World Journal of Advanced Research and Reviews

eISSN: 2581-9615 CODEN (USA): WJARAI

Cross Ref DOI: 10.30574/wjarr

Journal homepage: https://wjarr.com/

(RESEARCH ARTICLE)

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Assessment of phenotypic diversity and morphometry of indigenous chickens in Kabwe District, Zambia

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World Journal of Advanced Research and Reviews, 2024, 24(02), 631–638

Publication history: Received on 16 September 2024; revised on 30 October 2024; accepted on 02 November 2024

Article DOI: https://doi.org/10.30574/wjarr.2024.24.2.3278

Abstract

This study characterized Zambian indigenous chickens' phenotypes and morphometric traits in Kabwe District, Zambia, to create a base for breeding program development. To achieve this, 206 hens and 228 cocks we sampled in Kabwe district. Each sampled chicken was phenotyped for 4 qualitative traits: ear lobe color, shank color, comb type, and eye color. Individual linear body measurements were recorded from each chicken using a tailor's tape in centimeters, which included body length (BL), chest circumference (CC), corpus length (CL), keel length (KL), shank circumference (SC), shank length (SL), thigh circumference (TC), and thigh length (TL). The findings showed that the predominant phenotypes were single comb type (98.91%), orange eyes (80.44%), white shanks (33.70%), and red-white earlobe color (50%). The average body weight was 1698.24 g, which showed a significant positive correlation ($p<0.05$) with all linear body measurements. For both sexes, body weight correlated positively with all linear measurements, except in males where body length showed a nonsignificant negative correlation. A stepwise regression analysis indicated that chest circumference, keel length, body length, shank circumference, thigh circumference, and corpus length (CL) are significant predictors of body weight (R^2 = 76.90%, $P < 0.05$). Additionally, the CHAID data mining algorithm identified keel length as the primary predictor of body weight, with corpus length and thigh length also contributing, achieving an R^2 of 61.20%. These findings provide valuable insights for instituting chicken breeding programs aimed at enhancing productivity and selection decisions.

Keywords: Bodyweight; CHAID data mining algorithm; Correlation; Phenotypic characterization of chickens; Linear body measurements; Stepwise regression analysis

1. Introduction

Indigenous chicken production is a common venture, particularly among rural communities. Indigenous chickens are preferred due to their ability to mitigate household hunger and poverty (1, 2). These chickens are more prevalent among small-scale rural households due to their disease tolerance, their ability to endure challenging environments, and their relatively good growth rate (1, 3).

There are 1.6 million homes that raise indigenous chickens in Zambia, with a total population of 21 million indigenous chickens (Zambia Livestock Census, 2022). It was recently reported that in Zambia, consumption and income are the main reasons for producing these chickens (4). Despite these chickens' importance to households, their performance is

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low; specifically, they have lower survival rates and low body weights (1, 4, 5). It is characteristic of indigenous chickens to have late maturity, low egg weights, small clutch sizes, and small body proportions (6, 7).

Although indigenous chickens possess notable advantages and potential for thriving in tropical environments, they have faced challenges in meeting the nutritional needs of expanding populations due to their inferior performance compared to exotic chickens. However, their performance can be enhanced by breeding programs focusing on improving the traits of economic importance. Dahloum (8) reported that, for a breeding program to succeed, it is necessary to have these chickens characterized first. The first step in characterizing chickens is identifying chicken populations based on their phenotypic traits that are advantageous for breeding and selection (9). Therefore, the characterization of indigenous chickens is crucial for any improvement programs.

Other than linear body measurements, body weight is a critical trait in characterizing chickens. This is because, in some markets, chickens are priced on a per weight basis. However, the weighing scales required to measure this trait may not always be available to small-scale farmers or when available may not be easy to maintain. In this study, we used stepwise regression and the Chi-square automatic interaction detector (CHAID) algorithm to develop models farmers can use to estimate the body weight of chickens from linear body measurements. CHAID is one of the data mining algorithms used recently in animal sciences and involves three key stages: merging, splitting, and stopping. These stages are used repeatedly to build a decision tree with multiple splits. The merging stage, in particular, distinguishes CHAID algorithms from others in the construction of a regression tree (10).

Despite studies conducted on Zambian indigenous chickens in Northern, Muchinga, and Luapula provinces (4), the phenotypic characteristics of Zambian indigenous chickens in Kabwe, the provincial main city of the Central Province of Zambia, remain unknown. In particular, the use of stepwise regression and CHAID to predict body weight is also still limited. This study aimed to characterize the phenotypic and morphometric traits of indigenous chickens in Kabwe District and develop models to predict body weight, thus contributing to more effective selection and breeding decisions.

2. Materials and methods

2.1. Study location

The study was conducted in Mpima, a region within Kabwe District in Zambia's Central Province, which is in an agroecological zone (II) characterized by moderate rainfall, ideal for agricultural activities.

2.2. Sample size

Since the total chicken population in Kabwe was unknown at the time of the study, for this study the sample size was determined using the approach described by Thrusfield (11) applying the formula

$$n=Z^2P(1-P)/d^2$$

Where;
n represents the sample size,
Z corresponds to the Z-score for the desired confidence level,
P is the anticipated prevalence, and
d is the precision.

The sample size was estimated to be 81, based on an estimated 70% prevalence (indicating that about 70% of the population is involved in agriculture and related activities), with a 95% confidence interval and a 10% margin of error. However, 434 chickens comprising 206 females and 228 males were sampled. The sampling of the chickens was random among mature chickens that small-scale farmers extensively reared with minimal housing and inputs in terms of feed supplementation and medicines.

2.3. Data collection

Chickens were individually phenotyped for 8 linear body measurements that included the corpus length (CL), chest circumference (CC), thigh length (TL), thigh circumference (SC), shank circumference (SC), shank length (SL), keel length (KL), and body length (BL). An electronic weighing scale with a 0.01kg sensitivity was used to measure the live body weights of the chickens. A tailor’s tape was utilized to take linear body measurements as we described previously (3). Qualitative traits were obtained by observation according to the FAO guidelines (12).

2.4. Data analysis

The collected data were summarized as descriptive analysis using the MINTAB V18 statistical package. A student T-test was used to compare the means of the descriptives between the hens and cockerels. Pearson correlation coefficients between the linear body measurements and body weight were calculated. For the regression analysis, the model $Y = a + b_1X_1 + ... + b_nX_n$ was employed where; Y was the dependent variable in this case body weight, a = Intercept, b_1-b_n = regression coefficients of the independent variables; (linear body measurements), X_1-X_n = Independent variables (linear body measurements).

3. Results and discussion

Owing to the limitation of relevant information to warrant the successful implementation of breeding programs in Kabwe district, this study aimed to identify phenotypic traits and measure morphometric parameters of indigenous chickens to assess their suitability for breeding programs.

3.1. Phenotypic characteristics of Indigenous chickens in Kabwe

Table 1 shows the common phenotypes of Zambian indigenous chickens found in Kabwe district. This study revealed the presence of white, green, gray-blue, yellow, and black shanks. However, the white shanks were the most common, seconded by the black shanks. This finding agrees with what was reported in the Democratic Republic of Congo (13). However, a similar study from Kalomo in Zambia reported grey-blue as the most common shank color (3). Furthermore, Maharani (14) reported yellow as the most common shank color in a study conducted on Indonesian indigenous chickens. Shank color is a complicated trait influenced by multiple genes and genetic pathways, primarily involving melanin production (15). Therefore, several other factors that influence these pathways may be implicated in the differences in shank colors reported in this study and those reported elsewhere.

Table 1 Common phenotypes of Zambian indigenous chickens in Kabwe district of Zambia

Character	Percent (%)
Shank color	
White	33.70
Green	2.17
gray-blue	20.65
Yellow	15.22
Black	28.26
Comb type	
Single	98.91
Pea	1.09
Ear lobe color	
Red	35.87
White	14.13
Red-white	50.00
Eye color	
Orange	80.44
Brown	17.39
Pearl	2.17

This study revealed only two comb types: single and pea comb types. However, most sampled chickens had a single comb type, with less than 2% having a pea comb type. Similar results were reported in a study by Onasanya (16). The dominance of the single comb type in the study area suggests a potential adaptability and survival advantage (16). This is because chicken combs serve as a crucial thermo-regulatory structure for managing heat stress in birds (17).

This study revealed the existence of three (3) earlobe colors, namely the red, white, and red-white earlobe colors. However, the red-white earlobe colors dominated, with half of the sampled chickens having red-white earlobe colors. These results agree with the findings of Falculan (18), who found red and red/white earlobe colors to be the most prevalent. However, Maharani (14) reported that red earlobes were the most common in Indonesian local chicken breeds. The visible vascularization of epidermal cells contributes to the red earlobes found in most chicken breeds (19).

The study identified the presence of three (3) eye colors: brown, orange, and pearl color types. However, the orange color dominated, with a prevalence of over 80% of the sampled chickens having orange colors. This is similar to the color dominant in northern Zambia (4). Pigmentation in birds, including eye pigmentation, results from synthesizing two types of melanin: brown/black eumelanin and yellow/red pheomelanin (19).

3.2. Descriptive statistics

Table 2 shows the descriptive statistics of Zambian indigenous chickens in Kabwe. The results showed significant ($p<0.05$) sexual dimorphism in the body weight and all linear body measurements, with cockerels reigning superior over hens. While the body weight of the male reported in this study is less than that reported in southwest Ethiopia, the hens in the current study were heavier than the Ethiopian hens (20). Similarly, Brito (21) also reported sexual dimorphism in linear body measurements of Portuguese Autochthonous hen breeds. The sexual dimorphism could be as a result of the differences in the genetics between the cockerels and hens where males tend to grow relatively fast and bigger.

Table 2 Descriptive statistics of Zambian Indigenous chickens

Parameter	Cockerels	Hens	Overall Mean ± SEM	P value
Body Weight (g)	1986.47	1623.22	1782.49 ± 33.54	<0.000
Corpus Length (cm)	23.03	21.7	22.29 ± 0.18	<0.000
Chest Circumference (cm)	31.29	30.07	30.60 ± 0.16	<0.000
Thigh Length (cm)	15.36	13.21	14.15 ± 0.08	<0.000
Thigh Circumference (cm)	10.99	9.95	10.40 ± 0.09	<0.000
Shank Circumference (cm)	4.54	3.79	4.12 ± 0.03	<0.000
Shank Length (cm)	12.56	11.26	10.96 ± 0.06	<0.000
Keel Length (cm)	12.56	11.26	11.83 ± 0.08	<0.000
Body Length (cm)	44.64	40.97	42.58 ± 0.17	<0.000

SEM means mean standard error

3.3. Pearson correlation analysis

Table 3 shows a Pearson correlation analysis of the Zambian indigenous chickens in Kabwe. All linear body measurements positively and significantly ($p<0.01$) correlated with body weight in hens. Likewise, in male chickens, all linear body measurements positively and significantly ($p<0.01$) correlated with body weight except for the body length, which was insignificantly and negatively correlated to body weight ($p>0.05$). The positive correlation between body weight and most linear body measurements agrees with several previous studies (22, 23, 24). However, the magnitude of the correlation may vary due to some genetic and nongenetic factors. This positive correlation could imply that selection for any of these linear body measurements would result in a corresponding increase in body weight.

Table 3 Correlation Analysis of Zambia Indigenous chickens in Kabwe district (the top is for hens and the bottom is for the cockerels)

	BW	CL	CC	TL	TC	SC	SL	KL	BL
BW		0.558**	0.777**	0.224**	0.551**	0.454**	0.302**	0.594**	0.470**
CL	0.581**		0.648**	0.104	0.442**	0.353**	0.359**	0.500**	0.611**
CC	0.758**	0.468**		0.220**	0.618**	0.509**	0.286**	0.668**	0.481**
TL	0.486**	0.527**	0.530**		0.150*	0.361**	0.439**	0.306**	0.147*
TC	0.868**	0.732**	0.740**	0.549**		0.678**	0.11	0.588**	0.407**
SC	0.840**	0.541**	0.572**	0.289**	0.820**		0.279**	0.532**	0.421**
SL	0.586**	0.330**	0.615**	0.522**	0.574**	0.605**		0.297**	0.298**
KL	0.853**	0.500**	0.677**	0.243**	0.777**	0.828**	0.545**		0.376**
BL	-0.023	0.103	0.135*	0.153*	0.09	-0.093	0.232**	0.193**	

**=significant (p<0.01), *=significant (p<0.05), 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

3.4. Establishment of the optimum regression equation using stepwise regression

Table 4 Stepwise Regression

Female	**R^2**	**P value**
BW=-2155.09+125.67CC	0.604	<0.000
BW= -2699.53+115.93CC+20.44BL	0.616	0.003
BW=-2952.69+103.40CC+19.026BL+61.06KL	0.624	0.013
Males		
BW=-1895.33+353.26TC	0.753	<0.000
BW=-2890.36+210.89TC+203.73KL	0.834	<0.000
BW=-1064.55+200.82TC+226.71KL+-44.89BL	0.859	<0.000
BW=-2130.17+124.53TC+273.4KL+-54.14BL+112.69TL	0.883	<0.000
BW=-2327.21+111.37TC+253.51KL+-53.89BL+94.93TL+27.26CC	0.888	0.002
BW=-2727.11+87.29TC+222.8KL-46.74BL+95.61TL+32.1CC+125.21SC	0.890	0.036
Overall		
BW=-2332.9+347.76KL	0.610	<0.000
BW=-3548.12+220.69KL+88.84CC	0.716	<0.000
BW=-3626.67+114.91KL+89.35CC+319.23SC	0.749	<0.000
BW=-3465.92+107.4KL+76.78CC+230.66SC+65.15TC	0.758	<0.000
BW=-2984.17+116.99KL+80.01CC+230.79SC+65.48TC+-16.4BL	0.763	<0.000
BW=-3015.69+116.2KL+77.57CC+230.09SC+45.94TC+-18.5BL+18.44CL	0.769	<0.000

BW = bodyweight, KL=Keel length, CC = Chest circumference, SC = shank circumference, TC = thigh circumference, BL = body weight, CL = corpus = corpus length.

This study further sought to assess how body weight can be predicted from linear body measurements using stepwise regression and the results are in Table 4. In hens, the most optimum model retained chest circumference, body length, and keel length and this significant (p<0.05) model accounted for 62.4% of the total variation in the body weight. On the contrary, stepwise regression retained more linear body measurements in the optimum model for cockerels, which indicated that more linear body measurements in cockerels were significant <0.05) in estimating the body weight. The model contained thigh circumference, keel length, body length, thigh length, chest circumference, and shank circumference. This model was significant (p<0.05) in predicting the body of cockerels and accounted for 89% of the variations in body weight. The final model to predict the body weight of both cockerel and hen in Kabwe was also significant (p<0.05) and accounted for 76.90% of the variations in the body weight. This model contained keel length, chest circumference, shank circumference, thigh circumference, body length, and corpus length.

A study by Bila (24) in broilers developed models with body girth, body length, shank circumference, and shank length for cocks and a model with body girth, body length and shank circumference for hens. Another study established models to predict body weight, which included wing length, beak length, back length, and tail-to-back length (25). Taken together, the findings of this study and those reported in other studies suggest that linear body measurements can be relied on to predict body weight.

3.5. Chi-square automatic interaction detection (CHAID) model

This study went further to use the CHAID data mining algorithm to develop a model that predicts body weight from linear body measurements and this model is depicted in Figure 1. The CHAID algorithm with a 100:50 parent-to-child ratio revealed 11 nodes with R^2=61.20%. Of the 11 nodes, 8 nodes namely nodes 2, node 3, node 4, node 6, node 8, node 9, node 10, and node 11 were terminal nodes indicating that they couldn't be split any further.

CHAID revealed keel length was the most critical body measurement in predicting body weight. The corpus length and thigh circumference were also important linear body measurements detected by CHAID as they were identified in the second and third levels, respectively. Node 0 with a predicted body weight of 1782.49 g was split into 4 groups (adj p<0.000) based on their keel length. Chickens with keel length less or equal to 11.8 cm, keel length between 11.8 and 13.20 cm, keel length between 13.20 and 13.70 cm, and those with a keel length greater than 13.70 cm were allocated to nodes 1, node 2, node 3, node 4, respectively.

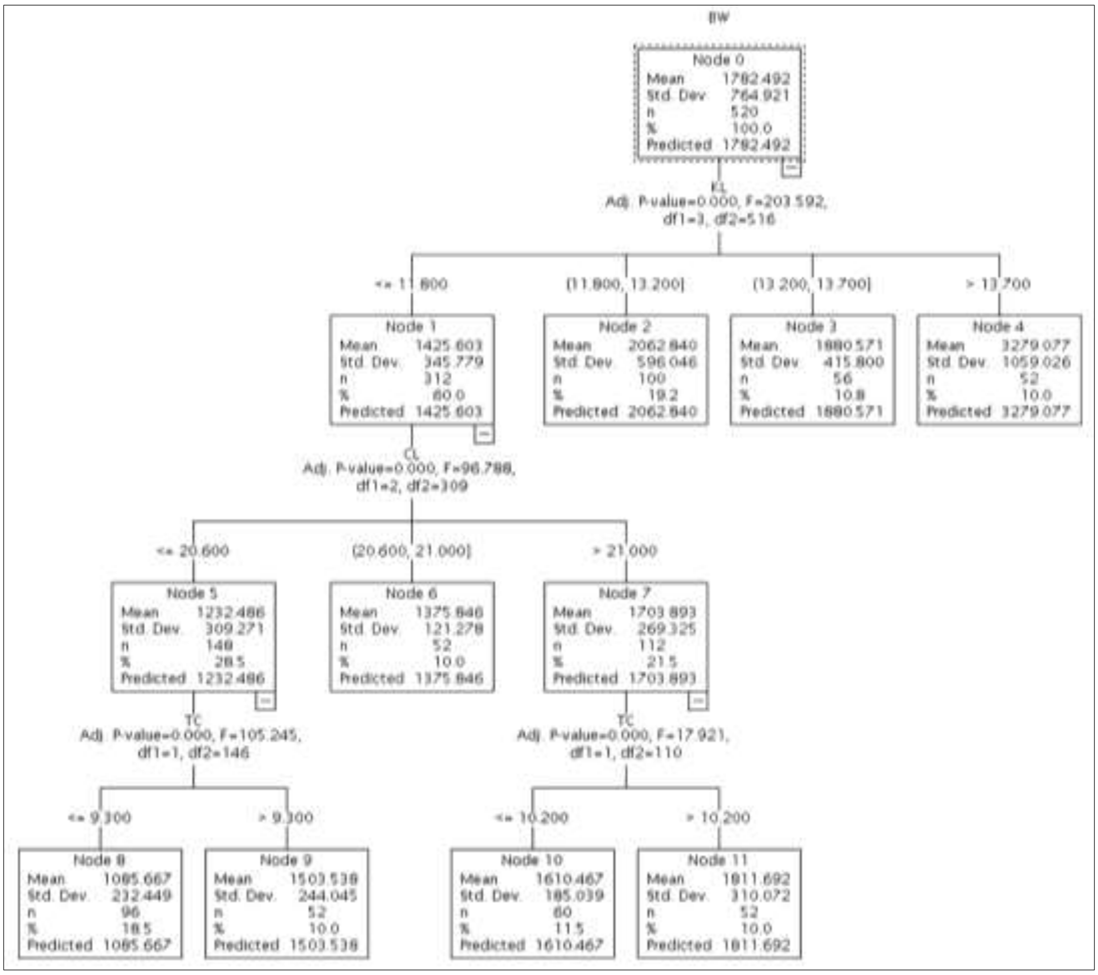

Figure 1 CHAID model to predict body weight of Zambian indigenous chickens in Kabwe

Node 1 was further split based on corpus length (adj. p value = 0.000) into 3 nodes. These were node 5 (CL≤20.60 cm), node 6 (20.60 cm < CL ≤ 21.00 cm) and, node 7 (CL ≥ 21.00 cm. Node 5 was further split based on the thigh circumference (adj. p value=0.000) into node 8 (TC ≤ 9.30 cm) and node 9 (TC > 9.30 cm). Lastly, based on thigh circumference, node 7 was split (adj p value = 0.000) into node 10 (TC ≤ 1020 cm) and node 11 (TC >10.20cm).

However, the heaviest chickens were found in node 4 and had a predicted weight of 3279.08 g while the chickens in node 8 with a predicted weight of 1085.67 cm were the lightest. This, therefore, means according to the CHAID algorithm, the heaviest Zambian indigenous chickens are those with a keel length longer than 13.70 cm and the lightest chickens are those with a keel length less than 13.70, corpus length less than 20.60 cm, and a thigh circumference of less or equal to 9.30 cm.

There is a limitation of information on the use of CHAID in predicting the body weight of indigenous chickens. CHAID has been employed to predict egg weight in Zambian indigenous chickens (26). It has been used in other livestock like in predicting the body weight of Thalli sheep (27). However, other data mining algorithms have been tried in chickens. Assan (23) using CART data mining algorithm identified body length, shank length and circumference, and body circumference as the main influencers of body weight. The same author using MARS data mining algorithm identified shank circumference as the key influencer of body weight. These differences in the main influencers of body weight may be attributed to the differences in breeds studied as Assan (23) singled out genotype among the key influencers of body weight in chickens. Different algorithms also have different prediction accuracies.

This study provides crucial insights into the phenotypic and morphometric diversity of indigenous chickens in Kabwe District, which can be directly applied to breeding programs aimed at improving chicken productivity in rural areas. The identified linear body measurements and predictive models will serve as practical tools for small-scale farmers and breeders.

4. Conclusion

This study revealed notable variations in phenotypes and associations between linear body measurements in indigenous chickens in Kabwe on which breeding programs can be based. The findings of this study may be helpful to breeders and small-scale farmers in making decisions for breeding and marketing.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

Statement of ethical approval

This study was approved by the institutional review committee under protocol number SMHS-MU1-2024-49 and all the procedures were as approved.

Authors' contribution

The SL designed the study, collected data, MM collected data and reviewed the manuscript, EN and TLT conducted data and reviewed the manuscript, JM and IMC reviewed the manuscript, and SH supervised the study and approved the final draft.

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