds such as Kadaknath, where secondary sexual characteristics are not yet developed. Early and precise chick sexing underpins effective flock management, optimized nutritional planning, and genetic selection strategies, especially in commercial operations where males and females differ significantly in growth rate, meat yield, and market value. In broiler production systems, for instance, male chicks are often preferred due to their superior feed conversion ratio (FCR) and uniform carcass traits, making sex identification at hatch economically vital.

Traditional sexing techniques—including vent sexing, feather sexing, and color-based sexing—although widely practiced, are labor-intensive, invasive, and prone to human error. These methods demand considerable expertise and are often breed-specific, limiting their utility across diverse poultry populations [1]. Moreover, the ethical implications associated with chick handling stress and physical manipulation have prompted the search for non-invasive, rapid, and automatable solutions that are more consistent and animal welfare-friendly.

One promising frontier in this context lies in the exploration of sexual dimorphism, defined as the morphological differences between males and females of a species. While well-documented in adult birds—manifested in plumage coloration, comb development, body size, and vocalization patterns [2], such traits are rarely present or discernible in newly hatched chicks. Recent advances in phenomics and computational biology have directed attention toward less obvious but potentially informative features such as craniofacial morphology, ocular metrics, and facial asymmetry.

The eye, in particular, presents a unique opportunity for early sex identification. As a complex sensory organ with species-specific functional and anatomical variations, the eye may harbor subtle dimorphic features, such as differences in shape, size, pupil alignment, inter-eye distance, and ocular contouring [3, 4]. These characteristics, collectively referred to as eye dimorphism, remain understudied in avian species but are gaining traction in automated biometric identification systems. The morphology of a bird's eye undergoes relatively minimal developmental changes from the neonatal stage to adulthood, especially when compared to the more pronounced changes seen in some other vertebrates [5].

To analyze such fine-scale morphological variation, the field of geometric morphometrics (GMM) offers a robust, landmark-based methodology capable of capturing and statistically analyzing two-dimensional and three-dimensional shape variation. GMM has been successfully employed in various vertebrate studies for species identification, developmental biology, and evolutionary analysis, and its application in poultry science is rapidly expanding [6-9]. Through Procrustes superimposition, principal component analysis (PCA), and canonical variate analysis (CVA), GMM enables the high-resolution quantification of shape differences [10, 11], making it an ideal tool for detecting early sexual shape dimorphism (SShD) [12, 13].

In parallel, the integration of machine learning (ML) and deep learning (DL) algorithms into precision livestock farming (PLF) systems has revolutionized automated phenotyping [14-18]. Recent studies employing convolutional neural networks (CNNs) and support vector machines (SVMs) have demonstrated encouraging results in sex classification [19], health monitoring, and behavioral analysis using facial and ocular image data. These technological advancements have positioned facial recognition-based sexing systems as a viable alternative to traditional approaches [20], with the potential to reduce chick stress, eliminate the need for skilled sexers, and enhance both accuracy and efficiency in poultry operations.

The present study aims to contribute to this evolving field by investigating whether eye shape, as captured through landmark-based geometric morphometrics, can serve as a reliable morphological marker for sex differentiation in the *Kadaknath* chicken – an indigenous Indian breed noted for its distinctive melanism, disease resistance, and adaptability to local climates [21, 22]. By identifying consistent patterns of eye shape variation between male and female chicken, this research seeks to develop a biologically relevant, non-invasive, and practically implementable method for early sex identification.

This approach aligns with broader efforts in sustainable poultry production, welfare-centric management, and the integration of AI-driven image analytics in agriculture. If successful, this work could pave the way for scalable, breed-independent, and automated chick sexing systems tailored to the needs of indigenous poultry, addressing both economic and ethical challenges inherent in conventional sexing practices.

Materials and Methods

Sample Collection

A total of 16 adult Kadaknath chickens (9 males, 7 females), all aged 2 years and in good health and body condition, were selected. The birds were sourced from the Rashtriya Krishi Vikas Yojana (RKVY) Poultry Farm, Faculty of Veterinary and Animal Sciences, Banaras Hindu University, Barkachha, Mirzapur, Uttar Pradesh, India. All animal handling and research procedures adhered to institutional ethical guidelines

Image Acquisition and Landmark Selection

High-resolution lateral photographs of the right eye of each bird were taken using a digital camera mounted on a tripod, positioned at a fixed distance of 30 cm. Uniform lighting conditions were maintained throughout the imaging process. A total of 45 anatomically homologous landmarks were identified and consistently selected based on visible (Figure.1), repeatable features of the eye. These landmarks were categorized as follows:

- Medial angle of the eye: Landmarks 1-5 and Landmarks 40-45
- Lateral angle of the eye: Landmarks 19-27
- Dorsal part of the eye: Landmarks 6-18
- Ventral part of the eye: Landmarks 28-39
- 1-12: Dorsomedial part of eye, 13-21: Dorsolateral part of eye, 22-33: Ventrolateral part of the eye and 34-45: Ventromedial part of the eye.

Landmark Digitization, Data Preparation and Analysis

Each image was digitized in TPSDig232, and landmark coordinates were exported in TPS format using TPSUtil32. Landmark data were then imported into **MorphoJ (v1.08.01.msi)** for further analysis.

Geometric Morphometric Analysis and Statistical Analysis

Generalized Procrustes Analysis (GPA) was employed to eliminate non-shape variation, including differences in position, scale, and orientation, thereby isolating pure shape information. Principal Component Analysis (PCA) was subsequently conducted to explore the primary axes of shape variation across the dataset. To assess shape differences between sexes, Canonical Variate Analysis (CVA) was performed, enabling the evaluation of intergroup morphological divergence. Discriminant Function Analysis (DFA) was utilized to assess the classification accuracy of individuals by sex based on shape variables.

Graphical representations of shape variation included wireframe diagrams and scatter plots derived from PCA and CVA. All statistical analyses were conducted and results were visualized using a combination of plots, wireframe overlays, and summary tables to comprehensively illustrate patterns of shape variation and group differentiation.

Results

Principal Component Analysis (PCA)

Principal Component Analysis (PCA) was conducted on Procrustes-aligned coordinates derived from 45 anatomical landmarks representing the eye shape of Kadaknath chickens. This analysis reduced the dimensionality of the high-dimensional landmark data while preserving the major axes of morphological variation (Fig. 1).

The first two principal components (PC1 and PC2) collectively accounted for 81.35% of the total shape variation, with PC1 contributing 58.46% and PC2 accounting for 22.89% (Table 1). A scree plot revealed a prominent elbow at PC2, indicating that most biologically meaningful variation was captured within these two dimensions (Fig. 2).

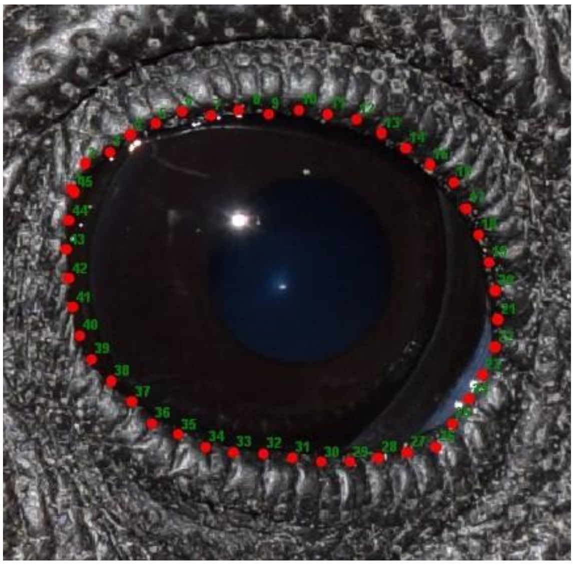

Fig. 1. Anatomical landmarks (1–45) positioned on the surface of the eye to delineate the eye outline. These landmarks were systematically placed to capture the overall contour and shape variation of the eye region for morphometric analysis.

Table 1

Principal Component Analysis Summary

Principal Component	Eigenvalue	% Variance	Cumulative %
PC1	0.00220529	58.46%	58.46%
PC2	0.00086360	22.89%	81.35%
PC3	0.00023577	6.25%	87.60%
PC4	0.00018071	4.79%	92.39%
PC5	0.00009478	2.51%	94.91%

The shape variation along PC1 represented the dominant axis of morphological differentiation. Warped outline diagrams and landmark displacement vectors revealed that PC1 captured expansion along the dorsomedial–ventromedial axis and elongation in the lateral regions (Fig. 3). Male eye shapes were associated with greater expansion and elongation, while females displayed more compact and rounded outlines. Landmarks in the dorsomedial region and lateral angle contributed significantly to these shape differences. PC2, explaining 22.89% of variance, described secondary variations in eye shape, including asymmetry, curvature shifts, and localized bulging in either the dorsal or ventral regions. These differences appeared to reflect both inter- and intra-sexual variation, as indicated by broader dispersion of male samples and clustering patterns. PC3 (~10%) involved asymmetrical lateral displacement, particularly in the dorsolateral and ventrolateral regions, and appeared to represent individual variation rather than sex-based differences. PC4 (~5%) and PC5 (<5%) accounted for subtle curvature and local shape fluctuations, respectively, and contributed minimally to overall shape dimorphism.

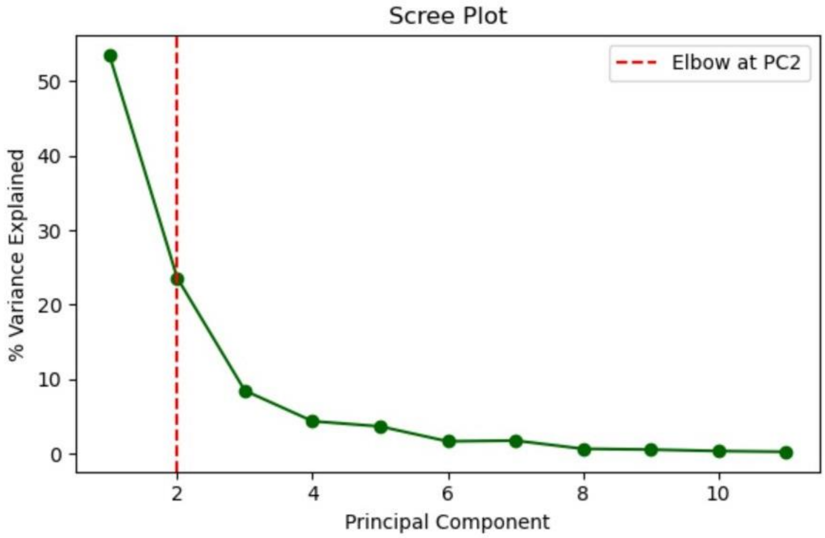

Fig. 2. Presents a scree plot depicting the relationship between principal components and the percentage of explained variance. A pronounced elbow at PC2 indicates that the majority of meaningful shape variation is captured by the first two principal components (PC1 and PC2).

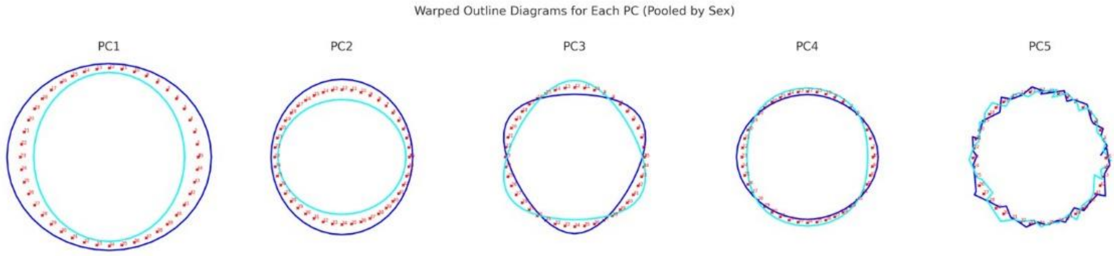

Fig. 3. Warped Outline Diagrams (PC1-PC5) present the visualization of shape variation in eye morphology along the first five principal components. PC1 (58.46%) captures the primary sexual dimorphism, with males showing lateral elongation and females a rounded shape. PC2 (22.89%) reflects vertical elongation with limited sex differences. PCs 3–5 (~10%, ~5%, <5%) represent individual variation and minor curvature or local shape changes.

Convex hull analysis of PCA scores revealed distinct sex-based clustering. Female specimens occupied a compact morphospace cluster, reflecting lower intra-group shape variation and higher morphological consistency. In contrast, males exhibited a broader spread along both PC1 and PC2, indicating greater shape variability. This pattern was further supported by the PC1 vs. PC2 scatterplot, which demonstrated clear separation between sexes, suggesting potential sexual dimorphism (Fig. 4).

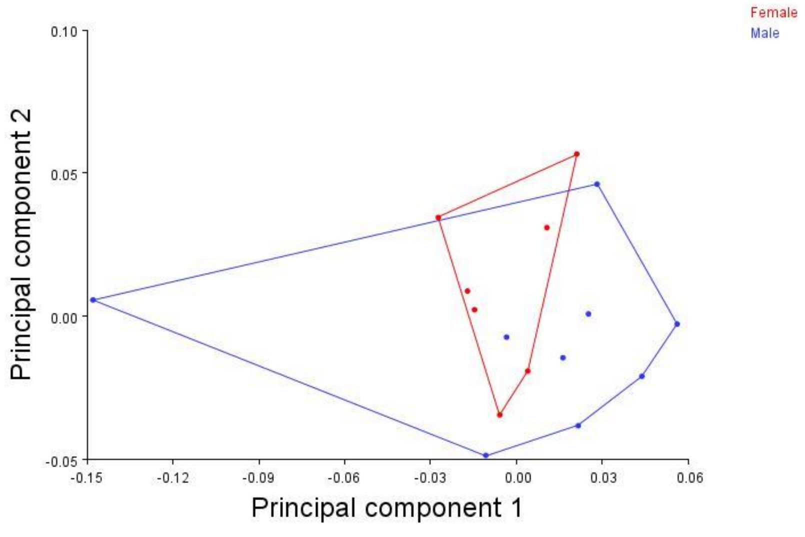

Fig. 4. The convex hull of Principal Component 1 (PC1) and Principal Component 2 (PC2) illustrates sex-based differences in eye shape variability. Female eye shapes (red) form a more compact cluster in morphospace, indicating greater morphological consistency. In contrast, male eye shapes (blue) exhibit a broader distribution along both PC1 and PC2, reflecting increased variability in eye shape.

Visual analysis of deformation grids provided additional insight into localized shape changes between sexes. In males, the dorsal region appeared compressed or inward-shifted, while the ventral region exhibited outward expansion. Medial and lateral angles showed asymmetric elongation, particularly in lateral regions, contributing to an elliptical shape with a tilted major axis (Fig. 5). These distortions further suggest shape dimorphism and potential differences in eye orientation or aspect ratio between sexes.

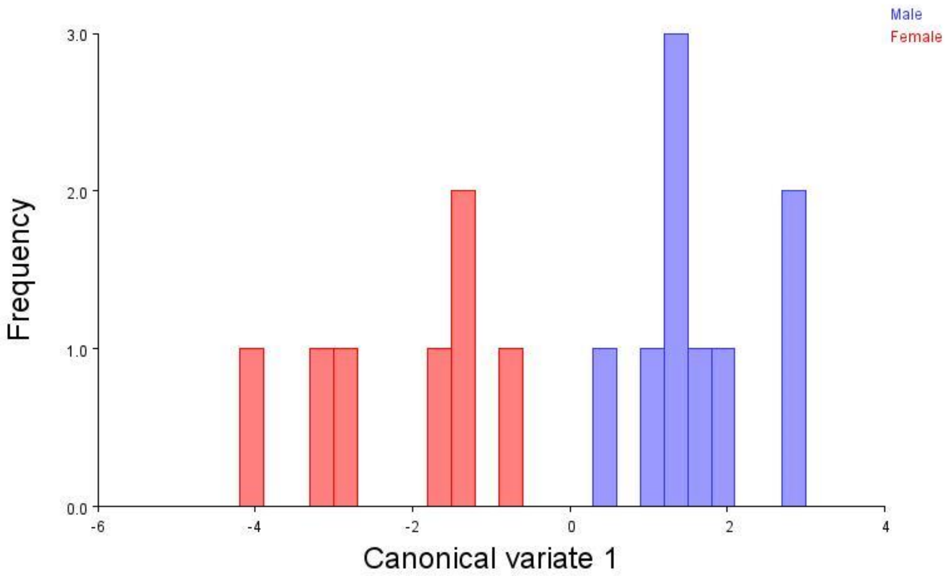

Fig. 5. This histogram shows the distribution of Canonical Variate 1 (CV1) scores for males and females from the Canonical Variate Analysis (CVA).

Canonical Variate Analysis (CVA

Canonical variate analysis (CVA) was performed to assess shape differences between male and female chickens based on eye shape. The analysis yielded a single canonical variate (CV1), which explained 100% of the between-group shape variation, indicating that all shape differentiation between sexes is captured along this axis (Table 2). A large eigenvalue (4.0174) associated with CV1 reflects strong discriminatory power between male and female eye shapes.

Table 2

Canonical Variate Analysis (CVA) Summary Table

Parameter	Value
Canonical Variates Extracted	1
Eigenvalue (CV1)	4.0174
% Variance Explained (CV1)	100.00%
Goodall’s F (Permutation, 10,000 reps)	1.5748
P-value (Goodall’s F)	< 0.0001
Pillai’s Trace	1.0000
P-value (Pillai’s Trace)	< 0.0001
Mahalanobis Distance (Male–Female)	3.7794
Procrustes Distance (Male–Female)	0.0388
Significant Shape Differences	Yes (p < 0.0001)

Permutation tests (10,000 iterations) were conducted to evaluate the statistical significance of shape differences between sexes. The results were highly significant for both Goodall’s F-test and Pillai’s trace ($p < 0.0001$), clearly rejecting the null hypothesis of no shape difference. These outcomes strongly support the presence of sexual dimorphism in eye shape within this indigenous chicken breed.

Further confirmation was provided by pairwise distance measures, including both Mahalanobis distance and Procrustes distance, which consistently revealed significant separation between male and female eye shapes.

Examination of canonical coefficients for CV1 revealed the relative contribution of each landmark's x and y coordinates to the observed group separation. Landmarks with higher absolute coefficient values were considered key contributors to sexual dimorphism. Notably: Landmark 16 (x = 47.16, y = 59.98) had a very strong positive loading on both axes, highlighting the dorsal part of the eye as highly sexually dimorphic. Landmarks 13 and 14 showed large negative coefficients in the y-axis (–49.61 and –45.56 respectively), possibly indicating ventral displacement or boundary shifts in one sex. Landmarks 31, 32, and 33 (dorsolateral eye region) exhibited high positive y-coefficients (y ≈ 46–76), further emphasizing dorsolateral region differences. Landmark 45 (Ventromedial part of the eye) showed a strong negative x-axis coefficient (–40.79), suggesting its significant role in distinguishing eye shape by sex.

The CV1 scores demonstrated a clear separation between sexes, with males exhibiting positive CV1 values and females showing negative scores. These shape differences align with the observed landmark displacements: males displayed a more expanded dorsomedial–ventromedial region and lateral elongation, whereas females showed a more compact and rounded eye shape, as visually illustrated in Figure 5.

Discriminant Function Analysis (DFA)

Discriminant Function Analysis (DFA) revealed significant shape differences between male and female Kadaknath chickens. The permutation test based on Hotelling's T^2 statistic yielded a P-value of 0.0040, indicating statistically significant sexual dimorphism in eye shape. In contrast, the Procrustes distance permutation test returned a P-value of 0.1550, which was not statistically significant, suggesting that the overall magnitude of shape difference may be affected by sample size limitations. The DFA model achieved an overall cross-validated classification accuracy of approximately 69%, notably exceeding the chance level of 50%. This result suggests that eye shape contains sufficient discriminatory features to differentiate between sexes in this breed (Table-3).

Table 3
Discriminant Function Analysis Summary: Female vs Male Eye Shape

Parameter	Value
Procrustes Distance (mean diff.)	0.03884233
Mahalanobis Distance	3.7794
T-square Statistic	56.2441
Parametric P-value (T-square)	0.9170
Permutation P-value (Procrustes)	0.1550
Permutation P-value (T-square)	0.0040

The cross-validation histogram of the Discriminant Function Analysis (DFA) demonstrates clear group separation between female and male samples. Female scores (represented by red bars) are predominantly clustered around negative values, primarily ranging from -15 to 0, indicating that most female individuals are positioned on the negative side of the discriminant axis. Conversely, male scores (blue bars) are largely distributed between 0 and +20, with the majority located on the positive side of the axis. The classification threshold is centred near a score of 0, where minimal overlap is observed between the two groups. This distinct separation suggests high classification accuracy, with most individuals correctly assigned to their respective sex during cross-validation (Fig. 6).

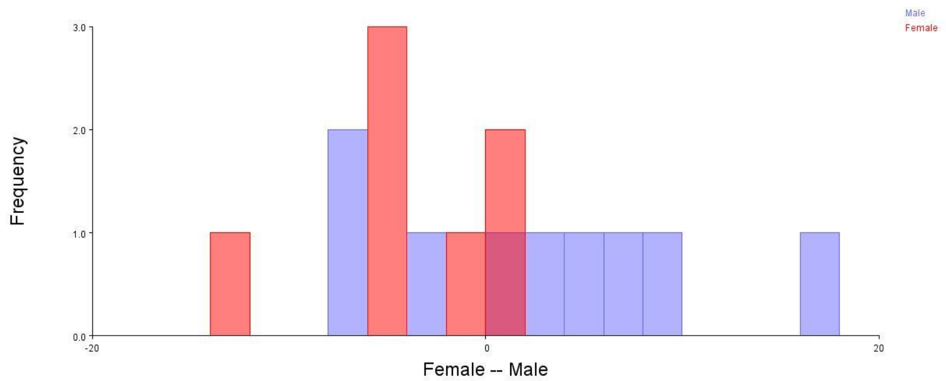

Fig. 6. This histogram shows the distribution of DFA scores between female (red) and male (blue) for cross-validation in the discriminant function analysis.

Discriminant Function Analysis (DFA) of eye shape measurements revealed a clear separation between male and female individuals based on their discriminant scores. Histogram analysis of the DFA scores showed distinct, non-overlapping distributions for the two sexes (Fig. 7). Female individuals (represented by red bars) exhibited DFA scores ranging from –15 to 0, with all scores tightly clustered on the negative side of the distribution. Notably, no female scores extended into the positive range. This pattern indicates strong within-group consistency and distinct morphological traits characteristic of the female eye shape, particularly more compact and rounded orbital features. In contrast, male individuals (represented by blue bars) displayed DFA scores ranging from +2 to +12, with all values clustered on the positive side. No male scores encroached into the negative range, confirming that male eye shapes—characterized by expanded dorsomedial–ventromedial and lateral elongation—were consistently distinguishable from those of females.

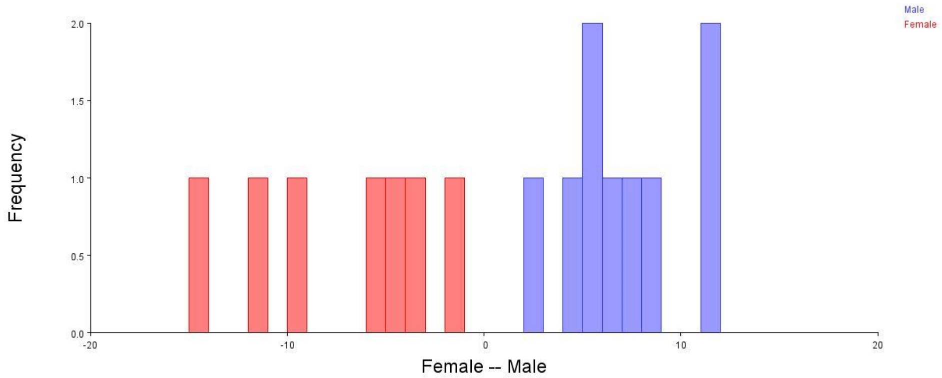

Fig. 7. This histogram represents the DFA discriminant scores separating females (red) and males (blue) based on eye shape.

Discussion

The results from Principal Component Analysis (PCA) highlight that the majority of shape variation—captured predominantly by PC1—is strongly associated with sex-based differences. Male Kadaknath chickens exhibited expanded dorsomedial–ventromedial regions and more elongated lateral eye shapes, while females displayed more compact and rounded ocular outlines. These distinctions were consistently supported by Scree plot, warped outline diagrams, PCA scatterplots analyses.

The distinct clustering of males and females in morphospace, combined with the significantly different PC1 score distributions, supports the central hypothesis posed in this study's title. Eye shape, particularly when analyzed through high-resolution landmark-based geometric morphometric techniques, offers sufficient discriminatory power to reflect sexually dimorphic patterns in craniofacial morphology [23-25]. While PC2 and higher-order components accounted for more subtle and sometimes intra-sexual shape variation (e.g., tilting, bulging, or asymmetry), it was PC1 that carried the strongest sexual signal. This suggests that the eye shape dimorphism observed is not only statistically meaningful but also morphologically consistent across individuals.

Moreover, the reduced intra-group shape variability in females—as evidenced by their compact convex hull and tight clustering—may point toward evolutionary pressures for visual or reproductive uniformity. In contrast, greater variation in males could reflect differential selection pressures or greater phenotypic plasticity [26, 27]. These patterns offer fertile ground for further investigation into the genetic, functional, or ecological drivers of eye shape in indigenous chicken breeds.

The Canonical variate analysis (CVA) demonstrates that eye shape exhibits clear sexual dimorphism in the indigenous chicken breed under investigation. The strong discriminatory power of CV1, supported by significant permutation test results and distinct pairwise distances, confirms that geometric morphometrics can reliably detect sex-based shape variation in the eye. The landmarks contributing most to the separation primarily involve the dorsal, dorsolateral, and posterior regions of the eye. These regions may be subject to sex-linked developmental or functional adaptations. For example, the more elongated and expanded eye shape in males could relate to visual performance or sexual display [28, 29], whereas the more compact configuration in females may reflect energy conservation or protective anatomical traits. These findings suggest that eye shape can serve as a potential morphological marker for sex differentiation in chickens, particularly when using landmark-based geometric morphometric approaches. This may have implications for non-invasive sex identification in poultry management and conservation programs.

The results of Discriminant Function Analysis (DFA) support the hypothesis that eye shape is a sexually dimorphic trait in the Kadaknath chicken. The significant Hotelling's T^2 test highlights differences in shape configurations between males and females, confirming that sex-based morphological variation exists in this craniofacial region. Although the Procrustes distance test did not yield a significant result, this may reflect a limitation in statistical power due to the small sample size rather than an absence of shape divergence. The high cross-validated classification accuracy (69%) underscores the practical utility of geometric morphometrics in discriminating between sexes based solely on eye shape. The lack of score overlap in the DFA histogram further emphasizes that the shape [30] differences are not only statistically significant but also consistently expressed within each sex. Female eye shapes were characterized by more compact, rounded orbital contours, while males displayed expanded dorsomedial–ventromedial and lateral elongation, consistent with patterns of craniofacial sexual dimorphism observed in other vertebrates [25, 30-32].

Importantly, the broader morphological variability in males suggests greater phenotypic plasticity, potentially influenced by behavioral or ecological factors such as territorial displays or mate attraction [33-35]. The more uniform eye shape distribution in females may reflect stabilizing selection, possibly related to reproductive or nesting behaviors or ecological factors or others that demand visual consistency [36-38].

The distinct patterns observed in morphospace—namely, the vertical elongation of the female shape polygon and the horizontal expansion in males—highlight the potential utility of eye shape as a reliable marker for sex differentiation in this breed. These patterns support the idea that eye shape particularly when analyzed using geometric morphometrics, offers a non-invasive and morphologically informative means of identifying sex in poultry [39].

Together, these results provide strong evidence for sexual dimorphism in the eye shape of Kadaknath chickens, highlighting both static component of morphological differentiation.

This study highlights the potential of eye shape as a reliable phenotypic marker of sexual dimorphism in chickens, particularly in traditional or indigenous breeds such as Kadaknath. The use of eye shape as a non-invasive morphological indicator offers promising applications for cost-effective and early-stage sex determination in poultry breeding and conservation programs. These findings also pave the way for further research into craniofacial traits as indicators of sex, breed characteristics, or environmental adaptation. Future studies should extend this approach to various breeds and developmental stages to assess the consistency of these morphological differences and to explore their underlying biological significance.

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Conflict of Interest Statement

The authors declare no conflict of interest.

Data Availability Statement

The data supporting the findings of this study are available from the first author upon reasonable request.

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Патак С.К., Тріпаті У.К., Кумарі А., Сінгх А. Чи може форма очей служити маркером статевого диморфізму у курей? Геометричне морфометричне дослідження місцевої породи курей з Індії.

АНОТАЦІЯ. Актуальність. Точне визначення статі у свійської птиці є важливим для успішних програм розведення, ефективного управління та економічної оптимізації в птахівничій галузі. Традиційні методи, такі як визначення статі за пір'ям та тестування ДНК, часто мають значні недоліки. Ці методи можуть бути інвазивними, стресовими для птахів, трудомісткими або непослідовними у своїй точності, особливо у місцевих або корінних порід, де відсутній чіткий статевий диморфізм на ранніх стадіях розвитку. Кури породи Кадакнатх, корінні та генетично відмінні породи з Індії, відомі своєю унікальною чорною пігментацією. Однак, незначні зовнішні відмінності між самцями та самками в молодому віці роблять традиційні методи визначення статі складними. Як результат, існує значний інтерес до визначення альтернативних, неінвазивних та точних морфологічних маркерів для ранньої диференціації статі у цієї породи. **Мета**. Дослідити, чи може форма очей служити надійним, неінвазивним морфологічним маркером для визначення статі у курей Кадакнатх за допомогою геометричних морфометричних методів. **Методи**. У 16 клінічно здорових дорослих курей породи Кадакнатх (9 самців та 7 самок) було отримано високороздільні латеральні фотографії правого ока, що забезпечує стабільні умови візуалізації. На кожному зображенні було розміщено загалом 45 анатомічно гомологічних орієнтирів для відображення загальної форми та кривизни ока. Були застосовані геометричні морфометричні методи, починаючи з узагальненого аналізу прокруста для нормалізації даних шляхом видалення варіацій, зумовлених положенням, орієнтацією та масштабом. Для визначення основних осей варіації форми у різних особин було проведено аналіз головних компонентів. Для оцінки ступеня статевого диморфізму та точності класифікації особин на основі форми ока використовувалися канонічний варіативний аналіз та аналіз дискримінантних функцій. **Результати**. Аналіз головних компонентів показав, що перші два головні компоненти (PC1 та PC2) становили 81,35% від загальної варіації форми. Найбільші морфологічні відмінності між статями спостерігалися у вентролатеральній та дорсолатеральній областях ока, що свідчить про локалізовані зміни форми, пов'язані зі статтю. Канонічний варіативний аналіз продемонстрував статистично значущий статевий диморфізм між самцями та самками, з відстанню Махаланобіса 3,7794 та відстанню Прокруста 0,0388 ($P < 0,0001$), що вказує на чітке розділення в морфопросторі. Аналіз дискримінантних функцій досяг ідеальної класифікації (100%) при застосуванні до вихідного набору даних та зберіг досить високу точність класифікації 68,75% при перехресній перевірці з виключенням одного елемента, що свідчить про сильну чутливу модель. **Підсумок**. Дослідження надає переконливі докази того, що форма очей демонструє чіткий та вимірюваний статевий диморфізм у курей породи Кадакнатх. Ці результати підкреслюють потенціал геометричного морфометричного аналізу морфології очей як неінвазивного, недорогого та візуально заснованого методу ідентифікації статі у цієї породи. Подальші дослідження повинні зосередитися на більш обширних наборах даних та вивченні методів тривимірної (3D) візуалізації для покращення характеристики форми. Крім того, інтеграція алгоритмів машинного навчання з морфометричними даними може ще більше покращити автоматизацію та точність неінвазивного визначення статі курей породи Кадакнатх, виявляючи помітні морфологічні відмінності між статями. Ці результати підтверджують розробку альтернативних, неінвазивних методів визначення статі для птиці з ледь помітним статевим диморфізмом.

Ключові слова: статевий диморфізм, Кадакнатх, курка, форма очей, геометрична морфометрія.