In-Situ Morphological Characterization of Indigenous Chicken Ecotypes in Uganda

Article *in* SSRN Electronic Journal · January 2022

DOI: 10.2139/ssrn.4068603

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Abstract

Genetic improvement of indigenous chickens (IC) is hindered by limited knowledge on the various chicken Ecotypes. This study characterized and assessed the genetic diversity of nine (9) IC Ecotypes based on phenotypic quantitative traits. A total of 576 IC (288 cocks and 288 hens) were sampled from 288 households across the 9 agro-ecological zones of Uganda. Data on linear body measurements and live-body weight of IC were collected using a field guide developed by African Union Inter-African Bureau for Animal Resources (AU-IBAR). In addition, 200 fertile IC eggs were purchased from each agro-ecological zone for the determination of weight and geometry parameters (egg length, breadth and volume). Over-all, body live weight (LWT), shank/tarsus length (SL), drumstick length (DL), thorax circumference (TC), body length (BL) of IC varied significantly ($P < 0.05$) across Ecotypes except tarsus circumference (TAC) of cocks. Cocks and hens on average weighed 2.2±0.53 and 1.6±0.58 kg respectively. On average, SL, DL, TC, BL, TAC was 9.8±1.23, 4.9±2.50, 16.2±1.63, 38.4±5.96, 24.7±4.93cm for cocks and 7.8±1.04, 3.9±0.53, 13.2±1.42, 33.8±5.29, 21.3±4.37cm for hens respectively. Body weight and all linear morphological traits except TAC were significantly ($P< 0.05$) influenced by Ecotype. Egg weight, breadth and volume varied signifcantly ($P < 0.05$) across Ecotypes except egg length. The traits and models for estimating live weight varied across Ecotypes. However, principle component analysis based on quantitative traits did not identify any distinct chicken Ecotype. The current study therefore confirms the phenotypic and more so genetic similarity across Ecotypes. The observed variation in quantitative traits across Ecotypes is ecologically induced. The difference in live weight estimation models further emphasizes the ecologically induced morphological variations across Ecotypes. Therefore, genetic improvement can be achieved through selection of superior individual chickens from across all Ecotypes.

Key words: Quantitative traits, Morphology, Ecological, Diversity, Selection

1.1 Introduction

In Uganda, indigenous chickens (IC) account for 87.7% of the 47.6 million total chicken population and produce 80% of the 907 million eggs produced [1]. IC are predominantly reared by subsistence resource-constrained farmers under the scavenging system, occasionally supplemented with local cereal grains and households own a flock size of 28 chickens on average [2], [3]. IC continue to support the social and economic wellbeing of many rural households through provision of income, meat and are part of many other social functions [3], [4]. IC play a pivotal role in nutrient utilization and recycling through scavenging and thus enhance performance of livestock-crop mixed farming systems [2]. In light of the harsh effects of climate change, indigenous chickens adapt well and over-come the challenges of water scarciry, declining feed resources, increased temperature and high incidence of diseases and parasites. Irrespective of the harsh conditions and constraints, IC are more beneficial and their profit margins are favourable given the low inputs under village conditions compared to commercial egg or meat type chickens [5].

In spite of the advantages associated with IC, their innate productive and reproductive performance has consistently remained low. In an attempt to increase their productivity, IC are at risk of genetic erosion resulting from their substitution or crossbreeding with imported breeds [6]. As such, the potential of IC in fighting hunger, poverty and attainment of sustainable development has not been fully exploited. In an effort to exploit the full potential of IC, the global plan of action for Animal Genetic Resources (AnGR) highlights the need for countries to characterize, establish diversity, distribution and determination of their comparative performance as the first strategic step towards improvement of IC genetic resources [7].

In an effort to trace the origin and diversity of IC, archaeological, historical and molecular approaches have been used to determine their entry points and distribution routes in Africa [8], [9]. All approaches concur with the fact that repeated introduction of chickens in Africa from multiple sites in Asia occured at different points via both water and land [9]. The decendants of chickens in East Africa and Uganda in particular are believed to have entered Africa through North Africa, around present Egypt and disepersed Southwards along the Nile Valley to Nubia [10]. These chickens are thought to have originated from Indus valley of Asia [11]. The second point of entry is the East African coast as a result of the India Ocean tradea and just like other crops and livestock, chickens were introduced in Africa [10]. These points of entry were furthur used by [12] to categorise African chickens into Cluster one (Northern and Central African chickens) and Cluster two (East African chickens). Overtime, chickens were dispersed in-wards through different nonlinear routes into the interior of Africa [9]. In East Africa and Uganda in particular, archaeological evidence traces presence of chickens at Kibiro between 1780 to 1880AD [13].

Traditionally, Ugandan IC have been categorized and identified based on the ecological zones of origin [4], [19]. Recently, IC have been characterized on the basis of phenotype, use and performance [4]. The high levels of phenotypic diversity across IC provides an opportunity for genetic improvement through identification and selection of highly performing breeding cocks and hens [4], [20]. The reported phenotypic diversity of Ugandan chickens is based on data collected from within the same or a few Ecotypes and does not follow the ecological zoning approach of categorizing chickens [4], [19]. To date, no comprehensive phenotypic and morphological studies have been carried out to confirm presence of distinct chicken Ecotypes. In addition, use of phenotypic traits is subjective, not confirmatory and necessitates a quantitative method of assessing diversity. Therefore, the aim of this study was to characterize and assess the genetic diversity of IC Ecotypes based on quantitative phenotypic traits.

1.2 Materials and methods

1.2.1 Study area

The study was conducted in nine agro-ecological zones of Uganda (Figure 1). The agro-ecological zones and their corresponding Ecotypes were; West Nile (Madi), Acholi (Acholi), Lango (Lango), Teso (Nteso) and Busoga (Nsoga), Buganda (Ngada), Bunyoro (Nyoro) and Ankole (Ankole). In each agro-ecological zone, two districts and two sub-counties per district with the highest indigenous chicken population were selected based on the livestock census of [21]. The study was approved by Gulu University Research Ethics Committee (GUREC-2020-18). The research protocol was also registered with the Uganda National Council for Science and Technology (UNCST) for final clearance (NO. A154ES).

Figure 1: Map of Uganda showing agro-ecological zones and the corresponding Ecotypes

1.2.2 Sampling and sample size

A total of 576 IC (288 cocks and 288 hens) were sampled from 288 households across the 9 agro-ecological zones of Uganda. Eight households were selected per sub-county. History of having kept indiginous chickens for a minimum of three years and ownership of a mature breeding cock were the criteria for selecting households. A minimum distance of 1km between households was maintained along transect drawn through the sub-county. In addition, 200 fresh fertile indigenous chicken eggs (1 - 5 days) per agro-ecological zone were purchased from willing households. Eggs were packed in paper trays and delivered to Gulu University poultry unit for determination of egg parameters (weight, length, breadth and volume) and subsequent artificial incubation.

1.2.3 Data collection

One mature breeding cock and hen per household were selected for quantitative morphometric body assessment. Data on linear body measurements (shank/Tarsus Length = SL; Tarsus circumference = TAC, Drumstick length = DL, Thorax circumference = TC, Body length = BL; Wattle length = WL; Neck length (NL) = NL; Comb height = CH; Comb length = CL; Head length = HL; Wing span = WAPN; Wing length = WL and Beak length = BKL) and live-body weight=LWT were collected using a field guide developed by African Union Inter-African Bureau for Animal Resources [22] as shown in Figure 2. A tailors measuring tape (cm) was used to measure the quantitative linear morphometric traits [23]. Live body weight was measured in kilograms using a hanging digital scale (WeiHeng WH-A25, China). Egg weight was measured using an analytical weighing scale (Model: FA2004, China). Egg breadth and length were measured using a digital caliper (Model: DIN 862, Vogel Germany). Egg volume, V was calculated using the following formular [24]:

$$V = 2.854LB$$

Where; L is egg length in millimeters, and B is the egg maximum breadth in millimeters.

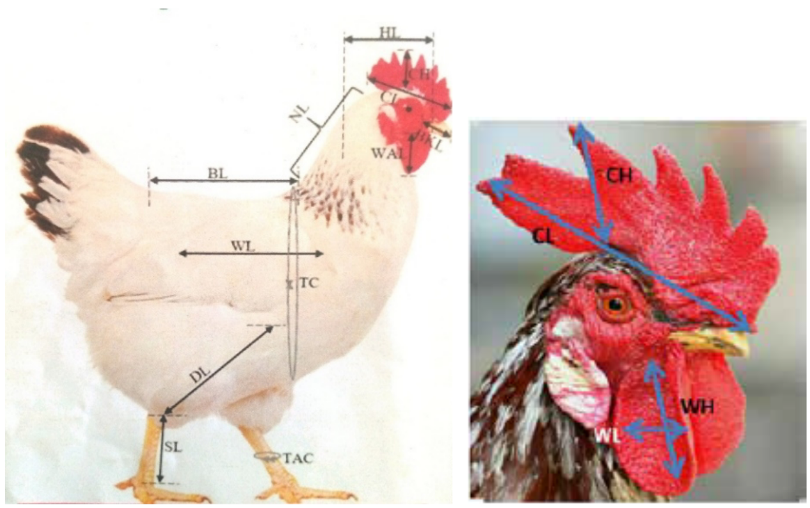

Figure 2: Illustration of morphometric measurements (AU-IBAR)

Shank/Tarsus Length (SL) =SL; Tarsus circumference =TAC, Drumstick length = DL, Thorax circumference = TC, Body length = BL; Wattle length = WL; Neck length (NL) = NL; Comb height= CH; Comb length = CL; Head length =HL; Wing span = WAPN; Wing length=WL; Beak length = BKL and Body live weight =LWT

1.2.4 Data analysis

The effect of Ecotype, sex and their interaction on quantitative traits were assessed by the general linear model package, version 3.5.1 [25]. Means were separated using the least significance difference at 5% level. The model used is shown below:

$$Y_{ijk} = \mu + A_i + B_j + (AB)_{ij} + e_{ijk}$$

(Y=measured variable-i; A=zone effect-i; B=sex effect-j AB= their interaction; e=residual error)

Pearson's correlation coefficients between live weight and selected morphometric traits were estimated and from the correlation matrix, the principal component factor analysis (PCA) was performed. The first two outstanding principal components (PC1 and PC2) were used to identify population clusters [25]. Linear morphological traits with the highest Pearson's coefficient with live body weight were used to derive power model equations for predicting live body weight of cocks and hens in each Ecotype [17].

1.3 Results

1.3.1 Effect of Ecotype, sex or their interaction on live body weight and linear morphological traits of nine indigenous chicken ecotypes

The effect of Ecotype and sex or their interaction on body weight and the five (5) linear morphological traits of nine (9) Ugandan IC Ecotypes are presented in Table 1. The average live body weight-LWT of Indigenous chicken Ecotypes was 2.2kg for cocks and 1.6kg for hens. LWT of IC varied significantly ($P < 0.05$) across Ecotypes. Teso (2.6kg) and Lango (2.55kg) Ecotypes produced the heaviest cocks while Ngisu (1.68kg), Ankole (1.71kg) and Nteso (1.7kg) Ecotypes produced the heaviest hens. Cocks (1.7kg) and hens (1.31kg) of Madi origin were the lighest Ecotype. Overall, the heaviest and lightest chicken Ecotypes originated from Teso and Madi, respectively.

The average shank length –SL across Indigenous chicken Ecotypes was 9.8cm for cocks and 7.8cm for hens. Shank length varied significantly across Ecotypes. Lango (11.3cm) and Acholi (10.7cm) cocks had the longest SL, Madi and Nyoro Ecotype cocks had the shortest SL of 9.4 and 9.3cm, respectively. Acholi (8.2cm) and Lango (8.4cm) hens had the longest SL, followed by Ngisu (10.1cm), Nganda (7.6cm) and Nyoro (7.5cm) Ecotype had the shortest SL. Over-all, Lango, Acholi and Nteso chickens had longer ($P < 0.05$) SL compared to Nsoga, Nganda, Ankole, Madi and Nyoro Ecotypes.

Over-all, tarsus circumference -TAC of Indigenous chicken Ecotypes was 4.9cm for cocks and 3.9cm for hens. Unlike cocks, the tarsus circumference of hens significantly ($P < 0.05$) varied across Ecotypes. Nyoro hens exhibited the largest tarsus circumference (4.3cm) followed Ankole (4.2cm) and Nganda (4.09cm) Ecotype. On the other hand, Madi hens exhibited the least tarsus circumference (3.4cm). On average, tarsus circumference was highest in the Nsoga, Ankole and Nyoro Ecotypes and lowest in Madi Ecotype.

Over-all, drumstick length -DL of Indigenous chicken Ecotypes was 16.2cm for cocks and 13.2cm for hens and varied significantly across Ecotypes ($P < 0.05$). DL of cocks was highest among Acholi, Ngisu and Nteso and lowest for Nyoro and Madi Ecotypes ($P < 0.05$). Nsoga, Ngisu and Nteso hens had the highest ($P < 0.05$) DL.

Generally, thorax circumference -TC of Indigenous chicken Ecotypes was 38.4cm for cocks and 33.8cm for hens and varied significantly ($P < 0.05$) across Ecotypes. The Ngisu and Nteso cocks and hens had larger ($P < 0.05$) TC compared to other Ecotypes. Ngisu and Teso had the largest TC followed by Nsoga, while Ankole Ecotype had the least ($P< 0.05$) TC.

Over-all, body length-BL of Indigenous chickens was 24.7cm for cocks and 21.3cm for hens and varied significantly ($P< 0.05$) across Ecotypes. Lango, Acholi, Nganda, Ankole and Nyoro had longer bodies (23.42, 22.6, 26.0, 25.91, 25.9cm) compared to Nteso and Ngisu Ecotypes (19.2 and 18.87cm) repectively.

The effect of sex on body weight and the five (5) linear morphological traits was significant ($P< 0.05$) across all Ecotypes. Cocks dominated hens in all the six measured traits (LWT, SL, TAC, DL, TC and BL). The effect of Ecotype on body weight and the linear morphological traits except TAC was significant ($P< 0.05$) across all Ecotypes. The Ecotype-sex interaction was only siginificant ($P< 0.05$) for LWT, DL and TC ($P < 0.01$). Shank length, tarsus circumference and body length where not influenced ($P > 0.05$) by the Ecotype-sex interaction. The Nteso cocks and hens were the heviest and Madi being the lighest(1.5kg) Ecotype produced the lightest cocks. Ngisu and Nteso Ecotype cocks and hens had longer DL but Madi chickens specifically cocks exhibited shorter DL. Ngisu and Nteso Ecotypes had similar but large thorax circumferance for both cocks and hens while Ankole Ecotype had the lowest TC.

Table 1: The effect of Ecotype, sex or their interaction on body weight and linear morphological traits of nine (9) IC Ecotypes

Trait	Sex	Ecotypes										Ecotype (E)	Sex (S)	E X S	R^2_{adj}
		Acholi	Ngisu	Nsoga	Nganda	Lango	Ankole	Nteso	Madi	Nyoro	All				
LWT/kg	C	2.39±0.53ab	2.44±0.46ab	2.17±0.57bc	2.29±0.46bc	2.55±0.47a	2.13±0.49c	2.6±0.51a	1.7±0.36d	2.2±0.41bc	2.2±0.53	***	***	*	0.33
	H	1.57±0.30ab	1.68±0.38a	1.57±0.27ab	1.52±0.33ab	1.59±0.25ab	1.71 ±1.21a	1.7±0.40a	1.31±0.23b	1.5±0.31ab	1.6±0.58				
	Aver.	1.9±0.64abcd	2.1±0.56abc	1.9± 0.53cd	1.9±0.55cd	2.1±0.61ab	1.9±0.95bcd	2.1±0.64a	1.5±0.36e	1.9±0.48d					
SL/cm	C	10.7±1.12ab	10.1±0.94bc	9.7±1.29cd	9.6±1.11cd	11.3±0.94a	9.3±1.00d	10.0±0.87c	9.4 ± 0.97d	9.3± 1.13d	9.8±1.23	***	***	.na	0.54
	H	8.2 ± 1.03a	8.04±0.67abc	7.6 ± 0.56bc	7.6±1.00c	8.4 ± 0.91a	7.59 ± 0.88bc	8.1±1.60ab	7.6±1.13bc	7.5±1.12c	7.8±1.04				
	Aver.	9.49±1.68b	9.07±1.32bc	8.63±1.436d	8.56±1.48d	9.91±1.70a	8.41±1.28d	9.02±1.59c	8.5±1.38d	8.34±1.44d					
TAC/cm	C	4.98 ± 0.76	4.67±0.64	4.47±0.57	4.88±0.69	4.83 ± 0.57	4.95 ± 0.64	4.73±0.48	4.3±0.78	4.95 ± 0.62	4.9±2.50	na	***	na	0.07
	H	3.67± 0.35cd	3.74±0.30c	3.68±0.35c	4.09±0.49b	3.74 ± 0.60c	4.21 ± 0.47ab	3.76±0.38c	3.4±0.47d	4.3 ± 0.50a	3.9± 0.53				
	Aver	4.32±0.88ab	4.21±0.69ab	4.56±0.48a	4.47±0.71ab	4.30±0.80ab	4.57±0.67a	4.2±0.65ab	3.9±0.78b	4.6±0.64a					
DL/cm	C	16.92±1.59a	17.13±0.90a	16.35±1.40ab	15.9±1.81bc	16.71 ±1.22ab	16 ±1.71bc	17±1.24a	15.3 ±1.47c	15.6±1.86c	16.2±1.63	***	***	*	0.53
	H	12.9±1.31ab	13.8±0.78a	13.7±1.91a	12.8±1.28b	12.7 ± 1.65b	13.2±1.28ab	13.7±1.57a	12.9±1.76ab	13.2±1.51ab	13.2±1.42				
	Aver.	14.9±2.47ab	15.4±1.91a	14.9± 1.87ab	14.3±2.22cd	14.8±2.48abc	14.6±2.05bcd	15.4±2.18a	14.1±1.97d	14.4±2.04cd					
TC/cm	C	38.9±4.47c	44.9±3.99a	42.2± 3.72b	34.2± 4.16c	40.4±6.24bc	34.5±3.51c	45.9±3.20a	39.5±2.95c	35.3±3.77c	38.4±5.96	***	***	**	0.52
	H	34.2±3.44b	38.7±2.40a	37.4±6.22a	31.2±3.46cd	33.6±3.80bc	31.6±3.06cd	38.1±7.21a	35.2±2.78b	31.8±3.51cd	33.8±5.29				
	Aver	36.59±4.61c	41.80±4.50a	39.77±5.64b	36.65±4.01c	37.10±6.19c	31.01±3.57d	42.0±6.80a	37.39±3.57c	36.5± 4.03c					
BL/cm	C	24.4±4.71a	20.3±2.60b	19.9±4.46b	27.9±4.18bc	25.1±3.88a	27.9±3.80bc	21.0±2.14b	23.2±3.07a	27.7±3.38bc	24.7±4.93	***	***	na	0.50
	H	20.84±6.69a	17.47±1.82b	16.86±2.36	24.3±3.04bc	21.61±2.87a	24.04±3.18bc	17.4±2.01b	20.30±2.84a	24.4±2.24bc	21.3±4.37				
	Aver	22.6±6.00ab	18.87±2.63c	18.38±3.86	26.0±4.06ab	23.42±3.83a	25.91±3.99ab	19.2±2.75c	21.74±3.27b	25.9±3.27ab					

Tarsus/shank Length = SL; Tarsus circumference =TAC, Drumstick length = DL, Thorax circumference = TC, Body length = BL; Wattle length = WL; Neck length (NL) = NL; Comb height= CH; Comb length = CL; Head length (HEDL); Wing span = WAPN; Wing length = WL; Beak length = BKL and Body live weight =LWT; ^{ns}*not significant; ***p < 0.001; ** p < 0.01; * p < 0.05.*

1.3.2 Egg weight and geometry of selected indigenous chicken Ecotypes

The weight and geometry of indigenous chicken eggs from selected ecologies are presented in Table 2. Over-all, indigenous chicken eggs weighed 41.13g. Egg weights were highest (P<0.05) in Nteso (42.73) while the Madi Ecotype (38.99g) produced the lightest eggs. All indigenous chicken Ecotypes produced eggs with similar volume except the Madi (5503mm^3) Ecotypes which produced eggs with the lowest volume (P<0.05). Egg length was similar across all Ecotypes (P>0.05). Egg breadth varied across Ecotypes with Nteso, Nsoga and Lango producing large eggs compared to Madi Ecotype (P<0.05).

Table 2: Egg weight and geometry of selected indigenous chicken Ecotypes

	Ecotypes							
Egg parameters	Nteso	Nsoga	Acholi	Lango	Madi	All	SEM	P-Value
Weight/g	42.73a	42.61a	41.65a	40.23b	38.99b	41.13	0.23	5.83x10^8
Length L/mm	52.29	52.22	52.11	52.14	51.91	52.13	0.12	0.911
Breadth/mm	38.44ab	38.64a	38.11b	38.44ab	37.11c	38.17	0.08	2.23x10^{10}
Volume V/mm^3	5740a	5768a	5672a	5723a	5503b	5684	21.36	3.39x10^4

1.3.3 Principle component analysis

The relationship among ecotypes based on morphological traits was visualised using the principal component analysis. The percentage variation explained by PC1and PC2 was 63.3% and 10.2% respectively. The first two outstanding principal components (PC1 and PC2) indicates overlapping among Ugandan chicken Ecotypes.

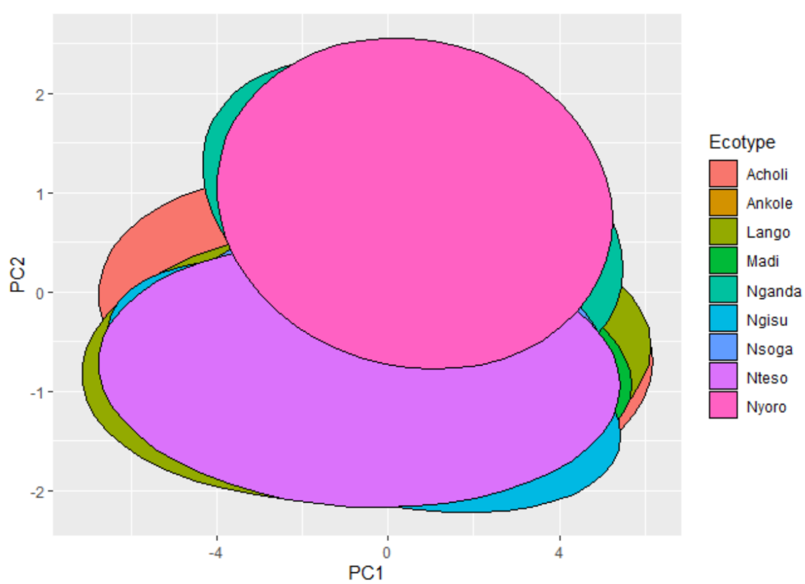

Fig.3. Principle component analysis of nine (9) IC ecotypes based on 9 morphological traits (PC1=63.3% and PC2=10.2%)

1.3.4 Ecotype diversity and live weight estimation models

The linear morphometric trait estimation models of live weight across chicken Ecotypes are presented in Table 3. Live body weight and selected linear morphometric traits had positive and strong associations across Ecotypes. The traits for estimating live weight varied across Ecotypes and sex of chicken. However, tarsus circumference was the dominant trait for estimating live weight across Ecotypes and sex.

Live weight (y) estimation of indigenous chicken Ecotypes based on linear morphometric traits (x)

Ecotype	Sex	Trait (x)	Pearson's coefficient[b]	Live weight (y) estimator across Ecotypes[c]	R^2_{adj}
Acholi	C	TAC	0.852	$y = 318.99x^{1.2512}$	0.9995
	H	SL	0.572	$y = 249.94x^{0.8731}$	0.9999
Lango	C	DL	0.579	$y= 38.505x^{1.4882}$	0.9996
	H	TAC	0.747	$y= 615.14x^{0.7222}$	0.9992
Madi	C	TAC	0.801	$y= 431.85x^{0.9402}$	0.9999
	H	CH	0.663	$y=1279x^{0.1668}$	0.8107
Ngisu	C	CL	0.820	$y= 663.65x^{0.6179}$	0.9973
	H	TAC	0.561	$y= 217.51x^{1.5492}$	0.9998
Nsoga	C	TAC	0.733	$y= 264.85x^{1.3927}$	0.9992
	H	BKL	0.598	$y= 327.08x^{1.2812}$	0.9998
Nteso	C	CL	0.807	$y= 647.12x^{0.6557}$	0.9950
	H	TAC	0.655	$y = 214.8x^{1.546}$	0.9994
Nganda	C	CH	0.617	$y = 1374x^{0.4239}$	0.9802
	H	CL	0.713	$y = 879.78x^{0.4867}$	0.9889
Nyoro	C	WL	0.657	$y=1381.3x^{0.3501}$	0.973
	H	CL	0.554	$y = 912.14x^{0.4767}$	0.9882
Ankole	C	TAC	0.686	$y = 301.62x^{1.2209}$	0.9998
	H	TAC	0.601	$y = 332.43x^{1.0698}$	1

Tarsus/shank Length (SL) =SL; Tarsus circumference =TAC, Drumstick length = DL, Wattle length = WL; Comb length = CL; BKL and Body live weight =LWT, [b]*The highest Pair-wise Pearson's correlation coefficient between trait (x) and live weight(y;)* [c]Power model equations.

1.4 Discussion

1.4.1 Live body weight and linear morphometric traits across Ecotypes

The average live body weights of 2.2±0.53 and 1.6±0.58 kg in the current study are similar to values of 2.3 and 1.6 kg for indigenous cocks and hens respectively reported by [17]. Previously, [4] reported slightly lower values of 2.1 and 1.4 kg for indigenous cocks and hens respectively. The high values of body length, drumstick length and thorax circumference reported by [17], was a result of a study involving only Nganda chicken. The disparity in morphometric traits observed between this study and others could be attributed to differences in field guidelines and individual errors when taking measurements. Live weight and morphometric traits of indigenous chickens are influenced by the nature or type of the agro-ecological zone. In the current study, ecological zones significantly affected live body weight and morphometric traits of indigenous chickens except tarsus circumference. Recently, [16] reported significant agro ecological effect on body weight and linear body traits except back length. Significant ecological effect on live body weight and morphometric traits has also been reported in indigenous chicken Ecotypes of Algeria [14] and Ethiopia [15], [18]. Indigenous chicken Ecotypes from three agro-ecological zones of Ethiopia had significant variations in body weight,wing span, comb length, beak length, breast angle and keel bone length [18]. In a recent study, chicken reared in highlands where reported to be heavier at maturiy and their survivability was higher than their counterpants in lowland ecologies. However, their egg production traits where not influenced by the agro-ecologies [26]. Chicken in highlands have been reported to perform better compared to when they are reared in lowland ecologies [27]. Similary, [28] reported low hatchabilities and survival rates in lowlands. However, body weight and egg prodoction traits were not affected by the agro ecologies. On the contraly, [29] reported higher live weight gain and more chances of survival for dual-purpose breeds reared in lowland agro ecologies.

The effect of ecology on body weight and morphometric traits is probably influenced by the variety of scavengeable feed resources, which are largely influenced by the climate, vegetation and farming systems practiced in the different zones [30], [31]. The variations in livebody weight of chicken across ecologies is as a result of genetic and environmental factors [14]. Precisely, the variation in body weight and linar morphometric traits observed among indigenous chickens was attributed to the breed and ecology or their interaction [32]. Origin of chicken Ecotypes could be another source of variation in body weight. The Madi Ecotype, West of the River Nile, which most likely belongs to Cluster one of African chickens, is the lighest of all the Ecotypes and this can be attributed to its origin [12]. The Madi Ecotype is likely to have originated from the Indus valley of Asia and entered Uganda along the River Nile to Nubia and finally into Uganda [11].

1.4.2 Egg weight and geometry across Ecotypes

The Madi Ecotype consistently produced eggs with the least weight, volume and breadth amongest all Ecotypes. The weight of Madi chicken eggs corresponds to the low weight chickens from the same ecology. Egg weight and geometry have been reported to influence hatching weight and post-hatch perfomance. Senbeta [33] reported higher hatching weights, body weight gain, feed intake and survival rates with increasing egg size. Apart from predicting hatchability and chick weight, egg geometry has an application in comparison of chicken morphology and diversity across ecologies [34]. In the current study, the variation in egg size could be an indicator of genetic variability especialy between Madi and other Ecotypes.

1.4.3 Principle component analysis

Overlapping of Ecotypes based on the first two principal components is evidence of absence of distinct chicken Ecotypes. The variations observed across the chicken Ecotypes are probably ecologically induced. As a result of human activities including trade and migration, the variation across chicken clusters reported by [12] have reduced due to planned or unplanned cross breeding. The absence of distinct chicken Ecotypes is as a result of social, economic and cultural interactions among communities across the different ecologies [35]. Crossbreeding and ecological effect are responsible for the creation of new sub-groups and phenotypic diversity among chickens Ecotypes reported by [4] and [20]. The eight indigenous chicken Ecotypes in Kenya belong to two distinct populations based on Principal Component Analysis-PC, where PC1 and PC2 contributed 27.28% and 8.97% [35]. Previously, [36] grouped Tanzanian indigenous chickens into three distinct populations with PC1 and PC2 explaining 89.9 and 5.13% of the variation respectiely.

1.4.4 Ecotype diversity and live weight estimation models

The traits and models for estimating live body weight varied across Ecotypes and sex of chicken. Similarly, [18] reported varying traits and models for estimating live weight of chicken Ecotypes across three agro-ecological zones of Ethiopia. In the present study, comb height and length were the best estimators of live weight for cocks and hens respectively for the Nganda chicken Ecotype. However, [17] reported thorax circumference as the best predictor of live weight for mature Nganda chicken Ecotype. Although chicken live body weight was generally predictable by breast angle, body length and shank circumference were specific to hens and cocks respectively [18]. Recently, [37] also indicated that body length is the best estimator of live weight among hens. High correlation coefficients of 0.70 and 0.64 between body weight and thorax circumference have been reported among Bangladesh and Ethiopian indigenous chickens [38] and [15] respectively. It is a common occurrence to have different studies presenting different traits as the best live weight estimators for one or all sexes. The potential sources of variation in traits for weight estimation is the use of different methodologies and inconsistences in measurement of linear body parts in different studies.

1.4.5 Ecotype-ecology interaction

In the current study, linear morphometric traits for estimating live weight varied across Ecotypes and sex of chicken. However, tarsus circumference was the dominant trait across Ecotypes for estimating live weight of either cocks or hens. This is because tarsus circumference did not vary significantly across ecotypes as compared to other traits. In a statistical modelling study involving indigenous female chicken, the values of body weight and length of linear body traits except back length were significantly influenced by the agro-ecologies (low land, Midland and Highlands) they occupy thus confirming Ecotype-ecology interaction [37]. Therefore, in the present study, apart from estimating body weight, the diversity in the weight estimation models is an indicator of wide morphological and consequently genetic variation within and across the chicken Ecotypes. The observed morphological variations across Ecotypes provides an opportunity for genetic improvement of indigenous chicken through selection [37].

1.5 Conclusion

On the basis of live weight and morphological traits, the current study provides no evidence of distinct IC Ecotypes. The observed variation in body weight and the morphological traits across Ecotypes is ecologically induced. Despite the similarity across Ecotypes, the Madi chicken weighs less and correspondingly produce eggs with the least weight, volume and breadth. The difference in weight estimation models further emphasizes the ecologically induced morphological variations across Ecotypes. Therefore, genetic improvement can be achieved through selection of superior individual chickens from across all Ecotypes.

Funding

This study was funded by African Union (AU) through the Native Chicken Project (AURG II-2-115-2018).

Declarations of interest

None

Author contributions

Beyihayo Geoffrey Akiiki: Conceptualization, Data collection, analysis, Compilation of initial manuscript draft. Elly Kurobuza Ndyomugyenyi & Richard Echodu: Review, Editing, Supervision Donald Kugonza: Supervision, Fund acquisition and Project administration.

Data
Genetic data and codes are available as supplementary files.

Acknowledgements
African Union (AU) is acknowledged for financing this study under the Native Chicken Project (Contract number: AURG II-2-115-2018). We are also grateful to the farmers in the participating agro-ecological zones for allowing us to use their chickens in the study.

All authors read and approved the final manuscript.

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