Xi'an Shiyou Daxue Xuebao (Ziran Kexue Ban)/
Journal of Xi'an Shiyou University, Natural Sciences Edition
ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 67 Issue 08 | 2024
DOI: 10.5281/zenodo.13292154

GENETIC, PHENOTYPIC AND ENVIRONMENTAL CORRELATIONS AND HERITABILTY ESTIMATES OF THE REPRODUCTIVE TRAITS OF THE NIGERIAN HEAVY LOCAL CHICKEN ECOTYPE HENS

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Abstract

Correlation is the statistical association between two random variables or bivariate data, while, heritability is a measure of the relative contribution of genes to the phenotypic value of a trait. The objective of this study was to investigate the genetic, phenotypic and environmental correlations and heritability estimates of the reproductive traits of the Nigerian heavy local chicken ecotype hens. A total of 145 and 150 point of lay pullets of the Nigerian heavy local chicken ecotype (NHLCE) from generation (G) 7 and G8 populations, respectively, were used for the study. The term generation G7 and G8 was used to describe birds that have been subjected to continuous selection by index for up to seventh and eighth generations. At 16th week of age, the point of lay hens were selected and placed in the battery cages to be monitored for short term egg production. The short term egg production lasted for 16 weeks (112 days). During these period of egg production, the hens were fed with formulated breeder's diet (layers mash) and clean drinking water served *ad libitum.* Routine management practices and medication were provided as at when due. Data on the following reproductive traits were collected. Such traits included Age at first egg (AGEFE), First egg weight (FEGGWT), Egg weight at 112 days egg production (EGGWT@112DEP), Body weight at first (BWFE), Average egg weight (AEW), Total egg number (TEN) and Body weight at 112 days egg production (BWT@112DEP). Data collected were subjected to genetic, phenotypic and environmental correlation analysis and heritability estimation. The results indicated that genetic correlations analysis between pairs of some selected reproductive traits were positive across generations G7 and G8. In generation G7, genetic correlation between BWFE and AEW recorded high coefficient of 0.694, while, generation G8 recorded moderate coefficient of 0.398. The heritability estimates ranged from low 0.12 on FEGGWT to high 0.40 on AGEFE in generation G7, whereas, in G8, it ranged from low 0.10 on TEN to moderate 0.39 on AEW.

Heritability estimates across populations indicated that whole population recorded higher heritability estimate compared to selected population and control population. It was therefore, concluded that body weight at first egg is positively correlated to average egg weight. Age at first egg has moderate to high heritability estimate 0.37 to 0.45 across generations G7 and G8. Also, the whole population recorded moderate to high heritability estimate 0.21 to 0.53, whereas, the selected and control populations recorded low to moderate heritability estimates (0.15 to 0.33) across the reproductive traits of the Nigerian heavy local chicken ecotype.

Keywords: Genetic, Phenotypic, Environmental, Correlation, Heritability, Reproductive Traits.

INTRODUCTION

The statistical association between two random variables or bivariate data, whether causal or not, is referred to as correlation or dependence in statistics. Correlations are valuable tools because they can reveal a predictive relationship that can be used in real-world situations (Bhandari, 2021). Correlation analysis can be used for predictive purposes. For instance, if two variables shows a strong correlation, changes in one variable can be used to predict changes in the other variable, and thus, it is valuable for forecasting and decision-making (Bhandari, 2021). The correlation coefficient is a statistical measure of the strength of a linear relationship between two variables. Its values can range from -1 to 1. A correlation coefficient of -1 describes a perfect negative, or inverse, correlation, with values in one series rising as those in the other decline, and vice versa. A coefficient of 1 shows a perfect positive correlation, or a direct relationship. A correlation coefficient of 0 means there is no linear relationship. Correlation coefficients are used in science and finance to assess the degree of association between two variables, factors, or data sets (Jason, 2024).

When two traits are related in such a way that one varies with the other directly (positively), or inversely (negatively), both traits are said to be correlated. There are three kinds of correlation namely phenotypic, genetic and environmental correlations. Phenotypic correlation is the observable (net) effect of all genetic and environmental factors that influence the two traits together (Ogbu, 2010). Genetic correlation which is also known as correlation of breeding values is the correlation of additive effect of genes affecting the traits (Ibe, 1998). Pleiotropy, linkage disequilibrium, and disparate breeding goals within a population are the causes of genetic correlation (Nordskog, 1981). Different breeding objectives and linkage disequilibrium are temporary or transient causes of genetic association, whereas pleiotropy is a permanent one. The magnitude and nature of the phenotypic and genetic correlations between two traits are of critical importance in the simultaneous selection of the traits (Tiwari *et al*., 2019). Correlation, whether it be phenotypic, genetic, or environmental, is an important concept in animal genetic improvement through multiple quantitative trait selection (Etterson, 2016). Positive genetic correlation means that both traits can be improved in the same direction whereas negative genetic correlation calls for carefulness in designing the selection programme to avoid a selection effort that is self-defeating (Lerner, 1958). Erroneous values of genetic and phenotypic correlations also reduce the efficiency of multiple -trait index selection (Sato *et al*., 1985).

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 67 Issue 08 | 2024
DOI: 10.5281/zenodo.13292154

Heritability is a measure of the relative contribution of genes to the phenotypic value of a trait. It is therefore, the proportion of total phenotypic variance due to average gene effect (Dalton, 1981; Ogbu, 2010). Heritability is one of the main genetic parameters, which expresses the degree of connection between phenotypic value and breeding value, or the phenotypic value as a pointer to breeding value. Furthermore, heritability is a factor in practically all breeding procedure formulas, and many practical decisions about procedure depends on the magnitude of heritability (Sanda *et al*., 2022). The term heritability is defined as the percentage of phenotypic diversity attributed to genetic variations (Tenesa and Haley, 2013). Natural selection uses heritability to estimate progress and setbacks in certain traits that a breeder hopes to achieve through breeding (Udeh *et al*., 2022). Reliable estimates of heritabilities are important in the design and execution of animal breeding plans and in making accurate predictions of direct and correlated responses to selection. Estimates based on variance components (sire, dam and sire + dam) or additive genetic effects from factorial or diallel mating designs were generally less varied because of the partitioning of the various variance components and the consequent estimation and removal of the compounding effects of maternal, non-additive and sex – linked variance components (Crawford, 1990; Laurin *et al*., 2018). Literatures have earlier reported on the heritability estimates of heavy ecotype chicken reproductive traits (Ogbu, 2010; Agbo, 2016). The objective of this study was to investigate the genetic, phenotypic and environmental correlations and heritability estimates of the reproductive traits of the Nigerian heavy local chicken ecotype hens

MATERIALS AND METHODS

Location of the Study

The study was conducted at the Local Chicken Breeding Section, Poultry Unit of the Department of Animal Science Teaching and Research Farm, University of Nigeria, Nsukka. Nsukka lies in the derived Savannah region, and is located on longitudes 7^0 24^1E and latitudes 5^0 22^1N with annual rainfall range of 986 – 2098mm. The climate is of humid tropical setting with relative humidity range of 56.01**-**100%. The average diurnal minimum temperature ranges between 20.99**-**370C (Okonkwo and Akubuo, 2007). Nsukka is characterized by two seasons of the year. The rainy season extends from April -October while the dry season spans from November-April with no sharp demarcation (Dateandtimeinfo, 2022).

Experimental Birds, Management and Design

A total of 145 and 150 point of lay pullets of the Nigerian heavy local chicken ecotype (NHLCE) from generation (G) 7 and G8 populations, respectively, were used for the study. The term generation G7 and G8 was used to describe birds that have been subjected to continuous selection by index for up to seventh and eighth generations. At

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16th week of age, the point of lay hens were selected and placed in the battery cages to be monitored for short term egg production.

The short term egg production lasted for 16 weeks (112 days). During these periods of egg production, the hens were fed with formulated breeder's diet (layers mash) and clean drinking water served *ad libitum.* Routine management practices and medication were provided as at when due. The percentage composition of the experimental diet is presented in Table 1.

Table 1: Layers/Breeders Diet (Experimental Diet)

Ingredients	Composition (kg)
Maize	50.195
Soya bean meal	25.30
Palm kernel cake	10.00
Limestone	9.50
Palm oil	2.00
Dicalciumphosphate	1.87
Vitamin premix	0.25
Sodium (Na)	0.25
Toxin binder (sodium bentonate)	0.25
Methionine	0.175
NaHCO2	0.17
Lysine	0.04
Total	**100.00**
Calculated Values	(%)
Crude Protein	16.60
Energy	2705kcl/kg
Crude Fiber	4.00
Crude fat	5.60
Calcium	4.00
Average Phosphorus	0.45
Lysine	0.78
Methionine	0.39
Sodium (Na)	0.18
Chloride	0.17

$NaHCO_3$ = Sodium bicarbonate, Vitamin premix contained the following per kg of feed: vitamin A = 10, 000 iu; vitamin E = 6iu; vitamin K = 2mg; riboflavin = 4.2mg; vitamin B12 = 0.01mg; pantothenic acid = 5mg; nicotinic acid = 20mg; folic acid = 0.5mg; choline = 3mg; Fe = 20mg; Mg = 56mg; Cu = 1.0mg; Zn = 5.0mg; Co = 1.25mg; iodine = 0.8mg; vitamin C = 0.5mg.

Data Collection

Data on the reproductive traits were collected. Such traits included Age at first egg (AGEFE), First egg weight (FEGGWT), Egg weight at 112 days egg production (EGGWT@112DEP), Body weight at first (BWFE), Average egg weight (AEW), Total egg number (TEN) and Body weight at 112 days egg production (BWT@112 DEP).

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Data Analysis

Data collected on reproductive traits of the hens were subjected to heritability estimation and some selected pairs of the reproductive traits were subjected to correlation analysis to ascertain their levels of association.

Statistical Models

The following statistical models were used for the analyses.

Genetic Correlation

The formula was given as:

$$r_G = \frac{CoVsx_1\,x_2}{\sqrt{\sigma_s^2\ (x1)}\ \sqrt{\sigma_s^2\ (x2)}}$$

Where

r_g = genetic correlation between traits x_1 and x_2

$CoVsx_1\,x_2$ = additive genetic (sire component) covariance between traits x_1 and x_2

$\sigma_s x_1$ and $\sigma_s x_2$ = additive genetic standard deviation for traits x_1 and x_2

The sire component of covariance (CoVs) is obtained from the formula

Phenotypic Correlation

The formula is given by Becker (1992) as

$$r_p = \frac{cov_W + cov_S}{\sqrt{\sigma_W^2\ (x1) + \sigma_S^2\ (x1)}\ \sqrt{\sigma_W^2\ (x2) + \sigma_S^2\ (x2)}}$$

Where

$cov_w x_1 x_2$ = covp(x_1 x_2) = phenotypic covariance between traits x_1 and x_2

$\sigma^2_{w(x1)} + \sigma^2_{s(x1)} = \sigma^2_{p(x1)}$= phenotypic variance of trait x_1

$\sigma^2_{w(x2)} + \sigma^2_{s(x2)} = \sigma^2_{p(x2)}$= phenotypic variance of trait x_2

Environmental correlation

The formula was given by Becker (1992) as

$$r_E = \frac{cov_W(x1\ x2) - 2cov_S(x1\ x2)}{\sqrt{\left(\sigma^2_{W(x1)} - 2\sigma^2_{S(x1)}\right)}\ \left(\sigma^2_{W(x2)} - 2\sigma^2_{S(x2)}\right)}$$

Where

$cov_w(x1\ x2)$ = error covariance between traits x_1 and x_2

$cov_s(x1\ x2)$ = sire covariance for traits x_1 and x_2

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Covariance between traits x_1 and x_2

$\sigma^2_{w(x1)} - \sigma^2_{w(x2)}$ = error variance of traits x_1 and x_2

$\sigma^2_{s(x1)} - \sigma^2_{s(x2)}$ = sire variance of traits x_1 and x_2

Heritability (h^2) Estimate

From the analysis of variance, the various sire components of variances were calculated and according to Becker (1992), the heritability of the individual traits was obtained, using the formula:

$$h^2_s = \frac{4\sigma^2_S}{\sigma^2_P}$$

Where

h^2_s = Heritability of sire

σ^2_S = Variance component of sire

σ^2_P = Total phenotypic variance

(Becker 1992)

Definition of Terms used in the Study

r_g = Genetic correlation

r_p = Phenotypic correlation

r_E = Environmental correlation

h^2 = Heritability estimate

SE = Standard error of the mean

G7 = Generation seven population

G8 = Generation eight population

Whole Population: This is the population of the NHLCE before selection

Control Population: This is the population of the NHLCE that were used to monitor the environmental effects on the birds

Selected Population: This is the population of selected Nigerian heavy local chicken ecotype

NHLCE = Nigerian heavy local chicken ecotype

AGEFE = Age at first egg: This was the age when the hen dropped her first egg.

FEGGWT = First egg weight: The weight of the first laid by a hen

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E-Publication: Online Open Access
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EGGWT@112DEP = Egg weight at 112 days egg production. This is also known as short term egg production period. This was measured by taking the egg weight after the hen has laid eggs for 112 days (16 weeks)

AEW = Average egg weight: This is the average weight of eggs laid by a hen

TEN = Total egg number: This is the total number of eggs laid by a hen

BWFE = Body weight at first: This is the weight of the hen when she laid her first egg

BWT@112DEP = Body weight at 112 days egg production: This is the body weight of a hen after laying eggs for 112 days (16 week)

RESULTS AND DISCUSSION

Genetic, Phenotypic and Environmental Correlation between Some Traits

The results of the genetic, phenotypic and environmental correlations between some pairs of selected reproductive traits in the whole population across generations G7 and G8 of the Nigerian heavy local chicken ecotype are presented in Table 2.

Table 2: Estimates of Genetic, Phenotypic and Environmental correlation of some pairs of selected traits in the whole population across generations G7 and G8 of the Nigerian heavy local chicken ecotype

Traits	Population	Generations					
		G7			G8		
		r_G	r_P	r_E	r_G	r_P	r_E
BWFE-TEN	Whole	0.322	0.260	-0.170	0.149	-0.011	-0.101
BWFE-AEW	Whole	0.694	0.490	0.130	0.398	0.185	0.097
TEN-AEW	Whole	0.152	-0.412	-0.511	0.194	0.026	0.017

BWFE = Body weight at first egg, AEW = Average egg weight, TEN = Total egg number, G7 = Generation seven population, G8 = Generation eight population, r_g = Genetic correlation, r_p = Phenotypic correlation, r_E = Environmental correlation

In the whole population, the genetic correlation between body weight at first egg and total egg number ranged from low to moderate across generations G7 and G8, while, environmental and phenotypic correlation recorded negative correlation. Correlation between body weight at first egg and average egg weight ranged from low to high and positive across generations G7 and G8, for genetic, phenotypic and environmental correlation. Correlation between total egg number and average weight was low across generations G7 and G8 for environmental, phenotypic and genetic correlation. Correlation between body weight at first egg and average egg weight ranged from low to high across generations G7 and G8 for environmental, phenotypic and genetic correlation. Also, correlation between total egg number and average egg weight ranged from low to high across generations G7 and G8 for environmental, phenotypic and genetic correlation. In the whole population, highest genetic correlation value (0.694) was recorded in the correlation between body weight at first egg and average egg weight, in generation G7

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and moderate value (0.398) recorded in generation G8. Moderate genetic correlation value (0.322) was also, obtained in correlation between body weight at first egg and total egg number. Phenotypic and environmental correlations in the whole population were low. It is usually normal to obtain positive, negative, low, moderate and high correlation values when different traits are correlated in any population. This is due to the fact that some traits are positively correlated while others are negatively correlated; some are weakly correlated, whereas others are strongly correlated (Momoh and Nwosu, 2008; Udoh and John Jaja, 2014). Oleforuh-Okoleh (2011) reported negative correlation across three generations of the Nigerian local light ecotype chickens, which is contrary to the report of this study which had both positive and negative correlations. The genetic correlation estimate obtained in correlation between body weight at first egg and total egg number in this study at generation G7 was higher than the range (-.0.01 to 0.03) reported by Agbo (2016). Similar trend was observed in genetic correlation between body weights at first egg and average egg weight (-0.001 to 0.03), (Agbo, 2016). In another study, Ogbu (2010) reported low estimate (0.01) of genetic correlation between body weight at first egg and egg number, which was lower than values reported in this study. The moderate and high genetic correlation recorded between body weight at first egg and total egg number, and between body weight at first egg and average egg weight is a welcome development. This implies that these traits have positive correlated responses, and genetic improvement in one of the traits would significantly amount to improvement in the other traits (Crum and Ellen, 2007). The genetic and phenotypic correlation values recorded in this study were higher than values reported by Cheng *et al*. (1996), who reported the genetic and phenotypic correlations between egg number and body weight at 40 weeks as 0.006 and 0.063, respectively. Also, for egg weight and body weight, a value of 0.617 and 0.424 were reported for genetic and phenotypic correlations, respectively. Francesch *et al*. (1997) gave a range of -0.22 to 0.19 and -0.18 to 0.14, respectively, as genetic and phenotypic correlations between egg number and egg weight in three Catalan poultry breeds. Nevertheless, the different correlation values reported in this study reflect the strength of association and response to common causal effect by individual traits as a result of many generations of selection by index (Kumar and Chong, 2018). The several fluctuations in correlation values obtained in this study suggests that the genes responsible for the reproductive traits in the Nigerian heavy local chicken ecotype are not yet “properly aligned‟ or “definitely linked‟ in relation to one another and having been under the influence of adverse environmental effects, these genes are still masked by genes for survival which at present seem preponderant in the local chicken population (Ibe, 1998; Ogbu, 2010).

Heritability Estimates of the Reproductive Traits

The heritability estimates and standard error (h^2±SE) of first egg weight, egg weight at 112 days egg production, age at first egg, average egg weight, total egg number, body weight at first egg and body weight at 112 days egg production for generations G7 and G8 hens of the Nigerian heavy local chicken ecotype are presented in Table 3.

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Table 3: The heritability estimates and standard error (h^2±SE) of First egg weight, Egg weight at 112 days egg production and Age at first egg, Average egg weight, Total egg number, Body weight at first egg and Body weight at 112 days egg production for generations G7 and G8 Hens of the Nigerian heavy local chicken ecotype

Parameters	Generations	
	G7 **(h^2)**	G8 **(h^2)**
AGEFE	0.45±0.29	0.37±0.21
FEGGWT	0.12±0.48	0.15±0.51
EGGWT@112DEP	0.30±0.68	0.25±0.23
AEW	0.14±0.63	0.39±0.36
TEN	0.23±0.12	0.10±0.24
BWFE	0.39±0.40	0.12±0.47
BWT@112DEP	0.20±0.00	0.16±0.36

AGEFE = Age at first egg, FEGGWT = First egg weight, EGGWT@16WKEP = Egg weight at 112 days egg production, AEW = Average egg weight, TEN = Total egg number, BWFE = Body weight at first, BWT@112 days egg production, h^2 = Heritability estimate, SE = Standard error, G7 = Generation seven population, G8 = Generation eight population

The results showed low to moderate heritability estimates in generation G7 reproductive traits except age at first egg which had high heritability estimate (0.45). Similarly, low to moderate heritability estimates were observed in generation G8 across the reproductive traits. The heritability estimate for first egg weight were moderate for both generations, also, heritability estimate for egg weight at 112 days egg production was moderate 0.30±0.68 in generation G7 and 0.25±0.012 in generation G8. The low heritability estimates recorded in some of these traits indicated that improvement on these traits would require other technical approach such as crossbreeding, other than selection. Similar trend had earlier been reported by Ogbu (2010) and Agbo (2016). The heritability estimates for age at first egg was high for generations G7, but moderate in generation G8. A breeder may be satisfied with the status quo because age at first egg has varying economic interpretations. Thus, moderate to high heritability indicates that genetic improvement to this trait would require less efforts. The results also, indicated low heritability estimates on body weight at first egg, body weights at 112 days egg production, average egg weights and total egg numbers in generations G8, moderate in generation G7. The heritability estimates of the reproductive traits in this study were lower than values reported by Agbo (2016) on BWFE, AEW and TEN in the Nigerian heavy local chicken ecotype.

The heritability estimate for BWFE, AEW and TEN were lower than values 0.636, 0.566 and 0.694 in G0, G1 and G2 generations reported by Ogbu (2010) for body weight at first egg. Furthermore, Ogbu (2010) reported 0.340, 0.432 and 0.344 as heritability estimates of average egg weight, 0.124, 0.135 and 0.236 as heritability estimates of total egg number in G0, G1 and G2, respectively. The results of this study are in agreement with Szwaczkowsk *et al*. (2003) who reported that there are variations in heritability estimate

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 67 Issue 08 | 2024
DOI: 10.5281/zenodo.13292154

of egg number and body weight in different strains of chicken. Heritability estimates of 0.28 reported by Luo *et al*. (2007) on egg number and 0.24 reported by Oni *et al*. (2001) on average egg weight of Rhode Island chickens were in the same range with the heritability estimates obtained in this study. Similarly, Agbo (2016) reported moderate to high heritability estimates on body weight at first egg, average egg weight and total egg number across G4, G5 and G6 generations of the Nigerian heavy local chicken ecotype. The low heritability estimates obtained in this study is expected and may be attributed to consistent selection programme that these traits have been subjected to for seven and eight generations. It implies that variability in these traits with several generations of selection are influenced more by environmental factors, rather, than genetic factors (Udeh *et al*., 2021). The low heritability estimates in this study could also, indicate that these traits are becoming more homogeneous due to continuous selection (Andrews, 2010). The low heritability estimates across generations and on some of these reproductive traits indicates that further selection would not yield much meaningful genetic progress (Niknafs *et al*., 2012). This is due to the fact that when heritability is tending towards zero, it implies that variability in the trait is more of environmental factor than genetics factor (Udeh *et al*., 2021).

The heritability estimates and standard error (h^2±SE) of body weight at first egg, egg weight at 112 days egg production, average egg weight and total egg number across whole, selected and control populations for generations G7 and G8 hens of the Nigerian heavy local chicken ecotype are presented in Table 4.

Table 4: The heritability estimates and standard error (h^2±SE) of Body weight at first egg, Egg weight at 112 days of egg production, Average egg weight and Total egg number across Whole, Selected and Control populations for generations G7 and G8 Hens of the Nigerian heavy local chicken ecotype

Population	Generation	BWFE (h^2)	BWT@112DEP (h^2)	AEW (h^2)	TEN (h^2)
Whole	G7	0.41±0.20	0.44±0.62	0.53±0.71	0.21±0.28
	G8	0.33±0.20	0.52±0.71	0.34±0.52	0.42±0.51
Selected	G7	0.20±0.12	0.21±0.64	0.32±0.43	0.20±0.64
	G8	0.16±0.31	0.23±0.50	0.15±0.36	0.15±0.34
Control	G7	0.20±0.46	0.33±0.50	0.26±0.14	0.30±0.48
	G8	0.21±0.51	0.16±0.41	0.20±0.17	0.25±0.40

BWFE = Body weight at first egg, BWT@112DEP = Body weight at 112 days egg production, AEW = Average egg weight, TEN = Total egg number, h^2 = Heritability estimate, SE. = Standard error, G7 = Generation seven population, G8 = Generation eight population.

The result indicated moderate to high heritability estimates among the traits in the whole population, low to moderate heritability estimates in the selected and control populations. The values obtained in generations G7 and G8 compared favourably with values reported by Agbo (2016) in generations G5 and G6 of the Nigerian heavy local chicken ecotype. Body weights at 112 days of egg production, average egg weights and total egg numbers

ISSN: 1673-064X
E-Publication: Online Open Access
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had low to high heritability estimates across generations G7 and G8, and across selected, whole and control populations, with generation G8 values constantly lower than generation G7. However, the heritability estimates in these reproductive traits were within range of values reported by Agbo (2016) across BWFE, AEW and TEN in the Nigerian heavy local chicken ecotype. The low heritability estimates recorded on body weight at first egg, body weight at 112 days egg production, average egg weight and total egg number in the selected population, in generation G8 birds indicated that selection would not yield much meaningful genetic progress (Niknafs *et al*., 2012), as further selection would cause more homogeneity in traits. This is because when heritability is tending towards zero, it implies that variability in the trait is more of environmental factor than genetics factor (Udeh *et al*., 2021). However, heritability estimates obtained in this study were higher than values reported by Ogbu, (2010) which ranged from 0.124 to 0.236 in these reproductive traits.

CONCLUSION

It was therefore, concluded that body weight at first egg is positively correlated to average egg weight. Age at first egg has moderate to high heritability estimate 0.37 to 0.45 across generations G7 and G8. Also, the whole population recorded moderate to high heritability estimate 0.21 to 0.53, whereas, the selected and control populations recorded low to moderate heritability estimates (0.15 to 0.33) across the reproductive traits of the Nigerian heavy local chicken ecotype.

Acknowledgement

The authors wish to thank the Department of Animal Science, University of Nigeria, Nsukka for providing the facilities for the research.

Conflict of Interest

The authors hereby declare that there is no conflict of interest.

Author’s Contribution

UFU: Design, methodology and statistical analysis, NCC: Original drafting of manuscript, UNP: Supervision and writing of manuscript, ANW: Initial design of the experiment and review editing, UCM: Assisted in data collection, UVC: Review, editing and experimentation, OEO: Assisted in data collection, review and analysis.

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Xi'an Shiyou Daxue Xuebao (Ziran Kexue Ban)/
Journal of Xi'an Shiyou University, Natural Sciences Edition
ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 67 Issue 08 | 2024
DOI: 10.5281/zenodo.13292154

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