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Genetic Evaluation of Semen Characteristics Traits Using a Multi-Trait Animal Model and Selection Index in Nigerian Local Chickens

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ABSTRACT

This study aims to investigate appropriate genetic models and selection indices to ascertain the genetic characteristics and breeding values in Nigerian local chicken cocks. A total of 614 records of six semen traits focusing on essential reproductive factors such as sperm volume, concentration, motility, viability, morphology, and pH. The average sperm volume was 0.26 ± 0.07 mL with a concentration of 3.53 ± 0.82 (10^9/mL). Sperm motility and viability averaged 76.90 ± 3.85% and 82.29 ± 10.21%, respectively, with a 74.98 ± 3.92% morphology. The pH of the semen was 7.31 ± 0.40. Model comparisons discovered that the multi-trait animal model using LG4 formed the most accurate genetic parameter estimates. Heritability values ranged from 0.20 for sperm volume to 0.40 for sperm concentration, motility, and viability, indicating a strong genetic influence on these parameters. There were favorable genetic and phenotypic relationships among characteristics, with substantial associations between volume, concentration, motility, and morphology. The selection index (SI) for the major features showed that sperm concentration (14% economic weight) was more important than motility (4%) and viability (5%). This study emphasizes the importance of sperm quality in breeding programs to improve reproductive success and genetic diversity in poultry production.

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INTRODUCTION

In the last couple of decades, the genetic increase of poultry has been a focal point for enhancing productivity and sustainability in poultry production systems worldwide (Okpeku et al., 2019). Nigerian local chickens (NLCs) represent a valuable genetic resource known for their adaptability to local environments and disease resistance

(Nwogwugwu et al., 2018). However, their reproductive performance, particularly semen characteristics, remains underexplored of regarding genetic evaluation and improvement strategies (Uzochukwu et al., 2019). Infertility is one of the major issues in poultry breeding with approximately 30% of the problems male-related (El-Kashef, 2021). Successful chick production is dependent on the cock's fertility and reproductive performance, which is governed mostly by the sperm quality it generates (Xuan et al., 2017). However, essentially been challenging to maintain fertility in breeder cocks over the years, notably in the humid tropics (Onasanya and Ikeobi, 2013). In these tropical regions, direct meteorological factors such as high ambient temperature and high relative humidity (which results in severe heat stress), besides other factors such as age, poor nutrition, and management, adversely affect the semen adept of producing cocks (Ayo et al., 2011; Ade et al., 2024). Sperm quality characteristics, such as sperm motility, concentration, viability, and morphology are crucial determinants in male fertility and are directly linked to reproductive success in poultry breeding programs (Mussa et al., 2023). Chicken spermatozoa have distinct structural and chemical properties components. Polyunsaturated fatty acids are essential components of avian spermatozoa which play a major role both in maintaining the physical properties and functions of the spermatozoa and in sperm-egg fusion (Khan et al., 2011).

Genetic evaluation using advanced statistical models such as multi-trait animal models provide a robust framework for assessing the heritability and genetic relationships among these semen characteristics (Casale, 2016). Understanding these genetic parameters is important for designing effective selection strategies aimed at improving semen quality in NLCs (Ghadimi et al., 2024). Schaeffer (1996) reported a significant increase in the proper genetic evaluation obtained when using a program genetic evaluation for one trait (Animal Model) besides from more than one trait (Multiple - trait Animal Model) and the random regression model for traits that are measured frequently and consistently on the animal relative with the actual Sire Model (Wiggans et al., 1984; Weller et al., 1987). Genetic assessment of individuals according to their BWs at various ages likewise, egg production traits are crucial for deciding individuals who specialize in producing eggs for hatching outside from table eggs (Wolc and Szwaczkowski, 2001).

Selection indexes, combining information from multiple traits and economic weights, provide a practical tool for breeders to prioritize traits of interest while considering the complex relationships between traits and their economic importance, Smith (1936), Hazel (1943), and their supervisor Lush developed selection index theory.

The standard tools used in animal breeding incorporate information about several qualities into a single value. The essence of this investigation was to analyze and identify an appropriate multi-trait Animal Model and Selection Index with covariance functions for improved individual genetic selection of semen traits in the Nigerian local chickens. Besides providing valuable insights into NLC breeding techniques, the findings of this investigation would act as a reference point for the strategic planning of genetic selection, particularly for the grandparents, offering substantial practical benefits.

MATERIAL and METHOD

Experimental Site

The study was conducted in the poultry section of the Department of Animal Teaching and Research Farm Science, Delta State University, Abraka, Delta State, Nigeria. Abraka is in the Ethiope East local government area of Delta State. It lies in a rainforest agroecological zone. Abraka has a mean temperature of 23.3^{o}C to 37^{o}C. It has a relative humidity of 68-80%, and monthly sunshine of 4-8 bars (Meteorological Station, 2024).

Mating Design and Management

Sixty local (60) sexually matured hens weighing 1.2kg and four (4) sexually matured cocks weighing 1.6kg were sourced from the local market in Abraka and its environs. The birds on arrival were housed into two groups, comprising all the hens in one pen while 4 cocks were housed in another pen and the period served as an acclimatization period for 3 weeks, the birds were fed with commercial feed (grower mash). After the 3 weeks, they were transferred and grouped into 15 dams to 1 cock, and individual dams were caged in a unit of a battery cage system in a hierarchical design. Mating was achieved using artificial insemination twice a week and eggs from the birds were collected daily for 5-7 days before they were transferred to an incubator. The eggs for each dam were identified by using an indelible marker pen. The still–air turner electric/automatic incubators with a capacity of 1000 eggs.

Routine management operations such as washing the water and feed troughs were implemented daily. Medication: antibiotics and anti-coccidia drugs were administered to the birds periodically via drinking water, and birds were also dewormed. Feeds were provided in adequate quantity twice a day, namely 8.30 am and 2.30 p.m., and were fed ad libitum with breeder's mash containing seventeen percent (17%) crude protein and 2700kcal ME/kg. In total, 1632 chicks were produced from the ten batches of the hatch. Chicks were tagged with leg tagged according to sire groups, brooded for three (3) weeks, and raised to twelve weeks of old using routine husbandry standards reported by Udeh and Ighobesuo (2023). Sexes were separated at nine (9) weeks old, with in total of 614 records of the NLCs' cocks were used. Chicks were fed with starter mash from day old to nine (9) weeks of age and grower mash from nine (9) to eighteen (8) weeks old. Daily routines such as washing drinkers, cleaning feeders, and sweeping the poultry house were implemented. The birds were vaccinated against Newcastle disease, infectious bursal disease, and fowl pox disease at the appropriate ages.

Semen Collection and Evaluation

Semen specimens were collected weekly (every Saturday) for over 18 months using the dorsal-abdominal massage technique (Burrow and Quinn, 1937) on 614 cock of the Nigerian local chickens that were selected from the population. Each sample was placed into a 1mL Eppendorf tube with 0.1 mL of IGGKPh diluent. To ensure proper analysis, the specimens were shielded from light and kept at 23–24°C during transport to the laboratory, where they were examined within 20 minutes of post-collection. The same individual performed the collection each time to ensure consistency between quality and quantity, and care was taken to avoid cross-contamination.

The volume of semen was measured with a graduated 1-mL syringe. A pH meter (HANNA HI98103) was applied to measure pH levels. Sperm motility was assessed by observing mass movement. A single drop of sperm was strategically inserted on a slide without a coverslip and examined under a light microscope with a magnification of 400x, using a scale of 1 to 5 based on Udeh et al., (2011) method. Sperm viability was evaluated simultaneously using eosin-nigrosine staining. A 5-μL drop of fresh semen was mixed with 20 μL eosin-nigrosine, left to air dry, and then examined under a light microscope at 1000× magnification. At least 300 sperm were counted to ascertain the percentage of live sperm, where stained sperm indicated dead sperm and unstained sperm indicated live sperm. Sperm abnormalities were assessed for morphological attributes such as head, tail, connecting piece, or terminal piece anomalies. A hemocytometer was used to detect sperm concentration. A 5-μL sperm specimen was diluted with 195 μL of sodium chloride, inserted into the hemocytometer, and counted using a light microscope at 400× magnification. Sperm concentration obtained as sperm × 109 per milliliter (Daryatmo et al., 2024).

Statistical Analysis

Data collected was subjected to descriptive statistics. The results of batch and semen were tested using analysis of variance (ANOVA). The additive genetic links matrix was used as described by Mrode and Thompson (2005). The model in matrix notation is stated accordingly:

$$\mathbf{y = Xb + Zs + e}$$

Where:
y = the vector of observation,
b = the vector of the fixed effect of batch and semen,
s = the vector of random sire effect, and
e = the random residual effects.
X and Z are design matrices that associate records with fixed and random side effects, respectively. The hypotheses are that E(y) = Xb and E(s) = E(e) = 0.
E signifies expectation (Mrode and Thompson, 2005).

Likewise, it is assumed that residual variance, including permanent environmental effects (σ^2_{pe}) and gene combination, is independently distributed with variance σ^2e.
Therefore,
var(e) = Iσ^2e = R,
var(s) = Aσ^2s and
var(y) = ZAZ'σ^2s + R,
where:
A signified the numerator relationship matrix for sires, σ^2s = 0.25σ^2a. Estimates of covariance and variance components were utilized to calculate genetic and phenotypic relationships.
The bivariate model in matrix notation is stated accordingly:

$$\begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix} = \begin{bmatrix} X_1 & 0 \\ 0 & X_2 \end{bmatrix} \begin{bmatrix} b_1 \\ b_2 \end{bmatrix} + \begin{bmatrix} Z_1 & 0 \\ 0 & Z_2 \end{bmatrix} \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} + \begin{bmatrix} e_1 \\ e_2 \end{bmatrix}$$

where:
for trait i (i = 1, 2),
yi = a vector of observations,
bi = a vector of fixed effect of batch and sex,
ai = a vector of random direct effect,
ei = a vector of random residual effect,
xi and zi are design matrices that combine observations to fixed and direct additive genetic information impacts (Mrode and Thompson, 2005).

Selection Index (SI)

The SI was determined using the three most heritable characteristics and their genetic link. Each trait's comparable economic value (v) was calculated by dividing its typical economic value by the entire economic value of all traits in the production system. The selection index (SI) equation proceeds as follows:

SI = (v1 × EBVtrait1) + (v2 × EBVtrait2) +... +(v3 × EBVtrait3).

where:

Selection index, v1, v2, and v3 reflect the typical economic values of sperm characteristics, while EBVtrait1, EBVtrait2, and EBVtrait3 are the anticipated breeding values.

The covariance functions utilized in the analysis were as follows:

Wilmink function (Wilmink, 1987):

WM: $Y(t) = a + bt + ct^2 + de^{-0.05t/18}$

Where:

Y= a estimated semen yield

a,b, c, and d = a regression coefficient

t = months in semen collection

Koops and Grossman Function (Koops and Grossman, 1991):

KG: $f(t) = Zm(t) = D/(1 + (a\exp(-bt) + ct))$,

Where:

D = months in semen collection (18 mths);

t =months in semen collection at mth 1, 2, 3, . . . , 18;

a,b,c = a regression coefficient.

Legendre polynomials functions (2^{nd}, 3^{rd}, and 4^{th} orders) (Gengler et al., 1999):

LG2 : $f(t) = L1 + L2 + L3$

LG3 : $f(t) = L1 + L2 + L3 + L4$

LG4 : $f(t) = L1 + L2 + L3 + L4 + L5$,

Where:

$L1 = 1$, $L2 = \sqrt{3}t$, $L3 =\sqrt{5/4}\,(3t^2 - 1)$,

$L4 =\sqrt{7/4}\,(5t3 - 3t$,

$L5 =\sqrt{9/64}\,(35t^4 - 30t^2 + 3)$,

$t =-1+2\,(t-tmin)$

$(tmax - tmin)$,

where t = the current month in semen data collection,

tmin = 1^{st} month in semen data collection,

tmax = 18^{th} months of semen data collection, respectively

The logarithm of the likelihood function and the Akaike Information Criterion (AIC) were used to assess the model fit and complexity. The log-likelihood function (logL) measures the goodness of fit in this model. The negative is two times the log-likelihood.

$-2\log L=-2\sum\log(f(y))$

Where:

yi = traits observed

$f(yi;\theta)$ = probabilities function determined by model parameters θ,

n = total number of observations

The AIC is calculated as follows:

$AIC = -2\log L + 2k$

Where:

k = total number of parameters in the model,

$-2\log L$ = the negative two times the log-likelihood.

All data analysis was performed using the average information restricted maximum likelihood (AIREMLF90) in the BLUPF90 family of programs written by Misztal et al., (2019).

RESULTS and DISCUSSION

Descriptive Statistics for Semen Traits of the NLC:

These findings provide a comprehensive overview of the reproductive parameters of Nigerian native chicken cocks, highlighting important characteristics, including sperm volume, concentration, motility, viability, morphology, and pH the data demonstrates that the average sperm volume was 0.26 ± 0.07ml, with a sperm concentration of 3.53 ± 0.82 ($10x^9$/mL). Motility and viability percentages were recorded at 76.90 ± 3.85%, and 82.29 ± 10.21% respectively, in average sperm morphology of 74.98 ± 3.92%. The average pH of the sperm was discovered to be 7.31 ± 0.40, indicating a slightly alkaline environment.

Table 1. The sperm traits of the Nigerian local chicken cocks.

Parameters	Nrec.	Mean	SD	Min.	Max.
Sperm volume (ml)	614	0.26	0.07	0.14	0.41
Sperm Concentration ($\times 10^9$/mL	614	3.53	0.82	2.15	5.17
Sperm motility (%)	614	76.90	3.85	70.12	85.18
Sperm viability (%)	614	82.29	10.21	68.45	90.08
Sperm morphology (%)	614	74.98	3.92	68.18	84.25
Sperm pH	614	7.31	0.40	6.36	8.15

Best-Fitting Model with Genetic Parameters.

Table 2 shows the model comparison results and genetic criteria for semen qualities in Nigerian native chickens. The multiple-trait animal model with LG2 had the least -2logL (−10152.46) and AIC (−10164.46) values for sperm volume, concentration, motility, viability, morphology, and pH, indicating it provides the most precise estimates of genetic factors for semen qualities in this dataset. The multiple-trait animal model with LG4 has the most significant −2logL and AIC values were unsuitable for the analysis. The predicted heritability values for sperm characteristics ranged from 0.20 (±0.001) for sperm volume, 0.40 (±0.02) for sperm concentration, 0.40

(±3.23) for sperm motility, 0.40 (±0.48) for sperm viability, and 0.40 (±0.01) for sperm pH. These figures represent the proportion of phenotypic variance due to genetic variation for each attribute.

Variance Components/Heritability//Repeatability/Statistic Criteria

Table 2. Calculated variance components, heritability, and statistical needed to construct mixed models with varied covariance functions for semen characteristics in Nigerian local chickens.

Traits	Models	σ^2_a	σ^2_{pe}	σ^2_e	h^2 (±SE)	t(±SE)	−2logL	AIC
	KG	0.001	0.002	0.002	0.20±0.001	0.60±0.002	−10152.46	−10164.46
	WM	0.001	0.002	0.002	0.20±0.001	0.60±0.002	−10152.46	−10164.46
Sperm volume	LG2	0.001	0.002	0.002	0.20±0.001	0.60±0.002	−10152.46	−10164.46
	LG3	0.001	0.002	0.002	0.20±0.001	0.60±0.002	−10152.46	−10164.46
	LG4	0.001	0.002	0.002	0.20±0.001	0.60±0.002	−10152.46	−10164.46
	KG	0.270	0.202	0.202	0.40±0.02	0.70±0.269	−974.28	−986.28
	WM	0.270	0.202	0.202	0.40±0.02	0.70±0.269	−974.28	−986.28
Sperm concentration	LG2	0.270	0.202	0.202	0.40±0.02	0.70±0.269	−974.28	−986.28
	LG3	0.271	0.204	0.214	0.39±0.02	0.68±0.269	−990.52	−1002.52
	LG4	0.271	0.206	0.218	0.39±0.02	0.69±0.269	−993.26	−1005.26
	KG	5.916	4.437	4.437	0.40±0.05	0.70±0.10	−2771.38	−2783.38
	WM	5.916	4.437	4.437	0.40±0.05	0.70±0.10	−2771.38	−2783.38
Sperm motility	LG2	5.916	4.437	4.430	0.40±0.07	0.70±0.10	−2771.38	−2783.38
	LG3	5.918	4.440	4.439	0.40±0.06	0.70±0.10	−2769.24	−2781.24
	LG4	5.921	4.445	4.441	0.40±0.06	0.70±0.10	−2770.48	−2782.48
	KG	41.66	31.25	31.25	0.40±0.23	0.70±5.71	−3990.92	−4002.92
	WM	41.66	31.25	31.25	0.40±0.23	0.70±5.71	−3990.92	−4002.92
Sperm viability	LG2	41.66	31.25	31.25	0.40±0.23	0.70±5.71	−3990.92	−4002.92
	LG3	41.68	31.30	34.12	0.39±0.02	0.68±5.51	−3995.36	−4007.36
	LG4	41.69	31.37	37.18	0.38±0.02	0.66±5.35	−4000.98	−4012.98
	KG	6.16	4.61	4.62	0.40±0.05	0.70±0.46	−2832.00	−2844.00
	WM	6.16	4.61	4.62	0.40±0.04	0.70±0.46	−2832.00	−2844.00
Sperm morphology	LG2	6.16	4.61	4.62	0.40±0.05	0.70±0.46	−2832.00	−2844.00
	LG3	6.15	4.63	4.60	0.40±0.04	0.70±0.46	−2830.70	−2842.70
	LG4	6.15	4.65	4.61	0.40±0.02	0.70±0.46	−2833.30	−2845.30
	KG	0.06	0.05	0.04	0.40±0.01	0.70±0.01	−372.92	−384.92
	WM	0.06	0.05	0.04	0.40±0.01	0.70±0.01	−372.92	−384.92
Sperm pH	LG2	0.06	0.05	0.04	0.40±0.01	0.70±0.01	−372.92	−384.92
	LG3	0.16	0.15	0.05	0.40±0.01	0.70±0.01	−671.82	−683.82
	KG4	0.18	0.17	0.05	0.40±0.01	0.70±0.01	−721.80	−733.80

Reproducibility values were consistently more than heritability values, ranging from 0.20 (±0.001) for sperm volume to 0.70 (±0.269) for sperm motility, indicating a strong association between these variables when measured repeatedly.

Table (3) shows the genetic and phenotypic relationships between several semen parameters of Nigerian native chicken cocks. The genetic links among semen variables were positive, ranging from 0.445 to 0.962, and the phenotypic links followed in the same direction as the genetic interactions.

Table 3. Genetic and phenotypic relationships of semen parameters in the Nigerian local cock.

Parameters	Sperm vol.	Sperm Conc.	Sperm mot.	Sperm via.	Sperm morph.	Sperm pH.
Sperm volume	1.000	0.886**	0.888**	0.445**	0.929**	0.909*
Sperm Concentration	0.886**	1.000	0.903**	0.447**	0.918**	0.904**
Sperm motility	0.88**	0.903**	1.000	0.506**	0.885**	0.921**
Sperm viability	0.445**	0.447**	0.506**	1.000	0.477**	0.480**
Sperm morphology	0.929**	0.918**	0.885**	0.477**	1.000	0.962**
Sperm pH	0.909**	0.904**	0.921**	0.480**	0.962**	1.000

**Correlation is significant at the 0.001 level, Semen characteristics in Nigerian local chicken cocks are correlated genetically (above the diagonal direction) and phenotypically (below the diagonal).

The selection index (SI) values were computed based on breeding values that have been calculated (EBVtrait1, EBVtrait2, and EBVtrait3). The comparable economic value (v1, v2, v3) of each sperm attribute was calculated by dividing the measured economic value by the overall economic significance of all reproductive parameters evaluated. Both viability and motility traits were equally significant; additionally, a moderately favorable genetic link was seen, thus, the relative economic values were determined at 0.4 for viability and 0.4 for motility traits. The economic value of sperm concentration has been determined to be 0.7. The decreased heritability value is expected compared to viability and concentration, as well as the genetic correlation values between the three sperm qualities.

The selection index (SI) equation is as follows: $SI = (0.7 \times EBV_{\text{semen concentration}}) + (0.4 \times EBV_{\text{sperm motility}}) + (0.4 \times EBV_{\text{sperm viability}})$.

Table 4. Compare selected traits of sperm for the flocks.

Trait	Mean	Economic weight (%)
Sperm Motility (%)	76.90	4%
Sperm Viability (%)	82.29	5%
Sperm Concentration ($\times 10^9$/mL)	3.53	14%

A proportion of attributes identified from the population showed that sperm concentration (14%) had the largest SI values when compared to viability and motility.

DISCUSSION

There has been genetic selection predominantly focusing on production parameters, like feed efficiency, meat yield, and growth improvement, also, egg production negatively affects poultry reproductive performance (Okpeku et al., 2019). Semen characteristics are critical for improved genes because they impact reproductive success, genetic variety, economic viability, and adaptation (Carvalho et al., 2023). Incorporating semen quality studies into breeding can improve genetic development and animal production sustainability (Gamborg and Sandøe, 2005).

Research on poultry semen generally shows volumes between 0.2 and 0.5 ml per ejaculation (Tarif et al., 2013). In the present investigation, the average sperm volume was discovered to be 0.26 ml, with significant variability (SD = 0.07 ml), which agrees similar to those described by Oke and Ihemeson, (2010). The outcomes on sperm concentration ($3.53 \pm 0.82 \times 10^9$/mL) are consistent and like those described by Gentry and Lumsden, (2008). Ewuola et al. (2018) reported sperm concentration ranging from 2 to 5 × 10^9/mL in broilers. The results on sperm motility are 76.90 ± 3.85%, and the range indicates good motility overall. This compared with the research by Ameen et al. (2014) indicates that motility rates for poultry generally fall between 70% and 80%, results are aligned with these findings, which indicates the traits are harmonious with are of generally good quality. Sperm viability in this investigation is 82.29 ± 10.21%. The viability ranges in typical poultry are between 68.45% to 90.08% and this indicates a range of sperm health among the population (Mussa et al., 2023). The wide standard deviation indicates that in the meantime, the average viability is high, but there are significant individual differences. Results sperm morphology is 74.98%, with a standard deviation is 3.92%. Normal sperm morphology in poultry is typically around 70% to 80%. Paul et al. (2016) and in this investigation, the findings are consistent with their findings, suggesting that the sperm in our studies have a similar morphological quality. Results sperm pH is 7.31, with a standard deviation (Sdev) of 0.39 in our research. Hu et al. (2013) and Daryatmo et al. (2024) it was reported that the pH of poultry sperm generally ranges from 7.0 to 8.0. Our findings fall well within this range, suggesting that the pH of the sperm is typical of good health in the Nigerian local cocks. High volume, motility, and concentration may be linked to successful fertility (Petrunkina et al. 2007). Successful fertility depends on sperm viability, and semen pH, which can be influenced by breed, age, diet, environmental elements, management approaches, stress, and hormonal issues, seasonal influences, and management factors (Perry et al., 2011).

Heritability estimates provide critical insights into the gene base for traits, and the proportion of phenotypic variation that can be ascribed to hereditary factors (Tixier et al., 2012). Understanding these estimates is essential for breeding schemes, such that they aid breeders in selecting traits that will respond to genetic improvement.

The heritability values in this investigation, of Nigerian native chickens typically ranged from 0.20 to 0.40. This study's heritability estimates were aligned with prior reports by Daryatmo et al. (2024) whose study on Thai chicken's native chickens, the heritability of seven sperm characteristics (volume, pH, color, viability, motility, abnormalities, and concentration) ranged between 0.04 and 0.225. Thirty-six (36) weeks old, the heritability estimates for White Leghorn roosters were 0.27, 0.34, and 0.26 sperm volume, concentration, and motility (Wollc et al., 2019). Age, strain, breeding techniques, genetics, temperature in the environment, and relative humidity can all contribute to differences in asserted estimations. Notably, characteristics including sperm concentration and viability showed heritability values near the upper end of this range in this current study, and this high heritability in sperm qualities increases the probability of passing them down from generation to generation. This estimated moderate heritability suggests a substantial genetic component influencing these characteristics, indicating genetic selection could effectively improve these semen characteristics.

The repeatability values presented in the table for semen traits of Nigerian local chickens are essential for assessing the dependability and consistency of these characteristics over time. These values shed insight into the degree to which permanent genetic factors contribute to the findings of variability in traits compared to temporary environmental influences. The repeatability values associated with various traits are notably diverse, with some traits showing higher consistency, sperm concentration (0.70±0.269), and motility (0.70±0.5.71) while others, like sperm pH (0.70±0.01), demonstrate lower repeatability. This variation highlights the effect of both balancing environment and genetic variables on these traits. Values less than 0.5 indicate features such as sperm volume consistently show repeatability values around 0.20, indicating that a significant portion of the variant is attributed to environmental or transitory influences. This suggests that measurements of sperm volume may be less perfect for breeding decisions, as they could vary significantly under different conditions. Values less than 0.5 on the other hand, traits like sperm concentration and motility, with repeatability values around 0.40, suggest a stronger influence of permanent factors. This higher repeatability indicates these traits are more predictable and dependable, making them more appropriate for selection in breeding programs (Sanda et al., 2014). Highly repeatable traits can result in more accurate Estimated Breeding Values (EBVs), allowing breeders to make sound conclusions that improve genetic gains in future generations (Melnikova et al., 2024). The genetic and phenotypic associations shown in Table 3 indicate the possibility for focused breeding methods in Nigerian chickens. Breeders can improve total fertility and reproductive performance by capitalizing on substantial relationships between sperm features, resulting in more productive and sustainable chicken production. The interaction of genetics and environmental effects necessitates a comprehensive understanding of trait relationships and breeding optimization outcomes effectively (Nwogwugwu et al., 2018). The genetic association among semen traits ranges from 0.445 to 0.962, indicating a significant positive relationship among most traits. For instance, the strong genetic link between sperm volume and morphology (0.929) suggests that selection for increased sperm volume may also enhance sperm morphology (Lahaye et al., 2004). Sperm concentration (0.886), the strong genetic link indicates that higher sperm volume is correlated with higher sperm concentration. This relationship aligns with the findings of Gentry et al. (2008) who observed that larger ejaculate volumes typically correlate with higher sperm counts. Sperm motility (0.888), similarly, there is a strong positive correlation between sperm volume and motility. This implies that larger volumes often contain more motile sperm, consistent with Warren and Henry (1975), who reported improved motility with increased sperm volume. Sperm viability (0.445), the moderate correlation indicates that while there exists a link between volume and viability, it is less pronounced. Yoshida et al. (2011) also found variability in how volume impacts sperm viability. Sperm pH (0.909), a strong positive correlation with pH suggests that volume is related to the pH of the sperm, which can affect sperm health, as noted by Hussain et al. (2007). Sperm motility (0.903), a strong favorable link indicates that higher sperm concentration is associated with higher motility. Gentry et al. (2008) and Yoshida et al. (2011) have similarly reported that increased sperm concentrations in general result in better motility. Sperm viability (0.447), the moderate correlation argues that while sperm concentration affects viability, the relationship is not as strong as with motility or morphology. Sperm morphology (0.918), quite a strong positive association, shows that higher concentrations correlate with better morphology, as also observed by Lahaye et al. (2004). Sperm pH ($r = 0.904^{**}$): The strong positive association with pH indicates that the sperm concentration is related to pH, which affects sperm health, consistent with findings from Hussain et al. (2007). Sperm motility (0.506), the moderate correlation shows that higher motility is correlated with better sperm viability, like results reported by Yoshida et al. (2011). Sperm morphology (0.885), a strong positive relationship suggests that better motility is associated with improved morphology, aligning with Lahaye et al. (2004). Sperm pH (0.921), the very strong correlation with pH indicates that higher motility corresponds to a more optimal pH environment, which supports the results of Hussain et al., (2007). Sperm Morphology (0.477), a moderately positive correlation indicates that better viability is somewhat related to better morphology. Almquist (1961) found similar moderate relationships. Sperm pH (0.480), the moderate correlation with pH suggests that viability is linked to pH levels, consistent with Hussain et al., (2007). Sperm pH (0.962), the very strong correlation with pH suggests that better morphology is strongly associated with a more optimal pH, reflecting findings from Hussain et al. (2007) and Lahaye et al. (2004). This is particularly relevant for breeding programs aiming to improve overall semen quality. Phenotypic correlations mirror genetic correlations, reinforcing the idea that these relationships are not solely genetic but also environmental factors that have effects. For instance, sperm motility shows a strong correlation with sperm concentration (0.903), indicating that environmental conditions affecting one trait may similarly impact the other (Adedeji et al., 2015).

Breeders can use the selection index to examine many qualities simultaneously, ranking them based on economic relevance and genetic variance (Hazel et al., 1994). Three traits are essential, but they serve different roles in ensuring reproductive success. Concentration has the highest economic weight, indicating its critical role in breeding programs, while motility and viability are also vital for ensuring that sperm can successfully fertilize the eggs. In a breeding program, focusing on these traits can enhance overall flock performance, enhance fertility rates, and optimize reproductive efficiency. Selecting traits with strong heritability can further ensure that improvements are maintained over generations.

CONCLUSION and RECOMMENDATIONS

An investigation of semen features in Nigerian local chicken cocks offers crucial information about their reproductive properties, with average values for sperm volume, concentration, motility, viability, morphology, and pH indicating generally better semen quality. The identified heritability estimates indicate a considerable genetic base for these qualities, emphasizing their potential for improvement via selective breeding methods. Positive genetic and phenotypic relationships across semen qualities suggest that strengthening one attribute may help others, increasing overall reproductive efficiency.

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Conflict of Interest

The authors have declared that there are no competing interests.

Authors' Contribution

The authors contributed equally to the success of this research.

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