Acta Scientific Veterinary Sciences (ISSN: 2582-3183)

Volume 5 Issue 8 August 2023

Research Article

Allometric Growth Models for Improvement of Size and Conformation in Crossbred Chickens

UC Isaac[1]*, OM Ejivade[1], J Ezea[2] and RJ Nosike[2]

[1]*Department of Animal Science and Technology, Faculty of Agriculture, Nnamdi Azikiwe University, Awka, Nigeria*

[2]*Department of Animal Breeding and Physiology, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria*

***Corresponding Author:** UC Isaac, Department of Animal Science and Technology, Faculty of Agriculture, Nnamdi Azikiwe University, Awka, Nigeria.

DOI: 10.31080/ASVS.2023.05.0720

Received: July 20, 2023

Published: July 29, 2023

Abstract

Allometric growth equations were obtained from log-linear regressions of log transformed data for shank length, drumstick length, body width and keel length as response variables and body weight as a predictor variable. Data were collected from Isa Brown × frizzled feathered (IB × F), Isa Brown × naked neck (IB × Na), Isa Brown × normal feathered (IB × N), frizzle feathered × Isa Brown (F × IB), naked neck × Isa Brown (Na × IB) and normal feathered × Isa Brown (N × IB) chicken genotypes at 2-10 (for mixed sexes) and 12-20 (for separate sexes) weeks growing phases on biweekly basis. Analysis of pooled data at 2-10 weeks indicated the occurrence of isometric growth of the shank in all genotypes, drumstick in Na × IB and N × IB, body width in all genotypes except Na x IB and keel in N x IB only. There was allometric growth of all linear traits relative to body weight in males and females of any genotype at the 12-20 weeks growing phase, although the rate of relative growth was higher in males than females. The results indicated that selection for improvement of body size based on relative growth response could be achieved with the linear structural components, especially shank length at 2-10 weeks growing phase, while improvement of specific body parts regardless of sex would be effective at 12-20 weeks growing phase in any of the genotypes studied.

Keywords: Log Transformation; Non-Linear Regression; Relative Growth; Body Weight; Linear Structural Components

Introduction

Growth is a biological process which results in increase in body mass and size of living things [1]. It is a result of complex interaction of genetic and non-genetic factors including feed and other environmental variables. Growth in poultry, as in other farm species, is usually measured by increase in different linear body components and body weight [2]. Body weight and linear structural body components or measurements are estimators of size and conformation which are important determinants of the economic values of meat animals [3]. Body weight is a sum total of increases in size of different structural components [1,4]. Thus, relative growth exists between body weight and linear structural body components. The rate at which linear parameters grow in relation to body weight and to one another determines the isometry or allometry of growth. An equal rate of growth between the body parts and the whole gives isometric growth; allometric growth occurs when there is a disproportionate or unequal rate of growth of body parts relative to the whole [5]. The linear structural body parts influence body size in poultry. For instance, the length of the keel in most cases is a determinant of the amount of muscle deposit around the breast region, which in turn determines the breast width. Positive correlation has been established between each of these linear parameters and body weight [6], indicating that prediction and indirect selection of body weight for increased body size can be achieved using the linear parameters [6]. The linear structural body components are vital selection indices for improving conformation in chicken [8].

The occurrence of allometric growth is important in poultry breeding for improving specific body parts [9]. For instance, in an area where demand for the lap or breast is high, breeders can select broilers showing higher growth rate in breast and drumstick relative to the whole body size to meet the market demand. The objective of this study was to determine the isometry/allometry of growth of linear structural body components to body weight of different chicken genotypes either as mixed or separate sexes in different growing phases for the purpose of selection for improved body size and conformation.

Materials and Methods

Stock and management

Thirty-six (36) exotic Isa Brown (9 cocks and 27 hens), 11 frizzle feathered (3 cocks and 8 hens), 10 naked neck (3 cocks and 7 hens) and 12 normal feathered (3 cocks and 9 hens) chickens were mated to produce 531 day-old chicks in twelve hatches at weekly intervals. The genotypes of the chicks with their respective numbers were 123 Isa Brown x frizzle feathered, 49 Isa Brown x naked neck, 116 Isa Brown x normal feathered, 137 frizzle feathered x Isa Brown, 42 naked neck x Isa Brown and 64 normal feathered x Isa Brown. Br ooding cages of 79 x 67 x 61 cm^3 dimension were constructed on deep litter pens of 2.65 x 1.67 m^2 dimension each and used to brood the chicks for a period of 4 weeks per hatched. The chicks were fed continuously with feed containing 2800 kcal metabolisable energy (ME)/kg and 20% crude protein (CP) at chick phase (0-6 weeks) and 2550 kcal ME/kg and 15% CP at grower phase (6-20 week). Cool, clean water was also provided to the chickens *ad libitum*. The chickens were administered New Castle disease vaccine at day-old. Vitamin supplements and antibiotics were given to the birds through drinking water routinely. The experimental environment and conditions were comfortable to the animals. The poultry house was of dwarf wall of about 0.90 cm high with wire guaze extending from the dwarf wall to the roof. This provided enough ventilation that kept the birds in their comfort zone without experiencing heat stress.

Data collection

Data were collected in a biweekly basis on body weight and linear structural traits of mixed/combined sexes at 2-10 weeks and separate sexes (males and females) at 12-20 weeks of age. Body weight was measured in grams (g) using Ohaus electronic sensitive weighing scale (Model CS5, 000) with sensitivity of 2.00 g. Shank length was measured as the distance from the hock joint to the tarso- metatarsus pad-Digit three joint. Drumstick length was measured as the length of the femur bone from ball and socket joint to the hock joint. Body width was measured as the circumference of the widest part of the anterior region and keel length, as the distance from the V-joint to the end of the sternum. The linear structural traits were measured with a tape in centimeters. All measurements were described according to [4] and [10].

Analytical procedure

The allometric growth equation was obtained using expression (1).

$Y = \alpha W^{\beta}$ ... (1)

where Y is the conformation trait, W is the body weight, α (alpha) is the initial growth constant and β (beta) is the coefficient of allometry. The constant, α and the coefficient, β were obtained by fitting the log-transformed data to the log-linear regression equation as expressed in (2).

$\text{Log}_{10}Y = \log\alpha + \beta\log_{10}W$....... (2)

The estimate α, of the initial growth constant was calculated by the formula:

= Antilog (log Y - βlogW).

The coefficient of allometry or distribution, $\hat{\beta}$, a measure of growth of each of the conformation traits relative to the whole body size [4], was obtained by the formula:

$\hat{\beta} = (\log Y - \log\alpha)/\log W$

The $\hat{\beta}$ is expected to be biased since the body weight it estimates is a random variable like the other conformation traits. An unbiased estimate of the body weight, $\hat{\beta}'$ was obtained by the formula:

$\hat{\beta}' = \hat{\beta}/r$

where r is the coefficient of correlation between logW and logY. A coefficient of isometric growth (0.33) which is an indication of equal rate of growth between any structural part and the body as a whole [12], was used to compare with the coefficients of allometry. There was isometric (proportionate) growth between any linear structural body components and the body weight where the $\hat{\beta}$ was equal to 0.33 or within the range of 0.30-0.39. [1], however, stated that isometric growth occurred when $\hat{\beta} = 1$.

Results

Table 1 shows the log-linear and allometric growth equations for linear structural traits of mixed sexes of the chicken genotypes (2-10 weeks). Shank length and body width showed isometric growth while drumstick length and keel length manifested allometric growth pattern in relation to body weight in most of the genotypes. The allometric growth estimate of 0.32 was observed between the shank length and body weight in Na × IB genotype.

In Tables 2-5, the allometric growth coefficients were all higher than 0.33, indicating that the linear structural body components grew at a higher rate to body weight in both males and females of every genotype. The allometric growth coefficients of males were generally higher than those of females.

Discussion

Relative growth rates of linear structural traits to body weight of mixed sexes of the chicken genotypes at 2-10 weeks growing phase

The observed isometric (equal rate of) growth of the shank and body width to the body weight (Table 1) indicated that the two linear traits could serve as body weight predictors at early growing phase. The predictability of body weight by shank length and body width has been affirmed by previous researchers [13-15]. This growth pattern is indicative of the existence of genetic correlation between the linear parameters and body weight. This view is supported by previous research [10,16].

The allometric growth estimate of 0.32 observed between the shank length and body weight in Na × IB indicated that the rate of body weight increase was slightly less than that of shank length, implying that Na gene impacted long shank to the genotype. The

Table 1: Log-linear and allometric growth equations for linear structural traits of mixed sexes of different chicken genotypes (2-10 weeks).

Linear Trait	Group	Log-linear	r^2 (%)	SE	Allometric	r	$\hat{\beta}$	$\hat{\beta}'$
SL	IB × F	Y = -0.13 + 0.31W	81.8	0.05	$SL = 0.72W^{0.31}$	0.904	0.31	0.34
	IB × Na	Y = -0.16 + 0.32W	84.8	0.05	$SL = 0.69W^{0.32}$	0.921	0.32	0.35
	IB × N	Y = -0.16 + 0.32W	75.3	0.06	$SL = 0.69W^{0.32}$	0.868	0.32	0.37
	F × IB	Y = -0.13 + 0.31W	82.5	0.05	$SL = 0.74W^{0.31}$	0.908	0.31	0.34
	Na × IB	Y = -0.10 + 0.29W	81.5	0.04	$SL = 0.79W^{0.29}$	0.903	0.29	0.32
	N × IB	Y = -0.13 + 0.30W	83.2	0.04	$SL = 0.74W^{0.30}$	0.912	0.30	0.33
DL	IB × F	Y = -0.09 + 0.42W	87.3	0.05	$DL = 0.81W^{0.42}$	0.935	0.42	0.45
	IB × Na	Y = 0.05 + 0.36W	83.3	0.05	$DL = 0.87W^{0.40}$	0.942	0.40	0.42
	IB × N	Y = -0.07 + 0.41W	84.2	0.06	$DL= 0.85W^{0.41}$	0.918	0.41	0.46
	F × IB	Y = -0.08 + 0.41W	88.3	0.05	$DL = 0.83W^{0.41}$	0.946	0.41	0.43
	Na × IB	Y = 0.05 + 0.36W	83.3	0.05	$DL = 1.12W^{0.36}$	0.913	0.36	0.39
	N × IB	Y = -0.03 + 0.39W	82.8	0.06	$DL = 0.93W^{0.39}$	0.910	0.39	0.38
BW	IB × F	Y = 0.37 + 0.35W	79.9	0.06	$BW = 2.34W^{0.32}$	0.894	0.35	0.39
	IB × Na	Y = 0.41 + 0.32W	73.1	0.07	$BW = 2.57W^{0.31}$	0.855	0.32	0.37
	IB × N	Y = 0.37 + 0.35W	85.0	0.05	$BW = 2.35W^{0.35}$	0.922	0.35	0.39
	F × IB	Y = 0.38 + 0.35W	87.3	0.04	$BW = 2.42W^{0.35}$	0.934	0.35	0.37
	Na × IB	Y = 0.41 + 0.33W	69.7	0.07	$BW = 2.57W^{0.33}$	0.897	0.33	0.40
	N × IB	Y= 0.38 + 0.34W	85.6	0.05	$BW = 2.40W^{0.34}$	0.925	0.34	0.37
KL	IB × F	Y = -0.18 + 0.38W	86.4	0.05	$KL = 0.66W^{0.38}$	0.929	0.38	0.41
	IB × Na	Y = -0.13 + 0.37W	83.5	0.06	$KL = 0.74W^{0.37}$	0.914	0.37	0.40
	IB × N	Y = -0.06 + 0.33W	76.9	0.06	$KL = 0.87W^{0.33}$	0.877	0.33	0.38
	F × IB	Y = -0.18 + 0.38W	80.5	0.05	$KL = 0.79W^{0.38}$	0.897	0.36	0.40
	Na × IB	Y = -0.10 + 0.36W	80.5	0.05	$KL = 0.79W^{0.36}$	0.897	0.36	0.40
	N × IB	Y = -0.15 + 0.38W	82.5	0.06	$KL = 0.71W^{0.38}$	0.908	0.38	0.42

IB × F = Isa Brown × Frizzle feathered, IB × Na = Isa Brown × naked neck, IB × N = Isa Brown × normal feathered, F × IB = Frizzle feathered × Isa Brown, Na × IB = Naked neck × Isa Brown, N × IB = Normal feathered × Isa Brown

SL: Shank Length; DL: Drumstick Length; BW: Body Width; KL: Keel Length; W: Body Weight

Y = Log_{10} (linear trait); W = $\log_{10}$ (body weight) SE: Standard Error result also revealed that the naked neck chickens had relatively small body size, an attribute which has commonly been reported in previous studies [16,17]. Small body size is an attribute of good layers, which has been reported to correlate positively with egg production [18]. Long shank and small body size may therefore serve as good indicators for high rate of lay in chicken. This view has previously been expressed by [19].

The allometric growth of drumstick length and keel length relative to body weight at 2-10 weeks was an indication that improved thigh and breast could be realised early enough by selecting birds with long drumstick and keel [20]. This has an advantage of shortened generation interval and less financial implications over selection at 12-20 weeks using the same linear traits which showed allometric growth in the 12-20 weeks growing phase.

Relative growth rates of linear structural traits to body weight of male and female chicken genotypes at 12-20 weeks growing phase.

The existence of allometric growth of the linear parameters relative to the body weight of male and female chickens of different genotypes (Tables 2-5) indicated that different body parts, especially the breast and keel, increased in greater proportion than body weight. With this growth pattern, selection can be done to shift the body mass to the intended body parts that will yield high economic value. The occurrence of allometric growth at this phase (12-20 weeks) is an evidence that growth is highly dependent on age [21], which invariably influences production. Age is an important factor in animal breeding, which enables selection to be targeted at the time maximum improvement can be realised [22]. The greater rate of growth of the linear traits relative to body weight at this phase also implied that the rate of body weight increase was faster at early growth, reaching a maximum, and gradually declining with age. This is a general observation in poultry especially broilers [23]. This growth pattern can serve as a guide in selection for growth traits for maximum improvement in poultry.

The greater allometric growth observed in males than females is attributed to sexual dimorphism, which is more pronounced in males than females [24,25]. Sexual dimorphism is inherent in livestock species. This has informed the basis for using stud males to improve unproductive females [26].

Conclusion

Table 2: Log-linear and allometric growth equations for shank length of male and female chickens of different genotypes (12-20 weeks).

Group	Sex	Log-linear	r^2 (%)	SE	Allometric	r	$\hat{\beta}$	$\hat{\beta}'$
IB × F	M	Y = 0.07 + 0.67W	87.1	0.04	$SL = 0.09W^{0.67}$	0.933	0.67	0.72
	F	Y = 0.76 + 0.56W	79.0	0.04	$SL = 0.17W^{0.56}$	0.889	0.56	0.63
IB × Na	M	Y = 1.10 + 0. s70W	81.3	0.04	$SL = 0.08W^{0.70}$	0.902	0.70	0.78
	F	Y = 1.04 + 0.67W	80.3	0.04	$SL = 0.09W^{0.67}$	0.896	0.67	0.76
IB × N	M	Y = 0.82 + 0.52W	56.2	0.04	$SL = 0.15W^{0.52}$	0.750	0.52	0.69
	F	Y = 0.44 + 0.43W	49.7	0.04	$SL = 0.36W^{0.43}$	0.705	0.43	0.61
F × IB	M	Y = 0.83 + 0.58W	82.8	0.03	$SL = 0.15W^{0.58}$	0.910	0.58	0.64
	F	Y = 0.82 + 0.57W	85.4	0.03	$SL = 0.15W^{0.57}$	0.924	0.57	0.62
Na × IB	M	Y = 0.78 + 0.56W	85.1	0.03	$SL = 0.17W^{0.51}$	0.911	0.51	0.61
	F	Y = 0.64 + 0.51W	83.0	0.03	$SL = 0.23W^{0.51}$	0.911	0.51	0.56
N × IB	M	Y = 0.72 + 0.54W	77.6	0.04	$SL = 0.19W^{0.54}$	0.881	0.54	0.61
	F	Y = 0.60 + 0.49W	85.5	0.04	$SL = 0.25W^{0.49}$	0.925	0.49	0.53

SL: Shank Length

IB × F = Isa Brown × Frizzle feathered, IB × Na = Isa Brown × naked neck, IB × N = Isa Brown × normal feathered, F × IB = Frizzle feathered × Isa Brown, Na × IB = Naked neck × Isa Brown, N × IB = Normal feathered × Isa Brown

Y = Log_{10} (linear trait); W = log_{10} (body weight)

M: Male; F: Female

SE: Standard Error

Table 3: Log-linear and allometric growth equations for drumstick length of male and female chickens of different genotypes (12-20 weeks)

Group	Sex	Log-linear	r^2 (%)	SE	Allometric	r	$\hat{\beta}$	$\hat{\beta}'$
IB × F	M	Y = -0.67 + 0.63W	86.6	0.03	$DL = 0.21W^{0.63}$	0.931	0.63	0.68
	F	Y = -0.24 + 0.48W	80.3	0.03	$DL = 0.58W^{0.48}$	0.896	0.48	0.54
IB × Na	M	Y = -0.82 + 0.69W	84.9	0.03	$DL = 0.15W^{0.69}$	0.921	0.69	0.75
	F	Y = -0.66 + 0.63W	82.9	0.03	$DL = 0.22W^{0.63}$	0.910	0.63	0.69
IB × N	M	Y = -0.36 + 0.52W	60.3	0.03	$DL = 0.44W^{0.52}$	0.777	0.52	0.67
	F	Y = -0.01 + 0.39W	47.4	0.03	$DL = 0.98W^{0.39}$	0.688	0.39	0.57
F × IB	M	Y = -0.24 + 0.48W	84.2	0.03	$DL = 0.58W^{0.48}$	0.918	0.48	0.52
	F	Y = -0.20 + 0.47W	85	0.03	$DL = 0.63W^{0.47}$	0.922	0.47	0.51
Na × IB	M	Y = -0.39 + 0.53W	82.7	0.03	$DL = 2.45W^{0.53}$	0.910	0.53	0.58
	F	Y = -.07 + 0.41W	65.8	0.04	$DL = 0.85W^{0.41}$	0.911	0.41	0.51
N × IB	M	Y = -0.35 + 0.52W	89.7	0.03	$DL = 0.45W^{0.52}$	0.899	0.52	0.58
	F	Y = -0.16 + 0.45W	78.1	0.03	$DL = 0.69W^{0.45}$	0.884	0.45	0.51

IB × F = Isa Brown × Frizzle feathered, IB × Na = Isa Brown × naked neck, IB × N = Isa Brown × normal feathered, F × IB = Frizzle feathered × Isa Brown, Na × IB = Naked neck × Isa Brown, N × IB = Normal feathered × Isa Brown

M: Male; F: Female

DL: Drumstick Length

Y = Log_{10} (linear trait); W = log_{10} (body weight)

SE: Standard Error

Table 4: Log-linear and allometric growth equations for body width of male and female chickens of different genotypes (12-20 weeks).

Group	Sex	Log-linear	r^2 (%)	SE	Allometric	r	$\hat{\beta}$	$\hat{\beta}'$
IB × F	M	Y = 0.12 + 0.45W	75.8	0.03	$BW = 0.32W^{0.45}$	0.870	0.45	0.52
	F	Y = 0.28 + 0.40W	65.9	0.04	$BW = 1.91W^{0.40}$	0.812	0.40	0.49
IB × Na	M	Y = -0.25 + 0.57W	78.9	0.03	$BW = 0.56W^{0.57}$	0.888	0.57	0.64
	F	Y = -0.03 + 0.49W	63.4	0.04	$BW = 0.22W^{0.49}$	0.796	0.49	0.62
IB × N	M	Y = -0.26 + 0.40W	49.4	0.03	$BW = s1.82W^{0.52}$	0.703	0.40	0.57
	F	Y = 0.24 + 0.41W	56.6	0.03	$BW = 1.74W^{0.41}$	0.752	0.41	0.55
F × IB	M	Y = -0.03 + 0.51W	78.3	0.03	$BW = 0.93W^{0.51}$	0.885	0.51	0.58
	F	Y = -0.01 + 0.49W	77.2	0.03	$BW = 0.98W^{0.49}$	0.879	0.49	0.56
Na × IB	M	Y = 0.13 + 0.45W	79.1	0.03	$BW = 1.37W^{0.45}$	0.890	0.45	0.51
	F	Y = 0.32 + 0.80W	64.6	0.03	$BW = 2.09W^{0.38}$	0.804	0.38	0.47
N × IB	M	Y = -0.18 + 0.43W	79.1	0.03	$BW = 1.54W^{0.43}$	0.889	0.43	0.48
	F	Y = 0.22 + 0.43W	84.3	0.03	$BW = 1.66W^{0.43}$	0.896	0.43	0.48

BW: Body Width

IB × F = Isa Brown × Frizzle feathered, IB × Na = Isa Brown × naked neck, IB × N = Isa Brown × normal feathered, F × IB = Frizzle feathered × Isa Brown, Na × IB = Naked neck × Isa Brown, N × IB = Normal feathered × Isa Brown

Y = Log_{10} (linear trait); W = log_{10} (body weight)

M: Male, F: Female, SE: Standard Error

Table 5: Log-linear and allometric growth equations for keel length of male and female chickens of different genotypes (12-20 weeks).

Group	Sex	Log-linear	r^2 (%)	SE	Allometric	r	$\hat{\beta}$	$\hat{\beta}'$
IB × F	M	Y = -0.50 + 0.50W	75.1	0.04	$KL = 0.32W^{0.50}$	0.867	0.50	0.52
	F	Y = -0.35 + 0.45W	70.0	0.04	$KL = 0.45W^{0.45}$	0.837	0.45	0.54
IB × Na	M	Y = -1.04 + 0.70W	80.0	0.04	$KL = 0.09W^{0.70}$	0.894	0.70	0.78
	F	Y = -0.70 + 0.59W	77.3	0.03	$KL = 0.20W^{0.59}$	0.879	0.59	0.67
IB × N	M	Y = -0.44 + 0.47W	44.4	0.04	$KL = 0.36W^{0.47}$	0.616	0.47	0.76
	F	Y = -0.32 + 0.44W	48.2	0.04	$KL = 0.48W^{0.44}$	0.694	0.44	0.63
F × IB	M	Y = -0.41 + 0.47W	68.3	0.04	$KL = 0.39W^{0.47}$	0.827	0.47	0.57
	F	Y = -0.35 + 0.45W	46.3	0.06	$KL = 0.45W^{0.45}$	0.879	0.45	0.56
Na × IB	M	Y = -0.45 + 0.49W	75.5	0.03	$KL = 0.35W^{0.49}$	0.869	0.49	0.56
	F	Y = -0.16 + 0.39W	79.7	0.03	$KL = 0.69W^{0.39}$	0.893	0.39	0.44
N × IB	M	Y = -0.33 + 0.44W	76.7	0.03	$KL = 0.47W^{0.44}$	0.876	0.44	0.50
	F	Y = -0.15 + 0.38W	80.1	0.03	$KL = 0.71W^{0.38}$	0.895	0.38	0.42

IB × F = Isa Brown × Frizzle feathered, IB × Na = Isa Brown × naked neck, IB × N = Isa Brown × normal feathered, F × IB = Frizzle feathered × Isa Brown, Na × IB = Naked neck × Isa Brown, N × IB = Normal feathered × Isa Brown

M: Male, F: Female

KL: Keel Length

Y = Log_{10} (linear trait); W = log_{10} (body weight)

SE: Standard Error

The study revealed the occurrence of both isometric and allometric growth of the linear structural body components to body weight at the two growing phases considered. At 2-10 weeks growing phase, shank length and body width showed equal rate of growth while drumstick length and keel length showed disproportionate growth rate in relation to body weight in most of the genotypes studied. At the 12-20 weeks growing phase, the body components grew at greater rates than the body weight in both males and females of any genotype. The coefficients of allometric growth were higher for males than females. It was deduced that only shank length and body width can be used to predict body weight at early growing phase regardless of sex and genotype. Improvement of specific body parts such as the thigh and breast can be achieved by selecting chickens which show allometric growth of the drumstick length and body width as early as 2 to 10 weeks of age considering both sexes and also at 12 to 20 weeks of age especially in males.

Conflict of Interest

The authors certify that there are no conflicts of interest in this study.

Bibliography

1. Alkan S., *et al.* "Allometric growth of body components in 11 generations selected Japanese quails of different lines". *Archives Geflügelk* 75.1 (2011): 13-19.

2. Ajayi FO., *et al.* "Estimation of body weight from linear body measurements in two commercial meat-type chicken". *Global Journal of Agricultural Sciences* 7.1 (2008): 57-59.

3. Gruber L., *et al.* "Body weight prediction using body size measurements in Fleckvieh, Holstein, and Brown Swiss dairy cows in lactation and dry periods". *Archives Animal Breeding* 61.4 (2018): 413-423.

4. Ibe SN and Nwakalor LN. "Growth patterns and conformation in Broilers: Influence of genotype and Management on isometry of growth". *Poultry Science* 66 (1987): 1247-1252.

5. Cardoso RCF and Negreiris-Fransozo ML. "A comparison of the allometric growth in a Uca leotodactyla (Crustacea: Brachyuran: Ocypodidae) from two subtropical estuaries". *Journal of Marine Biological Association U. K* 84 (2004): 733-735.

6. Olawumi S and Farinnako A. "Evaluation of the relationship between body weight and linear measurements in West African Dwarf Goat as influenced by sex and Agrovegetational zone". *Science International* 5.2 (2017): 63-67.

7. Worku A. "Body weight had highest correlation coefficient with heart girth around the chest under the same farmers feeding condition for Arsi Bale sheep". *International Journal of Agricultural Science and Food Technology* (2019).

8. Obike OM., *et al*. "Estimation of body weight from morphometric traits in three chicken strains using linear and quadratic models". *International Journal of Agriculture and Rural Development* 22.1 (2019): 4012-4018.

9. Xu B., *et al*. "Water". 15.4 (2023): 4824.

10. Isaac UC. "Phenotypic, genetic and environmental correlations between body weight and linear body traits of chicken genotypes". *Agrobiological Records* 4 (2020): 32-43.

11. Cock AG. "Genetic studies on growth and form in fowl. 1. Phenotypic variation in the relative growth pattern is shank length and body weight". *Genetic Resources* 4 (1963): 167-192.

12. Ojedapo LO., *et al*. "Prediction of body weight and other linear body measurements of two commercial layer strain chickens". *Asian Journal of Animal Sciences* 6.1 (2012): 13-22.

13. Sadick AM., *et al*. "Relationship between body weight and linear body measurements in the Cobb broiler chicken". *World Journal of Biology, Pharmacy and the Health Sciences* 4.02 (2020): 001-006.

14. Kabir M., *et al*. "Heritability estimates and the interrelationships of body weight and shank length in Rhode Island Red and White Chickens". *Pakistan Journal of Biological Sciences* 9.15 (2006): 2892-2896.

15. Nwaogwugwu UC., *et al*. "Evaluation of egg quality traits of local chickens in humid tropical environment of Umudike, South-East, Nigeria". *Animal Production Research Advances* 5.3 (2009): 183-188.

16. Isaac UC., *et al.* "Heritability of body weight and linear body measurements of Isa Brown x local chicken genotypes". *International Journal of Agriculture*, *Environment and Bioscience* 8.2 (2023): 90-102.

17. Isaac UC and Obike MO. "Phenotypic Correlations between Body Weight and Egg Production Traits of Local Chicken Genotypes in Humid Tropical Rain Forest of Umudike". *International Journal of Agriculture and Biosciences* 9.3 (2020): 128-133.

18. Rajkumar U., *et al*. "Genetic and phenotypic response in Vanaraja male line chicken under short term selection experiment". *Indian Journal of Animal Science* 86.11 (2016): 1287-1290.

19. Yahaya HK., *et al.* "Correlation between body weight and body conformation of two broiler stains under the same dietary treatment". *International Journal of Animal and Veterinary Advances*4.3 (2012): 181-183.

20. Mehlum H., *et al*. "Growth with age-dependent preferences". *The Journal of International Trade and Economic Development* 29.6 (2020): 665-676.

21. John-Jaja SA., *et al*. "Effects of age variance in repeatability estimates of egg dimension of Bovan Nera Black laying chickens". *Journal of Genetic Engineering and Biotechnology* 23.1 (2016): 219-226.v

22. Hecht L. "Correlation between body weight and body conformation of two broiler strain under the same dietary treatment". *International Journal of Animal and Veterinary Advances* 4.3 (2021): 181-183.

23. Zuidhof MI., *et al*. "Growth, efficiency, and yield of commercial broilers from 1957, 1978 and 2005". *Poultry Science* 93.12 (2014): 2970-2987.

24. Teather KL and Weatherhead PJ. "Allometry, adaptation, and the growth and development of sexually dimorphic birds". *OIKOS* 71.3 (1994): 515-525.

25. Yakubu A. "Discriminant analysis of sexual dimorphism in morphological traits of African Muscovy ducks". *Archivos de zootecnia* 60.232 (2011): 1115-2223.

26. Narinc D., *et al*. "Analysis of fitting growth models in medium growing chicken raised indoor system". *Trends in Animal and Veterinary Sciences* 1.1 (2010): 12-18.