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Prediction of Growth Rate and Body Weight of Sasso Chickens from Linear Body Measurements Using Path Analysis

Simushi Liswaniso[3], Bupe Haazele Haachilala[4], Oswin Chibinga[4], Joseph Simbaya[4], Louis Thobela Tyasi[5], Xue Sun[1,2], Ning Qin[1,2] and Rifu Xu[1,2]*

[1]Joint Laboratory of Modern Agricultural Technology International Cooperation, Ministry of Education, Jilin Agricultural University, Changchun, 130118, China
[2]Department of Animal Genetics, Breeding and Reproduction, College of Animal Science and Technology, Jilin Agricultural University, Changchun, 130118, China
[3]Department of Livestock Development, Ministry of Fisheries and Livestock Development, Mulungushi House. P. O. Box 50199, Lusaka, Zambia
[4]Department of Animal Sciences, School of Agricultural Sciences, University of Zambia, P O Box 32379, Lusaka, Zambia
[5]Department of Agricultural Economics and Animal Production, University of Limpopo, Private Bag X1106, Sovenga 0727, South Africa

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SL conducted the experiment and drafted the manuscript. BHH conducted the experiment. OC, JS, XS and NQ edited the manuscript. LTT Analyzed the data. RX supervised the study and approved the final draft.

Key words
Sasso Chicken, Body weight, Growth rate, Path analysis, Linear body measurements

ABSTRACT

Body weight (BW) at maturity is an essential trait in poultry farming as it determines the price of the chickens in most formal markets. However, the chicken growth rate is more critical as a performance-monitoring tool for farmers. Nonetheless, it is difficult to predict these two traits while chickens are still young without expensive means. Therefore, this study sought to identify traits from among the linear body measurements (LBM) that can be used to predict both the growth rate and final BW while chickens are still young. The study was conducted in Chongwe District of Zambia using one hundred and thirty-two (132) 8-weeks old Sasso T431 cockerels. The cockerels were managed using small-scale farmer free-range management system. The study found an overall growth rate of 18.10g/day and chickens reached a final BW of 2312.61 g at the end of the 12 weeks. Correlation analysis found that all LBM were positively correlated with the growth rate and final BW except the SC, which was negatively correlated, suggesting that selection for any LBM with a positive correlation in week eight would increase body weight and growth rate. Path analysis identified corpus length to have the highest direct influence on growth rate and BW. The Keel Length was identified to have the greatest indirect influence on growth rate and mature body weights. Therefore, farmers can use corpus length at 8 weeks to select chickens that will be expected to grow bigger and faster.

INTRODUCTION

Body weight (BW) at maturity is a trait of economic importance in poultry production (Tyasi *et al*., 2017). This is because, in most formal markets, chickens are priced according to their body weights (Norris *et al*., 2015). However, the growth rate of livestock remains the most crucial trait in monitoring the growth performance of any livestock business (Bazeley *et al*., 2016). The faster the chickens grow, the lesser the production costs as they spend fewer days in the production unit. Breeders breeding for meat in chickens select parents for the next generation to improve the growth rate and the market weight. However, there are limited ways to predict growth rate and market weight while chickens are still young. One of the methods breeders can use is identifying some phenotypic traits that they can use as indicators to predict growth performance (Kumar *et al*., 2018).

Previous studies have sought to correlate livestock's linear body measurements (LBM) with some traits of economic importance. These LBM have been associated with mature BW of indigenous free-range chickens (Liswaniso *et al*., 2020), African non-descript indigenous goats (Mathapo *et al*., 2022), and heifers weight (Turini *et al*., 2021).

* Corresponding author: poultryxu@jlau.edu.cn
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Earlier studies employed linear regression and correlation methods to relate LBM to traits of economic importance. One such study is that of Ajayi *et al*. (2008), which sought to use LMB to estimate the body weight of broilers.

However, Yakubu (2010) reported that correlation analysis between LBM may not account for the relationships in all dimensions and, as such, may be insufficient in assessing the causal effects relationship between variables of biological relations. Certain traits such as milk yield in cattle are affected directly during selection and breeding, while some are indirectly influenced (Keskin *et al*., 2005). Path coefficient and path analysis could help address this inadequacy. It is reported that path analysis computes both the direct and indirect effects on dependent variables via independent variables (Temoso *et al*., 2017). Path analysis has been used to evaluate how breast weights relate to broiler chickens body composition and production traits (Lorentz *et al*., 2011).

Despite so many works in predicting traits of economic significance, there is limited literature on estimating the growth rate and final BW of Sasso chickens from LBM taken in the early stages of life. Therefore, there is a need to find a way to predict chickens' growth rate and market weight before they reach maturity. This would help in planning and decision-making that aid in the selection of chickens. Thus, this study aims to achieve three objectives: (i) to determine the relationship between LBM at week 8 and the growth rate until market weight; (ii) to determine the relationship between the final BW of Sasso chickens and the LBM on week 8; and (iii) to use path analysis to identify the specific LBM of the young chickens (at week 8) which directly and indirectly influences growth rate and the final BW. The findings of this study might be helpful to aid Sasso chicken farmers and breeders in selecting chickens for improved market weight and growth rate.

MATERIALS AND METHODS

Experimental animals and management

The study was conducted at Tutu animal genetics research farm in Chongwe District of Zambia. Chongwe district is situated east of Zambia's capital, Lusaka (Chikalipah, 2020).

This study used 132 male Sasso T431 chickens purchased as day-old chicks from a commercial hatchery in Lusaka, Zambia. The chicks underwent brooding following all routine or breeder's management guidelines, including feeding, watering, and vaccinations. While in the brooding phase, the chicks had free access to a commercial starter diet for six weeks, after which the chicks were released and reared on a free-range management system to simulate small-scale farming conditions. The cockerels scavenged for their feed in a free-range management style with minimal maize bran supplementation. Watering points were set up for their drinking water. The chickens were provided with basic night shelter.

Traits measured

After a week (7th week) of acclimatizing to the free-range setup, at the beginning of week 8, LBMs were taken from individually identified cocks using a procedure stipulated in the FAO (2012) guide and as used in other research (Liswaniso *et al*., 2020). The linear body measurements taken included the corpus length (CL), corpus circumference (CC), thigh length (TL), thigh circumference (TC), shank circumference (SC), shank length (SL), keel length (KL), and body length (BL). The LBM were taken using a tailor's tape in centimeters only at the beginning of week 8. The initial body weight was taken on the same day as the LBM, while the final weight was taken on the last day of week 20. All weights were taken using a digital scale. The final weight divided by the number of days was taken as the growth rate (weight gain/days).

Statistical analysis

MINITAB V18 was used to calculate the mean's descriptive statistics and standard error. The same software tabulated the Pearson correlation coefficients between the LBM, final BW, and growth rate. The path coefficients were taken as the standardized partial regression coefficients (beta weights). This was to check for direct contrast of values to echo the relative prominence of independent variables in elucidating the variation of the dependent variable.

The path coefficient from a descriptive variable (X) to a response variable (Y) is as defined by (Mendes *et al*., 2005):

Pyxi=*bixi*/*sy* SxiSy

Where, Pyxi denotes the path coefficient from Xi to Y (i =CL, CC, TL, TC, SC, SL, KL, and BL), bi designates the partial regression.

RESULTS

Table I shows the descriptive statistics of the initial BW, final BW, Growth rate, and LBM (CL, CC, TL, TC, SC, SL, KL, BL). The chickens used in this study had an initial mean weight of 1206.96 g and a final weight of 2312.61 g. These chickens displayed an average growth rate of 18.10 g/day over ten weeks.

Table II shows Pearson's correlation coefficients of LBM with both growth rate (GR) and final BW. All LBM were positively correlated with growth rate except for SC (r= -0.022). However, only CL, BL, and TL had significant (P<0.05) correlations with the GR. The final BW had a positive correlation with all LBM, although only 6 LBM (CL, CC, TL, TC, SC, and BL) had a significant (P <0.05) correlation. The positive correlation between the LBM and the BW and the GR suggests that if the selection is done for any of these LBM, it will result in a corresponding increase in both the BW and GR.

Path analysis was exploited to check which LBM had direct and indirect effects on the growth rate, and the results are shown in Table III. Path analysis only recognized 3 LBMs (CL, SC, and BL) as having a significant (P<0.05) direct influence on the growth rate of Sasso chickens. Path analysis further revealed that CL had the highest direct effect on the growth rate while KL had the highest indirect impact on the GR acting through the CL.

Path analysis was used to determine the direct and indirect effects of these LBM on the final body weight of chickens, as shown in Table IV. Only 4 LBM (CL, TC, SC, and KL) significantly (P<0.05) and directly affected the final body weight. Path analysis further recognized CL to have the highest direct effect on the final body weight. KL was identified to have the highest indirect effect acting via CL.

Table I. Descriptive statistics of growth rate and LBM of Sasso chickens on free-range.

Variable	Mean ± SE
Initial weight (g)	1206.96 ± 13.92
CL (cm)	16.83 ± 0.13
CC (cm)	24.66 ± 0.11
TL (cm)	10.49 ± 0.08
TC (cm)	9.38 ± 0.15
SC (cm)	3.90 ± 0.03
SL (cm)	8.45 ± 0.05
KL (cm)	8.74 ± 0.07
BL (cm)	33.54 ± 0.17
Final weight (g)	2312.61 ± 34.59
Overall growth rate (g/day)	18.10 ± 0.75

BW, body weight; CL, corpus length; CC, chest circumference, TL, thigh length; TC, thigh circumference; SC, shank circumference; SL, shank length; KL, keel length; BL, body length, SE, standard error.

Table II. Pearson correlation matrix.

	CL	CC	TL	TC	SC	SL	KL	BL
CC	0.416**							
TL	0.204	0.181						
TC	-0.024	-0.077	-0.098					
SC	0.281**	0.584**	-0.061	0.112				
SL	0.217*	0.382**	0.405**	0.163	0.301**			
KL	0.370**	0.378**	0.311**	0.011	0.392**	0.409**		
BL	0.054	0.559**	0.400**	-0.111	0.289**	0.129	0.066	
Final weight	0.537**	0.546**	0.250*	0.240*	0.222*	0.2	0.175	0.219*
Growth rate	0.307**	0.16	0.207*	0.11	-0.022	0.054	0.155	0.205*

**- P<0.01, * P<0.05 level. For abbreviations, see Table I.

Table III. Path analysis of LBM and Growth rate of chickens.

Traits	Correlation with GR	Direct effects	In direct effects							
			CL	CC	TL	TC	SC	SL	KL	BL
CL	0.307**	0.325**		0.003	0.006	-0.005	-0.068	-0.016	0.048	0.014
CC	0.16^{ns}	0.008^{ns}	0.135		0.005	-0.015	-0.141	-0.029	0.049	0.147
TL	0.207*	0.028^{ns}	0.066	0.001		-0.018	0.015	-0.031	0.040	0.105
TC	0.11^{ns}	0.188^{ns}	-0.008	-0.001	-0.003		-0.027	-0.012	0.001	-0.029
SC	-0.022^{ns}	-0.241*	0.091	0.005	-0.002	0.021		-0.023	0.051	0.076
SL	0.054^{ns}	-0.076^{ns}	0.070	0.003	0.011	0.031	-0.073		0.053	0.034
KL	0.155^{ns}	0.129^{ns}	0.120	0.003	0.009	0.002	-0.095	-0.031		0.017
BL	0.205^{ns}	0.264*	0.018	0.005	0.011	-0.021	-0.070	-0.010	0.009	

* P<0.05 level, ^{ns}, non significant. For abbreviations, see Table I.

Table IV. Path analysis of LBM and final body weight of chickens.

Traits	Correlation with body weight	Direct effects	Indirect effects							
			CL	CC	TL	TC	SC	SL	KL	BL
CL	0.537**	0.327*		0.073	0.013	-0.006	-0.075	0.008	-0.078	-0.005
CC	0.546**	0.177 ^{ns}	0.052		0.011	-0.019	-0.155	0.013	-0.079	-0.048
TL	0.250*	0.062 ^{ns}	0.067	0.032		-0.024	0.016	0.014	-0.065	-0.035
TC	0.240*	0.247*	-0.008	-0.014	-0.006		-0.030	0.006	-0.002	0.010
SC	0.222*	-0.266*	0.071	0.103	-0.004	0.028		0.011	-0.082	-0.025
SL	0.200 ^{ns}	0.035 ^{ns}	0.071	0.067	0.025	0.040	-0.080		-0.086	-0.011
KL	0.175 ^{ns}	-0.21*	0.121	0.067	0.019	0.003	-0.104	0.014		-0.006
BL	0.219*	-0.087 ^{ns}	0.018	0.099	0.025	-0.027	-0.077	0.005	-0.014	

* P<0.05 level, ^{ns}, non significant. For abbreviations, see Table I.

DISCUSSION

The relationship between BW and LBM has been reported adequately, and many models to predict BW from LBM of chickens have been published (Tadele, 2019; Negash, 2021). This method is cheap and helpful, especially in places where weighing scales are hard to find due to costs or lack of technical know-how in cases of breakdowns. However, most studies focused on the relationship between LBM at maturity and the final body weight. There is limited information on the use of LBM to predict future performances.

This study sought to identify which LBM can be used to predict Sasso chickens' final BW and growth rate before they reach market weight. This study identified traits that farmers and breeders can use as early as the 8th week of age to select Sasso chickens that grow bigger and faster. This study chose path analysis for its ability to handle multicollinearity challenges that mere regression normally would not do.

Body weight is vital for its monetary translation at the time of sale, while the growth rate is a good monitoring tool for producers. The chickens in this study had an initial weight at week 8 of 1206.96±13.92 g and a final weight of 2312.61 g at week 20 giving an average growth of 18.10/day. A study by Singh *et al*. (2019) found that the indigenous Uttara chickens weighed 471.75 ± 10.79 g and 1465.93 ± 21.35 g in the 8th week and 20th week, respectively. The average growth rate of 18.10g/day recorded in this study was higher than the 8.8g/day, and 11.5 g/day recorded for Gassay and Mecha chickens, respectively (Egena and Kolawole, 2014). Moreover, by week 26, Sasso chickens can weigh up to 2776.00 g (Sanka *et al*., 2020) and would be ready for sale. The variations in growth performance between Sasso and the other chickens may be due to differences in breed, management, and environmental conditions used in the studies. However, the average body weight and growth rate of chickens varies with generations (Patel *et al*., 2020).

Correlation analysis revealed that only CL, TL, and BL correlated significantly (P <0.05) with the growth rate. This study also established a significant (P <0.05) correlation between final body weight and CL, CC, TL, TC, SC, and BL. Other studies have also found a positive relationship between LBM and BW in different breeds of chickens (Lattif, 2019; Negash, 2021; Liswaniso *et al*., 2023). The positive correlation between the LBM taken at 8 weeks with both the final body weight and growth rate suggests that if a selection is done for any of these LBM at week 8, it will result in a corresponding increase in growth rate and mature BW.

This study further employed path analysis to appreciate the direct and indirect relationships between LBM taken at week 8 and the final BW and the growth rate. This study revealed that CL had the highest direct effect on both mature weight and growth rate. A similar study on Zambian indigenous free-range chickens also found that CL had the highest direct impact on body weight (Liswaniso *et al*., 2020). In contrast to current findings, Bila *et al*. (2021) found the shank circumference to have the highest direct effect on the weight of Ross 308 male broiler chickens. While the results of this study are comparable to other studies, most studies related the final body with LBM taken at maturity. According to Magala *et al*. (2012), Nakkazi *et al*. (2015), and Sanka *et al*. (2020), the growth rate of chicks is influenced by many factors, including the production system, genotype, stocking density, nutrition, age, and sex.

CONCLUSION

This study established that the corpus length significantly influenced the growth rate and final body weight. This study also identified the keel length as having the most substantial indirect influence on the growth rate and final body weight. Therefore, small-scale farmers and breeders can select cockerels that have the potential to grow bigger and faster in free-range management systems by selecting those with higher corpus lengths just after the brooding stage.

DECLARATIONS

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IRB approval

The study was approved by the Institutional Research Protocol No. SMHS-MU1-2024-49.

Ethical statement

All procedures were conducted as approved by the Ethics Review Committee.

Conflict of interest

The authors have declared no conflict of interest.

REFERENCES

Ajayi, F., Ejiofor O. and Ironkwe, M.O., 2008. Estimation of body weight from linear body measurements in two commercial meat-type chicken. *Glob. J. Agric. agric. Sci*., **7**: 3. https://doi.org/10.4314/gjass.v7i1.2361

Bazeley, K.J., Barrett, D.C., Williams, P.D. and Reyher, K.K., 2016. Measuring the growth rate of uk dairy heifers to improve future productivity. *Vet. J.*, **212**: 9-14. https://doi.org/10.1016/j.tvjl.2015.10.043

Bila, L., Tyasi, T., Tongwane, T. and Mulaudzi, A., 2021. Correlation and path analysis of body weight and biometric traits of ross 308 breed of broiler chickens. *J. World's Poult. Res*., **11**: 2021. https://doi.org/10.36380/jwpr.2021.41

Chikalipah, S., 2020. The pyrrhic victory of fintech and its implications for achieving the sustainable development goals (sdgs): Evidence from fieldwork in rural zambia. *World J. Sci. Technol. Sustain. Dev*., **17**: 329-340. https://doi.org/10.1108/WJSTSD-06-2020-0058

Egena, S.S.A. and and Kolawole, R., 2014. An assessment of the relationship between body weight and body measurements of indigenous nigeria chickens (*Gallus gallus domesticus*) using path coefficient analysis. *Livest. Res. Rural. Dev*., **26**: 114-118.

FAO, 2012. *Phenotypic characterization of animal genetic resources*. In: *FAO animal production and health guidelines*. Rome, Italy.

Keskin, S., Kor A., Karaca S. and Lu H.M., 2005. A study of relationships between milk yield and some udder traits using path analysis in makkeci goats. *J. Anim. Vet. Adv*., **4**: 547-550.

Kumar, S., Dahiya, S., Dahiya, Z. and Patil, C., 2018. Prediction of body weight from linear body measurements in sheep. *Indian J. Anim. Res*., **52**: 4. https://doi.org/10.18805/ijar.B-3360

Lattif, F.H.A., 2019. The linear association between live body weight and some body measurements in some chicken strains. *Pl. Arch*., **19**: 595-599.

Liswaniso, S., Qin, N., Sun, X. and Xu, R., 2023. Phenotypic characterization of indigenous free range chicken in Kalomo, Zambia. *J. Anim. Pl. Sci*., **33**: 2023. https://doi.org/10.36899/JAPS.2023.3.0658

Liswaniso, S., Tyasi, T., Qin, N., Sun, X. and Xu, R., 2020. Assessment of the relationship between body weight and linear body measurement traits of Zambian indigenous free-range chickens using path analysis. *Sylwan*, **164**: 465-485.

Lorentz, L., Gaya, L., Lunedo, R., Ferraz, J., Rezende, F. and Michelan-Filho, T., 2011. Production and body composition traits of broilers in relation to breast weight evaluated by path analysis. *Sci. Agric*., **68**: 320-325. https://doi.org/10.1590/S0103-90162011000300008

Magala, H., Kugonza, D., Kwizera, H. and Kyarisiima, C., 2012. Influence of varying dietary energy and protein on growth and carcass characteristics of ugandan local chickens. *J. Anim. Prod. Adv*., **2**: 316-324.

Mathapo, M., Mugwabana, J. and Tyasi, T., 2022. Prediction of body weight from morphological traits of south african non-descript indigenous goats of lepelle-nkumbi local municipality using different data mining algorithm. *Trop. Anim. Hlth.*

Prod., **54**: 1-9. https://doi.org/10.1007/s11250-022-03096-9

Mendes, M., Karabayır, A. and Pala, A., 2005. Path analysis of the relationships between various body measures and live weight of american bronze turkeys under three different lighting programs. *Tarim Bilim. Derg*., **11**: 184–188. https://doi.org/10.1501/Tarimbil_0000000408

Nakkazi, C., Kugonza, D. and Kayitesi, A., 2015. The effect of diet and feeding system on the on-farm performance of local chickens during the early growth phase. *Livest. Res. Rural. Dev*., **27**: 204.

Negash, F., 2021. Predicting body weight of Ethiopian indigenous chicken populations from morphometric measurements. *Turk. Tarim Gida Bilim. Teknol. Derg*., **9**: 1138-1143. https://doi.org/10.24925/turjaf.v9i6.1138-1143.4119

Norris, D., Brown, D., Moela, A., Selolo, T., Mabelebele, M., Ng'ambi, J. and Tyasi, T., 2015. Path coefficient and path analysis of body weight and biometric traits in indigenous goats. *Indian J. Anim. Res.*, **49**: 573-578. https://doi.org/10.18805/ijar.5564

Patel, A.B., Bhagora, N.J., Savaliya, F.P., Mishra, R.K. and Lonkar, V.D., 2020. Performance of ankleshwar chicken reared under intensive management system in Gujarat. *Indian J. Vet. Sci. Biotech.,* **15**: 47–50. https://doi.org/10.21887/ijvsbt.15.4.9

Sanka, Y.D., Mbaga, S.H., Mutayoba, S.K., Katule, A.M. and Goromela, S.H., 2020. Evaluation of growth performance of sasso and kuroiler chickens fed three diets at varying levels of supplementation under semi-intensive system of production in tanzania. *Trop. Anim. Hlth. Prod*., **52**: 3315-3322. https://doi.org/10.1007/s11250-020-02363-x

Singh, M.K., Kumar, S., Sharma, R.K., Singh, S.K., Singh, B. and Singh, D.V., 2019. Genetic parameter estimates for juvenile body weight in indigenous uttara chickens. *Indian J. Anim. Res*., **53**: 429–434. https://doi.org/10.18805/ijar.B-3560

Tadele, A., 2019. Statistical modelling of indigenous chicken with body weight and linear body measurements in bench maji zone,south western ethiopia. *J. environ. Sci. Nat. Resour*., **22**: 63-67.

Temoso, O., Coleman, M., Baker, D., Morley, P., Baleseng, L., Makgekgenene, A. and Bahta, S., 2017. Using path analysis to predict bodyweight from body measurements of goats and sheep of communal rangelands in botswana. *S. Afr. J. Anim*., **47**: 854-863. https://doi.org/10.4314/sajas.v47i6.13

Turini, L., Conte, G., Bonelli, F., Madrigali, A., Marani, B., Sgorbini, M. and Mele, M., 2021. Designing statistical models for holstein rearing heifers weight estimation from birth to 15 months old using body measurements. *Animals*, **11**: 1846. https://doi.org/10.3390/ani11071846

Tyasi, T., Qin, N., Jing, Y., Mu, F., Zhu, H., Liu, D., Yuan, S. and Xu, R., 2017. Assessment of relationship between body weight and body measurement traits of indigenous chinese dagu chickens using path analysis. *Indian J. Anim. Res*., **51**: 588-593.

Yakubu, A., 2010. Path coefficient and path analysis of body weight and biometric traits in yankasa lambs. *Slovak J. Anim. Sci*., **43**: 17-25.