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Genetic variability in juvenile growth traits of Ugandan indigenous chicken populations raised under an intensive deep litter system

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Abstract. Uganda's indigenous chickens (IC) display significant phenotypic diversity in body weight (BW) and growth performance. However, there has been no study on the genetic diversity related to juvenile BW and growth performance in indigenous chicken populations (ICP), to support early selection of improved growth performance. The objective of this study was to assess the genetic variation in chicken juvenile BW and growth among selected ICP in Uganda. Three populations of IC were sourced from Apac, Lira and the National Semi-Arid Resources Research Institute (NaSARRI), as founder populations. Chicks were hatched from founder eggs, wing-banded and reared under identical conditions, in a deep litter system. Body weight was recorded weekly from hatch to four weeks of age. Hatch weight was higher ($P<0.01$) for Apac and Lira birds compared to NaSARRI. Mean Daily gain (ADG) was greatest for Lira and lowest for NaSARRI birds. The mean relative Growth Rate (RG) of chicks from Lira and Apac was comparable, but both were greater ($P<0.05$) than for NaSARRI. Broad-sense heritability estimates for BW0, BW1, BW2, BW3, and BW4 were 0.35, 0.50, 0.54, 0.47, and 0.56, respectively. Genotypic variances for BW measurements varied ($P<0.05$) among the ICP. The heritability estimates for ADG and RG were 0.41 and 0.49, respectively, with genotype variances differing significantly ($P<0.01$) across the ICP for both ADG and RG. These results demonstrate both phenotypic and genotypic variability in juvenile BW and growth performance. Moderate heritability and positive phenotypic correlations suggest that these traits can be effectively improved through selective breeding.

Key words: Backyard chickens, Growth performance, Hatch weights, Heritability, Phenotypic diversity

Introduction

Indigenous chickens (IC) in Africa are an important animal genetic resource (AnGR) kept and conserved mainly by small-scale backyard poultry farmers (Manyelo *et al*., 2020). Despite their importance, many IC breeds are characterized by low productivity (Pius *et al*., 2021), as well as significant phenotypic and genetic diversity (Ssewannyana *et al*., 2008; Yussif *et al*., 2022; Beyihayo *et al*., 2023). Rural farmers however, prefer these chickens, mainly due to their disease tolerance, adaptability to local climatic conditions, and ability to scavenge effectively in low-input free-range production systems (Mpenda *et al*., 2019). Indigenous chickens serve multiple roles, including providing income, food security, and nutritional benefits mainly for rural communities (Lubandi *et al*., 2019; Mujyambere *et al*., 2022). Moreover, IC products, such as eggs and meat, are preferred over those from commercial breeds, due to perceived superior taste (Kyarisiima *et al*., 2011; Manyelo *et al*., 2020).

However, the slow growth rate of IC increases the time required to attain market weight, thereby constraining the supply capacity of these birds. Therefore, selecting birds for enhanced body weight (BW) and growth rate is essential for improving IC populations, as these traits are significant in a profitable production system (Okeno *et al*., 2011; Ndung'u *et al*., 2020a).

In Uganda, efforts to improve IC with respect to body weight and growth rates have received limited attention, resulting in a dearth of scientific knowledge to inform genetic selection and improvement strategies, in line with evolving production systems, as well as changing producer and consumer demands. This gap hinders the future application of molecular selection techniques within IC populations. The objective of this study was to assess the genetic variation in chicken juvenile BW and growth among selected ICP in Uganda.

Materials and methods

Founder chicken populations and their management

Three populations of indigenous chickens (IC) were used in the study as source of parent stock. These included chickens from Apac and Lira districts, in northern Uganda; and a population previously bred for increased egg production and body weight at the National Semi-Arid Resources Research Institute (NaSARRI), in eastern Uganda. For the chickens from Apac and Lira, only households with no prior history of crossbreeding their indigenous chickens with exotic breeds were selected. This was confirmed by asking the household heads if they had kept any exotic chickens alongside indigenous breeds within the past ten years. Only farmers with no history of crossbreeding were included in the study.
To ensure genetic diversity and avoid sampling related birds, a minimum distance of 1 Km was maintained between sampled households. Additionally, not more than two birds (one cock and one hen) were collected from each household. Cockerels were selected based on having reached puberty and began mating.

Selected cockerels were required to weigh between 1.8 and 2.0 kg. For hens, the selection criteria included birds at the start of their first laying cycle, estimated to be between 5 and 8 months old, with a live body weight ranging from 1.2 to 1.4 kg. Hens were also required to have a laying capacity of 15 to 20 eggs per clutch, as recalled by the farmer.

After collection, the chickens were housed in group pens based on their source district, following a mating ratio of one cock to ten hens (Molapo and Kompi, 2015). They were quarantined for a two-week adaptation period at the Mukono Zonal Agricultural Research and Development Institute (MuZARDI). This quarantine period was essential to manage the stress caused by changes in the production system, particularly for scavenging birds.

During this time, the chickens were provided with a mix of supplemental multivitamins, and amino acids. Additionally, they were provided with broad-spectrum antibiotics, including oxytetracycline (25%) for three days and enrofloxacin (20%) for another three days to address any potential infections. Also, the birds were vaccinated against Newcastle Disease (NCD), Infectious Bronchitis (IBD), and Gumboro disease, with a one-week interval between each vaccination.

The chickens were fed a consistent layer diet containing at least 16.5% crude protein (CP) and 2800 kcal kg^{-1} DM of metabolizable energy. The birds had *ad libitum* access to clean drinking water and feed. Following the quarantine period, fertile eggs were collected and incubated for three weeks. Each weekly hatch constituted a batch.

Management of experimental birds

The birds used in the study were progeny of the previously assembled founder populations from each chicken group. Fertile eggs were collected from each population, labelled, and artificially incubated for three weeks. Upon hatching, chicks were wing-banded on day one, and their hatch weights were recorded. The birds were brooded using charcoal stoves as heat sources, with the heat gradually reduced as they aged. Initially, 24-hour artificial lighting was provided for the first 14 days, after which the lighting was gradually reduced to 12 hours of light and 12 hours of darkness, until the end of the brooding period.

The chickens were reared on deep litter in an open-sided poultry house, with coffee husks used as litter material. During the first seven days of brooding, chicks were given water-soluble vitamins in their drinking water. Vaccinations were administered as follows: Marek's disease (MD) on day 1, Newcastle disease (NCD) on day 5, infectious bursal disease (IBD) on day 14, and fowl pox on day 21. Throughout the experimental period, chicks were fed *ad libitum* on a starter ration containing 2,900 kcal kg^{-1} DM of metabolizable energy (ME) and 200 g kg^{-1} DM of crude protein (CP), until they reached four weeks old.

Experimental design

A total of 540 chicks were used in the experiment, sourced from freshly hatched eggs produced in three batches at the Mukono Zonal Agricultural Research and Development Institute (MuZARDI). For each batch, 60 healthy and high-quality chicks were randomly selected per population at hatch. These chicks were then divided into three sets as replicate groups (20 birds each). Consequently, there were 180 birds in total for all three populations per batch, leading to a cumulative total of 540 birds across the three batches. The study was laid out in a completely randomised design (CRD).

Data collection

The hatch weights of the birds were recorded on day one, using a sensitive digital scale (KERN PCB-2500-2, precision 0.01g, max 2500 g, KERN & SOHN GmbH, Germany). Thereafter, the birds' live body weights were recorded weekly, using a sensitive digital balance. The weekly mean daily gain (ADG) was calculated as the difference between the current and previous week's body weight, divided by 7 days. The overall ADG was determined by subtracting the hatch weight from the final body weight at week 4 and dividing the result by the 28-day measurement period.

Similarly, weekly relative growth rate (RGR) was calculated as the percentage difference in body weight between the current and previous week. This was done by dividing the weight difference by the previous week's body weight, then multiplying by 100, following the method suggested by (Tona *et al*., 2003). The overall RGR was calculated by dividing the difference between the final body weight at week 4 and the hatch weight by the hatch weight and expressing the result as a percentage.

Statistical analysis

Normality of distribution of the data was assessed using Levene's test, before the analysis of variance (ANOVA). Analyses of variance was performed using PROC MIXED procedures of SAS (SAS, 2001), with the chicken populations (P) as the fixed factor and batch number (B), replicates as the random factors in the model.

The least square means were generated using the LSMEANS statement of SAS. When significant differences were detected, means were separated using the TUKEY option in SAS. A linear univariate animal model as earlier proposed by Niknafs *et al.* (2012), was used to estimate the variance components, which was subsequently used for calculation of heritability of traits and phenotypic correlation between the traits, using the restricted maximum likelihood method (REML) in the R statistical software using the lme4 package. Phenotypic correlation between traits was performed to assess relationships between traits in R (R Core Team and Team, 2021). The following univariate animal model was used:

$$y = X\beta + Za + e$$

Where: y vector of observed values for the trait; $X\beta$ matrix of the fixed effects (chicken population, and sex); and Za matrix of random genetic effects and e is the residual error term.

Results

Body weight

The means of the traits under study are presented in Table 1. All the juvenile body weights measured varied significantly (P<0.05) across the chicken populations, and for the three study sites. The mean hatch weight varied significantly (P<0.05) between three chicken populations. The mean body weight of the chicks at week 4 (BW4), also varied significantly between the chicken populations.

Across the populations, mean weight at week 4 (BW4) was 123.2 g. However, the general trend was that birds from Apac and Lira, were always heavier than birds from NaSARRI.

Growth rate

The growth rate, measured as mean daily gain (ADG), showed significant differences (P<0.01) between chicken populations within each week, except for week 3 (ADG3), where no significant differences were observed (Table 1)

Across weeks, ADG estimates were comparable (P>0.05) between birds from Apac and Lira. However, the overall ADG from hatch to week 4 (ADGo), was similar (P>0.05) for Apac and Lira birds, but significantly higher for birds from the NaSARRI population.

Relative growth rate

When growth rate was measured as relative growth (RG), no significant differences were found within individual weeks across the chicken population (Table 1). However, there were significant differences in overall relative growth (RGo) from hatch to week 4, with birds from NaSARRI showing lower RG compared to those from Apac and Lira.

Genetic parameters of traits in the IC populations

The genetic parameters for juvenile body weight and growth traits in the studied chicken populations are shown in Table 2. Except for hatch weight, genotypes had a significant influence on all other juvenile body weight and growth traits examined. The broad-sense heritability of these traits was moderate, ranging from 0.24 to 0.56.

Table 1. Selected body weight and growth performance traits of indigenous chicken populations

Traits	Chicken population			SEM	*P* value
	Apac	Lira	NaSARRI		
BW0 (g)	26.2	25.4	24.9	0.70	0.0188
BW1 (g)	40.2[a]	39.8[a]	37.3[b]	1.89	<0.001
BW2 (g)	62.0[a]	62.2[a]	55.4[b]	3.75	<0.001
BW3 (g)	86.7[a]	90.0[a]	78.4[b]	2.45	<0.001
BW4 (g)	129.4[a]	130.2[a]	109.9[b]	6.95	<0.001
Growth rate					
ADG1	2.01[a]	2.06[a]	1.76[b]	0.103	<0.01
ADG2	2.82[a]	2.91[a]	2.42[b]	0.434	0.013
ADG3	3.09	3.14	2.86	0.475	NS
ADG4	5.54[a]	5.89[a]	4.44[b]	1.188	<0.01
ADG_o	3.71[a]	3.74[a]	3.04[b]	0.199	<0.01
Relative growth rate					
RG1 (%)	55.4	56.9	50.1	6.87	NS
RG2(%)	46.9	49.7	43.6	6.63	NS
RG3(%)	34.6	35.9	35.2	6.04	NS
RG4(%)	47.4	45.8	39.1	10.36	NS
RG_o(%)	410.4[a]	408.7[a]	344.8[b]	19.29	<0.01

BWO = hatch weight, BW1 = body weight at week 1, BW2 = body weight at week 2, BW3 = body weight at week 3, BW4 = body weight at week 4, ADG1 = mean daily body weight gain in first week, ADG2 = mean daily body weight gain in second week, ADG3 = mean daily body weight gain in week 3, ADG4 = mean daily body weight gain in week 4, and ADG_o = mean daily body weight gain between 0 - 4 weeks. Also, RG1 = mean relative growth in first week, RG2 = mean relative growth in second week, RG3 = mean relative growth in week 3, ADG4 = mean relative growth in week 4, RG_o = mean relative growth between 0 - 4 weeks, SEM = standard error of the mean, and NS = not significant

Correlation between parameters

Figure 1 illustrates the phenotypic correlations between body weight and growth performance traits in selected indigenous chicken populations. There was a moderately positive and significant correlation (r = 0.36) between hatch weight and body weight, at week 4 (BW4).

There a strong positive correlation was observed between BW4 and overall mean daily gain (ADGo) as well as between BW4 and overall relative growth (RGo), with values of 0.996 and 0.886, respectively (Fig. 1).

Discussion

The mean hatch weight of chicks in this study was similar to that reported by Beyihayo *et al*. (2023) for chickens from six agro-ecological zones of Uganda. However, it was slightly higher than the mean for three indigenous phenotypes (frizzled, normal, and naked neck feathered) at 22.9 g reported by Semahoro *et al.* (2018), and lower than the hatch weight of 41.5 g for the imported hybrid Kuroiler

Table 2. Trait means, variance components, and heritability of juvenile body weight and growth performance traits of indigenous chickens

Traits	Mean ± SEM	σ_g^2	σ_p^2	H^2	Genotype effect‡
BW0 (g)	25.30± 0.19	4.40	12.65	0.35	ns
BW1 (g)	39.7± 5.07	36.32	72.27	0.50	***
BW2 (g)	61.10± 5.07	187.98	342.13	0.55	***
BW3 (g)	85.18± 7.79	316.58	680.67	0.47	**
BW4 (g)	121.51± 12.37	917.84	2093.93	0.56	***
ADG1	2.06± 0.30	0.34	0.88	0.38	***
ADG_o	3.37± 1.01	4.66	10.78	0.43	***
RG1 (%)	57.94± 8.57	135.98	576.89	0.24	**
RG_o (%)	385.64± 46.40	12378.10	25295.13	0.49	**σ_g^2

σ_g^2= Genotypic variance, σ_p^2= phenotypic variance, H^2 = broad sense-heritability of traits, BW0 = Hatch weight of chicks, ADG_o = Mean daily gain in body weight of birds between hatch and week 4, RG_o = is relative growth of birds between hatch to week 4, and SEM = Standard error of the mean, ns is not significant

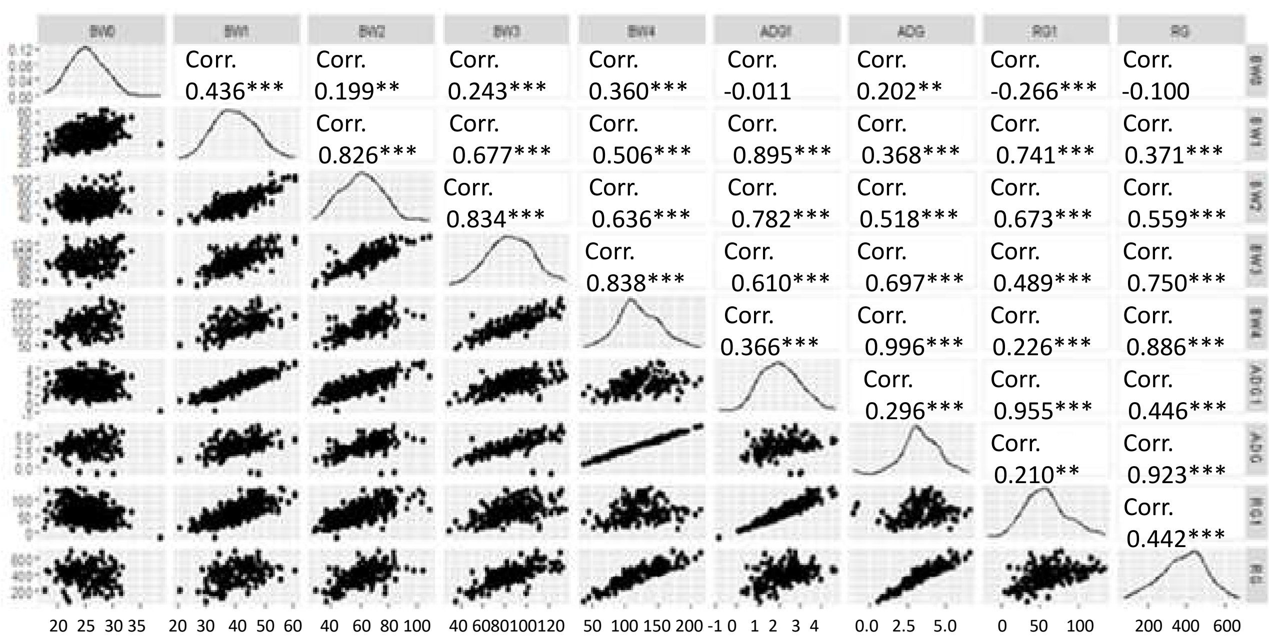

Figure 1. Phenotypic correlation between juvenile body weight and growth trait of indigenous chickens.

chicken breed (Semahoro *et al.*, 2018). The NaSARRI population had lower hatch weights compared to Apac and Lira populations, likely because the NaSARRI birds were previously selected for increased egg production, a trait negatively correlated with body weight in chickens (Beyihayo *et al.*, 2023). This variation in hatch weight may be linked to egg weight, as Apac and Lira hens were observed to lay heavier eggs than NaSARRI hens (Author, unpublished data). Indeed, previous research has demonstrated a strong correlation between egg weight, hatch weight, and post-hatch growth performance in poultry (Iqbal *et al.*, 2016; Ewonetu and Kasaye, 2018). Larger eggs tend to provide more nutrients, improving embryonic development and leading to higher chick hatch weights compared to smaller eggs (van der Wagt *et al.*, 2020).

The heritability estimates in this study were comparable to those reported by Beyihayo *et al*. (2023) for a larger collection of indigenous chickens in Uganda, as well as for local chicken populations in Iran of 0.33 (Firozjah *et al*., 2015). However, they were lower than the 0.46 heritability reported for Mazandaran native chickens (Niknafs *et al*., 2012) and the 0.46 mean heritability for global native chicken genotypes (Ndung'u *et al*., 2020). These differences in heritability may be influenced by the specific genotypes and production environments under which the estimates were obtained.

At week 4, the body weights of chicks from Apac and Lira populations were similar and comparable to the mean body weights of three chicken phenotypes raised in a deep litter system, as reported by Semahoro *et al*. (2018). However, the NaSARRI population had lower body weights than the Apac and Lira IC populations, which may be due to the size advantage observed in Apac and Lira chicks even at hatch. Heavier chicks tend to be more active and consume more feed, which likely contributed to their faster growth compared to the smaller NaSARRI chicks. Although heavier chicks tend to consume more feed, this difference in feed intake is not always statistically significant (Ulmer-Franco *et al*., 2010). However, differences in the relationship between feed intake and weight of chicks may differ due to breed difference. In white leghorn chickens, egg weight has been shown to influence post-hatch performance, with medium-sized chicks outperforming both small and large chicks (Ewonetu and Kasaye, 2018). A similar trend was observed in broiler chickens, where medium-sized chicks had better post-hatch performance (Yameen *et al*., 2021).

The mean body weight at week 4 in this study was less than half of that reported for local Venda chickens in South Africa (Norris and Ngambi, 2006), but only slightly lower than the 152.7 g reported for improved Horro chickens in Ethiopia at the same age (Taye *et al*., 2022). This suggests that selective breeding for improved body weight at this age is possible, especially given the moderate heritability estimate of 0.56 for week 4 body weight.

The overall ADG in this study (3.4 g/day) was lower than the 5.5 g/day calculated from data reported by Beyihayo *et al*. (2023). This difference could be attributed to the smaller diversity of chicken populations in the present study (three populations) compared to the six populations used by Beyihayo *et al*. (2023). Similarly, the relative growth rates (RG) in this study were lower than the 287.6% reported for a larger collection of chicken ecotypes by Beyihayo *et al*. (2023). The RG values for three indigenous phenotypes raised in a deep litter system (463.9%) and the Kuroiler breed (728.6%) reported by (Semahoro *et al*., 2018b) were also higher than those observed in the current study. The differences in relative growth rates are likely due to breed differences, particularly in the case of Kuroiler chickens, and may also be influenced by diet quality, as all birds were raised in the same production system.

The moderate heritability estimates for mean daily gain (ADGo) and relative growth rate (RGo) in these chicken populations suggest that these traits can be targeted in indigenous chicken improvement programs. Breeding for faster-growing birds that can reach market weight earlier than the current non-selected populations could be feasible.

The moderate to high positive phenotypic correlations between juvenile body weight and growth traits observed in this study indicate that these traits can be simultaneously improved in a well-structured indigenous chicken breeding program. Similar moderate correlations have been reported in other indigenous chicken populations from different agro-ecological zones of Uganda (Beyihayo *et al*., 2023).

Conclusion

The study revealed significant genetic variability in juvenile body weight and growth traits among selected Ugandan indigenous chicken populations, with moderate heritability estimates ranging from 0.24 to 0.56. This genetic diversity, combined with the moderate to high phenotypic correlations observed between body weight and growth traits, indicates that these traits can be effectively improved through targeted selection. Incorporating these traits into breeding programs for indigenous chickens can facilitate the development of faster-growing birds, contributing to enhanced productivity and early market readiness of ICP in Uganda. Since the heritability of juvenile traits is moderate and genetic variability exists, early selection (at hatch or within the first few weeks) can accelerate breeding progress. Early selection for body weight and growth traits will shorten the time to market weight.

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