

Phenotypic characteristics of native chickens in Libya based on morphometric and plumage traits

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Abstract. Ahmad HMA, Yousaf MR, Ahmed B, Kurnianto E, Lestari DA, Mustofa F, Sutopo S, Setiaji A, 2025. Phenotypic characteristics of native chickens in Libya based on morphometric and plumage traits. *Biodiversitas* 26: 3659-3673. Native Libyan chickens are a widely distributed poultry variety, while undisturbed types often lack distinctive characteristics. This study aimed to analyze phenotypic variations among Indigenous chickens across different regions of Libya using a qualitative approach. This study used a purposive sampling technique. A total of 200 chickens were sampled from Sirte, Abu Hadi, and Abongim. Data analysis using descriptive statistics, boxplot, Shannon Index, Coefficient of Variation (CV), Principal Component Analysis (PCA), ANOVA test and correlation test. The findings revealed that there were differences in the variation of phenotypic characteristics, indicating that genetic factors play a major role in shaping these traits. The most common feather color was black (36.5%). Black with a white side was the most common shank color (45.5%). The most common comb type was the pea comb (54%). Black (45%) and brown-yellow (46.5%) beak colors were most prevalent. Highly significant differences between regions occurred in leg color ($p = 0.008$) and beak color ($p = 0.018$), whereas highly significant differences between sexes were for all the traits ($p < 0.05$). Good correlations were also found between beak color and comb shape ($r = 0.777$), and leg color and feather color ($r = 0.776$). PCA analysis showed that the maximum variation in phenotypes was explained by feather color (79.16%). Environmental influences and local breeding practices contributed to the distribution. Preservation of native phenotypes has substantial conservation value because it provides resilient traits essential for local and regional agriculture and contributes to genetic diversity. Therefore, to enhance the sustainability, selective breeding programs should prioritize the maintenance and enhancement of the most common and adaptive traits.

Keywords: Comb shape, feather colors, Libya chicken, phenotypic characteristic, shank colors

INTRODUCTION

Native chicken, notable for its absence of specific characteristics, represents a common form of poultry in Libya. The phenotype and genetic composition of local chickens in Libya vary greatly (Zhang et al. 2022). Libyan people raise native chickens as livestock to provide them with meat and eggs for daily sustenance. Libyans still raise indigenous chickens using traditional techniques such as free-range scavenging, natural incubation of hens, little use of commercial feed, and reliance on locally accessible resources for care and shelter (Tardy et al. 2020). Even among chickens with unique characteristics, the population of native chickens is predicted to continue to decline and face extinction. The main causes of this decline are the inability to selectively breed native chickens for superior offspring and their innately low production rates (Meuser et al. 2021; Fulla 2022).

The decline of native chickens poses a significant threat to food security in these communities (Gržinić et al. 2023; Tenza et al. 2024), making their preservation a matter of utmost importance. Compared to commercial chickens, native chickens thrive in free-range housing systems where they graze and require less outside assistance, which requires close supervision and regulated conditions (Kpomasse et al.

2023). In addition, indigenous chickens are highly resilient to adverse weather conditions and common poultry diseases, reducing the need for expensive veterinary care (Hafez and Attia 2020; Nawaz et al. 2024).

Native chickens are a genetic storehouse of adaptable traits that are frequently lacking in commercial lines that undergo extensive breeding (Ariza et al. 2022). Therefore, it is essential to preserve the genetic resources of native chickens for future breeding. Recognizing their value and incorporating them into sustainable livestock development strategies begins with comprehending and recording their phenotypic traits (Loengbudnark et al. 2024). However, there is still a lack of published data on the phenotypic characteristics and performance of Indigenous Libyan chickens (Begna et al. 2025). Chebo et al. (2024) indicated that they are beneficial for livestock selection and crossbreeding (Nawaz et al. 2023). Phenotypic characterization studies are required to record variations in body shape, growth rate, egg production, and overall adaptability (Li et al. 2024).

Environmental factors influence phenotypic variance are described by variations in the quantitative features (Lamido et al. 2023; Tyasi et al. 2024). Indigenous chicken is a long-standing descendant of poultry in the nation. Domestication of green jungle chickens (*Gallus varius*) and

red jungle chickens (*Gallus gallus*) indicates the presence of native chickens (Eda 2021). In addition, Dahloum et al. (2016), native chicken is a type of chicken that has adapted to the Libyan environment. However, several superior native chicken breeds are currently recognized as a result of the development, purification, and breeding programs for various superior local chickens (Attia et al. 2024; Siddiqui et al. 2024). Native chickens in Libya often have a thin body form, long, black, white, or yellow legs, and a variety of feather colors (black, white, brown, yellow, and combinations) (Yaemkong et al. 2024).

Various types of chickens with different physical characteristics and variants are created as a result of the cultivation process, natural or random crossbreeding between breeds, and various environmental factors (Anyona et al. 2023). In addition to these benefits, native chickens have several drawbacks, such as the inability to obtain quality genetics and lower egg production when compared to broiler chickens (Yuliyanda and Arisandi 2024). According to Bozrayda and Hubara (2020), the use of commercial poultry breeds in Libya could lead to significant financial losses because genotypes chosen in temperate climates might react differently to different management and climate conditions. According to Gedara et al. (2020), little is known about the state of ND in backyard hens. The prevalence of ND Virus (NDV) infection in backyard chickens in various Tripoli locations during the summer and winter was 45%. Therefore, this study aimed to characterize the phenotypic characteristics of chickens native to Libya. This study is important because it will help preserve and sustainably use native chicken breeds in Libya. The originality of the research lies in its being a regionally applicable but moderately sized phenotypic characterization of Libyan native chicken and offers vital baseline data for breeding and conservation to ensure genetic diversity and enhance local poultry productivity.

MATERIALS AND METHODS

Study design and sampling

This study employed a descriptive cross-sectional design to assess the phenotypic characteristics of native chickens in Libya. A total of 200 chickens were sampled using purposive and random sampling techniques from three distinct regions: Sirte, Abu Hadi, and Abongim. These locations were selected to represent a range of ecological and socio-agricultural conditions that might influence phenotypic diversity. The Mediterranean coast town of Sirte has a semi-arid climate with moderate humidity; the peri-urban area of Abu Hadi exhibits mixed production systems that combine semi-intensive and traditional methods; and the more arid inland region of Abongim is home to extensive scavenging systems and dryland agroecosystems. In order to capture a wide range of environmental and cultural factors that might influence the expression of phenotypic traits in native chickens, these geographic and socioeconomic variations were purposefully chosen. To guarantee a wide representation of the local chicken population, chicken samples were randomly chosen from

smallholder farms and poultry shops in each area, as shown in Figure 1 and the Research Flowchart shown in Figure 2.

Data collection

Direct observation and documentation of phenotypic traits, including feather colors, shank colors, comb shapes, and beak colors, were used to collect data. To ensure the reliability of our evaluation, each trait was captured through photography and evaluated visually using a standard scale. Feather color categories such as white, black, brown, red, gray, or a mixture of various hues were used to document the dominant color. To guarantee measurement consistency, color grouping was done using guidelines for poultry color categorization. Shank colors, which were classified into conventional categories like yellow, black, white, gray, or a combination. In order to find patterns of variation among the chicken populations from the three regions, meticulous documentation was done since shank color might indicate certain genetic characteristics. Comb shapes were identified based on their form, including single combs, pea combs, rose combs, and others. Each sample was photographed for additional verification, and grouping was done according to the comb's observable morphology; beak colors were classified as yellow, black, white, gray, or mixed. Beak color variations may be a result of environmental adaptation or specific genetic traits common to local chickens.

Data analysis

Both qualitative observations and quantitative statistical techniques were used to measure phenotypic diversity. To find dominant patterns both within and between regions, the frequency distribution of each phenotypic trait was first computed. Furthermore, the relative variability of traits was measured using the Coefficient of Variation (CV), which sheds light on the extent of phenotypic dispersion within the population. The three regions' chicken populations were analyzed descriptively to find morphological differences. The main pattern and any variants were identified by looking at the frequency distribution of each attribute.

Analysis of the data was a combination of descriptive and inferential statistical techniques. Frequency distributions were calculated in order to identify the most common traits for the population. Shannon Diversity Index (H') was used to evaluate the diversity in every trait, with the more variable, the higher the value. The Coefficient of Variation (CV) was used as well to measure the degree of dispersion in phenotypic traits by region. Comparative statistics were run through one-way ANOVA to identify whether there were substantial differences in the distribution of traits between regions and between sexes. Post-hoc tests were run where appropriate. Principal Component Analysis (PCA) was done to identify the main factors contributing to total phenotypic variance, and boxplots were used to visually present variability and patterns by region. Correlation tests were also used to assess potential correlations between different phenotypic traits. This multi-modal approach enabled thorough examination of variation and variation at the individual and population levels in observable traits.



Figure 1. Libya native chicken

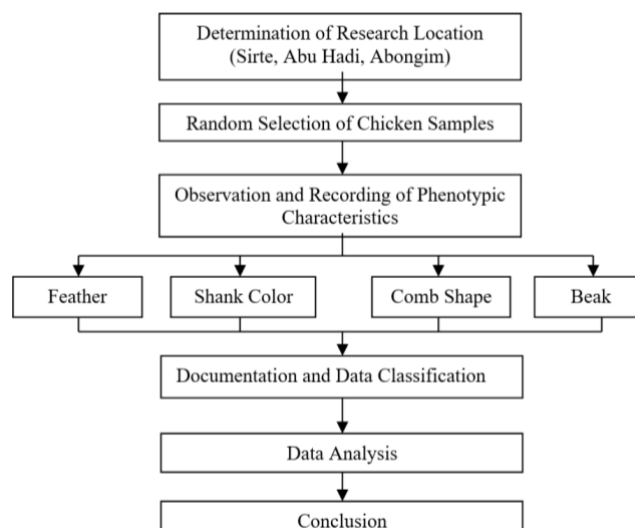


Figure 2. Research flowchart

Ethical statement

All the animal handling protocols in this research were conducted in line with existing ethical guidelines for animal use in research. The chickens were handled with utmost care to minimize stress, discomfort, and injury. There were no invasive or experimental treatments administered. Data acquisition was limited to observation and non-invasive evaluation. It was authorized for local poultry owners to gather data, and the purpose of the research was explained to them beforehand. The study protocol was reviewed and ratified by the institutional ethics committee to guarantee that national as well as international guidelines for animal welfare in scientific research were followed.

RESULTS AND DISCUSSION

Table 1 shows the qualitative characteristics of local chickens in Libya, with particular attention to feather color, shank color, comb form, and beak color in three different locations: Sirte, Abu Hadi, and Abongim. The entire sample consists of 200 chickens spread over various areas.

According to Table 2, descriptive analysis of the qualitative features of the local Libyan chicken indicates varying degrees of diversity within features. The maximum number of categories (7) is for the color of feathers, and black is the most common (36.5%). A Shannon-Wiener Index (H) value of 1.77 indicates that there is high diversity, i.e., local Libyan chicken has a wide and diversified range of feather colors across regions. Shank color was highly variable, with five categories and an H' value of 1.48, on the upper boundary of the moderate to high class. The "black with white sides" color is the most frequent leg color (45.5%), indicating intense genetic predisposition or local adaptation for this character.

In comb shape, five categories were seen, but only moderate diversity with an H' value of 1.20. The most common comb shape is pea comb (54%), which is likely

related to better thermoregulation under warm conditions like those of Libya. Beak color, however, was low to moderate with an H' of 1.03 and with only three categories under the control of brown-yellow (46.5%). The low diversity in this character can be related to genetic stability or local selection effects that maintain some traits. In general, the data indicate that Libyan chickens' phenotypes are very variable for visual characteristics such as beak color and leg color but uniform for characteristics such as comb shape and beak color. This information is important as a model for genetic preservation programs, selective breeding, and setting up in situ conservation programs to maintain the biodiversity of Libyan chickens.

Feather colors

The most common feather color was black, which was observed in 73 chickens (36.5%), followed by red, which was observed in 62 chickens (31.0%). There are 12 black and white chickens (6%) that show black and white feathers, which are in the less common category. White is the least prevalent feather color, appearing in only 5 chickens, while brown, silver, and Columbian feather hues are less common. This implies that genetic or environmental variables may influence the predominance of particular hues at various locations. According to this distribution, the most common feather colors among Libyan native chickens are black and red, which implies that these two colors morphs are predominant among the native chicken population of Libya. Compared to black and red feathers, brown feathers are less prevalent but rather common. White, black-and-white, silver, and Colombian are among the other color groupings that are often less common. The decreased prevalence of black-and-white chickens in Sirte (only 2 chickens), compared to Abu Hadi and Abongim (each with 5 chickens), may be due to regional variations in genetic composition or environmental factors that affect feather pigmentation (Figure 3).

Table 1. Variation of qualitative traits among native chickens in Libya

Trait	Color	Sirte (n)	Abu Hadi (n)	Abongim (n)	Overall (n)
Feather colors	White	1	4	0	5
	Black	24	28	21	73
	Red	21	20	21	62
	Brown	5	6	11	22
	Black and white	2	5	5	12
	Silver	7	5	4	16
	Columbian	4	1	5	10
	Overall	64	69	67	200
Shank colors	Slate	5	11	14	30
	Black with white side	25	30	36	91
	Yellow	22	17	13	52
	Straw	2	4	5	11
	Black and white	10	3	3	16
	Overall	64	65	71	200
Comb shape	Single	21	23	23	67
	Rose	1	0	0	1
	Pea	34	36	38	108
	Cushion	8	6	8	22
	Strawberry	0	1	1	2
	Overall	64	66	70	200
Beak color	Black	31	34	25	90
	Yellow	8	5	4	17
	Brown-yellow	25	27	41	93
	Overall	64	66	70	200

Note: n is number of heads

In every location, black was the most common coat color, especially in Sirte (24 individuals) and Abu Hadi (28 individuals). Additionally, red was widespread and equally distributed throughout the three sites (about 20-21

individuals per location). Abongim had a higher prevalence of brown (11 individuals), suggesting either breeder preference or local adaptation. While white was extremely uncommon and only found in Sirte and Abu Hadi, mixed colors, such as black and white and Columbian, were more common. In contrast, Sirte had a higher concentration of silver (7 individuals) than the other two places (Figure 4).

Figure 5 illustrates a boxplot that shows median feather color in Abongim and Sirte is around code 3 (Red), and this suggests that red feather color is the most common among these two cities. Abu Hadi, on the other hand, has a lower median at code 2 (Black), suggesting an increased incidence of black feathered chickens in the city. This points towards a possible regional variation in the most common feather color among the sampled population. As for variability, Sirte and Abongim have a broader Interquartile Range (IQR) than Abu Hadi, indicating more variability in feather coloration among birds in these two towns. Sirte exhibits the broadest range, from White (1) to Columbian (7), indicating the highest feather color variety. Abu Hadi has a stronger range with most of the data points between White (1) and Brown (4), and a lower highest feather color value than the other two cities. There are a few outliers within Abu Hadi (data points 124, 125, 127, 129, 130, 131, and 133), which are feather colors at the upper part of the range (such as Silver or Columbian). The outliers suggest that although most chickens in Abu Hadi have darker or less complex feather colors, there are some with more complex or rarer traits. This boxplot indicates that feather color distribution varies among areas, with Sirte and Abongim being more varied and Abu Hadi being more uniform in feather color. These variations could potentially be accounted for by regional fashion for breeding, environment, or genetic differentiation between the local chicken populations.

Table 2. Descriptive statistics indicating diversity of qualitative traits in native Libyan chickens (n = 200)

Trait	No. of categories	Most common category (% of total)	Range (Min-Max) (n)	Shannon Index (H')
Feather color	7	Black (36.5%)	0-28	1.77
Shank color	5	Black with White Side (45.5%)	2-36	1.48
Comb shape	5	Pea (54.0%)	0-38	1.20
Beak color	3	Brown-Yellow (46.5%)	4-41	1.03

Note: n: Number of heads, Shannon Index (H'): Measure of diversity



Figure 3. Feather colors of native chickens in Libya

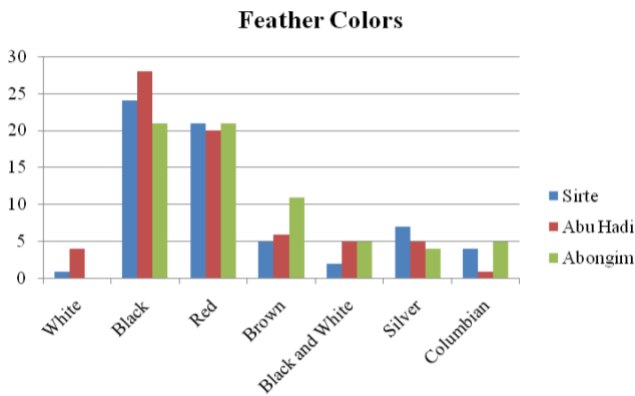


Figure 4. Comparison feather colors traits across regions

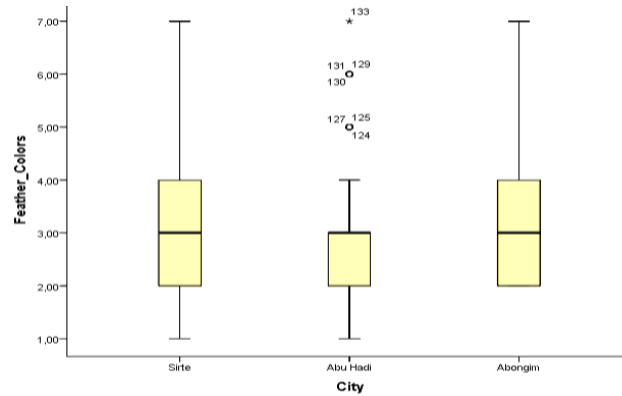


Figure 5. Boxplot comparison of feather colors traits across regions



Figure 6. Shank colors of native chicken in Libya

Shank colors

The most prevalent shank color variant, black with a white side, was found in 91 chickens (45.5%), followed by yellow (52 chickens, 26%). Thirty chickens (15%) had slate-colored shanks, while the least common hues were straw and blue-white, observed in 11 and 16 chickens, respectively. The significant genetic variability among Libya's indigenous chicken groups may be the cause of the notable differences in shank color, underscoring the complexity of this study. The prevalence of black-with-white-side shanks suggests that local chicken populations are heavily influenced by genetics. The most prevalent genotype in all three locations was black with white sides, which indicates that shank color varied somewhat genetically throughout Libya (Figure 6).

A likely wide genetic distribution is suggested by the dominance of black shank with white sides in all regions, particularly in Abongim (36 animals) and Abu Hadi (30 animals). Perhaps as a result of local breeder preferences or environmental variations, yellow was less common in Abongim (13 animals), more common in Sirte (22 animals),

and less common in Abu Hadi (17 animals). In Abongim, slate (bluish gray) was most prevalent (14 animals), whereas Sirte had the fewest (5 animals). In contrast, there was minimal variation in the number of straws and black and white colors across all three regions (Figure 7).

Boxplot in Figure 8 indicates that in all three cities, the median shank color is coded as 3 (Yellow), suggesting that yellow is the most common shank color in all cities. The IQRs for each of the three cities are almost similar to one another, suggesting that there was quite uniform variation in shank color in Sirte, Abu Hadi, and Abongim. Most of the chickens in all cities have shank colors ranging from codes 2 (Black with White Side) to 4 (Straw). Each city also has some outliers on the upper end of the scale (code 5 = Black and White), indicating the presence of chickens with less frequent shank color traits. Chickens 61, 62, and 63 are outliers in Sirte, while those of 127, 128, and 129 are outliers in Abu Hadi. Abongim also has outliers (chickens 198 and 200), showing the presence of the Black and White shank color, which is less common in the whole population. The distribution of shank colors is consistent

over the three regions from code 1 (Slate) to code 4 or 5. Consistency here means that the distribution of shank coloration tends to be even across regions. However, the outlier patterns show that the count of rare shank colors like Black and White varies slightly by city, with Sirte tending to have a couple of more outliers than the others. Yellow shanks dominate all the cities, although each region includes a small number of chickens with uniquely different shank colors. The presence of outliers, especially those showing Black and White shanks, can reflect inherent genetic differences or nonconformist breeding practices in certain locations.

Comb shape

The most common comb form was the pea comb, which was present in 108 chickens (54%), followed by the single comb, which was present in 67 chickens (33.5%). There are very few cushions and strawberry combs (just 22 and 2, respectively). Only one chicken had a rose comb, making it the least common. Given the absence of notable variance, it is possible that the comb form is inherited regularly and is generally constant across geographic regions. The prevalence of pea combs indicates that they could give local chickens an adaptive edge in Libya's climate. The fact that single and pea comb forms are so common in all three locations indicates that the local chicken populations in Libya are more genetically composed of these comb types (Figure 9).

The pea comb form exhibited a consistent phenotypic trend and was the most prevalent across all sites, especially in Abongim (38 individuals), followed by Abu Hadi (36 individuals) and Sirte (34 individuals). With almost equal numbers (21-23 individuals) in all three sites, the single comb form was also fairly prevalent. Moderately more cushion forms were discovered in Sirte and Abongim (8 individuals each) than in Abu Hadi (6 individuals). The strawberry and rose forms, on the other hand, were extremely uncommon, appearing at only one or two locations (Figure 10).

Figure 11 shows the boxplot illustrating all three cities, the most common comb shape coded as 3 (Pea) represents that the Pea comb is the most common among chicken populations. The range for each city, from code 1 (Single) to code 3 (Pea), illustrates that the majority of chickens possess Single, Rose, or Pea comb shapes, while fewer chickens possess Cushion and Strawberry comb shapes. The whiskers are code 5 in Abu Hadi and Abongim, and

code 4 in Sirte, showing that in Abu Hadi and Abongim, there is a more diverse range of comb shapes, namely the less frequent Cushion and Strawberry types, to be found. This shows a relatively higher diversity of comb structure within the two regions compared with Sirte. Above all, the data is outlier-free, so that the comb shape distribution is very evenly spread and no extreme deviations occur in either of the regions. Generally, the pea-comb shape dominates the Sirte, Abu Hadi, and Abongim flocks of chickens. Abu Hadi and Abongim, however, have more diversity in comb shapes, possibly due to local breeding practices or genetics. Sirte, however, despite some variation, has a relatively narrower range of types.

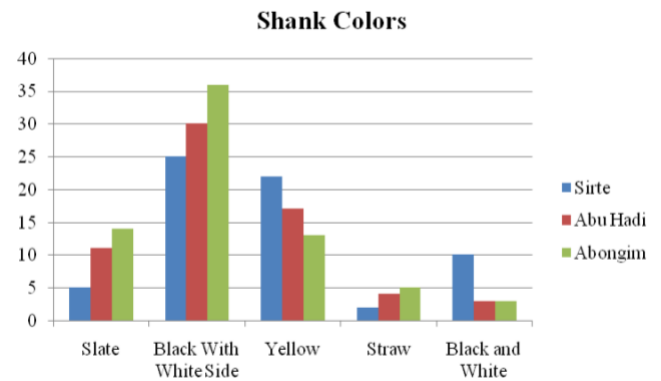


Figure 7. Comparison of shank colors and traits across regions

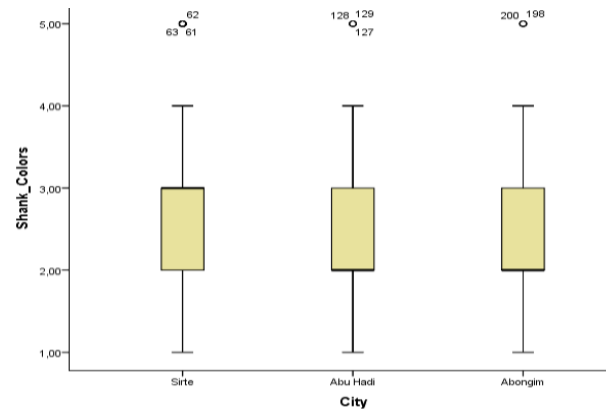


Figure 8. Boxplot shank colors traits across regions



Figure 9. Comb shape of native chicken in Libya

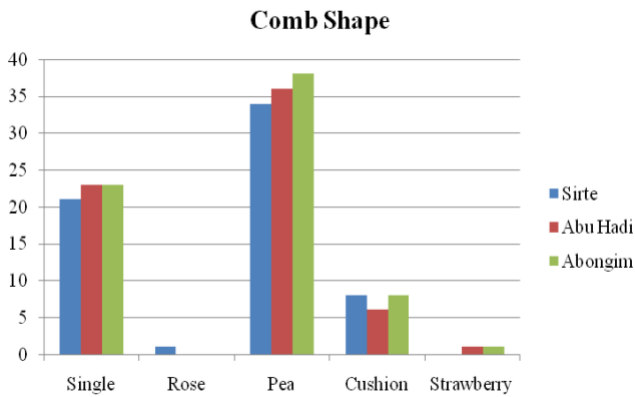


Figure 10. Comparison of comb colors and traits across regions

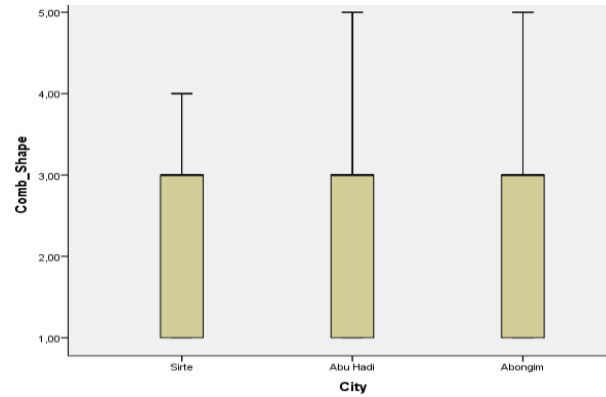


Figure 11. Boxplot comb colors traits across regions

Beak color

The most common beak color was brown-yellow, which was observed in 93 chickens (46.5%), and black, which was observed in 90 chickens (45%). The least frequent beak color was yellow, which occurred only 17 times (8.5%). Native chickens have a high genetic presence of deeper pigmentation, as seen by the predominance of brown-yellow and black beaks. Black may be the most common beak color among Libyan native chicken populations, as evidenced by the very high frequency of black beaks in all three towns. Conversely, brown-yellow peaks exhibited notable variance and were most prevalent in Abongim, indicating that geographical variations may affect the distribution of color. This implies that the color of the beaks of native Libyan chickens is mostly determined by genetic factors (Figure 12).

The most common beak coloration was brown-yellow, especially in Abongim (41 individuals), which was more common than in Abu Hadi (27 individuals) and Sirte (25 individuals). This could indicate genetic differences or local adaptation. Black people were also common; they were most common in Abu Hadi (34 people) and Sirte (31 people), but they were less common in Abongim (25 people). In Abongim, yellow was the least common and comparatively uncommon (4 individuals) (Figure 13).

Figure 14. showed the comb shape trait distribution in all three cities, median comb shape is labeled as 3 (Pea), indicating the Pea comb is the most prevalent among chicken populations. Interquartile Range (IQR) in each city varies from code 1 (Single) to code 3 (Pea), showing most

of the chickens are Single, Rose, or Pea comb shapes, and there are fewer of the remaining ones being Cushion and Strawberry combs. Whiskers extend to code 5 in Abongim and Abu Hadi, and code 4 in Sirte, suggesting that more diverse comb shapes, in particular the less frequent Cushion and Strawberry types, are present in Abu Hadi and Abongim. This suggests a slightly higher diversity of comb morphology in the latter two locations than in Sirte. Surprisingly, there are no outliers from the data, and this indicates that the comb distribution shape is relatively even and there are no extremely high deviations from either of the regions. The Pea comb shape dominates the Abu Hadi, Abongim, and Sirte chicken populations. Abu Hadi and Abongim do exhibit a greater range of comb shapes, possibly due to local breeding habits or genetic diversity. Sirte, while still variable, has a less extensive range of comb type.

The Principal Component Analysis (PCA) in Table 3 shows that the first Principal Component (PC1), Feather Color, having an eigenvalue of 3.167 explains 79.16% of the overall variation observed. The value indicates that most of the phenotypic variation is explained by a single principal component. The second, third, and fourth components all have extremely low eigenvalues (all<1) and explain very small percentages of the total variation (less than 10% for each component). This indicates that PC1 encompasses most of the useful information about phenotypic character variation and that the other components add little useful information to the classification or separation of individuals based on phenotypic traits.

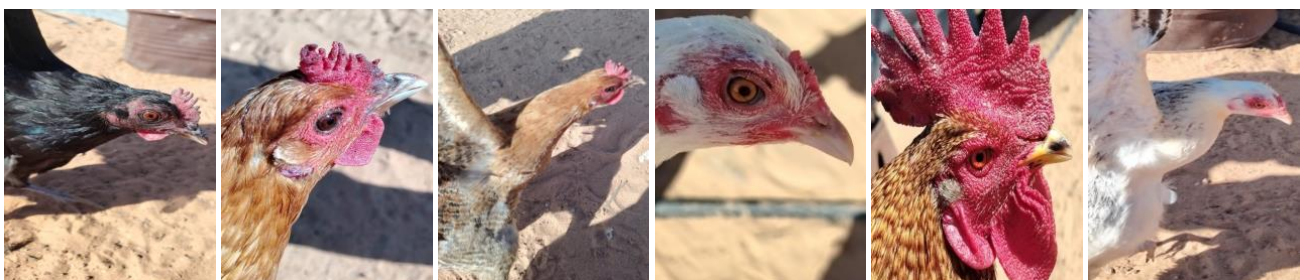


Figure 12. Beak color of native chicken in Libya

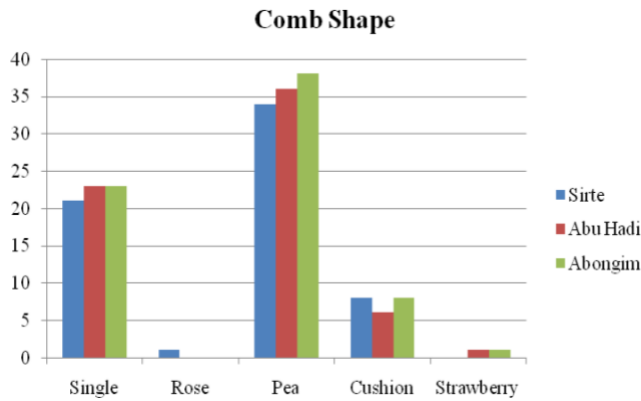


Figure 13. Comparison beak color of native chicken in Libya

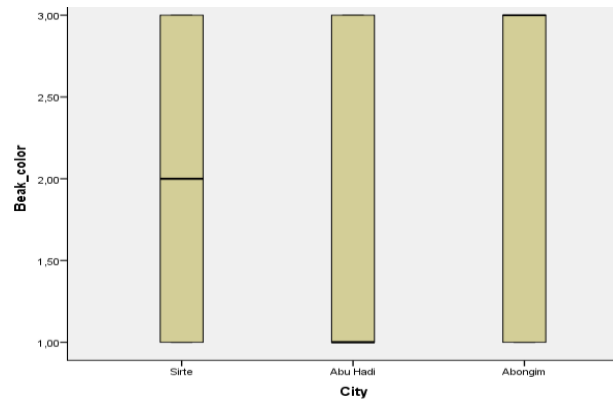


Figure 14. Boxplot beak colors traits across regions

Table 3. Total variance of Principal Component Analysis (PCA) analysis of diversity of qualitative traits in native Libyan chickens

Component	Total variance explained					
	Initial eigenvalues			Extraction sums of squared loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.167	79.163	79.163	3.167	79.163	79.163
2	0.389	9.736	88.899			
3	0.234	5.843	94.742			
4	0.210	5.258	100.000			

Note: n = 200 heads (individual chickens), Eigenvalue: Indicates the amount of variance carried by each principal component, % of Variance: The proportion of the total variance explained by each component. Only component 1 was retained for interpretation, as it explains 79.16% of the total variance. Extraction Method: Principal Component Analysis

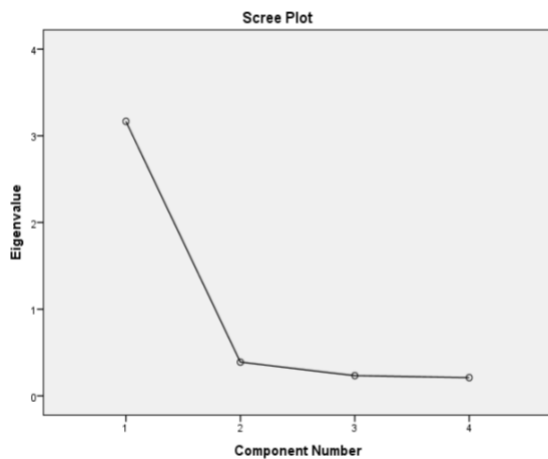


Figure 15. Principal Component Analysis (PCA) plot analysis of diversity of qualitative traits in native Libyan chickens

This finding supports field observations of consistent patterns in the distribution of some of the features, such as the frequency of black and red feathers, black shank color with white sides, and pea-shaped combs. That the patterns are consistent means that these features do not arise from random variation but are likely to be regulated by a combination of strong genetic factors and environmental selection pressures, namely adaptation to the extreme local climate of Libya. Genetically, the dominance of a single major principal component in a PCA would suggest that

most of the observed traits are highly correlated and can be explained by a single source of variation. This would be suggestive of the possible presence of well-adapted local breeds and stability in their phenotypic characteristics. Furthermore, the geographical distribution of phenotypic traits (e.g., the frequency of a certain color in Sirte or Abu Hadi) also implicates local selection and husbandry practices in having a significant influence on regionally distinctive characteristics.

Based on the screen plot results from the Principal Component Analysis (PCA) analysis in Figure 15, it can be concluded that only the first Principal Component (PC1), feather colors, has an eigenvalue greater than 1, while the other components have much lower values. This indicates that feather colors are most contributory in accounting for variation in the phenotypic data of the Sirte, Abu Hadi, and Abongim local Libyan chickens. The dominance of the feather colors suggests that most of the chicken phenotypic variation can be summarized in a single principal dimension, most likely because of the occurrence of spectacular traits such as feather color (black and red), leg color (black and white), and comb shape (pea-colored and single-comb). That there is a clear elbow in the scree plot after the first component also confirms the reality that subsequent components add little to the variability in the data.

Biologically, the results imply a great level of genetic diversity among the local chicken populations, which could be the result of adaptation and natural selection to the environment, particularly to hot climatic conditions. This confirms the hypothesis that these local chickens possess

unique adaptive characteristics, as expressed in the homogeneity of feather color, comb type, and leg color. Therefore, these prevailing characteristics can be the focus of conservation and genetic improvement. The result corroborates the fact that the distribution differences in phenotypic traits are not random but are determined by environmental conditions and selection pressures that are genetic, thereby rendering Libyan local chickens a genetic resource of worth that should be conserved and developed.

Table 4 provide information regarding the variation of the phenotypic trait among native chickens from three Libyan regions: Abu Hadi, Sirte, and Abongim. The test indicates that beak color and shank color have statistically significant regional differences with p-values of 0.018 and 0.008, respectively. This implies that regional effects may influence these traits due to genetic variation or adaptation to the environment. On the other hand, feather coloration and comb shape were not significantly dissimilar between the regions and had p-values of 0.154 and 0.603, respectively. These observations suggest that feather coloration and

comb type are more uniformly distributed between the sampled regions and might be less susceptible to geographic or ecological differences. Overall, this analysis indicates that while some qualitative traits are similar, others vary with region, which could potentially be beneficial for breeding, conservation, or further genetic studies of native Libyan chickens.

Table 5 presents a test for phenotypic comparison between sexes, revealing statistically significant differences in feather color, shank color, comb shape, and beak color among male and female local chickens in Libya. P-values for all four traits are below the 0.05 level, proving that sex affects the expression of these observable traits. Most specifically, feather color ($p = 0.048$) and shank color ($p = 0.0461$) show significant differences between males and females, suggesting that sexual dimorphism may be involved in pigmentation and the coloring of the legs. The shape of the comb also shows a significant difference by sex ($p = 0.018$), and this concurs with previous observations in poultry biology.

Table 4. ANOVA test results comparing phenotypic characteristics by regions

ANOVA	Source of variation	Sum of squares	df	Mean square	F	Sig. (p-value)
Feather_colors	Between groups	8.543	2	4.272	1.889	0.154
	Within groups	445.452	197	2.261		
	Total	453.995	199			
Shank_colors	Between groups	10.776	2	5.388	4.894	0.008
	Within groups	216.904	197	1.101		
	Total	227.680	199			
Comb_shape	Between groups	1.226	2	0.613	0.507	0.603
	Within groups	238.369	197	1.210		
	Total	239.595	199			
Beak_color	Between groups	7.355	2	3.677	4.126	0.018
	Within groups	175.600	197	0.891		
	Total	182.955	199			

Note: n: 200 chickens sampled, df: Degrees of freedom, F-value: Ratio of variance between groups to variance within groups, p-value (Sig.): Significance level, values <0.05 are considered statistically significant

Table 5. ANOVA test results comparing phenotypic characteristics by sex

Trait	Source of variation	Sum of squares	df	Mean square	F	Sig. (p-value)
Feather colors	Between groups	1.104	1	1.104	0.484	0.048
	Within groups	452.891	198	2.286		
	Total	453.995	199			
Shank colors	Between groups	0.381	1	0.381	0.338	0.0461
	Within groups	227.299	198	1.148		
	Total	227.680	199			
Comb shape	Between groups	0.159	1	0.159	0.131	0.018
	Within groups	239.436	198	1.209		
	Total	239.595	199			
Beak color	Between groups	0.078	1	0.078	0.087	0.049
	Within groups	182.877	198	0.923		
	Total	182.955	199			

Note: n: 200 heads (individual chickens), df: Degrees of freedom, F-Value: Fisher's test statistic used to compare variances, Sig. (p-value): Probability of observing such a result if the null hypothesis is true

The morphology of the comb is more developed in males due to the effects of hormones. Beak color also varies significantly between sexes ($p = 0.049$), which can be the result of either genetic expression or environmental interaction based on gender-related behavior or diet. These findings highlight sex as a major factor in the phenotypic diversity of Libyan local chickens. The finding is pertinent to breeding programs where selection of traits may be divergent depending on whether males or females are to be utilized and to conservation activities that aim at preserving the entire range of phenotypic diversity of the local chicken population.

Table 6 shows findings of the correlation tests provide insights into interrelations among the various phenotypic characteristics, feather color, shank color, comb shape, and beak color, and with the city of origin of Libyan native chickens. The majority of the phenotypic characteristics have positive, high, and statistically significant correlations. Specifically, feather color is strongly associated with shank color ($r = 0.776$, $p < 0.01$), comb shape ($r = 0.700$, $p < 0.01$), and beak color ($r = 0.681$, $p < 0.01$). These values suggest that chickens sharing the same feather color are also most likely to share the same shank, comb, and beak attributes. Similarly, shank color is positively correlated with comb shape ($r = 0.720$, $p < 0.01$) and beak color ($r = 0.679$, $p < 0.01$), and comb shape and beak color are most highly correlated in the data ($r = 0.777$, $p < 0.01$). This indicates that these phenotypic traits can be genetically linked or influenced by common environmental factors.

In contrast, the phenotypic characters' association with the city variable is largely weak. City is weakly and negatively correlated with shank color ($r = -0.176$, $p < 0.05$), suggesting geographical location has a gentle negative relationship with shank color difference. Beak color is also weakly but significantly positively correlated with city ($r = 0.161$, $p < 0.05$). Yet, the feather color ($r = 0.046$, $p = 0.517$) and comb shape ($r = 0.037$, $p = 0.598$) do not show any significant correlation with city, which means that these traits are less influenced by geographic location. This study reveals that phenotypic traits in Libyan local chickens are extremely correlated, and location (city) has little but significant influence on some traits like shank and beak color. The findings may be useful for breeding programs

and conservation initiatives that aim to retain region-specific traits and increase genetic diversity.

Discussion

ANOVA results (Table 4) revealed regional variations in shank color ($p = 0.008$) and beak color ($p = 0.018$), but not in feather color and comb shape. This would suggest that geographical location could have more influence on certain traits than on others. The significant differences in beak and shank color could be the result of environmental influences such as climate, soil, or diet, and/or genetic diversity among the populations. The more uniform distribution of feather color and comb shape, however, could reflect a shared ancestral gene pool or the same selection breeding preference in the areas. Feather color varied most in Sirte and Abongim, with red being dominant, but Abu Hadi showed an overwhelming majority of black-feathered chickens with fewer exceptions. Shank color was largely yellow across all cities, but with a few variants (like black and white) as outliers, more so in Sirte and Abongim. This is indicative of the concept of common but locally diverged gene flow. Comb shape and beak color were also predominantly influenced by the common forms (Pea-shaped and yellow), but Abu Hadi and Abongim again exhibited greater variation, suggesting higher morphological diversity possibly due to less structured breeding or environmental heterogeneity.

Sex analysis (Table 5) revealed statistically significant differences for all four characters ($p < 0.05$), of which the shape of the comb ($p = 0.018$) and color of feathers ($p = 0.048$) were most diverged. The findings indicate sexual dimorphism in local chickens, where traits like the size and coloration of the comb are larger or differently expressed in males than in females. This is in agreement with earlier biological knowledge that comb morphology is regulated by sex hormones like testosterone, and secondary sexual characteristics are generally more pronounced in the male for reproductive purposes. Sexual dichromatism in beak and shank color may also reflect diet, behavior, or hormone-mediated pigmentation.

Table 6. Correlation test results comparisons phenotypic characteristics

		Feather_colors	Shank_colors	Comb_shape	Beak_color	City
Feather_colors	Pearson correlation	1	0.776**	0.700**	0.681**	0.046
	Sig. (2-tailed)		0.000	0.000	0.000	0.517
	N	200	200	200	200	200
Shank_colors	Pearson correlation	0.776**	1	0.720**	0.679**	-0.176*
	Sig. (2-tailed)	.000		0.000	0.000	0.013
	N	200	200	200	200	200
Comb_shape	Pearson correlation	0.700**	0.720**	1	0.777**	0.037
	Sig. (2-tailed)	.000	0.000		0.000	0.598
	N	200	200	200	200	200
Beak_color	Pearson correlation	0.681**	0.679**	0.777**	1	0.161*
	Sig. (2-tailed)	.000	0.000	0.000		0.023
	N	200	200	200	200	200
City	Pearson correlation	0.046	-0.176*	0.037	0.161*	1
	Sig. (2-tailed)	0.517	0.013	0.598	0.023	
	N	200	200	200	200	200

Note: **: Correlation is significant at the 0.01 level (2-tailed), *: Correlation is significant at the 0.05 level (2-tailed)

Correlation studies (Table 6) revealed very strong and highly significant positive correlations among the phenotypic characters, particularly between comb shape and beak color ($r = 0.777$) and feather color and shank color ($r = 0.776$). This suggests the possibility of common genetic control or developmental processes influencing multiple traits simultaneously. The minor yet significant correlations between city and traits like shank color ($r = -0.176$, $p = 0.013$) and beak color ($r = 0.161$, $p = 0.023$) confirm that location has some influence on phenotype, though not as powerfully as inter-trait relations.

Principal component analysis (Table 3 and Figure 15) also confirmed that feather color is the most significant contributor to the overall phenotypic variation of the sampled populations, as the first principal component explained 79.16% of the total variance. This emphasizes the visual and genetic importance of feather coloration in local chicken phenotypic diversity. The obvious "elbow" in the scree plot makes the case for using a single principal component for capturing most variation, making future phenotype-based genetic or conservation analyses simpler.

The conclusions of this study demonstrate a wide range of phenotypes in native chickens in Libya. The notable variance in beak, shank, and feather color raises the possibility that the observed variety was influenced by genetic drift or other environmental stresses. The prevalence of black and red feather hues is in accordance with earlier research on indigenous chicken populations, which generally display deeper pigmentation as a kind of adaptation to local environmental circumstances, such as protection against solar radiation (Wang et al. 2022). Selective breeding or natural selection mechanisms that favor particular features in particular places may be the cause of the differences in shank and beak colors. For example, darker shank and beak hues may be associated with infection resistance or other adaptive benefits (Osaiyuwu et al. 2023).

The lack of notable variations in the comb form suggests that this characteristic may be more firmly controlled by genetic inheritance and less affected by environmental influences (Tremblay and Hamet 2019). These findings advance our knowledge of the genetic variety observed in native chickens and serve as a foundation for future breeding initiatives that aim to maintain desired characteristics. The existence of notable variance in several variables further implies that the phenotypic qualities of native chickens in Libya are significantly influenced by local adaptation. Future studies should examine the genetic foundation of these differences and evaluate how they affect overall environmental adaptation, disease resistance, and production (Otecko et al. 2019).

Given that other phenotypic variables, such as feather or shank color, exhibited notable regional variation, this finding suggests that the comb shape trait may not show as much regional variation in the local chicken population in Libya. This implies that either the characteristic may not be as significantly affected by selective breeding or other environmental conditions, or that the genetic variation in comb shape may be more consistent throughout the various regions (Lyu et al. 2022). In summary, the comb shape distribution's lack of statistical significance indicates that

comb form is a less variable attribute among Libya's indigenous chicken population. This might indicate that this phenotypic trait is expressed more steadily or consistently throughout geographical areas, possibly because of genetic homogeneity or other elements that prevent notable diversity in comb forms (Chu et al. 2023).

The results indicate a non-uniform distribution of beak colors among Libyan native chickens and that geographical differences significantly influence the frequency of particular beak colors. Selective breeding techniques, environmental factors, or genetic variation among geographical areas may influence the expression of beak color in these chickens. Significant differences between the actual and predicted frequencies of beak color categories in various regions are reflected, especially in the distribution of black and brown-yellow beak colors (Al-Atiyat et al. 2023). According to these results, some beak colors could be more common in some areas than in others, which might be a result of regional breeding customs or genetic predispositions among Libya's indigenous chicken populations. The analysis concluded that the distribution of beak color varied significantly among the locations under investigation. Both genetic and environmental factors may influence the phenotypic variety of local chickens in Libya, as suggested by this result. Knowledge of these differences can help improve local chicken breeds, inform breeding plans, and preserve the genetic diversity of the population (Gebru et al. 2023).

These findings show notable differences in the phenotypic traits of local chickens in various Libyan areas. The hue of the feathers is one of the most noticeable variations. Red and black feathers were predominant in all three regions, with red being the most common, followed by black coming in second. In native chicken populations, the prevalence of these two hues indicates a substantial genetic effect favoring these characteristics (Chebo et al. 2023). Regional differences were also noticeable, especially in Abongim, where the majority of chickens had red feathers, but Sirte and Abu Hadi had more black feathers. The fact that there are almost no white-feathered chickens in Abongim and fewer black-and-white chickens in Abu Hadi suggests that local breeding preferences or environmental conditions may affect feather color.

The shank color distribution of the three regions likewise followed a consistent pattern, with the most prevalent phenotype being black with white sides. This implies that among native chickens from Libya, this specific hue could be a genetically dominant characteristic or offer adaptive benefits. Slate, straw, and black-and-white shanks were less common than yellow shanks, which were the second most common hue. According to Yaemkong et al. (2024), the rather consistent distribution of black and white-sided shanks in all three regions indicates that this characteristic is probably maintained by natural adaptation to the local environment or selective breeding.

The study found that the most commonly observed phenotypes in terms of comb morphology were single and pea combs. The most common comb type was the pea comb. Due to their effectiveness in thermoregulation, the preponderance of peas and single combs indicates that these

traits are better adapted to Libya's climatic circumstances. Rose and strawberry combs are not very common, which might mean that they are less suited to the local environment or that local breeding procedures do not favor them (Rozenberg et al. 2022).

The color of the beaks was another significant phenotypic characteristic investigated by Pan et al. (2024). Given that black beaks are more common in Sirte and Abu Hadi, this hue may represent a genetically dominant characteristic of these areas. In contrast, the brown-yellow beak was more prevalent in Abongim, highlighting possible regional genetic differences in indigenous chickens. According to Huang et al. (2020), the comparatively low frequency of yellow beaks indicates that this genotype is recessive or less preferred by natural or selective breeding in the Libyan environment.

These findings are corroborated by the statistical analysis of feather color differences, which showed notable variances in phenotypic features among the three locations. Genetic and environmental factors, rather than chance, were responsible for the variations in feather color distribution between regions (Kim et al. 2019). A higher frequency of particular hues within particular locations may indicate regional selection pressures or breeding methods that favor particular features. Furthermore, the comparatively greater frequency of red and black feathers may be related to their possible benefits for heat absorption, concealment, or social dominance in flocks (Kong et al. 2024).

A study by Moto and Rubanza (2023) evaluated the phenotypic diversity of the native chicken population in Tanzania's central zone, namely in the Dodoma and Singida counties. Pea comb (6.8%) was the second most common comb type, according to the data, behind single comb (90.9%). Multicolored plumage was the most common (66%), with black coming in second (14%). 59.1% of the shanks were yellow, which predominated over the others. Ekeocha et al. (2021) investigate the phenotypic traits of native chickens in the local governments of Ikole, Ekiti East, and Oye in Nigeria. The findings indicated that the three research sites had four distinct shank colors: cream, yellow, brown, and black. While brown is less prevalent in the three research locations, yellow shank is more prevalent in the local governments of Oye, Ikole, and Ekiti East (54.24%, 65%, and 61.67%, respectively). The most prevalent comb type was single.

In Zambia's Northern, Muchinga, and Luapula regions, Liswaniso et al. (2024) describe the phenotypes of these hens and their production technique. Brown (27.88%) and mixed (26.77%) plumage colors, white skins (91.45%), and shanks (48.70%) were the most prevalent qualitative characteristics, according to the results. Yussif et al. (2023) investigate the variety of Ugandan native chicken breeds. The findings indicated that normal-feather strains accounted for over 90% of the native chickens, with sporadic occurrences of frizzles, polydactyl, ptilopody, and bare neck characteristics in both sexes. In comparison to yellow skin, the most prevalent skin colors among the chickens were dark (49.0% hen; 43.8% cock) and white (38.3% hen; 42.4% cock). However, proportionately, the most shanks were yellow (41% cock; 29% hen). The most prevalent iris

(eye) colors in both sexes were orange and brown. Cocks had huge oval-shaped earlobes that were mostly red (70%), whereas hens typically had little spherical earlobes of various colors. Wattles were nearly always found, and the single-comb variety predominated in both sexes.

Poultry farming plays a vital role in the lives of rural people because it provides a source of income and food security. Native chickens, often referred to as local or Baladi chickens, exhibit remarkable resilience to various environmental conditions and traditional management techniques. Al-Yousef (2007) researched the distribution and characteristics of Indigenous (Baladi) chickens in Saudi Arabia. The results of these two investigations showed that local chickens varied significantly in terms of body shape, feather color, comb type, and shank color. They're not very big. Makkah, Jeddah, and Madina were home to the majority of the massive Baladi projects (>1,000 chickens). Qasim, Madina, Makkah, Durma, and Qatif are home to medium-sized farms with 250-600 chickens. Makkah, Qasim, and Hofuf are home to smaller farms (less than 250 chickens). Poultry farmers who raised chicks as their primary source of income comprised 23% of the major Baladi projects (Al-Yousef 2007). Despite their relatively modest size, these chickens are resilient owing to their high genetic diversity. Additionally, there are differences in the distribution of poultry farms; in some areas, smaller farms predominate, whereas in others, large-scale Baladi enterprises are more prevalent.

The phenotypic diversity observed in Libyan native chickens is consistent with trends observed in native chicken populations in other countries, particularly in Africa and parts of Asia. The diversity, both within and between regions, underscores the richness of agrobiodiversity existing within traditional livestock systems. In Libya, the black and red feather colors, pea and single comb types, and black-and-white shank colors are the dominant features, which represent trends in surrounding nations such as Nigeria, Tanzania, Uganda, and Zambia, in which they are dominant. For instance, in Nigeria (Ekeocha et al. 2021) and Tanzania (Moto and Rubanza 2023), there was yellow and black shank coloration and prevalence of single comb, while in Uganda and Zambia, there was prevalence of multicolored and dark feather phenotypes—indicating adaptation to the existing environments.

In comparison, Libyan chickens seem to maintain a wider and more evenly spread variation in some traits, notably feather color ($H' = 1.77$) and shank color ($H' = 1.48$). This is just above reported values in some East African nations, perhaps indicating less intense selection pressure and more intermating among ecotypes in Libya. The incidence of abnormal characteristics, such as cushion and strawberry combs or silver and Columbian feathering in Libyan chickens, only acts to emphasize this genetic variety. These non-standard phenotypic variants may be regarded as reservoirs of potentially beneficial alleles, with the potential for choice of trait in breeding programs to improve productivity, hardness, or disease resistance (Liu et al. 2023).

From agrobiodiversity and biodiversity perspectives, the wide variation of Libyan chickens illustrates the ability

of these birds to adapt to different ecological and management systems. Agrobiodiversity encompasses not only genetic diversity across and between the food crops and animals that are used as food and in agriculture, but also the ecosystem services they offer (Gioiosa et al. 2025). The phenotypic traits exhibited—e.g., dark feathers for solar protection, comb forms for heat dissipation, or coloring of the shank that could be associated with resistance traits—are expressions of this diversity. Conservation of such diversity is essential to climate-proof poultry production against climate change, emergent disease threats, and shifting consumer expectations (Guerrero et al. 2023).

Their breeding implications are important. The phenomenon of phenotypic differences between locations and sexes suggests that location-based or sex-based breeding programs could be beneficial. For example, the well-documented sexual dimorphism of comb and feather traits suggests that male and female expressions of traits need to be considered separately through selective breeding to avoid unwanted loss of trait variation. In addition, strong regional variation in beak and shank color indicates phenotypic patterns are controlled by local selection pressures (environmental or cultural) and breeding programs will have to account for them in order to maintain local adaptation (Kreiner et al. 2025).

The high between-trait correlations, for example, between comb shape and beak color ($r = 0.777$), would suggest pleiotropic genetic mechanisms or linked gene regions that would be susceptible to simultaneous selection. Selection for one observable characteristic, e.g., preferred comb type, can have an unwitting effect on other characteristics, e.g., beak color, which could be desirable or less desirable. There is thus a desire for a breeding system that addresses more than one trait in an integrative perspective, which could be supported through genomic tools. Apart from this, farmers' preferences and needs, as well as native knowledge, can enhance adoption and sustainability (Mengistu 2024).

Farmers select chickens not only according to performance traits but also on cultural, beauty, or market preference, for example, comb type or plumage color. By honoring and embracing these interests, breeding programs can support local livelihoods and cultural heritage, as well as genetic diversity conservation. Conservation of phenotypic diversity in Libyan chickens serves overarching food and nutritional security goals. Local chickens are generally a significant factor in rural economies, offering resilience where commercial strains cannot, in adverse conditions or limitations of inputs. Upkeep of the phenotypic and genetic purity of the populations is thus not just a scientific or conservation concern but an obligation of socioeconomics (Yaemkong et al. 2024).

Environmental adaptation and regional advantages

The phenotypic traits manifested in Libyan local chicken darker feather pigmentation, black or black-white shank color, and pea comb types that are dominant can be adaptive to the current ecological conditions of the region. Darker feather coloration has been thought to be protective from UV radiation and assist in thermoregulation in hot climates, especially in arid or semi-arid conditions such as

Sirte and Abu Hadi (Chebo et al. 2023). Similarly, pea and single combs, which were most common, have been associated with increased heat tolerance due to their compact nature, minimizing surface area exposed to sunlight (Rozenberg et al. 2022). These traits are consistent with those of other native chicken populations in the Mediterranean and North Africa. For example, studies of native chickens in Tunisia and Algeria have also reported a predominance of darker plumage color and compact comb types, which are believed to be a result of natural selection under the onslaught of harsh climatic conditions. This would suggest that these kinds of features are not only widespread throughout the region but also perhaps indicative of region-specific adaptation mechanisms. The geographic diversity in the distribution of characteristics throughout Libya, such as the predominance of brown-yellow beaks in Abongim, may demonstrate localized environmental pressures or cultural selection preferences (Wang et al. 2025).

Phenotypic diversity and conservation of genetic resources

The wide-ranging phenotypic diversity observed in this study underscores the importance of local chickens as a reservoir of genetic resources essential for long-term sustainability in the chicken industry. Such diversity enhances the potential for local breeds to perform well under varying environmental conditions, including resilience to local diseases without over-reliance on external inputs like antibiotics or formulated feeds (Takahashi 2025). With the extensive range of observable traits—ranging from plumage to comb and shank characteristics—local chickens make an important contribution to agro-biodiversity in Libya. This agro-biodiversity is not only necessary for ecosystem resilience but also for future breeding and conservation programs. Against the backdrop of global climate change and increasing pressures on commercial poultry production systems, preservation of these local genotypes can provide genetic material for the development of new strains that are both productive and resilient. Consolidation of conservation by documentation, phenotypic and genetic characterization, and community-based breeding programs can sustain rural livelihoods while safeguarding Libya's rich poultry biodiversity. It opens doors for the integration of native chickens into national food security, biodiversity conservation, and sustainable agriculture policies (Maxted et al. 2023).

In conclusion, there were 200 chickens surveyed that consisted of 64 Abu Hadi, 69 Sirte, and 67 Abongim (numbers fluctuated slightly between characteristics due to incomplete and non-uniform data). The results show a high level of genetic diversity, which is of significance in the conservation of germplasm and the development of local chicken breeding programs in Libya. Local Libyan chickens are phenotypically highly variable, particularly for leg color ($H' = 1.48$) and feather color ($H' = 1.77$), with black legs and black-and-white legs being the most prevalent categories. Comb shape was moderately variable ($H' = 1.20$), but beak color was low to moderate ($H' = 1.03$). These findings display the great genetic potential and are of interest to conservation programs, selective breeding,

and in situ conservation of indigenous Libyan chickens. The results also indicated significant variation between regions for leg color ($p = 0.008$) and beak color ($p = 0.018$), while plumage color and comb shape were not significantly different. Similarly, clear sex differences were also evident for all the phenotypic traits ($p < 0.05$), indicating sexual dimorphism. Significant correlations between comb shape and beak color ($r = 0.777$) and between leg color and plumage color ($r = 0.776$) indicated possible common genetic control. PCA analysis identified that plumage color was the primary factor that determined phenotypic variation and accounted for 79.16% of total variance.

Local breeding habits, such as selective mating for certain traits or specific mating routines, and environmental forces can shape the prevalence of some traits, where genetic factors are mainly responsible. Strong genetic forces and potential adaptive benefits within Libyan weather conditions are reflected in the prevalence of black and red pigmentation of the feathers and black shanks with white faces. In addition, the higher prevalence of pea and single combs may be a sign of their role in local climatic stress thermoregulation and survival. Statistical tests also validate that these phenotypic variations are non-random but rather a function of the underlying genetic and environmental factors.

The findings highlight the importance of phenotypic variation to enhance in situ conservation efforts by selecting and preserving characters that enhance adaptability, disease resistance, and productivity in local environments. Identification and conservation of these adaptive traits can assist in conserving rural livelihoods, especially among smallholder farmers who utilize indigenous chickens as a source of livelihood and food security. Besides, this phenotypic information presents a rich platform for genetic improvement schemes, which permit the generation of strong, locally adapted lines of chickens with no attendant loss of biodiversity. The merging of conservation and sustainable use of the native genetic resources will be crucial in ensuring long-term poultry productivity and agrobiodiversity in Libya.

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