Hosted by

Characterization of Qualitative and Quantitative Traits of Five Strains of Zambia Indigenous Chicken

Mayoba Barbara Moono[1,*], Wilson N M Mwenya[1], Kolawole Odubote[1], Mubanga Mwale[2]

[1]Department of Animal Science, University of Zambia, Lusaka, Zambia

[2]Department of Livestock Development, Ministry of Fisheries and Livestock, Lusaka, Zambia

Correspondence Author: Mayoba Barbara Moono moonomaya@gmail.com

Department of Animal Science, The University of Zambia, Lusaka, Zambia

https://orcid.org/0009-0005-8862-4647

DOI 10.53974/unza.jabs.8.3.1341

ABSTRACT

This study assessed the phenotypic characteristics of five indigenous chicken strains from Zambia's Luapula, Northern, Muchinga, Southern, and Lusaka provinces, providing baseline data for a selective breeding program aimed at improving performance. A total of 100 chickens (74 females and 26 males) were sampled. Qualitative traits were observed, and quantitative traits such as body weight, body length, thigh length and circumference, chest circumference, shank length and circumference, wingspan, and keel length were measured. Males had significantly higher live body weights and measurements than females (P < 0.05), with average mature male weight at 1.88 kg and females at 1.63 kg. Frizzled-feathered males had significantly higher shank lengths (10.8 ± 0.76 cm) than females. No significant strain differences among males were noted in wingspan or live weight. Naked-neck males had the highest live weight, while short-legged males had the lowest for all the strains. Normal-feathered, Naked-neck and Frizzled females had similar shank lengths and circumferences, significantly higher than dwarf females. The study found high positive correlations between body weight and other measurements (P < 0.01), except for body length and thigh length circumference in naked-neck females. Chickens were distributed as normal-feathered (44%), white-spotted (19%), naked-neck (17%), short-legged (13%), and frizzled-feathered (7%). The dominant comb type was single (96%), followed by pea (3%), and rose (1%). Grey shank colour was most common (33%), followed by white (31%), black (18%), and yellow (17%), with green at 1%. White earlobe colour was universal (100%), and eye colours were predominantly brown (42%), followed by black (31%) and grey (23%), with white and grey being the least common (1% and 3%). The phenotypic diversity within these strains suggests great potential for improving indigenous chicken performance through selective breeding.

KEYWORDS: *Indigenous chicken, strains, phenotypic, Zambia*

INTRODUCTION

The livestock sub-sector in Zambia is regarded as a crucial part of agriculture which serves as a vital source of food, income, draught power, and also possesses aesthetic value (MFL, 2023). According to MFL (2023), it accounts for 42% of the agricultural sector's GDP, which translates to 3.2% of the national GDP, and provides 50% of employment in rural areas. Among livestock, small ruminants and poultry are particularly vital for rural households in many developing countries. Poultry, in particular, has proven essential by providing food security and economic stability (Conan et al., 2012; Manyelo et al., 2020; Singh et al., 2023).

Poultry production in Zambia is an important component of the agricultural sector that contributes to global food security, economic development, and the nutritional well-being of people. Yunusa et al. (2014) and Liswaniso et al. (2023) agree that its importance for the rural economy is immense in different countries due to its contribution to global food security and economic development. Among the avian species, chickens are the most kept in Zambia.

According to the National Livestock Census, over 80% of smallholder households own at least one chicken, making chickens the most common type of poultry and livestock among smallholder households in Zambia (Harrison et al., 2024). MFL (2023), points out that the Southern Province has the highest number of chicken-raising households at (17.7%), followed by the Eastern Province at (15.7%) while the North-western Province has the lowest number of households engaged in chicken production at 5.7 per cent. This demonstrates chicken production's critical role in providing food security and a source of income.

Chickens are raised to produce meat and eggs; their products and by-products are affordable and serve as a substantial source of protein. In Zambia, chicken production encompasses broilers that are kept for meat production, layers, on the other hand, are valued for their high egg production, and indigenous chickens that provide dual-purpose benefits of meat and eggs. Recently, chicken production in Zambia appears to be shifting towards indigenous chicken production. This shift is driven by consumer preference and economic opportunities due to indigenous chicken's potential for sustainable production, a trend similarly observed in Nigeria, by Ajayi, (2010) highlighting the growing reliance on indigenous chicken production. Among chickens, indigenous chickens account for the largest numbers at 26,162,649 followed by broilers (5,325,381) and layers at 2,065,451 (MFL, 2023).

In Zambia, indigenous chickens are widely distributed in rural and urban households. In contrast to exotic chicken breeds, indigenous chickens exhibit remarkable resilience, disease resistance, and adaptability to challenging environmental circumstances, which allow them to thrive in low-input free-range or semi-intensive systems. However, many challenges hinder their production.

A study by Liswaniso et al., (2024) reviewed that the most common challenges under these production systems are diseases, nutrition, and lack of better-performing breeds. Additionally, theft, predators, lack of capital, lack of housing, lack of information, and price fluctuation are of great concern. However, the key issue is that indigenous chickens generally display lower productivity in terms of both egg yield and growth rate. Their low egg yield is attributed to their natural inclination towards broodiness and nurturing their eggs (Ajayi, 2010), as they spend extended periods incubating, which reduces their egg-laying frequency and limits overall productivity. While this trait is a disadvantage in commercial poultry farming focused on maximizing egg production, it is beneficial in areas without modern technology, (Jiang, 2010). In such regions, broody hens provide a natural and self-sustaining method of replenishing the flock, supporting small-scale farmers in maintaining a stable poultry population and enhancing food security. However, despite their inherent strengths, Singh et al., (2016) and Padhi, (2016) suggest that the genetic potential of indigenous chickens has not been fully exploited.

These constraints highlight the need for interventions to enhance the productivity and sustainability of indigenous chicken farming. Therefore, there is a need for genetic improvement to support small-scale producers, conserve genetic diversity, and promote sustainable agricultural development. Improvement and conservation of indigenous chicken resources demand characterization of the available phenotypes which is beneficial for the selection of superior birds (Dahloum, 2016).

Phenotypic characterization is essential for the genetic improvement of indigenous chickens (IC) in Zambia. Most governments in Sub-Saharan Africa often focus on crossbreeding indigenous and exotic chickens to enhance performance, but this approach risks genetic erosion and the loss of pure indigenous strains, (Mwacharo et al., 2013). To ensure improvement, selection should prioritize high-performing ICs and the first step in improving specific traits is selecting chickens with the best characteristics, which requires both phenotypic and molecular characterization.

According to Bekele et al. (2015), phenotypic characterization is vital for developing sustainable breeding programs for local avian genetic resources, it is a foundational step that guides the utilization and conservation of Indigenous livestock breeds and identifies phenotypic variations within and between breeds which is crucial for improvement and selection programs targeting specific economic traits. By understanding the phenotypic traits and variations within indigenous strains, breeders can make informed decisions that preserve genetic diversity while improving productivity. A study by Kanyama et al. (2022) concluded that there is limited information on the characterization of ICs in Zambia. Most previous studies have focused on the general population rather than variations within specific Zambian indigenous chicken strains (Liswaniso et al., 2023).

Therefore, this study aimed to assess the variations in phenotypic traits among and within Zambian indigenous chicken strains to contribute to ongoing research for developing breeding programs. It validates and provides additional information on phenotypic variations among Indigenous strains, including Short-legged, Naked neck, Frizzle feathered, Normal feathered, and White-spotted. Ultimately, this study will enhance existing inventories and aid in designing breeding programs to improve the production performance of ICs. It will provide critical insights into the phenotypic diversity of ICs in Zambia, contributing to the development of effective breeding programs.

MATERIALS AND METHODS

Sampling areas

The chickens for the study were sampled from five provinces of Zambia namely Muchinga, Luapula, Northern, Southern, and Lusaka provinces of Zambia based on the population of ICs and provinces with less dilution with exotic chicken breeds. Two districts were selected for their remoteness in each province and a minimum of two villages were randomly picked for the acquisition of the foundation stock.

Study area

The study was conducted at the University of Zambia, School of Agricultural Sciences' Field Station (15◦24'S 28◦20'E and elevation of 1261m above sea level) on the Great East Road campus. The area experiences a tropical climate with rainfall ranging between 700mm to 1400mm annually. Throughout the study period, the mean ambient temperature ranged from 9◦C in the cold season to 30◦C in the hot season. The annual average relative humidity was 61.5%.

Foundation stock

A total of 100 chickens (26 cockerels and 74 hens) sexually mature ICs that are healthy and at least 20 weeks old birds belonging to five strains of Zambian ICs which included Naked Neck, White-spotted, Normal feathered, Frizzle-feathered, and short-legged were acquired for the study.

Management of the chickens

The chickens from the sampling areas were transported to the study area in well-ventilated cages in a van. Upon arrival at the School of Veterinary Medicine, the chickens were treated for external parasites using Akheri dust (a pesticide), which was administered by gently placing each bird in a bag with its head exposed to minimize discomfort.

The chickens were then housed in the quarantine poultry house for 21 days. Fresh, clean water mixed with a stress pack was provided to the drinkers, and a layer diet containing 17% crude protein and 3.6% calcium was offered ad libitum. The following morning, the chickens were dewormed by adding Piperazine to their drinking water for three days. Dosages were carefully adjusted, and the deworming process was closely monitored.

In addition to that, all the chickens received anticoccidial medications and vaccinations for Newcastle, Gumboro, and fowl pox, following the recommended vaccination program for breeding chickens. A comprehensive health assessment was conducted for all chickens and any signs of illness were promptly addressed with appropriate treatments according to established guidelines. High standards of hygiene and cleanliness were maintained throughout the experiment to support the well-being of the chickens, through regular cleaning and disinfection.

After the quarantine period, the chickens then moved from the School of Veterinary Medicines' Animal Production Unit to the experimental poultry houses at the School of Agricultural Sciences' field station. They were then kept under an improved management system. This included providing proper housing according to strain in 2.7×3.2m deep litter pens to protect them from predators and harsh weather conditions, balanced diets with ad-libitum access to fresh, clean water, and a layer diet feed daily, to meet all their nutritional requirements and regular health care interventions such as vaccinations and parasite control.

Biosecurity measures

Biosecurity measures were implemented throughout the experiment. This was carried out by limiting access to the poultry houses. Foot baths and hand wash stations were placed at the entrance of each poultry house, the foot baths were cleaned regularly and disinfectant was added to maintain hygiene.

Data collection and analysis

The chickens were observed individually for various phenotypic traits which included sex, comb type, and size, plumage colour and pattern, feather morphology, shank colour, ear-lob colour, and eye colour, according to the description by FAO (2012). The morphometric parameters that were collected included body length (BL), keel length (KL), thigh length (TL), shank length (SL), shank circumference (SC), chest circumference (CC), and corpus length (CL). The body measurements were taken using a common tailor's measuring tape graduated in centimetres. Measurements were taken by the author throughout data collection to avoid variation between individuals as suggested by Yunusa et al., (2014). Each chicken's body weight (BW) was measured using an electronic weighing scale with a sensitivity of 1mg.

The measurements mentioned above were recorded and stored in MS Excel 2016.

For statistical analysis, STATA, statistical software was utilized for both quantitative and qualitative data analyses. Duncan's multiple range test was used to separate the means for significant variables.

The statistical model: $Y_{ijk} = \mu + \alpha_i + \beta_j + \varepsilon_{ijk}$

Where, Y_{ijk} = observation on the kth chicken belonging to jth sex and ith strain.

μ = population mean;

α_i = fixed effect of the ith strain;

β_j = fixed effect of the jth sex;

ε_{ijk} = random error associated with the kth chicken belonging to the jth sex of the ith strain

Assumption: $\varepsilon_{ijk} \sim N(0, \sigma 2)$

RESULTS

Distribution of chickens collected across provinces for the study

Table 1 shows the distribution of chickens across the five provinces. The study revealed that most of the total ICs sampled were. Normal feathered, with the highest numbers reflected in Muchinga province. This was also reflected in Luapula province. However, this was not the case in Lusaka Province where no normal-feathered birds were sampled. Tables 2 and 3 show the qualitative and quantitative traits of chickens from the five strains obtained from across the provinces for the study.

Quantitative traits

Table 4 shows the means and standard error of body weight and linear body measurements by province (area). Tables 5 and 6 show the means and standard error of body weight and linear body measurements by sex and strain.

Correlations

Table 7 presents the matrix of correlation between body measurements of all the strains. Tables 8, 9, 10, 11, and 12 show the correlations between body measurements within the five strains.

DISCUSSION

Colored plumage varied across the five provinces and strains from mixed to white as shown in Tables 2 and 3. The most common colors were mixed, brown and black which confirms the findings by Liswaniso et al. (2024) who found that brown plumage color was the most common at (27.88%). The majority of the ICs had mixed and black plumage colours sampled across Luapula, Muchinga and Northern provinces. Brown plumage colour was the most common in the Naked-neck and Normal feathered strains as shown in table 3. The majority of the frizzle-feathered ICs had black plumage color while mixed plumage color was the most common within the short-legged strain. White plumage colour was the least common across all strains which could be attributed to its cultural significance in many traditions (Manyelo et al., 2020), white-coloured birds are often associated with purity and are therefore reserved for use in ceremonial practices rather than general production.

This selective preference likely reduces their representation in the broader population of ICs. Similarly, Liswaniso et al. (2024) reported that white plumage color was found in very small proportions among ICs sampled from Muchinga, Northern and Luapula provinces of Zambia. On the other hand, Hailemichael (2013) reported very diverse plumage colors in ICs of Ethiopia and concluded that the diversity in plumage color is a feature for camouflaging, adaptability and survival. Adekoya et al. (2013) reported similar observations in Nigerian ICs, and concluded that diverse plumage color is an adaptability and survival feature.

Shank color varied from the most common color grey to the least common color green across the five provinces. The black shank colour was more common in the Frizzle-feathered strain, the yellow shank colour was not found in this strain but was found in the Naked-neck strain. The grey shank colour was more common among the short-legged chickens. The white shank color was found mostly in the white-spotted strain while green was the least common and was only found in the Normal-feathered strain. The variations in shank colour seen in this study are similar to those of ICs in Kalomo, Southern province which agrees with the findings by Liswaniso et al. (2023) who reported grey and green shank colours as the most common in Kalomo. According to Smyth, (1990), the variations in shank colour could be attributed to dietary carotenoid pigments in the epidermis, the presence or absence of melanin and as a result of the presence of black as well as yellow pigments in the epidermis.

Single comb type was more predominant than the pea and rose type shown in Tables 2 and 3. It was expected to find a single comb type in this study as the most common comb type as similar studies on characterization of ICs in Zambia and elsewhere obtained similar results. The single comb type was the most common in Kalomo district of the Southern province, Muchinga, Luapula and Northern provinces as reported by Liswaniso et al. (2023, 2024). These findings are consistent with Machete, (2023) among the Tswana chickens in Botswana. The dominance of the single comb, which is the largest comb type, suggests its advantage in selection and adaptability to tropical climates with high atmospheric temperatures (Liswaniso et al., 2023). The rose comb type was only found in the Normal-feathered strain, pea comb types were found in the Naked-neck and Normal-feathered strains, and no cushion types were observed. The absence of the cushion comb type could be attributed to genetic factors, as this comb type may not be prevalent within the genetic pool of the studied population. Additionally, selective breeding or natural selection in the local environment may have favoured the single comb type that offers better adaptability to climatic conditions (Apuno et al., 2011).

Eye color varied from orange being the most predominant to black the least common across all strains as shown in table 2 and 3. Brown was more common in the Frizzled-feathered strain than any other strain while orange eye color was more common in the Naked-neck and Normal-feathered.

Similarly, Liswaniso et al. (2024) reported 78.07% of the ICs had orange eyes in all the provinces studied, followed by yellow, brown, and pearl at 11.52%, 9.29%, and 1.12%, respectively. The absence of yellow eye colour among the ICs in this study could be attributed to genetic variation among the sampled populations, environmental influences or differences in sampling locations and strains studied. These findings agree with Dahloum et al. (2016) and Markos et al. (2020) who found that ICs of Algeria and Tanzania had predominantly orange and brown eye colours. According to Eskindir et al. (2013), variation in eye colour to a large extent depends on the carotenoid pigments and blood supply to several structures within the eye.

The study found that ICs from Southern and Lusaka provinces had higher live body weights at 2.12 kg and 2.04 kg while birds from the Northern province had the lowest live body weights at 0.91 kg. Male birds observed were heavier than females with mean body weights of 1.88 kg in males and 1.63 kg in females, respectively. According to a previous study by Bekele et al. (2021), male birds were significantly superior in all linear body measurements, similarly, Liswaniso et al. (2024) and Machete, (2023) report sexual dimorphism in linear body measurements which according to Yakubu et al. (2009) can be attributed to the usual between-sex differential hormonal effects on growth.

There were no significant differences in live weight among males of the five strains of ICs. Among males of the five strains, the Naked neck had the highest live weight, followed by frizzle feathered, Normal feathered, white-spotted, and short-legged, these findings align with those of Ige et al. (2012) who also reported higher live weight in Naked neck. However, Adekoya et al. (2013) found the highest body weight in the normal strain followed by the Naked neck and lastly frizzle feathered strain these variations could be due to the differences in the production environment. Naked-neck females weighed more than Normal-feathered males as shown in table 6.

These findings are in agreement with Melaku (2016) and Halima et al. (2007), who reported that sex and agroecology interaction had significant effects on chest circumference and body weight of ICs. The average body weight of ICs found in this study was lower than those from Tanzania (Msoffe et al., 2001) but heavier as compared to lighter ICs reported in Northwest Ethiopia (Halima et al., 2007) and Nigeria (Daikwo et al., 2011). The variations in body weight of ICs from different countries might be attributed to the differences in their genetics, differences in age at maturity, differences in environment, and feeding practices. Kgwatalala et al. (2012) reported similar weights and chest circumferences in the Naked neck, Normal strain, and short-legged strain.

There were no significant differences (P>0.05) in corpus and keel length among Normal, Naked neck, frizzle-feathered, and between the white-spotted as well as short-legged males as shown in Table 6. Similarly, there were no significant differences among the female chickens of the five strains. The corpus and keel length of ICs from other countries have not been documented and therefore, information on the keel and corpus length of ICs from several African countries may not be available to make comparisons.

There were no significant differences (P>0.05) in thigh length among normal, Naked neck, frizzled, and white-spotted as shown in Table 6. There were no significant differences in thigh circumference between the Naked neck and white-spotted males and between the normal-feathered and frizzle-feathered males. However, males of the four strains had significantly higher thigh length and thigh circumference than the short-legged males (Table 6). Similarly, there were no significant differences (P>0.05) in thigh circumference among normal, Naked neck, frizzled, and white-spotted females. There were no significant differences in thigh length between the Naked neck and normal feathered and between the white-spotted and frizzle-feathered females.

However, males of the four strains had significantly higher thigh length and thigh circumference than the short-legged females. Similar thigh length among Normal, Naked neck, white-spotted and Frizzle-feathered strains of ICs found in this study is consistent with Liswaniso et al. (2023, 2024) among ICs sampled from Kalomo, Southern province, Muchinga, Luapula and Northern provinces of Zambia and Liyanage et al (2015) who reported similar thigh lengths and circumferences among Normal, Naked neck and Frizzle-feathered strains of Indigenous Tswana chickens.

There were no significant differences (P>0.05) in shank length and shank circumference among normal, Naked neck, frizzled, and white-spotted as shown in Table 5. However, males of the four strains had significantly higher shank length and shank circumference than short-legged (Table 6). Similar shank length between the Naked neck males, found in this study is consistent with Machete, (2023) who reported similar shank lengths, in Tswana Naked neck chickens. Among males of the five strains, the frizzled-feathered had the highest shank length and shank circumference followed by Naked-neck, normal-feathered, white-spotted, and lastly short-legged strain. However, Machete (2023) found higher shank length and shank circumference in Naked necks than frizzled males, the author suggests that relatively higher values of shank circumference in ICs may indicate suitability for meat production rather than for egg production.

There were no significant differences in wingspan and live weight among males of the five strains of ICs. There were no significant differences (P>0.05) in wingspan among females of normal and Naked neck, frizzle feathered and white-spotted, and short-legged strains of indigenous chickens. However, females of the normal and Naked neck strains had significantly higher wingspan than females of short legged strain. Similar wing span between female normal, frizzled and Naked neck is consistent with Liyanage et al (2015) who reported similar wing spans in three strains of Sri Lankan village chickens and Machete (2023) in Tswana chickens. Among the five strains, Naked neck females had the highest wingspan followed by normal, white-spotted, frizzled and lastly short legged females. The wingspan measurements of ICs were found to be generally higher in Southwest Ethiopia Northwest Algeria and Bauchi State of Nigeria and lower in indigenous chickens of Northwest Ethiopia. The observed variations in wingspan could be attributed to the differences in IC genotypes, feed availability and other environmental factors (Melesse, 2011).

The correlation coefficients from this study varied from high to low, positive and significant (p <0.001), while for some particular strains, some body measurements showed a negative correlation with body weight. The high correlation of linear body measurements with bodyweight implies that a favorable relationship exists among these traits and they could be included in the selection index to achieve positive genetic progress to improve live weight.

Generally, among all the ICs, the highest correlation was between BW and CL while the lowest was between WS and BW, as shown in Tables 7 and 8. In males, there was a high positive correlation between BW and CC followed by BW and TC while the highest correlation in female chickens was between BW and CL followed by TL and BW which aligns with findings by Liswaniso (2024) among male and female ICs of Luapula, Muchinga, and Northern provinces. However, these findings do not align with the findings of Liswaniso et al., (2024) who reported a high positive correlation between TC, KL, and BW in male ICs in Kabwe on the other hand, CC and BW showed the highest positive correlation among the females.

Among the Naked-necks, males and females showed a very high positive correlation between BW and CC, WS showed a negative correlation with BW and CC in males while TL was negatively correlated to BL and SL as shown in Table 8. On the other hand, Normal feathered males and females did not show any negative correlations between body measurements and weight, instead, there was a high positive correlation between CL and CC with body weight as shown in Table 9. Similar correlation estimates were reported by (Yakubu et al., 2009) Among Normal feathered and Naked-neck chickens of Nigeria.

According to Table 10, white-spotted males showed a high positive correlation between CC and BW while CL was highly positively correlated to BW. All other body measurements were positively correlated to each other except BL and CC. These findings are similar to those reported by (Ajayi et al., 2012) who reported the highest correlation coefficients between BL and BW among ICs of Nigeria; however, this was not the case among the frizzle feathered males, CC, CL, TL, TC, SL, and SC were highly positively correlated to BW while CL, TL, SL and WS were negatively correlated with BW as shown in Table 11.

As shown in Table 12, most body measurements were highly positively correlated with BW among the short-legged males except KL and TL. On the other hand, all body measurements were highly positively correlated to BW in the females. The variations in correlations between body measurements among the five strains can be attributed to differences in the genetic makeup, a similar conclusion was made by Yakubu et al. (2018) who also reported variations in phenotypic correlations Sasso, Kuroiler and Fulani ICs in Nigeria.

The high and significant correlations between body measurements and body weight suggest that they could be used to predict body weight. This is because an increase in any of the body measurements will consistently lead to a corresponding increase in the body weight of the chickens (Ajayi et al., 2008).

ACKNOWLEDGEMENTS

This study was supported by the Ministry of Science and Technology, Maxwell House, Los Angeles Boulevard, P. O. Box 50464, Lusaka, Zambia

Ethical approval

The study was conducted with approval (No. 1595 2021) by ERES Converge, Lusaka, Zambia. The feeding, housing, handling, and experimentation involving the chickens were conducted following the guidelines outlined (ASA, 2020)

Author contributions

MBM and MM conceived and designed the study, collected and analyzed data, and wrote the manuscript draft; WNMM supervised the study, IKO designed and supervised the study and reviewed the manuscript. All authors have approved the final manuscript to be published.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Data availability statement

The data that support the findings of this study are available from the corresponding author upon request.

REFERENCES

Abadula, T. A., Jilo, S. A., Hussein, J. A., & Abadura, S. Z. (2022). Poultry Production Status, Major Constraints, and Future Prospective. Journal of World's Poultry Science, 1(1), 22–28. https://doi.org/10.58803/JWPS.V1I1.4

Adekoya, K. O., Oboh, B. O., Adefenwa, M. A., & Ogunkanmi, L. A. (2013). Morphological Characterization of Five Nigerian Indigenous Chicken Types. http://ir.unilag.edu.ng:8080/handle/123456789/3518

Ajayi, F. (2010). Nigerian Indigenous Chicken: A Valuable Genetic Resource for Meat and Egg Production. Article in Asian Journal of Poultry Science. https://doi.org/10.3923/ajpsaj.2010.164.172

Bekele, G., Kebede, K., & Ameha, N. (2015). On-farm Phenotypic Characterization of Indigenous Chicken and their Production System in Bench Maji Zone, South Western Ethiopia. Science, Technology and Arts Research Journal, 4(1), 68–73. https://doi.org/10.4314/STAR.V4I1.10

Dahloum, L., Moula, N., Halbouche, M., & Mignon-Grasteau, S. (2016). Phenotypic characterization of the indigenous chickens (Gallus gallus) in the northwest of Algeria. Archives Animal Breeding, 59 (1): 79–90.

Daikwo, S., Odah, E., Ogah, D., & Baba-onoja, E. (2018). Qualitative Traits Variation in Indigenous Chickens of Bekwarra, Nigeria. Asian Research Journal of Agriculture, 9(1), 1–6. https://doi.org/10.9734/arja/2018/41389

FAO. (2012). Phenotypic characterization of animal genetic resources. In FAO Animal Production and Health Guidelines: Vol. No 11.

Hailemichael, N. (2013). On-farm phenotypic characterization of indigenous chickens and chicken production system in southern zone of Tigray, Northern Ethiopia

(Doctoral dissertation, MSc Thesis Submitted to the School of Graduate Studies of Haramaya University, Haramaya, Ethiopia. 106pp).

Halima, H., Neser, F. W. C., Van Marle-Koster, E., & De Kock, A. (2007). Phenotypic variation of native chicken populations in northwest Ethiopia. Tropical Animal Health and Production, 39(7), 507–513. https://doi.org/10.1007/S11250-007-9032-2

Harrison, S. J., Moono, M. B., & Odubote, I. K. (2024). Production Systems and Management Practices of Chicken Populations in Zambia. Sustainable Agriculture Research, 13(1), 61. https://doi.org/10.5539/sar.v13n1p61

Ige, A. O., Salako, A. E., Yakubu, A., Ojedapo, L. O., Adedeji, T. A., & Adeoti, T. M. (2012). Comparison and prediction of morphological characteristics of Frizzled Frizzled Feather and Naked Neck Chicken in Derived Savannah zone. Production Agriculture and Technology Journal, 8(2), 68-75.

Kanyama, C. . ., Moss, A. . ., & Crowley, T. . . (2022). Strategies of promoting sustainable use and conservation of indigenous chicken breeds in Zambia: lessons from low-income countries. F1000Research, 11, 251. https://doi.org/10.12688/f1000research.75478.2

Liswaniso, S., Mweni, M., Moono, M. B., Nambeye, E., Mweni, M. W., Tyasi, T. L., Mufungwe, J., Chimbaka, I. M., & Harrison, S. (2024). Assessment of phenotypic diversity and morphometry of indigenous chickens in Kabwe District, Zambia https://doi.org/10.30574/wjarr.2024.24.2.3278

Liswaniso, S., Qin, N., Shan, X., Sun, X., & Xu, R. (2023). Phenotypic Characterization of Indigenous Free Range Chickens in Kalomo, Zambia. Journal of Animal and Plant Sciences, 33(3), 655–665. https://doi.org/10.36899/JAPS.2023.3.0658

Liyanage, R. P., Dematawewa, C. M. B., & Silva, G. L. L. P. (2015). Comparative Study on Morphological and Morphometric Features of Village Chicken in Sri Lanka. Tropical Agricultural Research, 26(2), 261–273. http://fangrsl.org

Machete, J. B. (2023). Phenotypic and genetic characterization of different strains of indigenous

Tswana chickens in Kweneng and southern districts of Botswana. https://researchhub.buan.ac.bw/handle/13049/711

Manyelo, T. G., Selaledi, L., Hassan, Z. M., & Mabelebele, M. (2020). Local Chicken Breeds of Africa: Their Description, Uses and Conservation Methods. Animals 2020, Vol. 10, Page 2257, 10(12), 2257. https://doi.org/10.3390/ANI10122257

Melesse, A., Maak, S., Schmidt, R., & von Lengerken, G. (2011). Effect of long-term heat stress on some performance traits and plasma enzyme activities in Naked-neck chickens and their F1 crosses with commercial layer breeds.

Livestock Science, 141(2–3), 227–231. https://doi.org/10.1016/J.LIVSCI.2011.06.007

Ministry of Fisheries and Livestock. (2023). Livestock Survey Report Republic of Zambia.

Msoffe, P. L. M., Minga, U. M., Olsen, J. E., Yongolo, M. G. S., Juul-Madsen, H. R., Gwakisa, P. S., & Mtambo, M. M. A. (2001). Phenotypes including immunocompetence in scavenging local chicken ecotypes in Tanzania. Tropical Animal Health and Production, 33(4), 341–354. https://doi.org/10.1023/A:1010544221028/METRICS

Mwacharo, J. M., Bjørnstad, G., Han, J. L., & Hanotte, O. (2013). The History of African Village Chickens: An Archaeological and Molecular Perspective. African Archaeological Review, 30(1), 97–114. https://doi.org/10.1007/s10437-013-9128-1

Padhi, M. K. (2016). Importance of Indigenous Breeds of Chicken for Rural Economy and Their Improvements for Higher Production Performance. Scientifica, 2016. https://doi.org/10.1155/2016/2604685

Patrick M. Kgwatalala. (2012). Growth performance of different strains of indigenous Tswana chickens under intensive management system. African Journal of Agricultural Research, 7(16), 2438–2445. https://doi.org/10.5897/ajar11.1220

Singh, P. K., & Sharma, A. (2016). Phenotypic characterization and documentation of animal genetic resources in India: A review. In Indian Journal of Animal Sciences (Vol. 82, Issue 12).

Smyth Jr, J. R. (1990). Genetics of plumage, skin and eye pigmentation in chickens. Developments in Animal and Veterinary Sciences, 22, 109-167.

Yakubu, A., Kuje, D., & Okpeku, M. (2009). Principal Components as Measures of Size and Shape in Nigerian Indigenous Chickens. Www.Thaiagj.Org Thai Journal of Agricultural Science, 42(3), 167–176. www.thaiagj.org

Yakubu, A., Ogah, D., & Barde, R. (2008). Productivity and egg quality characteristics of free range naked neck and normal feathered Nigerian indigenous chickens. Journal of Poultry Science, 7(6), 579–585.

Yunusa, A. J., & Adeoti, T. M. (2014). Multivariate Analysis for Body Weight and Some Linear Body Measurements of Nigerian Indigenous Chickens. Slovak J. Anim. Sci., 2014(3), 142–148.

APPENDICES

Appendix A. Tables
Appendix. A.1

Table 1: Distribution of chickens collected across provinces for the study

train %	**Northern**	**Luapula**	**Muchinga**	**Lusaka**	**Southern**	**Overall (%)**
Sample size	**7**	**8**	**24**	**4**	**57**	**100**
Naked neck	14.29	12.50	12.50	50.00	17.54	17.00
Frizzle-Feathered		25.00			8.77	7.00
Normal-Feathered	42.86	37.50	41.67		49.12	44.00
Short-Legged			29.17	50.00	7.02	13.00
White-Spotted	42.86	25.00	16.67		17.54	19.00

Appendix A.2

Table 2: Frequencies of some qualitative traits of chickens obtained from across the provinces for the study

Trait	Expression	Northern %			Luapula %			Muchinga %			Lusaka %			Southern %			Total %
		Female	Male	Overall	Female	Male	Overall	Female	Male	Overall	Female	Male	Overall	Female	Male	Overall	
Plumage color	Black	20.00		14.29	16.67	50.00	25.00	13.33	22.22	16.67		50.00	25.00	32.61		26.32	23.00
	Brown	20.00	50.00	28.57	16.67	50.00	25.00	46.67	11.11	33.33	50.00		25.00	34.78	18.18	31.58	31.00
	Grey							6.67		4.17				4.35		3.51	3.00
	Mixed	60.00	50.00	57.14	50.00		37.50	33.33	66.67	45.83	50.00	50.00	50.00	28.26	81.82	38.60	42.00
	White				16.67		12.50										1.00
Skin color	White	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Shank color	Black	20.00		14.29	33.33	50.00	37.50	13.33	22.22	16.67				19.57	9.09	17.54	18.00
	Green								11.11	4.17							1.00
	Grey							33.33	11.11	25.00	50.00	50.00	50.00	43.48	45.45	43.86	33.00
	White	60.00	50.00	57.14	33.33		25.00	40.00	33.33	37.50				23.91	45.45	28.07	31.00
	Yellow	20.00	50.00	28.57	33.33	50.00	37.50	13.33	22.22	16.67	50.00	50.00	50.00	13.04		10.53	17.00
Comb type	Rose														9.09	1.75	1.00
	Single	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	50.00	100.00	75.00	95.65	90.91	94.74	96.00
	pea										50.00		25.00	4.35		3.51	3.00
Earlobe color	White	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Eye color	Black								11.11	4.17				2.17		1.75	2.00
	Brown	40.00		28.57	16.67	50.00	25.00	26.67	11.11	20.83				32.61	27.27	31.58	27.00
	Orange	20.00	100.00	42.86	66.67		50.00	33.33	77.78	50.00	100.00	100.00	100.00	47.83	72.73	52.63	53.00
	Pearl	40.00		28.57	16.67	50.00	25.00	40.00		25.00				17.39		14.04	18.00

Appendix A.3

Table 3: Distribution of qualitative traits of chickens from different strains by sex

		Strain %															
Trait		**Naked neck**			**Normal feathered**			**White-spotted**			**Frizzled feathered**			**Short Legged**			
	Expression	Female	Male	Overall	Female	Male	Overall	Female	Male	Overall	Female	Male	Overall	Female	Male	Overall	**Total%**
Plumage colour	Black	25.00	20.00	23.53	40.63	16.67	34.09				50.00	33.33	42.86	9.09		7.69	23.00
	Brown	41.67	40.00	41.18	43.75	25.00	38.64				50.00		28.57	45.45		38.46	31.00
	Grey	16.67		11.76	3.13		2.27										3.00
	Mixed	16.60	40.00	23.53	9.38	58.33	22.73	100.00	100.00	100.00		66.67	28.57	45.45	100.00	53.85	42.00
	White				3.13	0.00	2.27										1.00
Skin colour	white	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Shank colour	Black	33.33		23.53	25.00	8.33	20.45				50.00	66.67	57.14		50.00	7.69	18.00
	Green					8.33	2.27										1.00
	Grey	41.67	60.00	47.06	43.75	25.00	38.64				25.00		14.29	54.55	50.00	53.85	33.00
	White				12.50	33.33	18.18	93.33	100.00	94.74	25.00	33.33	28.57	27.27		23.08	31.00
	Yellow	25.00	40.00	29.41	18.75	25.00	20.45	6.67		5.26				18.18		15.38	17.00
Comb type	Single	91.67	100.00	94.12	93.75	91.67	93.18	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	96.00
	Rose					8.33	2.27										1.00
	Pea	8.33		5.88	6.25		4.55										3.00
Earlobe colour	White	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Eye colour	Black				3.13	8.33	4.55										2.00
	Brown	25.00		17.65	37.50	16.67	31.82	6.67		5.26	75.00	66.67	71.43	27.27	50.00	30.77	27.00
	Orange	58.33	80.00	64.71	46.88	75.00	54.55	46.67	100.00	57.89	25.00	33.33	28.57	36.36	50.00	38.46	53.00
	Pearl	16.67	20.00	17.65	12.50		9.09	46.67		36.84				36.36		30.77	18.00

Appendix A.4

Table 4: Body weight and linear body measurement means by province

Trait	Luapula	Lusaka	Muchinga	Northern	Southern	P	mean
Body weight (kg)	1161.75^{b} ± 251.8	2037^{a} ± 40.57	1043.38^{b} ± 66.00	905.14^{b}±102.64	2116.26^{a} ±58.93	0.000	1694.46 ± 67.36
Body length (cm)	34.18^{a}±1.46	37^{a} ± 1.68	35^{a} ± 0.99	33^{a} ± 1.84	37.14^{a} ± 0.48	*0.025*	36.1 ± 0.42
Corpus length (cm)	20.03^{b} ± 1.13	24.75^{a} ± 1.38	20.67^{b} ± 0.59	20^{b} ± 1	23.89^{a} ± 0.37	*0.000*	22.57 ± 0.33
Chest circumference (cm)	22.94^{b} ± 1.84	27.75^{a} ± 0.48	22.54^{b} ± 0.43	21.14^{b} ± 1.28	27.84^{a} ± 0.34	*0.000*	25.71 ± 0.38
Keel length (cm)	10.84^{ab} ±0.83	11.13^{ab} ± 0.52	10.67^{ab} ± 0.28	9.57^{b} ± 0.48	12.21^{a} ± 0.20	*0.000*	11.50 ± 0.17
Shank circumference (cm)	4.04^{bc} ± 0.26	4.5^{ab} ± 0.2	3.92^{bc} ± 0.14	3.57^{c} ± 0.17	5.09^{a} ± 0.13	*0.000*	4.59 ± 0.10
Shank length (cm)	8.55^{a} ± 0.51	8.75^{a} ± 0.92	7.67^{a} ± 0.37	7.57^{a} ± 0.57	9.27^{a} ± 0.21	*0.001*	8.69 ± 0.18
Thigh length (cm)	13.19^{a} ± 0.80	12^{a} ± 0.91	12.5^{a} ± 0.63	12.14^{a} ± 0.59	14.05^{b} ± 0.30	*0.039*	13.39 ± 0.25
Thigh circumference (cm)	7.75^{b} ± 1.11	8.63^{ab} ± 0.24	7.21^{b} ± 0.30	7^{b} ± 0.62	9.66^{a} ± 0.24	*0.000*	8.69 ± 0.21
Wing span(cm)	33^{a} ± 1.87	36.38^{a} ± 2.01	32.88^{a} ± 1.03	33.43^{a} ± 2.42	34.79^{a} ± 0.57	*0.365*	34.16 ± 0.47

*Different superscripts across the rows mean significant differences (P<0.05), and the same superscript means no significant differences (P>0.05) across the rows, mean and Standard error of the mean (SEM), n = 100.

Appendix A.5

Table 5:Mean performances of body weight and linear body measurements by strain

Trait	Naked neck	Normal feathered	White-spotted	Frizzled feathered	Short legged	P	Mean
Body weight (kg)	1991.06^{a} ±105.79	1862.41^{a} ±99.39	1361.74^{bc} ±174.15	1793^{ab} ±179.788	1171.35^{c} ±189.59	0.000	1694.46 ±67.36
Body length (cm)	38.97^{a} ±0.58	37.35^{a} ±0.495	32.61^{b} ±0.80	37.7^{a} ±1.395	32.31^{b} ±1.26	*0.025*	36.10 ±0.42
Corpus length (cm)	24.91^{a} ±0.46	23.25^{b} ±0.43	20.49^{cd} ±0.74	22.91^{bc} ±0.93	20.05^{d} ±0.999	*0.000*	22.57 ±0.33
Chest circumference (cm)	27.21^{a} ±0.79	26.15^{a} ±0.42	23.83^{b} ±1.2	27.93^{a} ±1.73	23.75^{b} ±0.99	*0.000*	25.71 ±0.38
Keel length (cm)	12.38^{a} ±0.37	11.40^{ab} ±0.21	11.32^{ab} ±0.57	11.57^{ab} ±0.59	10.92^{b} ±0.47	*0.000*	11.50 ±0.17
Shank circumference (cm)	4.81^{b} ±0.21	4.53^{b} ±0.11	4.33^{b} ±0.21	5.97^{a} ±0.75	4.18^{b} ±0.24	*0.000*	4.59 ±0.10
Shank length (cm)	9.18^{ab} ±0.34	9.28^{a} ±0.21	8.26^{b} ±0.38	9.27^{ab} ±0.84	6.36^{c} ±0.29	*0.001*	8.69 ±0.18
Thigh length (cm)	14.64^{a} ±0.45	14.17^{a} ±0.298	12.52^{b} ±0.65	14.13^{ab} ±0.61	10^{c} ±0.36	*0.039*	13.39 ±0.25
Thigh circumference (cm)	10.28^{a} ±0.48	8.43^{b} ±0.26	8.53^{b} ±0.62	9.2^{ab} ±0.697	7.45^{b} ±0.498	*0.000*	8.69 ±0.21
Wing span(cm)	34.59^{a} ±0.63	35.72^{a} ±0.695	33.65^{a} ±1.19	33.26^{ab} ±0.85	29.55^{b} ±1.32	0.365	34.16 ±0.47

Appendix A.6

Table 6: Mean performances of body weight and linear body measurements by sex and strain

Trait	Sex	Naked Neck	Normal feathered	White-spotted	Frizzled Feathered	Short Legged
Body weight (kg)	Male	2185.6[a] ±276.8	1828[a] ±112.75	1757[ab] ±494.66	2063.67[a] ± 373.92	1520[b] ±440
	Female	1910[a] ±97.05	875.31[d] ± 214.25	1256.33[b] ±177.87	1590[b] ±105.69	1108[c] ±145.13
Body length (cm)	Male	40.8[a] ±0.73	40.22[a] ±0.85	36.5[b] ±1.5	41[a] ±1.52	37.5 ±1.5
	Female	40[a] ±0.66	36.28[b] ±0.48	31.56[c] ±0.74	35.23[c] ±0.94	31.36 ±1.28
Corpus length (cm)	Male	25.2[a] ±1.15	24.71[a] ± 0.80	22.5[b] ±1.85	25.07[a] ± 1.09	23.5[ab] ±2.5
	Female	24.79[a] ±0.48	25.70[a] ±0.47	19.96[b] ±0.77	21.3[b] ±0.62	19.42[b] ±1.02
Chest circumference (cm)	Male	29[a] ±1.70	26.86[a] ±0.28	26.5[a] ±2.02	29.16[a] ± 3.89	25.5[b] ±2.5
	Female	26.47[a] ±0.82	25.89[b] ±0.49	23.12[b] ±1.39	27[a] ±1.47	23.43[b] ±1.09
Keel length (cm)	Male	13[a] ± 1.21	12.06[b] ± 0.43	13.4[a] ± 1.57	12.67[b] ±0.88	13 ±1.0
	Female	12.12[b] ±0.19	11.15[c] ± 0.23	10.76[d] ±0.54	10.75[d] ± 0.55	10.55 ±0.46
Shank circumference (cm)	Male	5.28[a] ± 0.45	4.97[a] ±0.26	4.68[a] ±0.45	5.66[a] ±1.16	4.5[a] ±0
	Female	4.61[a] ± 0.23	4.37[a] ±0.11	4.23[a] ±0.24	6.2[a] ±1.11	4.12[a] ±0.29
Shank length (cm)	Male	10.6[a] ±0.4	10.29[a] ±0.45	10.25[a] ±1.11	10.8[a] ±0.76	7.5[b] ±0.5
	Female	8.58[b] ±0.33	8.90[b] ±0.21	7.73[b] ±0.26	8.13[b] ±1.08	6.15[b] ±0.30
Thigh length (cm)	Male	16.4[a] ±0.93	15.83[a] ±0.59	16[a] ±2.16	15.66[a] ±0.33	11.5[b] ±0.5
	Female	13.91[a] ±0.33	13.55[ab] ±0.28	11.59[b] ± 1.39	12.97[b] ±0.476	9.73[b] ± 0.35
Thigh circumference (cm)	Male	11[a] ± 1.30	9.54[b] ±0.61	10.5[a] ±2.18	9.33[b] ±1.76	8[c] ±1.0
	Female	9.97[b] ± 0.43	8.02[c] ±0.24	8[c] ± 0.50	9.1[b] ±0.37	7.35[c] ±0.57
Wing span(cm)	Male	35.7[a] ± 1.21	39.83[a] ±1.36	40.5[a] ±3.20	35.33[a] ±1.01	37.25[a] ±3.25
	Female	34.13[a] ±0.19	34.17[a] ±0.63	31.82[b] ±0.76	31.7[b] ±0.37	28.15[c] ±0.99

Appendix A.7

Table 7: Correlation analysis of the body weight and Linear Body measurements for all strains by sex (above the diagonal is female, and below is male).

	BW	CL	CC	TL	TC	SC	SL	KL	BL	WS
BW		0.817***	0.721***	0.729***	0.626***	0.570***	0.679***	0.655***	0.687***	0.549***
CL	0.771***		0.623***	0.658***	0.551***	0.435***	0.634***	0.531***	0.792***	0.560***
CC	0.870***	0.624***		0.464***	0.676***	0.687***	0.489***	0.482***	0.553***	0.343***
TL	0.480***	0.606***	0.419***		0.494***	0.349***	0.712***	0.410***	0.634***	0.597***
TC	0.805***	0.632***	0.853***	0.587***		0.605***	0.448***	0.592***	0.524***	0.365***
SC	0.740***	0.682***	0.804***	0.532***	0.679***		0.270***	0.424***	0.434***	0.2675***
SL	0.677***	0.675***	0.594***	0.725***	0.574***	0.620***		0.361***	0.575***	0.570***
KL	0.723***	0.480***	0.649***	0.492***	0.769***	0.653***	0.486***		0.466***	0.491***
BL	0.561***	0.719***	0.435***	0.481***	0.318***	0.519***	0.511***	0.279***		0.552***
WS	0.353***	0.404***	0.282***	0.345***	0.429***	0.237***	0.533***	0.369***	0.165***	

*** Correlation is significant at the $P<0.001$ level, CL= Corpus Length, CC= Chest Circumference, TL= Thigh Length, TC= Thigh Circumference, SC= Shank Circumference, SL=Shank Length, KL=Keel Length, BL=Body Length, WS=Wingspan.

Appendix A.8

Table 8: Correlation analysis of the body weight and linear body measurements within Naked neck strain (above the diagonal is female, and below is male).

Trait	**Naked neck**									
	Wt.	**CL**	**CC**	**TL**	**TC**	**SC**	**SL**	**KL**	**BL**	**WS**
Wt.		0.23***	0.92***	0.40***	0.87***	0.66***	0.34***	0.70***	0.02***	0.29***
CL	0.29***		0.22***	0.17***	0.23***	0.13***	0.28***	0.16***	0.52***	0.27***
CC	0.86***	0.30***		0.26***	0.77***	0.48***	0.39***	0.82***	0.07***	0.23***
TL	0.09***	0.82***	0.38***		0.35***	0.31***	-0.09***	0.22***	-0.12***	0.16***
TC	0.88***	0.30***	0.97***	0.37***		0.85***	0.02***	0.61***	0.28***	0.15***
SC	0.79***	0.64***	0.55***	0.35***	0.66***		0.27***	0.37***	0.35***	0.24***
SL	0.28***	0.91***	0.29***	0.65***	0.19***	0.46***		0.26***	-0.10***	0.62***
KL	0.73***	0.25***	0.65***	0.29***	0.82***	0.79***	-0.05***		0.14***	0.19***
BL	0.32***	0.60***	0.52***	0.84***	0.63***	0.56***	0.27***	0.73***		-0.33***
WS	-0.02***	0.07***	0.88***	-0.03***	0.61***	-0.10***	0.34***	0.94***	-0.21***	0.20***

***Correlation is significant at the p<0.001 level ,CL= Corpus Length, CC=Chest Circumference ,TL=Thigh Length, TC= THigh Circumference, SC= Shank Circumference, SL= Shank Length, KL=Keel Length, BL=Bloody Length ,WS=Wingspan

Appendix A.9

Table 9: Correlation analysis of the body weight and linear body measurements within Normal feathered strain (above the diagonal is female, and below is male)

Trait	**Normal feathered**									
	Wt.	**CL**	**CC**	**TL**	**TC**	**SC**	**SL**	**KL**	**BL**	**WS**
Wt.		0.82***	0.85***	0.72***	0.61***	0.82***	0.76***	0.61***	0.56***	0.24***
CL	0.86***		0.71***	0.54***	0.51***	0.76***	0.74***	0.53***	0.65***	0.29***
CC	0.89***	0.78***		0.52***	0.59***	0.75***	0.73***	0.56***	0.49***	0.15***
TL	0.40***	0.45**	0.58***		0.52***	0.59***	0.75***	0.73***	0.56***	0.28***
TC	0.67***	0.75***	0.86***	0.37***		0.53***	0.67***	0.50***	0.51***	0.26***
SC	0.68***	0.80***	0.76***	0.71***	0.63***		0.69***	0.60***	0.55***	0.17***
SL	0.71***	0.71***	0.63***	0.51***	0.44***	0.66***		0.32***	0.51***	0.15***
KL	0.82***	0.76***	0.79***	0.54***	0.65***	0.74***	0.78***		0.32***	0.51***
BL	0.82***	0.75***	0.68***	0.52***	0.44***	0.64***	0.62***	0.74***		0.33***
WS	0.39***	0.34***	0.54***	0.06***	0.46***	0.38***	0.65***	0.66***	0.66***	

*** Correlation is significant at the P<0.001 level, CL= Corpus Length, CC= Chest Circumference, TL= Thigh Length, TC= Thigh Circumference, SC= Shank Circumference, SL=Shank Length, KL=Keel Length, BL=Body Length, WS=Wingspan.

Appendix A.10

Table 10: Correlation analysis of the body weight and linear body measurements within the white-spotted strain (above the diagonal is female, and below is male)

Trait	**White-spotted**									
	Wt.	**CL**	**CC**	**TL**	**TC**	**SC**	**SL**	**KL**	**BL**	**WS**
Wt.		0.84***	0.47***	0.64***	0.70***	0.75***	0.7***	0.86***	0.58***	0.71***
CL	0.93***		0.52***	0.71***	0.49***	0.72***	0.63***	0.66***	0.80***	0.72***
CC	0.98***	0.85***		0.3***	0.71***	0.81***	0.49***	0.33***	0.35***	0.18***
TL	0.80***	0.96***	0.69***		0.51***	0.53***	0.70***	0.51***	0.53***	0.41***
TC	0.99***	0.97***	0.95****	0.89***		0.77***	0.76***	0.61***	0.35***	0.28***
SC	0.95***	0.97***	0.90***	0.87***	0.97***		0.76***	0.57***	0.57***	0.52***
SL	0.73***	0.83***	0.65***	0.90***	0.81***	0.68***		0.58***	0.64***	0.50***
KL	0.98***	0.95***	0.94***	0.88***	0.99***	0.92***	0.86***		0.56***	0.78***
BL	0.09***	0.45***	-0.1***	0.62***	0.23***	0.35***	0.38***	0.17***		0.75***
WS	0.92***	0.99***	0.84***	0.96***	0.97***	0.97***	0.83***	0.94***	0.47***	

*** Correlation is significant at the P<0.001 level, CL= Corpus Length, CC= Chest Circumference, TL= Thigh Length, TC= Thigh Circumference, SC= Shank Circumference, SL=Shank Length, KL=Keel Length, BL=Body Length, WS=Wingspan

Appendix A.11

Table 11: Correlation analysis of the body weight and linear body measurements within Frizzle-feathered strain (above the diagonal is female, and below is male)

Trait	**Frizzle feathered**									
	Wt.	**CL**	**CC**	**TL**	**TC**	**SC**	**SL**	**KL**	**BL**	**WS**
Wt.		-0.33***	0.97***	-0.13***	0.84***	0.84***	-0.91***	0.98***	0.52***	-0.36***
CL	0.61***		-0.54***	0.47***	0.23***	-0.70***	0.50***	-0.12***	0.50***	-0.27***
CC	0.98***	0.45***		-0.32***	0.70***	0.95***	-0.96***	0.89***	0.38***	-0.34***
TL	0.93***	0.85***	0.86***		0.23***	-0.58***	0.54***	0.03***	0.03***	0.60***
TC	0.99***	0.63***	0.98***	0.95***		0.43***	-0.61***	0.47***	0.77***	-0.42***
SC	0.99***	0.59***	0.99***	0.93***	0.99***		-0.97***	0.70***	0.26***	-0.38***
SL	0.99***	0.59***	0.99***	0.92***	0.99***	0.99***		-0.82***	-0.49***	0.55***
KL	0.99***	0.63***	0.65***	0.98***	0.94***	0.65***	1.0***		0.63***	-0.39**
BL	0.34***	0.95***	0.17***	0.65***	0.37***	0.33***	0.32***	0.37***		-0.87***
WS	0.28***	-0.59***	0.45***	-0.08***	0.25***	0.29***	0.30***	0.25***	-0.81***	

*** Correlation is significant at the P<0.001 level, CL= Corpus Length, CC= Chest Circumference, TL= Thigh Length, TC= Thigh Circumference, SC= Shank Circumference, SL=Shank Length, KL=Keel Length, BL=Body Length, WS=Wingspan.

Appendix A.12

Table 12: Correlation analysis of the body weight and linear body measurements within Short-legged strain (above the diagonal is female, and below is male).

Trait	**Short Legged**									
	Wt.	**CL**	**CC**	**TL**	**TC**	**SC**	**SL**	**KL**	**BL**	**WS**
Wt.		0.87***	0.89***	0.46***	0.74***	0.84***	0.46***	0.29***	0.88***	0.68***
CL	1.0***		0.79***	0.30***	0.57***	0.66***	0.32***	0.13***	0.71***	0.59***
CC	1.0***	1.0***		0.40***	0.85***	0.89***	0.54***	0.41***	0.85***	0.75***
TL	-1.0***	-1.0***	-1.0***		0.61***	0.62***	0.65***	0.32***	0.42***	0.70***
TC	1.0***	1.0***	1.0***	-1.0***		0.86***	0.50***	0.54***	0.63***	0.71***
SC	-	-	-	-	-		0.78***	0.33***	0.76***	0.79***
SL	1.0***	1.0***	1.0***	-1.0***	1.0***	-		0.28***	0.59***	0.67***
KL	-1.0***	-1.0***	-1.0***	1.0***	-1.0***	-	-1.0***		0.45***	0.13***
BL	1.0***	1.0***	1.0***	-1.0***	1.0***	-	1.0***	-1.0***		0.59***
WS	1.0***	1.0***	1.0***	-1.0***	1.0***	-	1.0***	-1.0***	1.0***	

*** Correlation is significant at the P<0.001 level, CL= Corpus Length, CC= Chest Circumference, TL= Thigh Length, TC= Thigh Circumference, SC= Shank Circumference, SL=Shank Length, KL=Keel Length, BL=Body Length, WS=Wingspan.