Journal of
Innovative Agriculture

Research Article
DOI: https://doi.org/10.37446/jinagri/rsa/10.1.2023.26-37

Assessment of phenotypic variation in the local quail (*Coturnix coturnix*) populations of Ghana

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Received: 13 November 2022
Accepted: 15 February 2023
Published: 31 March 2023

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Volume: 10
Issue: 1
Pages: 26-37

The study was conducted to identify the phenotypic variation between local quail populations in three agro-ecological zones (AEZs) of Ghana. A total of 540 quails (180 males and 360 females) were involved in the study. In all, five morphometric traits: body weight (BW), body length (BL), shank length (SL), body girth (BG), and wing length (WL) were used for the investigation. The data collected were subjected to analysis of variance as well as canonical discriminant analysis using Minitab19 software. It was revealed that sex had no significant (*$p>0.05$*) effect on morphometric traits measured except BW. Agro-ecological zone however, influenced all morphometric traits. The BW of local quails in the transitional zone (218.32g) was significantly (*$p<0.05$*) heaviest, followed by those in the Semi-deciduous forest (211.66g) and then Coastal Savanna (187.68g). Furthermore, it was deduced from the canonical discriminant analysis that the most vital trait for discriminating among the populations was BW. The Coastal Savanna had the local quail population with the highest similarity (71.7%); implying that quails within this AEZ may have come from related sources with similar genetic identity while the Semi-deciduous Forest had the lowest (12.2%) similarity, which could be due to the fact that the birds may have come from different sources. The largest Mahalanobis distance (D^2) was found between the Coastal Savanna and the Semi-deciduous forest (2.46) and therefore, an inter-breeding program could be designed for quails selected from these two AEZs. Further studies could consider the molecular characterization of local quail populations within the three AEZs to provide additional

information for decision making in designing of appropriate breed improvement scheme for quails.

Keywords: *quails, discriminant analysis, morphometric traits, agro-ecological zone, Mahalanobis distance, Coturnix coturnix*

INTRODUCTION

Phenotypic characterization is a way of identifying and describing diversity within and between distinct breeds of an organism in a given area and under given management, considering the social and economic indicators that influence them (FAO, 2012). Hassan et al. (2019) and Ali et al. (2021) reported that phenotypic characterization precedes any other form of characterization and it is the building block on which genetic and molecular characterization is built. Variations in phenotypic traits in a local quail population are influenced by both genetic and environmental factors (Ofori & Hagan, 2020; Ofori et al., 2021; Chimezie et al*.,* 2022). Despite the numerous studies on quails, the local quail populations in Ghana are not phenotypically characterized, making it difficult to undertake any meaningful breeding program. Quail production is becoming popular as an unconventional source of cheaper and readily available animal sources of protein for both rural and urban communities in Ghana. Currently, there is no known breed improvement work on quails, hence the need to identify the local quail populations so as to suggest an appropriate breed improvement strategy to be employed for this valuable poultry species. Any improvement in the local quail populations would go a long way to increase the productivity of quails leading to increased animal protein in the country (Dudusola et al., 2018). Quail production has become necessary because most people are beginning to realize the socio-economic significance of quails as a non-traditional alternative poultry species. Chimezie et al*.* (2022) observed that cross breeding and enhanced environmental factors such as improved feeding and housing promote the growth of quails; these could improve the productive and reproductive performance of the local quail populations (Himel et al., 2020). There is therefore the need to channel resources to increase quail production for increased food and nutrition security in Ghana. Phenotypic characterization of quails would reveal the variations that exist in the local populations to enhance the planning and developing of appropriate breeding strategies for their future improvement. The objective of the study was to apply univariate and multivariate analysis for the assessment of the phenotypic variation of the local quail populations in selected agro-ecological zones of Ghana.

MATERIALS AND METHODS

Description of the study area

The investigation was carried out in three AEZs of Ghana; that is the Coastal savannah, Semi-deciduous Forest and the Transitional Zone. This study area was selected because these areas are known to have the highest number of commercial poultry farms and probable local quail populations in Ghana. The Coastal Savanna lies between latitude $05^{0}07$N and longitude $001^{0}17$W. The average relative humidity, rainfall, and temperature of this AEZ are in the range of 70-85%, 600-1200mm, and 24-30^{0}C respectively. The Semi-deciduous Forest also lies between latitude $06^{0}14$N and longitude $07^{0}36$W with annual rainfall, temperature, and humidity range of 1200-1600mm, 24-31^{0}C, and 60-80%, respectively. Also, the Transitional AEZ lies between latitude $07^{0}36$N and longitude $06^{0}14$W with annual rainfall, temperature, and humidity of 1100-1400mm, 25-36^{0}C, and 50-70%, respectively. Figure 1 is an ecological map displaying the various AEZs of Ghana, including the study area.

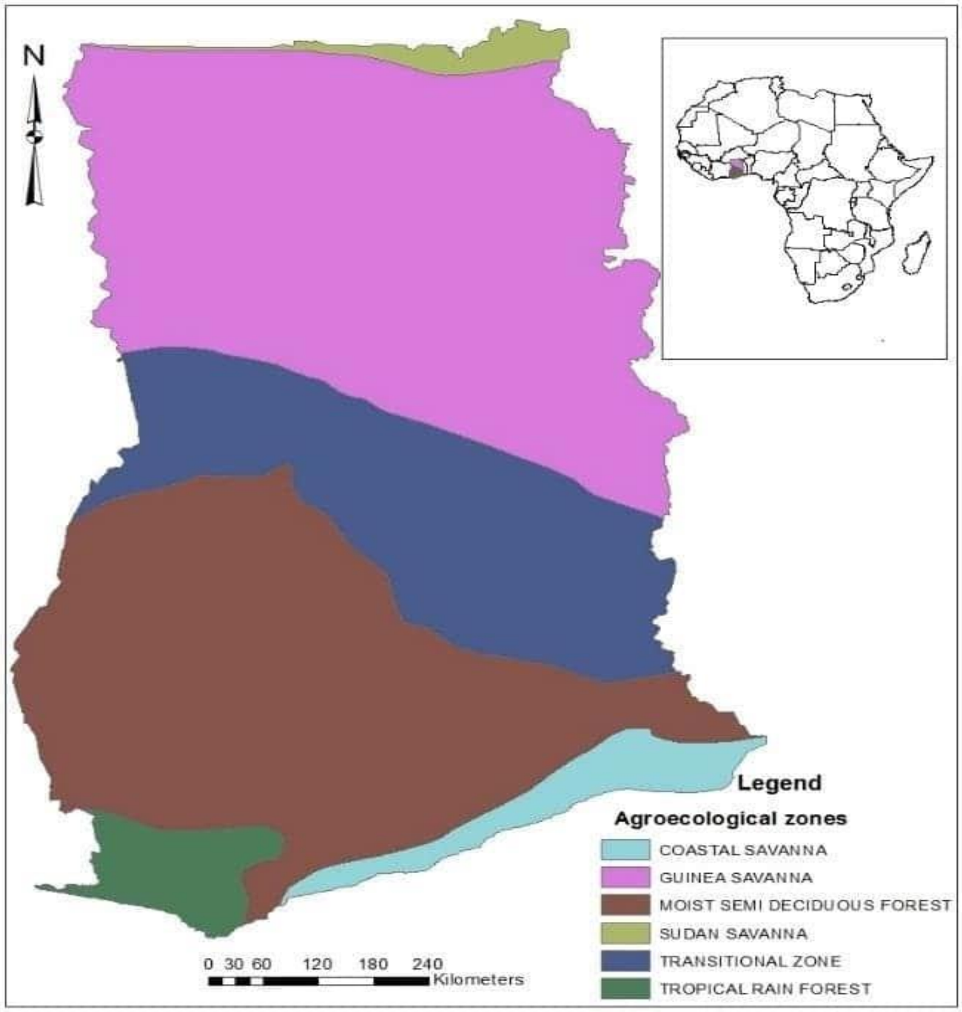

Figure 1. Ecological map displaying the various AEZs of Ghana

Research approach and sampling

This on-farm study employed a survey as the research approach and a purposive sampling technique for selecting quail farms and birds as suggested (FAO, 2012). A total of 540 matured local quails were sampled from selected farms within the three AEZs (180 from each AEZ) for morphometric measurement. The male-to-female ratio used was 1:2 with 60 males and 120 females from each AEZ. The birds were managed under a strict intensive system of animal production where feed and water were provided *ad libitum*.

Data collection for quantitative traits

The quantitative traits which were measured with a digital hanging spring balance, vernier caliper, and measuring tape were: Body weight (BW) [Figure 2], Body length (BL) [Figure 3], Shank length (SL) [Figure 4], Body girth (BG) [Figure 5], Wing length (WL) [Figure 6].

Body Weight (BW) (g): Live weight of quails recorded using a digital hanging spring balance

Figure 2. Measurement of body weight using a hanging spring balance

Body Length (BL): the length was taken from the nasal opening, along its gently stretched neck and back, to the tip of its pygostyle.

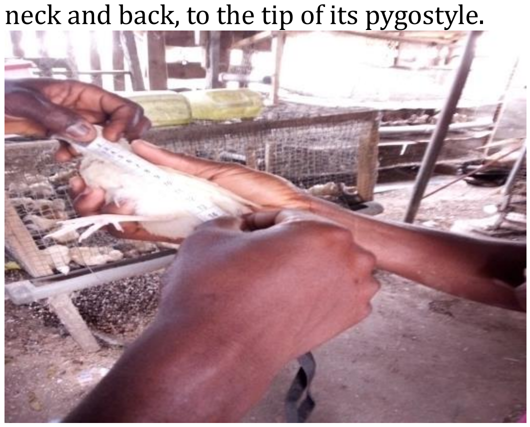

Figure 3. Measurement of body length using measuring tape

Shank Length (SL**)**: length of the shank from the hock joint to the spur of either leg or footpad by a set of Vernier calipers.

Figure 4. Measurement of shank length using a vernier caliper

Body Girth (BG) was taken as measuring tape was looped around the region of the breast under the wings.

Figure 5. Measurement of body girth using measuring tape

Wing Length (WL) was the distance from the humerus coracoid junction to the distal tip of the phalanges digits, using a tape measure.

Figure 6. Measurement of wing length using measuring tape

Data analysis

Univariate analysis (Analysis of variance)

The data was subjected to the analysis of variance (ANOVA) using the generalized linear model procedure of Minitab 19 (Minitab, 2020). Differences in means were separated using the Tukey pairwise comparisons method at a 5% level of significance. The model used to test the effects of sex and agro-ecological zone on morphometric traits (variables) is as follows:

$R_{ijk} = \mu + X_i + A_k + e_{ijk}$

Where,

R_{ijk} = individual observation of each trait;

μ = overall mean;

X_i = effect of i^{th} sex (i = male, female);

A_k = effect of k^{th} agro-ecological zone (k = Coastal Savanna-1, Semi-deciduous Forest-2 and Transitional Zone-3);

e_{ijk} = random error related to each record

Multivariate analysis (Canonical discriminant analysis)

Canonical discriminant analysis was carried out using Minitab 19 for morphometric differentiation and classification of the local quail populations using the Mahalanobis distance, according to the following model (Ofori et al., 2021):

$$D^2 = (x - m)^T \cdot C^{-1} \cdot (x - m)$$

Where,
D^2–: the Mahalanobis squared distance
x–: the vector of observation of morphometric trait
m–: the vector of mean values of independent morphometric variables
T–superscript: Transposed matrix
C^{-1}–: the inverse covariance matrix of independent morphometric variables

RESULTS AND DISCUSSION

Influence of Sex and Agro-ecological zone on quantitative traits of local quails

The means and standard deviations of the morphometric traits of the local quail populations within the three AEZs are presented in Table 1. The results of the study showed that sex did not significantly ($p>0.05$) influence the linear body traits of quails, but it significantly ($p<0.05$) affected body weight. Thus, female quails (209.25g) were relatively heavier than the males (202.52g); implying that body weight revealed sexual dimorphism which could be due to the fact that alleles controlling the trait may be limited or repressed in expression in the males than the females (Coyne et al., 2008; Momoh et al., 2014; Akintan et al., 2017; Ofori et al., 2021). The difference in body weight at maturity between male and female quails could also be due to the development of the sex cell (eggs in females) and sperms (in males). The imbalance of secretion of growth hormones at maturity could lead to differences in the BW. In quails, a fully developed egg cell has an average weight of 10g while the weight of sperm is less than 1g. The difference in weight between the two-sex cells could bring about the BW variation between male and female quails. These findings agree with the study of Rathert et al. (2017) who recorded no significant difference ($p>0.05$) in chest depth and chest width of matured male and female quails but noticed a significant difference ($p<0.05$) in body weight with females (182.00g) been heavier than males (166.23g). On the contrary, a study conducted by other authors including Wamuyu et al. (2017), Tavaniello et al. (2014), Olawumi (2015), Qureshi et al. (2016) and Kadraoui et al. (2020); discovered no significant ($p>0.05$) difference in the body weight of male and female quail.

Also, the outcome of the current research showed that the average BW of a matured quail within the three AEZs are 187.68g, 211.66g, and 218.32g for Coastal Savanna, Semi-deciduous Forest, and Transitional Zone respectively. The BW of quails was significantly ($p<0.05$) influenced by the AEZ; the highest BW (218.32g) was recorded for quails within the Transitional Zone while the lowest BW (187.68g) was observed for matured quails within the Coastal Savanna AEZ. Likewise, AEZ influenced most of the linear body traits that were measured; quails in the Transitional Zone and Semi-deciduous Forest recorded slightly higher values than those in the Coastal Savanna. The differences in BW and linear body traits of quails in the different AEZs could be due to differences in environmental factors and management practices such as nutrition, housing, animal welfare as well as breeding practices. Thus, quails within the Transitional Zone, which had the highest BW (218.32g), may have been improved through selective breeding and good management practices.

Table 1 Means ± standard deviations of morphometric traits of local quail populations as influenced by sex and AEZ

Factor/Trait	BW (g)	SL (cm)	BG (cm)	BL (cm)	WL (cm)	N
AEZ						
Coastal Savanna	187.68 ± 1.79^{a}	3.81 ± 0.02^{b}	8.87 ± 0.02^{a}	17.64 ± 0.06^{b}	9.73 ± 0.04^{a}	180
Semi-deciduous	211.66 ± 1.79^{b}	3.96 ± 0.02^{a}	8.87 ± 0.03^{a}	18.13± 0.06^{a}	9.57 ± 0.04^{b}	180
Transitional Zone	218.32 ± 1.79^{c}	3.95 ± 0.02^{a}	8.87 ± 0.23^{a}	18.20 ± 0.06^{a}	9.57 ± 0.04^{b}	180
Sex						
Female	209.25 ± 1.24^{a}	3.92 ± 0.02^{a}	8.85 ± 0.01^{a}	18.01 ± 0.04^{a}	9.66 ± 0.03^{a}	360
Male	202.52 ± 1.75^{b}	3.90 ± 0.01^{a}	8.88 ± 0.01^{a}	17.98 ± 0.05^{a}	9.58 ± 0.04^{a}	180

BW: Body Weight, BL: Body length, BG: Body girth, SL: Shank length, WL: Wing Length, AEZ: Agro-ecological zone, N: Number of observations

^{abc}Means that do not share a letter down a column are significantly different (*p<0.05*)

Correlation among morphometric traits

Table 2 shows the Pearson correlation among the morphometric traits; low negative and low positive significant (*p<0.05*) correlation coefficients noticed among the various traits measured. The highest association was found between BW and BL, which implies that improvement in BL could lead to a subsequent improvement in BW. Also, a low negative correlation was observed between BW and some linear body traits (SL and BG) at maturity. This means that increase in BW does not result in an appreciable increase in the linear body measurement. This outcome disagrees with the study of Chimezie et al. (2022) who observed a significantly (*p<0.05*) high and positive correlation coefficient between body weight and other linear measurements in both sexes of quails. The difference between the current study and that of Chimedzie et al. (2022) could be due to the age of the quails used in the study. Chimedzie et al. (2022) considered the productive and reproductive performance from day-old chick to 8 weeks old while the present study involved only matured quails from 6 weeks old and beyond.

Table 2. Pearson correlations among morphometric traits

Trait	BW (g)	SL (cm)	BG (cm)	BL (cm)
SL (cm)	0.043			
BG (cm)	0.022	-0.023		
BL (cm)	0.224	0.050	0.052	
WL (cm)	-0.098	0.023	-0.015	-0.086

Pearson correlation is significant at (*p<0.05*)

Multivariate differentiation and classification of local quail populations in Ghana

Most discriminating traits

According to Obike et al. (2016), morphometric measurement is useful in identifying differences between quail populations. Therefore, morphometric measurements are helpful for the discrimination of local quail populations. Table 3 shows the proportion of total variance attributable to the discriminating abilities of the various traits. Lower values of Wilks lambda show higher discriminating power; BW had the highest discriminating abilities followed by BL, SL and WL, which conform to the study of Ogah (2013). In other words, the results of the stepwise discriminant analysis show that BW was the most vital trait in discriminating between the quails in the three AEZs with an F-value of 83.45. Also, BL was the second trait with the highest discriminating power with an F-value of 27.27, which is closely followed by SL (15.86) and WL (4.28). BG recorded the least discriminating power with an F-value of 0.01. The findings of the present work are similar to that of Obike et al. (2016) who reported that these morphometric traits (BW, BL, SL and WL) were priority traits in the discrimination of Japanese quail populations.

Table 3. Discriminating power of morphometric traits

Trait	Wilks λ	F-statistics	Sig.
BW	0.76	83.45	0.00
SL	0.94	15.86	0.00
BG	1.00	0.01	0.99
BL	0.91	27.27	0.00
WL	0.98	4.28	0.00

Partitioning of variances

Table 4 shows the Eigenvalues, cumulative variance, canonical correlation and standardized discriminant coefficient depicting the total variations explained among the local quail populations within the three AEZs by each canonical variable. Two discriminant functions were extracted whose significance was tested with the Wilks' Lambda (0.68, 0.99) and Chi-square (206.39, 1.80) and provided validity for the canonical discriminant analysis. The first canonical variable explained 99.3% of the total variation, which can be considered reasonably high whiles the second canonical variable, explained only 0.7% of the total variation.

Table 4. Total sample standardized canonical coefficient, canonical correlation and total variations explained by each canonical variable

Traits	Linear discriminant coefficient 1	Linear discriminant coefficient 2
BW	0.82	-0.53
BL	0.47	0.18
BG	0.04	-0.02
SL	0.35	0.85
WL	-0.03	0.05
Eigenvalue	0.47	0.003
% of variance	99.30	0.7
Cumulative variance explained	99.30	100
Canonical correlation (r)	0.56	0.058
Chi-square	206.39	1.80
Wilk's Lambda	0.68	0.99
P-value	0.00	0.41

It is apparent that for the traits used in this study, only Can 1 is essential to explain the total variation (100%) among the populations. As indicated earlier, the canonical discriminant analysis showed how each morphometric trait contributes to the total variation of the population; BW and BL had the highest weight in discriminating among the population. Also, the two canonical variables presented high weight for BW showing its importance in both discriminating and classifying the population. In all, linear discriminant coefficient 1 had higher power than linear discriminant coefficient 2, therefore, Can1 serves as the most discriminating variable in distinguishing between the local quail population. The addition of each independent variable measured forms the canonical variate. The first canonical variate had a significantly higher canonical correlation (r=0.56) with the population while the second canonical variate had a weak correlation (r=0.058) with the population, which indicates that Can 1 explained much of the total variation among the three populations. The variations in morphometric traits among the three AEZs could be due to different strains of quails and also the development of adaptive features for survival and reproduction within each AEZ. This observation was similarly reported by Ogah (2013).

Classification of local quails into various populations

Except for those in the Semi-deciduous Forest, the discriminant analysis classified the majority of the individual local quails into their respective populations. The Coastal Savanna had the local quail population with the highest similarity (71.7%) with an error level of 28.3%, while the Semi-deciduous Forest had the lowest (12.2%) with an error level of 87.8%. Furthermore, with an error level of 41.1%, 58.9% of the local quail population was correctly classified into the Transitional Zone. The high similarity (low differences) of quails in the Coastal Savanna suggest that the birds may have been obtained from similar sources; the effect is that there could be intermixing (genetic exchange) and high inbreeding levels within the population. This could result in inbreeding depression and therefore farmers within this agro-ecological zone should be advised to obtain breeding stock from different AEZs, other than the Coastal Savanna. On the other hand, the low similarity of birds in the Semi-deciduous Forest indicates the birds may be unique from different sources and therefore within population improvement can be encouraged. The findings of the studies were consistent with the findings of Himel et al. (2020) who reported similar trend in Japanese quail population.

Table 5. Classification matrix of the number of observations and percentage classified into populations of local quail based on morphometric traits

Populations (P)	P1	P2	P3
P1 (Coastal Savanna)	129 **71.7**	50	31
P2 (Semi-Deciduous)	44	22 **12.2**	43
P3 (Transitional Zone)	7	108	106 **58.9**
Prior probability	0.33	0.33	0.33
Error level for Populations	28.3	87.8	41.1

Differentiation of population

The Table 6 indicate the pairwise squared Mahalanobis distance and probability values which shows the degree of differentiation of the local quail population within the three AEZs. Seemingly, quails within the Semi-deciduous Forest and the Transitional Zone were closest (0.085) whiles the largest evaluated Mahalanobis distance (D^2) was found between the Coastal Savanna and the Semi-deciduous Forest (2.46). The shortest distance between the Semi-deciduous Forest and the Transitional Zone could be an indication of indiscriminate movement of quails by farmers between the two AEZs expedited by geographical proximity; hence resulting in inbreeding. The largest estimated distance between the Transitional Zone and the Coastal Savanna could be due to reduced interbreeding activities between the two populations, as these are separated by wide geographical area.

Table 6. Pairwise Square Mahalanobis distance between local quail populations based on morphometric traits

	P1	P2	P3
P1(Coastal Savanna)		1.75	2.46
P2(Semi Deciduous Forest)			0.085
P3(Transitional zone)			

CONCLUSION

The results of the study showed that sex did not significantly ($p>0.05$) influence the linear body traits of quails but it significantly ($p<0.05$) affected body weight; indicating that BW exhibited sexual dimorphism. Also, the highest association was found between BW and BL, which implies that improvement in BL could lead to a subsequent improvement in BW. Discriminant analysis showed that BW was the most vital trait in discriminating the three populations and hence should be a priority trait in differentiation studies of quail populations. Furthermore, it is evident that for the traits used in this study, only Can 1 is essential to explain the total variation (100%) among the population. The Coastal Savanna had the local quail population with the highest similarity (71.7%); implying that quails within this AEZ may have come from related sources with similar genetic identity while the Semi-deciduous Forest had the lowest (12.2%) similarity, which could be due to the fact that the birds may have come from different sources. The largest Mahalanobis distance (D^2) was found between the Coastal Savanna and the Semi-deciduous Forest (2.46) and therefore an inter-breeding program could be designed for quails selected from these two AEZs. Further studies could consider molecular characterization of local quail populations within the three AEZs to provide additional information for decision making in designing of appropriate breed improvement scheme for quails.

ACKNOWLEDGMENTS

This project was fully funded by the Samuel and Emelia Brew-Butlar School of Graduate Studies research Grant of the University of Cape Coast. The authors also appreciate all quail farmers within the three AEZs for making their birds available for this research especially to Prof. Michael Osei Adu, the Coordinator of the AG Carson Technology Center, University of Cape Coast.

AUTHOR CONTRIBUTIONS

Conceptualization: [Richard Asante Botwe, Julius Kofi Hagan, Samuel Ayeh Ofori, Bismark Yeboah]; *Methodology*: [Richard Asante Botwe, Julius Kofi Hagan, Samuel Ayeh Ofori, Bismark Yeboah]; *Formal analysis and investigation*: [Richard Asante Botwe, Julius Kofi Hagan, Samuel Ayeh Ofori, Bismark Yeboah]; *Writing - original draft preparation*: [Richard Asante Botwe, Samuel Ayeh Ofori]; *Writing - review and editing*: [Richard Asante Botwe, Julius Kofi Hagan, Samuel Ayeh Ofori]; *Funding acquisition*: [Richard Asante Botwe]; *Resources*: [Richard Asante Botwe, Bismark Yeboah]; *Supervision*: [Julius Kofi Hagan, Samuel Ayeh Ofori].

COMPETING INTERESTS

The authors declare they have no conflict of interest. The manuscript has not been submitted for publication in other journal.

ETHICS APPROVAL

Not applicable

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