

# Canonical discriminant analysis for selected morphometric traits of native chicken in Libya

Hasan M.A. Ahmad<sup>1,2</sup>, Sutopo Sutopo<sup>1</sup>, Edy Kurnianto<sup>1</sup>, Asep Setiaji<sup>1\*</sup>

<sup>1</sup>Department of Animal Science, Faculty of Animal and Agricultural Science, Universitas Diponegoro, Jl. Prof Sudarto SH, Tembalang, Semarang 50275, Central Java, Indonesia.

<sup>2</sup>Department of Animal Science, Faculty of Animal and Agricultural Sciences, Sirte University, PO Box 674, Sirte, Libya.

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\*Correspondence:

Corresponding author: Asep Setiaji  
E-mail address: aseps Setiaji93@gmail.com

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## ABSTRACT

This study evaluated morphometric traits of native chickens from three Libyan regions Abongim, Abu Hadi, and Sirte using Canonical Discriminant Analysis (CDA) to determine key traits for population differentiation. Six traits were measured in males and females: upper thigh length (UTL), lower thigh length (LTL), foot length (FL), third finger length (TFL), comb height (CH), and chest length (CL). Descriptive statistics indicated clear sexual dimorphism, with males generally larger and exhibiting greater variability in sexually dimorphic traits, while females showed greater uniformity, especially in skeletal dimensions. CDA revealed that Canonical Variate 3 (CAN 3) contributed most to discrimination, with FL, LTL, CH, and TFL being the most influential traits. Males exhibited higher classification accuracy (up to 75.48% in Abu Hadi) than females (maximum 58.21% in Sirte), suggesting greater morphometric divergence in males. Overall, the results indicate a largely homogeneous genetic background among Libyan native chickens with minor regional differences, particularly in limb and comb traits. This baseline morphometric information is valuable for supporting genetic conservation, selective breeding, and sustainable utilization strategies, although integration with molecular data is recommended to enhance population differentiation.

## Introduction

In Libya, poultry are crucial for supplying animal protein, with native chickens being particularly favored due to their resilience, ability to thrive in tough conditions, lower feed needs, minimal land usage, and greater disease resistance compared to commercial broilers (Dal Bosco *et al.*, 2021). The country is home to various native chicken breeds, each possessing unique traits influenced by their natural environments. Despite their significance, these chickens are predominantly reared on a small scale, which restricts their productivity in less-than-ideal conditions. Their growth is relatively slow, taking around six months to reach a weight of one kilogram, while broilers achieve this in just two months (Campbell *et al.*, 2021). Although native chickens make up about 25–30% of the national poultry population exceeding 2.5 million birds their production potential and economic significance are often undervalued (El-Safty, 2012; Al-Jumaili *et al.*, 2020).

To boost productivity while adapting to local conditions, crossbreeding initiatives between commercial layers and native hens have been established. These initiatives heavily depend on morphometric measurements quantitative metrics like body weight, shank length, chest girth, and beak length which are crucial for assessing growth performance and pinpointing desirable traits (Çakar *et al.*, 2023; Davis and Simmen, 2023). Morphometric data are extensively utilized to describe phenotypic variations in poultry populations and form the foundation for selection in genetic enhancement programs (Abdel-Kafy *et al.*, 2021; Franzoni *et al.*, 2021). Native chickens play a vital role not only in farm livelihoods and biodiversity conservation but also in sustainable poultry production. Nonetheless, successful breeding strategies necessitate the precise identification and measurement of economically significant traits through morphometric characterization (Chaikuad *et al.*, 2022; Herrera-Alcaíno *et al.*, 2023).

While morphometric research on commercial broilers is fairly preva-

lent, there is a scarcity of data on the phenotypic and genetic diversity of native chickens in Libya. This lack of information poses a challenge to the development of specific selection and breeding programs. Considering the ecological and economic importance of these birds, a comprehensive morphometric analysis is crucial. Canonical Discriminant Analysis (CDA) offers a robust multivariate statistical method for differentiating and categorizing populations based on morphometric characteristics, allowing for the identification of significant variables that contribute to population differentiation. Consequently, this study utilized CDA to assess the morphometric traits of native Libyan chickens, aiming to facilitate future genetic enhancement, conservation, and breeding initiatives (Amato and Castellini, 2021; Poccai and Santiago-Blay, 2022; Wang *et al.*, 2024). The study sought to establish foundational data to aid in the genetic preservation, selective breeding, and sustainable use of native chickens in Libya. The results are anticipated to highlight the importance of local poultry biodiversity and guide national and regional strategies for managing animal genetic resources.

## Materials and methods

This study adopts a quantitative approach to investigate the genetic characteristics of Libyan indigenous chickens through the analysis of morphometric traits. The research was conducted from December 2024 to February 2025 across three regions in Libya were: Abongim, Abu Hadi and Sirte. The number of chickens sampled were 71, 71, and 64, respectively. The recorded morphometric traits include upper thigh length (UTL), lower thigh length (LTL), foot length (FL), third finger length (TFL), cockscomb height (CH), and chest length (CL).

Descriptive statistics were employed to summarize the data by sex. For the morphometric data, a General Linear Model (GLM) was applied to assess differences among the three regions. To further distinguish between the chicken populations, discriminant analysis was conducted. This

analysis aimed to identify key variables that most effectively differentiate the three region. The methodological framework included an analysis of the canonical structure, cross-validation to evaluate the accuracy of group classification, and visual mapping of population distribution based on discriminant scores. The canonical discriminant function analysis played a central role by highlighting the primary sources of variation among the regions, thereby clarifying the morphometric traits that contributed most significantly to group separation. The model used in the Canonical Discriminant analysis was as follows:

$$C = \mu + \mu_1 Y_1 + \mu_2 Y_2 + \mu_3 Y_3$$

Where:  $\mu_1$ ,  $\mu_2$  and  $\mu_3$  are the estimate of canonical coefficients and  $Y_1$ ,  $Y_2$  and  $Y_3$  indicated regions of chicken populations (Abongim, Abu Hadi and Sirte, respectively). The discriminant analysis was performed using the Statistical Analysis System (SAS) On Demand for Academics (SAS, 2021).

## Results and Discussion

### Morphometric patterns and sexual dimorphism

Morphometric measurements from Abongim, Abu Hadi, and Sirte revealed significant uniformity in body size, indicating a largely common genetic foundation among these groups. In males, the upper thigh length was slightly longer in Abu Hadi ( $10.77 \pm 2.10$  cm) compared to Abongim ( $10.73 \pm 1.97$  cm) and Sirte ( $10.55 \pm 2.08$  cm), while the lower thigh length remained consistent across all locations ( $12.11$ – $12.13$  cm). The lengths of the foot and third toe were also notably stable across regions, whereas comb height was greatest in Abu Hadi ( $3.69 \pm 1.03$  cm), possibly due to local selection for ornamental features. Females showed even more uniformity. The upper thigh length was longest in Abu Hadi ( $9.24 \pm 1.47$  cm), closely followed by Sirte ( $9.21 \pm 1.49$  cm) and Abongim ( $9.13 \pm 1.53$  cm). Measurements of the lower limb and comb height (highest in Sirte at  $0.98 \pm 0.56$  cm) also demonstrated consistency, potentially influenced by environmental or hormonal factors.

Descriptive statistics highlighted clear sexual dimorphism: males were larger and exhibited more variability in traits like comb height (CV = 0.95%) and upper thigh length (CV = 4.17%), consistent with other avian studies showing males with more pronounced and variable ornamental traits due to genetic–hormonal influences (Chen *et al.*, 2024). Conversely, traits such as foot length (CV = 0.11% in females) and chest length were highly stable, suggesting structural and reproductive selection pressures favoring consistency (Maynard *et al.*, 2023). These results illustrate the biological pattern where males often show greater morphological variability, while females maintain stable traits essential for survival and reproductive success a trend observed in broader avian morphometric research (Rotimi, 2024).

Table 1. Descriptive Statistic for morphometric traits of Libyan chicken used in the study.

| Traits | Male             |      | Female           |      |
|--------|------------------|------|------------------|------|
|        | Mean $\pm$ SD    | CV   | Mean $\pm$ SD    | CV   |
| UTL    | 10.68 $\pm$ 2.04 | 4.17 | 9.19 $\pm$ 1.49  | 2.22 |
| LTL    | 12.12 $\pm$ 1.39 | 1.94 | 10.31 $\pm$ 0.89 | 0.81 |
| FL     | 9.46 $\pm$ 0.92  | 0.85 | 6.75 $\pm$ 0.34  | 0.11 |
| TFL    | 7.70 $\pm$ 0.56  | 0.31 | 5.86 $\pm$ 0.71  | 0.51 |
| CH     | 3.56 $\pm$ 0.97  | 0.95 | 0.92 $\pm$ 0.50  | 0.25 |
| CL     | 11.55 $\pm$ 1.77 | 3.15 | 8.37 $\pm$ 0.32  | 0.1  |

UTL: upper thigh length; LTL: lower thigh length; FL: foot length; TFL: third finger length; CH: cockscomb height, and CL: chest length.

### Multivariate analysis via canonical discriminant analysis (CDA)

CDA indicated that Canonical Variate 3 (CAN 3) possessed the greatest ability to differentiate between both genders. For females, the most significant traits were foot length, lower thigh length, comb height, and

third toe length. In contrast, for males, the dominant traits were third toe length, foot length, comb height, and upper thigh length. CAN 1 and CAN 2 had a minimal impact, suggesting that only a specific set of morphometric traits is responsible for population differentiation. Although canonical plots showed weak clustering in females, males exhibited moderate regional differentiation. Cross-validation results supported this observation: classification accuracy for males was as high as 75.48% (Abu Hadi), compared to a maximum of 58.21% for females (Sirte), indicating that morphometric divergence is more evident in males, likely due to sexually selected traits. Similar methodologies in other research corroborate these findings. For example, CDA applied to broiler performance identified live weight and carcass weight as primary discriminators across treatments (Rosário *et al.*, 2008). In Nigerian indigenous chickens, principal component and discriminant analyses found that traits such as thigh length, shank length, and breast girth were highly informative for distinguishing genotypes, with classification accuracy also being robust (>85%). Furthermore, Daikwo *et al.* (2015) achieved 100% correct classification between normal-feathered and frizzle-feathered chickens using discriminant analysis, highlighting the effectiveness of morphometric traits as powerful genotype discriminators when divergence is significant.

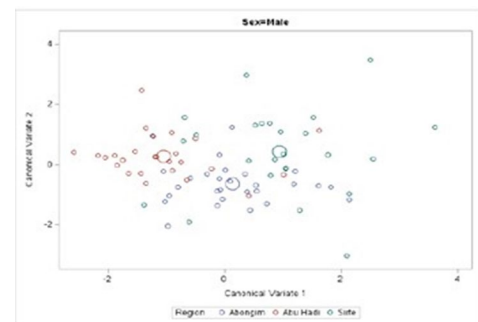


Fig. 1. The canonical representation of the male chickens in three regions.

Table 2. Morphometric traits of Libyan chicken in three regions.

| Sex    | Traits | Abongim          | Abu Hadi         | Sirte            |
|--------|--------|------------------|------------------|------------------|
| Male   | UTL    | 10.73 $\pm$ 1.97 | 10.77 $\pm$ 2.10 | 10.55 $\pm$ 2.08 |
|        | LTL    | 12.12 $\pm$ 1.4  | 12.13 $\pm$ 1.39 | 12.11 $\pm$ 1.44 |
|        | FL     | 9.46 $\pm$ 0.95  | 9.39 $\pm$ 0.92  | 9.54 $\pm$ 0.92  |
|        | TFL    | 7.73 $\pm$ 0.53  | 7.74 $\pm$ 0.59  | 7.62 $\pm$ 0.56  |
|        | CH     | 3.51 $\pm$ 0.90  | 3.69 $\pm$ 1.03  | 3.49 $\pm$ 0.99  |
|        | CL     | 11.56 $\pm$ 1.80 | 11.58 $\pm$ 1.78 | 11.52 $\pm$ 1.81 |
| Female | UTL    | 9.13 $\pm$ 1.53  | 9.24 $\pm$ 1.47  | 9.21 $\pm$ 1.49  |
|        | LTL    | 10.33 $\pm$ 0.97 | 10.35 $\pm$ 0.85 | 10.24 $\pm$ 0.87 |
|        | FL     | 6.76 $\pm$ 0.37  | 6.77 $\pm$ 0.33  | 6.72 $\pm$ 0.31  |
|        | TFL    | 5.88 $\pm$ 0.72  | 5.88 $\pm$ 0.64  | 5.83 $\pm$ 0.79  |
|        | CH     | 0.88 $\pm$ 0.49  | 0.90 $\pm$ 0.47  | 0.98 $\pm$ 0.56  |
|        | CL     | 8.36 $\pm$ 0.30  | 8.36 $\pm$ 0.31  | 8.38 $\pm$ 0.36  |

UTL: upper thigh length; LTL: lower thigh length; FL: foot length; TFL: third finger length; CH: cockscomb height, and CL: chest length.

Table 3 . Total Canonical Structure of Libyan chickens based on Morphometric.

| Traits | Female |       |       | Male  |       |       |
|--------|--------|-------|-------|-------|-------|-------|
|        | CAN 1  | CAN 2 | CAN 3 | CAN 1 | CAN 2 | CAN 3 |
| UTL    | -0.03  | -0.24 | 0.68  | -0.07 | -0.05 | 0.22  |
| LTL    | 0.11   | -0.13 | 0.70  | -0.01 | -0.00 | 0.18  |
| FL     | 0.14   | -0.18 | 0.83  | 0.11  | 0.02  | 0.29  |
| TFL    | 0.08   | -0.02 | 0.64  | -0.12 | -0.12 | 0.45  |
| CH     | -0.20  | -0.06 | 0.69  | -0.14 | 0.08  | 0.23  |
| CL     | -0.08  | -0.02 | 0.45  | -0.02 | -0.01 | 0.21  |

Implications for conservation and breeding

The uniformity in skeletal measurements among Libyan chickens from different areas indicates either a shared genetic background or similar environmental adaptations (Jia *et al.*, 2023). In contrast, traits such as comb height, which showed more variation, might be influenced by sexual selection or local breeding practices and could be useful indicators in conservation and selection efforts (England *et al.*, 2022). Notably, the limitations of morphometric data, especially in differentiating female populations, underscore the necessity for additional molecular tools. Incorporating genomic markers like SNP panels or mitochondrial DNA analysis would improve classification precision and better inform conservation and breeding strategies (Dong *et al.*, 2024; Phuynoi *et al.*, 2024).

Table 4. Cross-Validation of Classification Based on Morphometric The Percentage of Individual Chicken Classified Into Their Respective Region (Number of Animal chickens Is Indicated By Values In Parentheses).

| Male     |          |          |          |
|----------|----------|----------|----------|
|          | Abongim  | Abu Hadi | Sirte    |
| Abongim  | 0.58(20) | 0.59(3)  | 0.55(5)  |
| Abu Hadi | 0.52(3)  | 0.75(21) | 0.69(2)  |
| Sirte    | 0.67(4)  | 0.59(4)  | 0.73(17) |
| Total    | 0.59(27) | 0.71(28) | 0.69(24) |
| Female   |          |          |          |
|          | Abongim  | Abu Hadi | Sirte    |
| Abongim  | 0.46(21) | 0.44(11) | 0.54(11) |
| Abu Hadi | 0.46(18) | 0.41(13) | 0.49(8)  |
| Sirte    | 0.46(10) | 0.54(5)  | 0.58(24) |
| Total    | 0.46(49) | 0.45(29) | 0.56(43) |

Conclusion

Native Libyan chickens from the regions of Abongim, Abu Hadi, and Sirte exhibit a high degree of morphometric consistency, suggesting a common genetic foundation, with slight variations primarily in limb and comb characteristics. Males are generally larger and display more variability than females, highlighting sexual dimorphism, while females exhibit more skeletal stability. Canonical Discriminant Analysis pinpointed foot length, lower thigh length, comb height, and third finger length as the most significant traits for distinguishing populations, with males showing higher classification accuracy. These foundational data are crucial for conservation and breeding initiatives, although incorporating molecular tools is advised to enhance population differentiation and support the sustainable management of genetic resources.

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Conflict of interest

The authors have no conflict of interest to declare.

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