

A COMPARISON OF PHENOTYPIC CHARACTERISTICS OF ZAMBIAN INDIGENOUS CHICKENS IN AGROECOLOGICAL REGIONS II AND III OF ZAMBIA

Simushi Liswaniso^{1*}

¹ Department of Animal Sciences, School of Agricultural Sciences, University of Zambia, Lusaka 32379, Zambia

ORCID ID: <https://orcid.org/0000-0003-0809-0699>

*Corresponding author: smliswaniso@gmail.com

Received July 14, 2026	Revised September 10, 2026	Accepted September 23, 2026	Published September 30, 2026
DOI: https://doi.org/10.35219/jards.2026.3.05	Article type Research Article	Pages 70-82	

Abstract

Understanding the phenotypic diversity of chickens within a population is essential for designing improvement and conservation programs. This study compared the phenotypic characteristics of chickens in agroecological regions II and III of Zambia. A total of 794 mature indigenous chickens were evaluated for body weight, linear body measurements, and qualitative morphological traits. These chickens were also observed for plumage colour, skin colour, shank colour, comb type, earlobe colour, and eye colour. Results showed that males had significantly higher body weights and all linear body measurements ($p < 0.001$), and this sexual dimorphism was more pronounced in AER II than in AER III. Chickens in AER II had significantly higher body weights (1.78 kg) than those in AER III (1.55 kg) ($p < 0.01$). Principal component analysis revealed a clear difference between the two regions, despite considerable overlap, indicating that agroecological regions influenced the phenotypic characteristics of chickens. All linear body measurements were positively and significantly correlated with body weight in both regions ($p < 0.01$). Significant differences ($p < 0.001$) were observed in eye colour, comb type, skin colour, plumage colour, earlobe colour, and shank colour ($p < 0.05$) between AER II and AER III. However, eye colour showed the strongest association with agroecological region (Cramer's $V = 0.421$). The current study revealed notable phenotypic variation in qualitative and quantitative traits among Zambian indigenous chickens across regions. These findings provide baseline phenotypic information to support breeding, conservation, and genetic improvement of Zambian indigenous chickens.

Keywords: chicken breeding; indigenous chickens; linear body measurements; phenotypic characterization; sexual dimorphism; village chickens

1. Introduction

Indigenous chickens are integral to rural livelihoods in Zambia, contributing to household food security, income generation, and improved nutrition. They represent a substantial proportion of the national poultry population and are commonly kept by smallholder farmers due to their adaptability to low-input production systems, efficient utilization of locally available feed resources, and resilience to challenging environmental conditions (Harrison et al., 2024; Liswaniso et al., 2023). Despite their significance, indigenous chicken populations in Zambia have received limited attention in structured

breeding and conservation programs, thereby resulting in insufficient data on their diversity and production potential across various ecological settings.

Phenotypic characterization is recognized as a critical initial step in the identification, conservation, and improvement of animal genetic resources. Morphological and morphometric traits provide essential data for assessing variation within and between populations, identifying unique ecotypes, and establishing selection criteria for breeding programs (Chebo et al., 2023). In indigenous chickens, traits such as body weight, linear body measurements, plumage colour, comb type, skin colour, and shank pigmentation are frequently used to describe population diversity and adaptation to local production environments (Liswaniso et al., 2023; Moono et al., 2025). Collecting such baseline information is critical in developing countries, where molecular characterization is often constrained by financial and technical limitations.

Environmental conditions are major determinants of phenotypic trait expression in indigenous livestock populations. Variations in rainfall, temperature, vegetation, and management systems contribute to differences in growth performance, body conformation, and other morphological characteristics among chickens raised in diverse ecological contexts (Kebede et al., 2023). Comparative analysis of indigenous chicken populations across distinct agroecological zones facilitates a deeper understanding of phenotypic diversity within local genetic resources. However, since phenotypic variation results from both environmental and genetic factors, phenotypic observations alone are insufficient to fully elucidate the mechanisms underlying population differentiation.

Recent developments in ecological niche modeling, species distribution modeling, and landscape genomics have improved the capacity to investigate relationships between environmental conditions and genetic adaptation in indigenous livestock populations (Gebru et al., 2022; Kebede et al., 2024; Kebede et al., 2023). These methodologies demonstrate that environmental predictors can define ecotypes and clarify adaptive variation with greater precision than conventional agroecological classifications. Nonetheless, phenotypic characterization remains a fundamental step for documenting existing diversity and generating baseline data to inform future genomic and ecological research (Mogano et al., 2024).

In Zambia, earlier studies described the physical traits and production systems of indigenous chickens in certain districts and communities only (Liswaniso et al., 2024; Liswaniso et al., 2023; Moono et al., 2025). But there is little comparative data on chickens in Agroecological Regions II and III. These regions have different rainfall, vegetation, and farming potential, which can affect chicken traits (Makondo & Thomas, 2020). Understanding how chickens vary in these areas is important for creating breeding, conservation, and management plans that fit local needs.

This study compared the physical characteristics and body measurements of indigenous chickens raised in Agroecological Regions II and III of Zambia. It examined differences in body size and shape, as well as other traits, and explored how these measurements relate. The goal was to provide baseline data for future breeding, conservation, and genetic improvement efforts.

2. Material and Methods

2.1 Study location

The study was conducted in Zambia's Agroecological Region II (AER II) and Agroecological Region III (AER III). These regions were selected because they differ substantially in annual rainfall, vegetation cover, and agricultural production potential according to Makondo and Thomas (2020), thereby representing contrasting production environments for indigenous chickens. Specifically, three provinces (Eastern, Central, and Southern) represented AER2, with five districts sampled in each province: Nyimba and Katete in Eastern, Kabwe and Chikankata in Central, and Kalomo in Southern. For AER III, three provinces were considered: Northern, Muchinga, and Copperbelt. Districts sampled from this region were five in total: Mambwe and Mungwi in Northern Province, Chinsali in Muchinga Province, and Masaiti in Copperbelt Province. A visualization of the sampled areas is shown in Figure 1.

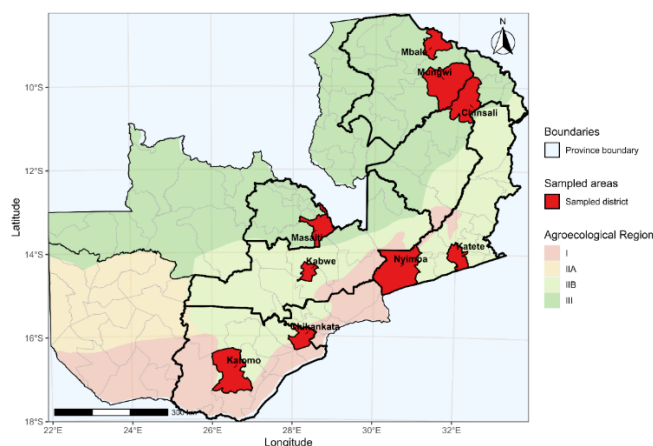


Figure 1. Map of Zambia showing the agroecological regions of Zambia and the sampled areas.

Source: Author designed

2.2 Sampling and sample size

For this study, households and chickens were sampled using a multistage sampling approach. A total of 794 sexually mature chickens were sampled, comprising 560 hens and 234 cocks. These were distributed as 442 in AER II (244 hens and 98 males) and 452 in AER III (316 hens and 136 cocks). Sample sizes differed across regions because the number of eligible birds in sampled households varied by location. Districts and sampling locations were purposively selected to represent the target agroecological regions. Households keeping indigenous chickens were then identified and sampled. When more than one eligible sexually mature chicken was available, individuals were selected using simple random sampling. Sexually mature chickens were defined as birds older than five months and exhibiting secondary sexual characteristics.

2.3 Data collection

Each sampled chicken was phenotyped individually using FAO procedures (FAO, 2012) as applied by Liswaniso et al. (2024). Briefly, body weight was measured in kg using an electronic balance, and linear body measurements (in centimeters) were taken with a tailor's measuring tape. These included corpus length (CL), chest circumference (CC), thigh length (TL), thigh circumference (TC), shank circumference

(SC), shank length (SL), keel length (KL), and body length (BL). The specific body reference points for each linear measurement were as described in the FAO guide for phenotypic characterization of farm genetic resources (FAO, 2012). Qualitative traits, including plumage colour, skin colour, shank colour, comb type, earlobe colour, and eye colour, were observed and recorded in accordance with the FAO (2012) guide. All measurements and observations were taken by the same trained observer.

2.4 Data analysis

Data were entered and cleaned in Excel. MINITAB V21 was used for all analyses. An independent-samples t-test was used to compare the means of quantitative traits between regions and sexes, and the results are presented as means $\pm$ standard error of the mean (SEM). Statistical significance was declared at $P < 0.05$. Data normality was assessed using the Anderson–Darling test, and homogeneity of variances was evaluated using Levene's test prior to conducting parametric analyses. Qualitative traits were presented as frequencies per AER. Pearson correlation coefficients were calculated to assess relationships among body weight and linear body measurements. To identify which body measurements were key predictors of body weight, a stepwise regression was used, and the regression analysis included only independent variables that demonstrated significant correlations with live weight, prioritizing those with the highest correlation coefficients when generating predictor models. The linear model used was as follows:

$$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6$$

Where $Y = BW$, the dependent variable; β_0 is the intercept; and X_1 – X_8 represent the independent variables CL, CC, TL, TC, SC, SL, KL, and BL, respectively. β_1 to β_8 denote the regression coefficients for the independent variables X_1 through X_6 , and ϵ represents the residual error.

3. Results

3.1 Quantitative trait variation and sexual dimorphism

Table 1 presents the mean weights and linear body measurements of chickens across the two agroecological regions of Zambia studied. The study found that, in both regions, males generally had higher values for all traits than females. Sexual dimorphism was evident across all traits, with body weight showing the highest values. Overall, sexual dimorphism was greater in chickens sampled from AER II than in those from AER III.

Table 1. Mean ($\pm$ SD) and sexual dimorphism index (SDI) for quantitative traits of Zambian indigenous chickens in agroecological regions II and III

Trait	AER II		SDI (%)	AER III		SDI (%)
	Female	Male		Female	Male	
BW (kg)	1.56 $\pm$ 0.36	2.31 $\pm$ 0.58	48.63	1.41 $\pm$ 0.26	1.89 $\pm$ 0.44	33.6
CL (cm)	21.29 $\pm$ 1.81	24.40 $\pm$ 2.23	14.6	20.49 $\pm$ 1.46	22.45 $\pm$ 2.74	9.55
CC (cm)	28.99 $\pm$ 3.04	33.39 $\pm$ 4.39	15.17	27.37 $\pm$ 2.96	30.12 $\pm$ 3.41	10.03
TL (cm)	13.85 $\pm$ 1.61	15.86 $\pm$ 1.86	14.52	12.70 $\pm$ 1.56	14.51 $\pm$ 1.82	14.29
TC (cm)	9.08 $\pm$ 1.41	11.28 $\pm$ 1.81	24.2	8.74 $\pm$ 1.50	10.04 $\pm$ 1.76	14.84
SC (cm)	4.06 $\pm$ 0.44	4.90 $\pm$ 0.75	20.72	4.21 $\pm$ 0.75	4.78 $\pm$ 0.77	13.5
SL (cm)	10.09 $\pm$ 1.19	12.31 $\pm$ 1.81	22.05	9.47 $\pm$ 1.47	11.52 $\pm$ 1.39	21.64
KL (cm)	11.15 $\pm$ 1.07	13.15 $\pm$ 1.48	17.9	10.67 $\pm$ 1.19	12.36 $\pm$ 1.54	15.87
BL (cm)	40.71 $\pm$ 2.99	47.07 $\pm$ 3.63	15.64	39.47 $\pm$ 3.38	44.47 $\pm$ 4.56	12.69

Source: Authors' calculations based on research data.

Note: Values are presented as mean $\pm$ standard deviation (SD). BW = body weight; CL = corpus length; CC = chest circumference; TL = thigh length; TC = thigh circumference; SC = shank circumference; SL = shank length; KL = keel length; BL = body length; AER = agroecological region; SDI = sexual dimorphism index. $SDI (\%) = [(male\ mean - female\ mean) / female\ mean] \times 100$. Positive SDI values indicate larger measurements in males than in females.

The SDI revealed regional variation in sexual dimorphism across the two regions (Table 1). Body weight showed the highest sexual dimorphism. The thigh circumference, shank length, and shank circumference relatives showed high sexual dimorphism, ranking second, third, and fourth, respectively. The corpus length and thigh length exhibited the lowest sexual dimorphism across the agroecological regions, indicating relatively smaller sex-related differences.

3.2 Effects of agroecological region and sex on quantitative traits

This study revealed that both sex and agroecological region affected the body weight and linear body measurements of Zambian indigenous chickens (Table 2). Chickens in AER II generally had higher body weight and linear body measurements than those in AER III. Sex had the most significant effects on all the studied quantitative traits, with males outperforming females. The largest regional differences were observed for chest circumference (30.25 vs. 28.18 cm), body length (42.53 vs. 40.84 cm), and body weight (1.78 vs. 1.55 kg), all of which were higher in AER II than in AER III. Significant AER $\times$ sex interactions were observed for body weight, corpus length, chest circumference, thigh circumference, shank circumference, and body length.

Table 2. Effects of agroecological region, sex, and their interaction on quantitative traits of Zambian indigenous chickens

Trait	Agroecological region		Sex		P-value		
	AER II	AER III	Male	Female	Region	Sex	AER $\times$ Sex
BW (kg)	1.78	1.55	2.07	1.47	<0.001	<0.001	<0.001
CL (cm)	21.95	21.04	23.27	20.84	<0.001	<0.001	<0.001
CC (cm)	30.25	28.18	31.48	28.07	<0.001	<0.001	0.001
TL (cm)	14.43	13.25	15.08	13.2	<0.001	<0.001	0.455
TC (cm)	9.71	9.13	10.56	8.89	<0.001	<0.001	<0.001
SC (cm)	4.3	4.38	4.83	4.15	0.089	<0.001	0.01
SL (cm)	10.73	10.09	11.86	9.74	<0.001	<0.001	0.435
KL (cm)	11.73	11.18	12.7	10.88	<0.001	<0.001	0.126
BL (cm)	42.53	40.84	45.56	40.01	<0.001	<0.001	0.015

Source: Authors' calculations based on research data.

Note: Estimated marginal means are presented for each agroecological region and sex. P-values are based on a two-way analysis of variance evaluating the main effects of agroecological region and sex, and their interaction (AER $\times$ Sex). BW = body weight; CL = corpus length; CC = chest circumference; TL = thigh length; TC = thigh circumference; SC = shank circumference; SL = shank length; KL = keel length; BL = body length; AER = agroecological region.

3.3 Principal component analysis of quantitative traits

Table 3 presents a principal component analysis of body weight and linear body measurements of indigenous chickens from Zambia in AER II and AER III. Two principal components with eigenvalues greater than 0.8 were extracted. Together, they accounted for 72.16% of the phenotypic variation in the studied indigenous chickens. The first principal component (PC1), with positive loadings on all traits, accounted for 63.17%. The second principal component (PC2) accounted for 8.99% of the total variance and had the highest positive loadings on shank circumference. Communalities in this study ranged from

0.638 to 0.811, with body weight and shank circumference showing the highest communalities of 0.811, while thigh circumference exhibited the lowest (0.638).

Table 3. Principal component loadings and communalities (h^2) of quantitative traits of Zambian indigenous chickens

Trait	PC1	PC2	Communality (h^2)
BW (kg)	0.871	-0.227	0.81
CL (cm)	0.807	-0.006	0.652
CC (cm)	0.778	-0.285	0.686
TL (cm)	0.801	0.221	0.69
TC (cm)	0.789	0.123	0.638
SC (cm)	0.688	0.58	0.811
SL (cm)	0.819	0.055	0.674
KL (cm)	0.87	0.081	0.764
BL (cm)	0.709	-0.516	0.769
Eigenvalue	5.685	0.809	
Variance explained (%)	63.17	8.99	
Cumulative variance (%)	63.17	72.16	

Source: Authors' calculations based on research data.

Note: Principal component analysis (PCA) was performed using the correlation matrix of quantitative traits. Loadings represent the correlation between each trait and the corresponding principal component. Communality (h^2) represents the proportion of variance in each trait explained by the retained principal components. BW = body weight; CL = corpus length; CC = chest circumference; TL = thigh length; TC = thigh circumference; SC = shank circumference; SL = shank length; KL = keel length; BL = body length; PC = principal component.

The principal component analysis (PCA) biplot (Figure 2) indicated modest phenotypic differentiation between Zambian indigenous chickens from AER II and AER III. Although the two populations overlapped considerably, chickens from AER II predominantly clustered on the positive side of PC1, which was associated with higher body weight, body length, chest circumference, corpus length, and keel length. Conversely, chickens from AER III showed a broader distribution along PC2 and were more closely associated with shank circumference and thigh length.

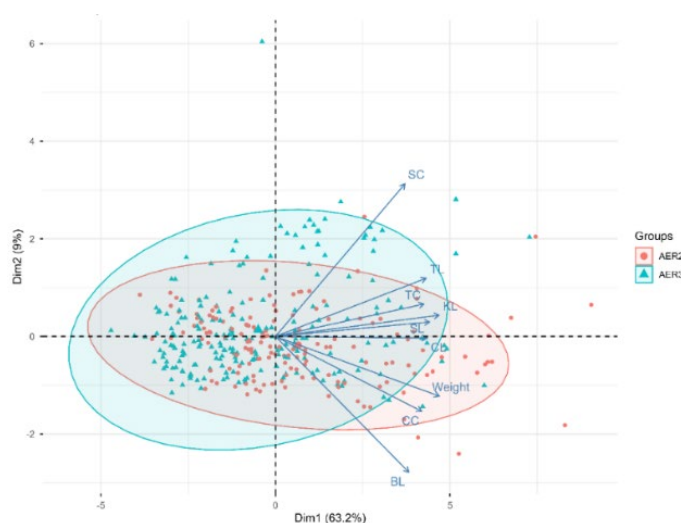


Figure 2. Principal component analysis (PCA) biplot showing the distribution of indigenous chickens from Agroecological Region II (AER II) and Agroecological Region III (AER III) based on quantitative traits.

Source: Authors' calculations based on research data.

3.4 Relationships among quantitative traits

Table 4 presents correlations between body weight and linear body measurements in chickens across AER II and AER III. All traits showed significant positive correlations across all agroecological regions studied. Body weight showed moderate-to-strong positive associations with all linear body measurements, with the strongest correlations for keel length ($r = 0.795$) in AER II and for chest circumference ($r = 0.680$) in AER III.

Table 4. Correlation analysis of body weight and linear body measurements of Zambian indigenous chickens. The top is for AER III and the bottom is for AER II

	Weight	CL	CC	TL	TC	SC	SL	KL	BL
Weight		0.647**	0.680**	0.471**	0.584**	0.427**	0.562**	0.625**	0.633**
CL	0.724**		0.513**	0.605**	0.605**	0.585**	0.534**	0.655**	0.399**
CC	0.717**	0.596**		0.485**	0.534**	0.384**	0.562**	0.578**	0.451**
TL	0.642**	0.512**	0.533**		0.616**	0.652**	0.758**	0.707**	0.404**
TC	0.706**	0.562**	0.536**	0.620**		0.553**	0.616**	0.615**	0.345**
SC	0.713**	0.533**	0.471**	0.544**	0.508**		0.582**	0.700**	0.210**
SL	0.689**	0.571**	0.603**	0.597**	0.521**	0.485**		0.712**	0.444**
KL	0.795**	0.636**	0.652**	0.504**	0.641**	0.626**	0.631**		0.467**
BL	0.721**	0.629**	0.589**	0.505**	0.564**	0.463**	0.637**	0.726**	

Source: Authors' calculations based on research data. BW = Body weight, CL = Corpus length, CC = Chest circumference, TL = Thigh length, TC = Thigh circumference, SC = Shank circumference, SL = Shank length, KL = Keel length, BL = Body length. **Significant at $P < 0.01$.

3.5 Prediction of body weight from linear body measurements

Table 5 presents stepwise multiple regression models for predicting body weight from linear body measurements. The results identified keel length and chest circumference as key predictors of body weight for Zambian indigenous chickens in AER II and AER III, respectively. In AER II, the subsequent inclusion of corpus length, shank circumference, chest circumference, thigh circumference, body length, and shank length improved the model's predictive ability, yielding a final R^2 of 0.826 and an adjusted R^2 of 0.822. In AER III, the inclusion of body length, corpus length, thigh circumference, thigh length, keel length, and shank length improved the model's predictive ability, yielding a final R^2 of 0.699 and an adjusted R^2 of 0.694.

Table 5. Pairwise regression predicting body weight of Zambian indigenous chickens from Linear body measurements

Regression Equation	R^2	Adjusted R^2
AER II		
Weight = $-1.639 + 0.291KL$	0.632	0.631
Weight = $-2.508 + 0.205KL + 0.084CL$	0.712	0.71
Weight = $-2.607 + 0.155KL + 0.070CL + 0.238SC$	0.76	0.757
Weight = $-2.760 + 0.116KL + 0.053CL + 0.230SC + 0.033CC$	0.79	0.788
Weight = $-2.651 + 0.090KL + 0.044CL + 0.211SC + 0.030CC + 0.058TC$	0.81	0.807
Weight = $-2.916 + 0.062KL + 0.036CL + 0.220SC + 0.027CC + 0.054TC + 0.020BL$	0.82	0.817
Weight = $-2.859 + 0.057KL + 0.033CL + 0.213SC + 0.024CC + 0.052TC + 0.017BL + 0.033SL$	0.826	0.822
AER III		
Weight = $-0.690 + 0.080CC$	0.462	0.461
Weight = $-1.571 + 0.058CC + 0.036BL$	0.595	0.594
Weight = $-2.139 + 0.042CC + 0.030BL + 0.060CL$	0.671	0.668
Weight = $-2.044 + 0.037CC + 0.030BL + 0.049CL + 0.032TC$	0.681	0.679
Weight = $-2.023 + 0.039CC + 0.031BL + 0.056CL + 0.042TC - 0.027TL$	0.69	0.686
Weight = $-1.990 + 0.036CC + 0.030BL + 0.051CL + 0.038TC - 0.038TL + 0.035KL$	0.696	0.692

Weight = $-1.956 + 0.035CC + 0.029BL + 0.052CL + 0.035TC - 0.046TL + 0.029KL + 0.021SL$	0.699	0.694
---	-------	-------

Source: Authors' calculations based on research data.

Note: BW = Body weight, CL = Corpus length, CC = Chest circumference, TL = Thigh length, TC = thigh circumference, SC = Shank circumference, SL = Shank length, KL = Keel length, BL = Body length, AER = Agroecological region, R^2 = Coefficient of determination

3.6 Distribution of qualitative traits across agroecological regions

Table 6 presents qualitative traits across the two agroecological regions. Significant differences were observed in eye colour, comb type, skin colour, plumage colour, earlobe colour, and shank colour ($P < 0.05$) between AER II and AER III. Eye colour showed the strongest association with agroecological region (Cramer's $V = 0.421$). This was followed by shank colour ($V = 0.341$), plumage colour ($V = 0.269$), and earlobe colour ($V = 0.251$). By contrast, skin colour and comb type exhibited the weakest associations with agroecological regions, respectively. Furthermore, mixed plumage colour, white skin, and a single comb type were dominant in both regions. Variations in the frequency distributions of shank, earlobe, and eye colors were also evident between the two agroecological regions.

Table 6. Distribution of qualitative traits and association with agroecological region in indigenous chickens

Trait	Category	AER II % (N)	AER III % (N)	χ^2	<i>P</i> value	Cramer's <i>V</i>
Plumage colour	Black	72 (21.1)	13.27 (60)	57.34	< 0.001	0.269
	Brown	46 (13.5)	27.88 (126)			
	Mixed	180 (52.6)	36.73 (166)			
	Other	2 (0.6)	7.08 (32)			
	White	42 (12.3)	15.04 (68)			
Skin colour	White	334 (97.7)	88.05 (398)	23.65	< 0.001	0.173
	Yellow	8 (2.3)	11.95 (54)			
Shank colour	Black	18 (5.3)	2.21 (10)	92.1	< 0.001	0.341
	Green	46 (13.5)	19.47 (88)			
	Grey	76 (22.2)	15.93 (72)			
	Grey-blue	70 (20.5)	3.1 (14)			
	White	62 (18.1)	36.28 (164)			
	Yellow	70 (20.5)	23.01 (104)			
Comb type	Cushion	4 (1.2)	3.54 (16)	9.93	0.019	0.112
	Pea	8 (2.3)	0.44 (2)			
	Rose	16 (4.7)	4.42 (20)			
	Single	314 (91.8)	91.59 (414)			
Earlobe colour	Blue	8 (2.3)	0 (0)	50.05	< 0.001	0.251
	Red	130 (38.0)	47.79 (216)			
	Red-white	150 (43.9)	24.34 (110)			
	White	54 (15.8)	27.88 (126)			
Eye colour	Brown	116 (33.9)	10.18 (46)	140.78	< 0.001	0.421
	Orange	172 (50.3)	87.17 (394)			
	Pearl	20 (5.8)	2.65 (12)			
	Red	34 (9.9)	0 (0)			

Source: Authors' calculations based on research data. Values are presented as frequency (% within agroecological region). χ^2 = Chi-square statistic; V = Cramer's V effect size. N is sample size

4. Discussion

4.1 Quantitative trait variation and sexual dimorphism

Male chickens generally had significantly higher body weight and linear body measurements than females ($p < 0.05$), confirming pronounced sexual dimorphism in the studied populations. These observations are not unique to this study, as similar findings have been reported in indigenous chickens elsewhere. For instance, Liswaniso et al. (2023), Badubi et al. (2006), Chekilie et al. (2025), and Begna et al. (2025) reported higher body weights and larger body dimensions in male chickens than in female chickens. The larger body weight and body dimensions in males are largely due to physiological and hormonal differences that promote greater growth and skeletal development. Sexual dimorphism was highest for body weight in both AER II and AER III, whereas thigh circumference, shank length, and shank circumference also showed relatively high dimorphism indices. Notably, sexual dimorphism was more pronounced in AER II than in AER III, suggesting that environmental conditions may affect the degree to which sex-related differences are expressed. Taken together, these findings demonstrate that both sex and the production environment contribute to variation in the phenotypes of Zambian indigenous chickens.

4.2 Effects of agroecological region and sex on quantitative traits

This study revealed that the agroecological region affected the size of Zambian indigenous chickens. Notably, chickens from AER II were heavier than those from AER III. Furthermore, chickens from AER II dominated their AER III counterparts in most linear body measurements. These findings align with earlier reports by Bekele et al. (2022) and Muluneh et al. (2023), who reported significant differences in body weight and morphometric traits of Ethiopian chickens across regions and districts. The larger differences in body weight and morphometry between the two agroecological regions may be attributed to environmental differences. These environmental differences may affect the available scavenging feed resource base and management practices, which could explain differences in chicken size between regions. Nonetheless, not all traits were affected by agroecological region; shank circumference showed no significant differences between regions. This indicates that traits do not respond to environmental differences in the same way. However, the observed differences in phenotypic traits between the two agroecological regions show that agroecological conditions affect phenotypic expression in Zambian indigenous chickens.

4.3 Principal component analysis of quantitative traits

This study further employed principal component analysis to summarize the quantitative traits of the Zambian indigenous chickens. The first two principal components accounted for over 72% of the variation, signifying that a relatively small number of underlying dimensions explained most of the observed variation in the morphometric traits. PC1 alone accounted for over 63% of the total phenotypic variation and had the highest loadings on body weight, keel length, shank length, corpus length, and thigh length. This indicated that the first principal component largely captured overall body size and growth-related traits. Similar findings were reported by Maharani et al. (2021) in indigenous chickens in Indonesia, where the first of the two principal components accounted for over 70% of the phenotypic variation, with high loadings on body weight and several other linear body measurements. Oguntunji et al. (2023) also reported similar findings in Nigerian chickens. The dominance of body

weight, keel length, shank length, corpus length, and thigh length in PCA 1 indicates that these traits are key drivers of the variations in morphometrics in the current study populations.

The PCA visualization showed a clear difference between chickens from the two regions, despite considerable overlap between the two populations. This indicates that agroecological regions affect the phenotypic characteristics of Zambian indigenous chickens. Nonetheless, the two populations still share considerable similarities in their morphometrics. Mustafa et al. (2021) also showed that morphometrics could distinguish populations into distinct groupings, while noting that such groupings could be jointly influenced by genetic and non-genetic factors. Similarly, another study by Markos et al. (2024) reported that chickens from different agroecological regions of Ethiopia could be differentiated by their morphological traits. However, the overlap observed in the current study may suggest that these populations share a common ancestry, similar production systems, and ongoing genetic exchange. The PCA results confirm that body-size traits are the main drivers of variation among Zambian indigenous chickens and that phenotypic variation is primarily influenced by agroecological regions, without fully separating these chicken populations into distinct groupings.

4.4 Relationships among quantitative traits

The Pearson correlation coefficient revealed that in both AER II and AER III, body weight significantly correlated with all linear body measurements. In AER II, the highest correlation was with keel length, and in AER III, it was with chest circumference. Several other studies have reported similar findings. Nweke-Okorochoa et al. (2022) reported that body weight significantly and positively correlated with all linear body measurements in Nigerian indigenous chickens. A similar finding was reported in Sundanese native chickens (Yahia et al., 2026). These strong correlations between body weight and linear body measurements indicate that selection for any of these traits would result in a considerable increase in the body weight and size of Zambian indigenous chickens.

4.5 Prediction of body weight from linear body measurements

A pairwise regression analysis revealed that, in both agroecological regions, body weight could be predicted from a smaller set of linear body measurements. Notably, the key predictors differed between the regions, with AER II retaining keel length and AER III retaining chest circumference as the crucial predictors. This difference indicates that the relationship between body weight and linear body measurements is not uniform. Additionally, the increase in predictive model accuracy as more linear body measurements were added suggests that no single predictor of body weight in Zambian indigenous chickens can 100% predict body weight. A similar study reported by Yahia et al. (2026) also found chest circumference as a key predictor of body weight in large native Sudanese chickens. Similarly, Chimezie et al. (2025) reported keel length as a key predictor of body weight in Noiler chickens. Using path analysis in Zambian indigenous chickens, corpus length and thigh circumference were key predictors of body weight in cocks and hens, respectively (Liswaniso et al., 2020). A study by Kebede et al. (2023) confirmed that agroecological regions influence the relationship between linear body measurements and their body weights. However, predictive models that are specific to the agroecological regions would therefore be useful to small-scale farmers that wouldn't afford weighing scales.

4.6 Distribution of qualitative traits across agroecological regions

This study revealed a range of variations in the qualitative traits of Zambian indigenous chickens, indicating phenotypic diversity within this population. Specifically, eye colour, shank colour, earlobe type and colour, and plumage colour varied considerably. Several other studies have reported phenotypic diversity in similar qualitative traits, such as in Zambia (Liswaniso et al., 2024) and in Ethiopia (Mustefa et al., 2021). Considerable regional differences were observed in most of the qualitative traits studied in this study. This indicated differences in phenotypic characteristics between AER II and AER III. The discrepancies in trait prevalence reflect differences in farmers' selection preferences, environmental conditions, and genetic exchange between communities, as well as inbreeding history. Notwithstanding these differences, considerable variation was observed within populations, indicating that a wide range of qualitative traits remains preserved in Zambian indigenous chicken populations.

5. Conclusions

The present study demonstrated substantial phenotypic variation among Zambian indigenous chickens in both qualitative and quantitative traits across Agroecological Regions II and III. Sex was the most important factor affecting body weight and linear measurements, with males generally larger than females, and agroecological region also explained variation in body size and several qualitative traits. Although the relative contribution of environmental conditions, management practices, and underlying genetic diversity cannot be determined from phenotypic data alone, the differences observed are most likely due to a combination of these factors. Principal component analysis showed moderate differentiation between the two agroecological regions, but with considerable overlap suggesting the populations remain morphometrically similar but with measurable regional variation. The positive correlation of body weight with linear body measurements suggests that these traits could be used as useful selection criteria for body weight improvement in smallholder production systems.

Together, the results provide baseline phenotypic information that will underpin future conservation, genetic improvement and sustainable utilization of Zambian indigenous chicken genetic resources in Zambia.

5.1 Practical implications

Our findings suggest that improvement programs should account for agroecological variation rather than if a single selection strategy will perform equally well across production environments. Chickens raised in contrasting regions appear to respond differently to local environmental conditions, feed availability, and management systems, factors that likely influence both growth and external morphology. Selection programs based on region-specific performance would therefore be expected to retain adaptive characteristics while improving productivity. Equally important, the strong relationships between body weight and several linear body measurements indicate that simple field measurements could be used to estimate body weight with reasonable accuracy where scales are unavailable. Such approaches are particularly relevant for village production systems, where low-cost selection and recording methods remain essential.

5.2 Study limitations and future research

Interpretation of the present findings should be considered within the scope of the study. Only two agroecological regions were represented, and phenotypic measurements alone cannot distinguish

genetic differences from environmentally induced variation. Gene flow among neighboring communities, differences in farmer selection practices, disease pressure, and seasonal fluctuations in feed resources may also have contributed to the observed patterns. Future work should integrate genomic analyses with phenotypic characterization across all agroecological regions of Zambia and incorporate environmental and management variables. This would yield a better understanding of population structure, adaptive variation, and breeding potential, and would allow conservation and improvement programs to be based on both observable performance and underlying genetic diversity.

Acknowledgements

Gratitude to the field officers of the Department of Livestock Development for the support during data collection.

References

- Badubi, S., Rakereng, M., & Marumo, M. (2006). Morphological Characteristics and Feed Resources Available for Indigenous Chickens in Botswana. *Livestock Research for Rural Development*, 18.
- Begna, D., Bacha, T., Boki, S., & Bekana, K. (2025). Characterization of Indigenous Chicken Phenotypes in Liban Jawi District, Ethiopia: A Qualitative and Quantitative Analysis. *PLoS ONE*, 20. <https://doi.org/10.1371/journal.pone.0307793>
- Bekele, B., Melesse, A., Woldegiorgiss, W., & Dessie, T. (2022). Multivariate Analysis of Morphometric Traits to Differentiate the Indigenous Chicken Reared under Different Agro-Ecologies of Ethiopia. *Veterinary Integrative Sciences*, 20, 775-791. <https://doi.org/10.12982/VIS.2022.060>
- Chebo, C., Melesse, A., & Betsha, S. (2023). Morphological Descriptors of Indigenous Chickens: As a Selection Guide. *Journal of Applied Animal Research*. <https://doi.org/10.1080/09712119.2023.2274956>
- Chekilie, A., Taye, M., & Wondimagegn, K. (2025). Phenotypic Characteristics of Indigenous Chicken in Awi Zone, Amhara Regional State, Ethiopia. *Advances in Applied Sciences*, 10, 29-37. <https://doi.org/10.11648/j.aas.20251002.12>
- Chimezie, V., Ayeni, B., Akande, B., Akintunde, A., & Ademola, A. (2025). Assessment of Genetic Diversity in Funaab Alpha, Kuroiler, and Noiler Chicken Genotypes. *Egyptian Journal of Animal Production*, 62, 147-159. <https://doi.org/10.21608/ejap.2025.358142.1102>
- FAO. (2012). *Phenotypic Characterization of Animal Genetic Resources* (Vol. 11). Food and Agriculture Organization of the United Nations. <https://www.fao.org/4/i2686e/i2686e00.pdf>
- Gebru, G., Belay, G., Vallejo-Trujillo, A., Dessie, T., Gheyas, A., & Hanotte, O. (2022). Ecological Niche Modelling as a Tool to Identify Candidate Indigenous Chicken Ecotypes of Tigray (Ethiopia). *Frontiers in Genetics*. <https://doi.org/10.3389/fgene.2022.968961>
- Harrison, S. J., Moono, M. B., & Odubote, I. K. (2024). Production Systems and Management Practices of Chicken Populations in Zambia. *Sustainable Agriculture Research*. <https://doi.org/10.5539/sar.v13n1p61>
- Kebede, F. G., Derks, M. F. L., Dessie, T., Hanotte, O., Barros, C. P., Crooijmans, R. P. M. A., Komen, H., & Bastiaansen, J. W. M. (2024). Landscape Genomics Reveals Regions Associated with Adaptive Phenotypic and Genetic Variation in Ethiopian Indigenous Chickens. *BMC Genomics*, 25(1), 284. <https://doi.org/10.1186/s12864-024-10193-6>
- Kebede, F. G., Komen, H., Dessie, T., Hanotte, O., Kemp, S., Alemu, S. W., & Bastiaansen, J. W. M. (2023). Agroecologies Defined by Species Distribution Models Improve Model Fit of Genotype by Environment Interactions to Identify the Best Performing Chicken Breeds for Smallholder Systems [Original Research]. *Frontiers in Sustainable Food Systems*, Volume 7 - 2023. <https://doi.org/10.3389/fsufs.2023.1305799>

- Liswaniso, S., Mwambilwa, K., Odubote, K., & Tyasi, T. L. (2024). Zambian Indigenous Chicken Genetic Resources: Phenotypic Characteristics and Their Production Systems among Small-Scale Farmers. *Frontiers in Veterinary Science*. <https://doi.org/10.3389/fvets.2024.1429869>
- Liswaniso, S., Qin, N., Shan, X., Sun, X., & Xu, R. (2023). Phenotypic Characterization of Indigenous Free Range Chickens in Kalomo, Zambia. *The Journal of Animal and Plant Sciences*. <https://doi.org/10.36899/JAPS.2023.3.0658>
- Liswaniso, S., Tyasi, T. L., Qin, N., Sun, X., & Xu, R. (2020). Assessment of the Relationship between Body Weight and Linear Body Measurement Traits of Zambian Indigenous Free-Range Chickens Using Path Analysis. *Sylwan*, 164(11), 465-485.
- Maharani, D., Mustofa, F., Sari, A., Fathoni, A., Sasongko, H., & Hariyono, D. N. H. (2021). Phenotypic Characterization and Principal Component Analyses of Indigenous Chicken Breeds in Indonesia. *Vet World*, 14(6), 1665-1676. <https://doi.org/10.14202/vetworld.2021.1665-1676>
- Makondo, C., & Thomas, D. (2020). Seasonal and Intra-Seasonal Rainfall and Drought Characteristics as Indicators of Climate Change and Variability in Southern Africa: A Focus on Kabwe and Livingstone in Zambia. *Theoretical and Applied Climatology*, 140. <https://doi.org/10.1007/s00704-019-03029-x>
- Markos, S., Belay, B., & Dessie, T. (2024). Morphometric Differentiation of Three Chicken Ecotypes of Ethiopia Using Multivariate Analysis. *PLoS ONE*, 19, e0295134. <https://doi.org/10.1371/journal.pone.0295134>
- Mogano, R. R., Mpofu, T. J., Mtileni, B., & Hadebe, K. (2024). South African Indigenous Chickens' Genetic Diversity, and the Adoption of Ecological Niche Modelling and Landscape Genomics as Strategic Conservation Techniques. *Poultry Science*. <https://doi.org/10.1016/j.psj.2024.104508>
- Moono, M. B., Mwenya, W. N. M., Odubote, I. K., & Mwale, M. (2025). Characterization of Qualitative and Quantitative Traits of Five Strains of Zambia Indigenous Chicken. *University of Zambia Journal of Agricultural and Biomedical Sciences*. <https://doi.org/10.53974/unza.jabs.8.3.1341>
- Muluneh, B., Taye, M., Dessie, T., Wondim, D. S., Kebede, D., & Tenagne, A. (2023). Morpho-Biometric Characterization of Indigenous Chicken Ecotypes in North-Western Ethiopia. *PLoS ONE*, 18(6), e0286299. <https://doi.org/10.1371/journal.pone.0286299>
- Mustefa, A., Kenfo, H., Belayhun, T., Hailu, A., & Assefa, A. (2021). Morphometric and Morphological Characterization of Chicken Resources Adapted to Pastoral and Agropastoral Areas of Southern Ethiopia. *Genetic Resources*, 2(4), 72-84. <https://doi.org/10.46265/genresj.NDFM2712>
- Nweke-Okorocho, O. G., Agaviezor, B., & Chineke, C. (2022). Phenotypic and Genetic Correlations between Body Weight and Linear Body Measurements of Nigerian Local and Improved Chickens. *IJISRT Journal*, 423-426.
- Oguntunji, A., Putra, W., & Ajala, F. (2023). Principal Component Analysis of Morphostructural Indices of Noiler Chickens. *Scientific Papers Animal Science and Biotechnologies*, 54.
- Yahia, A., Elshaikh, M., Babiker, M., & Badri, T. (2026). Body Weight Prediction from Linear Body Measurements in Sudanese Large Native Chicken. *Turkish Journal of Agriculture - Food Science and Technology*, 14, 172-176. <https://doi.org/10.24925/turjaf.v14i1.172-176.8271>