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Egg Production Characteristics and Adaptive Traits of F_1 Backcross Progenies Derived from Normal-Feathered, Naked-Neck, and Frizzle Crossbred Chickens under Humid Tropical Conditions

By

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Abstract

Poultry production in humid tropical environments is constrained by chronic heat stress, which adversely affects reproductive performance, egg quality, and overall adaptability of laying birds. The incorporation of adaptive major genes such as naked-neck (Na) and frizzle (F) into crossbreeding programmes offers a promising strategy for enhancing productivity under such climatic stress. This study evaluated egg production characteristics, egg quality traits, and adaptive performance of F_1 backcross progenies derived from normal-feathered (NF), naked-neck (Na), and frizzle (F) indigenous chickens crossed with an exotic broiler breeder strain (Anak) under humid tropical conditions. The experiment was conducted at the Poultry Unit of the Teaching and Research Farm, Michael Okpara University of Agriculture, Umudike, Nigeria (05°29'N, 07°33'E; 122 m above sea level), characterised by high ambient temperature (27–36°C), relative humidity (57–91%), and annual rainfall of approximately 2,177 mm. Ninety (90) parental birds comprising 45 indigenous genotypes (NF, Na, and F) and 45 exotic breeders were used to generate F_1 progenies through main and reciprocal crosses using artificial insemination. The laying trial lasted 90 days following attainment of point-of-lay at 18 weeks. Data were analysed using a Randomised Complete Block Design with genetic group as fixed effect and hatch as a block, and means were separated using Duncan's Multiple Range Test at $P < 0.05$. Significant ($P < 0.05$) genotypic differences were observed in body weight at first egg (BWFE), age at first egg (AFE), average weight of first egg (AWFE), and short-term egg number (EN_{90}). Reciprocal crosses consistently outperformed main crosses, highlighting the importance of maternal and non-additive genetic effects. The frizzle × exotic (F × E) reciprocal cross recorded the highest BWFE (2000 g), earliest maturity (146 days), and superior egg weight at first lay (47.55 g), while Na × E also demonstrated early maturity and high egg output. Short-term egg production was highest in Na × E (40.70 eggs) and F × E (41.02 eggs), indicating improved laying intensity under thermal stress conditions. External and internal egg quality traits were likewise significantly influenced by genotype. F × E birds exhibited superior egg weight, shell weight, shell thickness, albumen weight (21.72 g), yolk weight (15.45 g), albumen height (8.98 mm), and Haugh unit (155.17), reflecting enhanced structural and internal egg quality. Correlation analyses revealed strong positive associations between egg weight and most egg quality traits, suggesting that selection for egg weight would concurrently improve albumen and yolk yield. Positive correlations between BWFE and egg production traits indicate that heavier pullets at sexual maturity tend to exhibit improved early laying performance, although some genotype-specific trade-offs were observed. The results demonstrate that incorporation of naked-neck and frizzle genes through reciprocal crossbreeding significantly enhances reproductive performance, egg quality, and adaptive capacity under humid tropical conditions. The superiority of F × E and Na × E reciprocal crosses underscores the combined influence of adaptive major genes, maternal effects, and heterosis. Strategic exploitation of these genotypes can contribute to *the development of climate-resilient laying chickens suited to tropical production systems, thereby improving productivity, profitability, and sustainability of poultry enterprises in hot–humid environments.*

Keywords: *F_1 backcross; naked-neck gene; frizzle gene; egg production; egg quality; humid tropics; adaptive traits; reciprocal crossbreeding; poultry genetics.*

Introduction

Poultry production remains one of the fastest-growing subsectors of Nigeria's livestock industry, contributing significantly to national food security, employment generation, and household income. Nigeria's poultry population is estimated at approximately 180 million birds, producing about 454 billion tonnes of meat and 3.8 million eggs annually (ASL 2050, 2018). Despite this contribution, per capita consumption of poultry meat and eggs remains below recommended nutritional standards compared with developed economies.

Indigenous chickens constitute a substantial proportion of Nigeria's poultry population and play an indispensable role in rural livelihoods. They provide affordable, high-quality animal protein and serve as a source of financial security for smallholder households (Gueye, 2003; Alabi et al., 2006). However, Nigerian local chickens are generally characterised by small body size, slow growth rate, late sexual maturity, low egg weight, and modest egg output compared with improved commercial layer strains (Pedersen, 2002; Gondwe, 2004). Their populations are genetically heterogeneous, exhibiting considerable phenotypic variability, which suggests the presence of exploitable genetic diversity for improvement programmes (Msoffe et al., 2001; Fayeye et al., 2005).

Although indigenous Nigerian chickens have not been formally classified into distinct breeds (Ibe, 2001), several strains possess major genes that exert direct and indirect effects on productive traits and quantitative trait loci (Fayeye et al., 2006). Among these are plumage-reducing genes, notably the naked-neck (Na) and frizzle (F) genes, which are associated with thermoregulatory advantages (Peters, 2000).

Heat stress is a major environmental constraint in tropical and subtropical poultry production systems. Elevated ambient temperature, especially when accompanied by high relative humidity, adversely affects feed intake, endocrine function, egg production rate, egg weight, shell quality, and overall laying performance (Mahrous et al., 2003; Chen et al., 2009; Fathi et al., 2013). Under such conditions, conventional high-producing layer strains often fail to express their full genetic potential due to genotype–environment interactions.

Genetic strategies aimed at enhancing thermal tolerance through plumage modification have therefore attracted considerable research attention. The naked-neck and frizzle genes reduce feather coverage, thereby increasing body surface area for heat dissipation and decreasing thermal insulation (Galal and Fathi, 2001; 2002; Nwachukwu et al., 2006; Mahrous et al., 2008). The thermoregulatory benefit of the Na gene has been linked to increased triiodothyronine (T_3) concentration (Decuypere et al., 1993) and enhanced sensible heat loss from exposed body regions (Yahav et al., 1998). Similarly, the frizzle gene alters feather structure through outward curling, reducing heat insulation and improving convective heat dissipation (Fathi et al., 2013).

Reduced feather mass may also spare dietary protein otherwise utilised for feather synthesis, potentially redirecting nutrients towards egg production and body tissue deposition (Adomako, 2009). Importantly, the naked-neck and frizzle genes exhibit pleiotropic effects on economically important traits, including growth rate, feed efficiency, egg production, egg weight, and reproductive performance (Galal, 2000; El-Safty, 2006; Mahrous, 2008). Consequently, their incorporation—either singly or in combination—has been advocated for the development of poultry lines adapted to hot and humid environments (Horst, 1988; Thiruvenkadan et al., 2010; Rajkumar et al., 2011; Mahrous and El-Dlebshany, 2011).

Despite these advances, limited information exists regarding the egg production characteristics of F_1 backcross progenies derived from normal-feathered, naked-neck, and frizzle crossbred chickens under humid tropical conditions. Understanding the laying performance, onset of lay, egg production rate, egg mass, and egg quality parameters of such genotypes is essential for designing sustainable breeding strategies tailored to tropical environments. Evaluating these crossbred progenies will provide insight into the extent to which plumage-reducing genes can mitigate heat stress effects and enhance reproductive efficiency under humid tropical conditions.

Poultry production in tropical regions is constrained by persistently high ambient temperatures and elevated relative humidity. Heat stress negatively affects feed intake, hormonal regulation, ovarian function, egg production rate, egg size, shell quality, and overall reproductive efficiency. Consequently, egg output per bird is often suboptimal, contributing to low per capita egg consumption in many developing countries.

While indigenous chickens exhibit adaptive traits suited to harsh environmental conditions, they are generally characterised by low egg production, small egg size, and delayed sexual maturity. Conversely, exotic commercial layer strains possess high genetic potential for egg production but often demonstrate reduced adaptability and productivity under humid tropical conditions.

There is therefore a pressing need to develop genotypes that combine environmental adaptability with improved egg production performance. However, empirical data on the laying performance of F_1 backcross progenies carrying plumage-reducing genes under humid tropical environments

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remain limited. This knowledge gap restricts evidence-based breeding decisions for sustainable egg production in tropical systems.

The integration of thermoregulatory plumage-modifying genes into poultry breeding programmes represents a promising genetic strategy for mitigating heat stress in tropical environments. The naked-neck and frizzle genes reduce feather coverage and enhance heat dissipation, thereby improving thermal balance and potentially stabilising reproductive performance under high ambient temperatures.

Fast-growing and high-producing birds generate substantial metabolic heat due to increased feed intake and elevated metabolic rate. When heat production exceeds heat loss capacity, physiological stress impairs reproductive function and egg production. By facilitating heat dissipation, plumage-reducing genes may support improved laying persistence, egg weight, and egg quality under humid conditions.

Crossbreeding indigenous chickens with exotic strains provides an opportunity to exploit heterosis and breed complementarity, combining adaptability with improved production potential. Because plumage-reducing genes exhibit pleiotropic effects, their positive influence on thermoregulation may concurrently enhance other economically important traits, including egg production characteristics.

Therefore, evaluating the egg production performance of F_1 backcross progenies bearing normal-feathered, naked-neck, and frizzle genotypes is essential for developing resilient layer lines suited to humid tropical conditions. The findings from this study will contribute to sustainable poultry breeding strategies aimed at improving egg output, enhancing food security, and increasing profitability in tropical production systems.

Materials and Methods

Study Location

The experiment was conducted at the Poultry Unit of the Teaching and Research Farm, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria. Umudike is located at a latitude of 05°29′N and a longitude of 07°33′E, approximately 122 m above sea level. The area lies within the humid rainforest agro-ecological zone of South-Eastern Nigeria and is characterised by a hot–humid tropical climate.

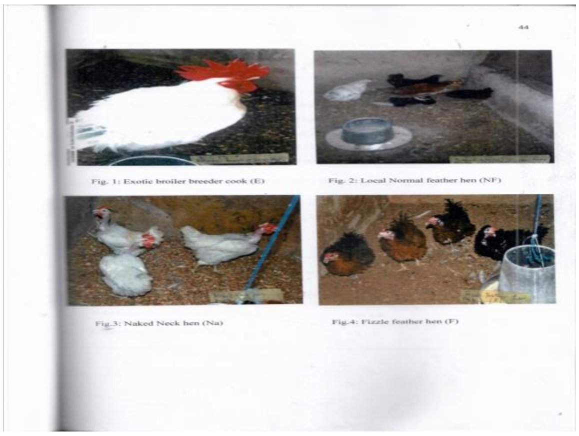
The mean daily maximum and minimum temperatures range from 27–36°C and 20–26°C, respectively, with relative humidity varying between 57% and 91%. The average annual rainfall is approximately 2,177 mm. These climatic conditions typify the warm–wet tropical environment and present substantial thermal challenges for poultry production, making the location suitable for evaluating adaptive and productive performance under humid tropical conditions.

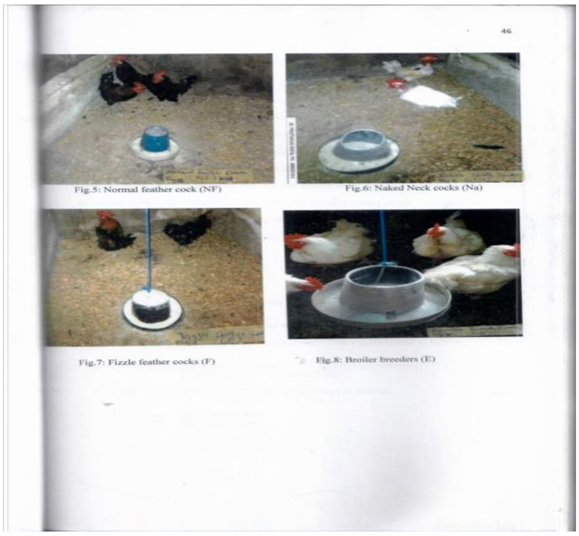
Experimental Birds and Breeding Procedure

Procurement and Management of Parent Stock

A base population of ninety (90) adult chickens, aged 48 weeks, was used for the breeding programme. The population comprised 45 indigenous birds representing three genotypes including Normal-feathered (NF), Naked-neck (Na) and Frizzle (F); 45 exotic broiler breeder birds (Anak strain). All birds were sourced from the Teaching and Research Farm of the University.

The parent stock was managed under a deep-litter system and fed a commercial layer mash. Feed and clean drinking water were provided *ad libitum*. A photoperiod of 18 hours per day (12 hours natural daylight and 6 hours artificial light) was maintained to optimise reproductive performance. Routine vaccination schedules and standard prophylactic medications (antibiotics, anticoccidials, and anthelmintics) were administered according to veterinary recommendations.





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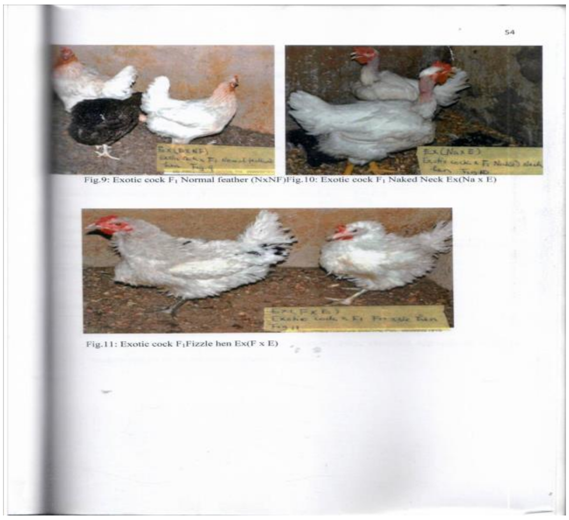

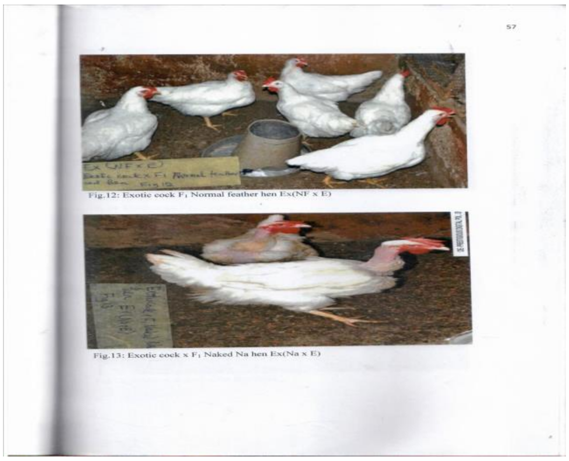

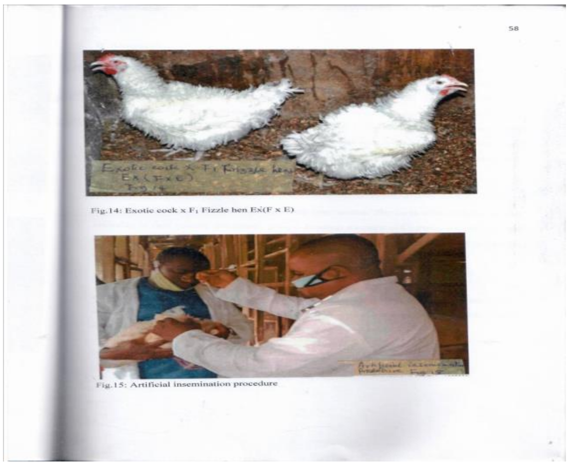

Mating Scheme and Production of F_1 Crossbred Progenies

A main and reciprocal crossbreeding design was employed to generate F_1 hybrid progenies. Due to marked differences in body size between indigenous and exotic birds, artificial insemination was adopted following the procedure described by Lake et al. (1985). Birds were randomly assigned to breeding pens at a mating ratio of 2 females:1 male.

Main Crosses:

i. Exotic cock (E) × Normal-feathered hen (NF)

ii. Exotic cock (E) × Naked-neck hen (Na)

iii. Exotic cock (E) × Frizzle hen (F)

Reciprocal Crosses:

i. Normal-feathered cock (NF) × Exotic hen (E)

ii. Naked-neck cock (Na) × Exotic hen (E)

iii. Frizzle cock (F) × Exotic hen (E)

All F_1 progenies possessed 50% exotic blood.

Fertilised eggs were collected daily, stored for a maximum of 7 days at 10–14°C and 75–80% relative humidity, fumigated, and incubated under standard incubation conditions. Hatched chicks were individually wing-tagged for identification.

Management of F_1 Backcross Progenies

Brooding Phase (0–6 Weeks)

Chicks were brooded in genotype-specific pens under deep litter. Supplemental heat was provided using hurricane lanterns and 60-W incandescent bulbs per pen. A commercial starter diet containing approximately 23% crude protein was fed from day-old to 6 weeks of age.

Vaccination against Newcastle disease (ND) and Infectious Bursal Disease (IBD) was administered at 7, 14, 21, and 28 days of age following standard vaccination protocols. Water was provided *ad libitum*.

Growing and Laying Phase

At 18 weeks of age, birds were considered point-of-lay and transferred to the laying pens under a deep-litter management system.

A commercial layer mash containing 16.5% crude protein was provided *ad libitum*. Clean drinking water was supplied continuously. A photoperiod of 18 hours per day (12 h natural + 6 h artificial light) was maintained throughout the laying period. A booster dose of Newcastle disease vaccine (Lasota strain) was administered via drinking water.

The laying trial lasted 90 days (short-term laying period) to evaluate egg production and adaptive performance traits.

Data Collection

Egg Production Parameters

The following production traits were recorded:

i. **Age at First Egg (AFE):** Number of days from hatch to first oviposition.

ii. **Body Weight at First Egg (BWFE):** Live body weight measured on the day the first egg was laid using a digital top-loading scale.

iii. **Average Weight of First Egg (AWFE):** Weight of the first egg laid.

iv. **Short-term Egg Number (EN_{90}):** Total number of eggs laid per hen during the first 90 days of lay.

v. **Hen-day Egg Production (%)**

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vi. **Laying Mortality (%):** Calculated as the proportion of birds that died during the laying period relative to the initial number at point-of-lay.

Egg Quality Parameters

Egg quality traits were evaluated at 60 days of lay.

i. **Egg weight (g):** Measured using an electronic balance (0.01 g sensitivity).

ii. **Yolk weight (g)**

iii. **Albumen weight (g)**

iv. **Yolk width (mm):** Measured using digital callipers (0.01 mm precision).

v. **Yolk height (mm)**

vi. **Albumen height (mm):** Measured using an Ames tripod micrometre.

vii. **Shell thickness (mm):** Measured using a micrometre screw gauge (Ames 25-MS).

viii. **Yolk Index (YI)**

ix. **Haugh Unit (HU)**

Experimental Design and Statistical Analysis

The experiment was conducted using a Randomised Complete Block Design (RCBD), with genetic group as the main treatment factor and hatch as the blocking factor. The statistical model was:

$Y_{ijk} = \mu + G_i + H_j + e_{ijk}$

Where,

Y_{ijk} = k^{th} individual in the i^{th} genetic group and in the j^{th} block

μ = Overall population mean

G_i = Effect of i^{th} genetic group (i = 1…6).

H_j = Blocked effect of j^{th} hatch (j = 1….5)

e_{ijk} = Random residual error, assumed to be independently, identically and normally distributed with zero mean and constant variance.

Data were analysed using Analysis of Variance (ANOVA) as described by Steel and Torrie (1980) using SAS software (Version 9.0, 2018). Significant means were separated using Duncan's Multiple Range Test (Duncan, 1955).

Correlation Analysis

Pearson's correlation coefficients were computed to determine:

i. The relationship between body weight at first egg (BWFE) and egg production parameters.

ii. The association between egg weight at 60 days of lay and egg quality traits.

Phenotypic correlation (r_p) was calculated as:

$$\text{Phenotypic } r = \frac{Cov_{p12}}{(\sigma^2 p_1).\sigma^2 p_2}$$

Where Cov_{p12} is the phenotypic covariance of the progeny means between the two traits, and $\sigma^2 p_1$ and $\sigma^2 p_2$ are the phenotypic variance for each trait.

Statistical significance was declared at $P < 0.05$.

Results and Discussion

Egg Production Characteristics of F₁ Backcross Progenies

The egg production characteristics of F_1 backcross progenies derived from normal-feathered (NF), naked-neck (Na), and frizzle (F) crossbred chickens under humid tropical conditions are presented in Table 1. Significant ($P < 0.05$) variations were observed among the genetic groups for body weight at first egg, age at first egg, egg weight at first egg, and short-term egg number (90 days), indicating strong genotypic influence on reproductive performance.

Reciprocal crosses generally outperformed the main crosses in most egg production parameters, suggesting the influence of maternal and possible cytoplasmic effects. Birds from the F × E reciprocal cross exhibited the highest body weight at first egg (2000.00 g), followed by Na × E (1604.00 g) and NF × E (1494.60 g), while the main crosses recorded comparatively lower values. The superiority of reciprocal crosses may reflect favorable additive and non-additive genetic effects, including dominance and maternal inheritance, which are known to influence early reproductive performance in chickens.

Body weight at first egg is a critical determinant of subsequent laying performance and egg size. Heavier pullets at sexual maturity often produce larger eggs and exhibit improved persistency of lay. The present findings align with earlier reports that genotype significantly influences body weight at sexual maturity and laying performance (Adedokun&Sonaiya, 2001; Ibe, 1993). The heavier body weight observed in F × E birds may indicate enhanced adaptability of the frizzle genotype under humid tropical conditions, possibly due to improved heat dissipation associated with reduced feather coverage.

Age at first egg (AFE) differed significantly among the genetic groups. Reciprocal crosses, particularly F × E (146 days) and Na × E (148 days), attained sexual maturity earlier than most main crosses. Early maturity is desirable in tropical production systems as it shortens the non-productive rearing phase and enhances lifetime egg output. Similar mean ages at first egg (157–165 days) have been reported across different agro-ecological zones in Nigeria (Adedokun&Sonaiya, 2001). Furthermore, Ibe (1993) observed that naked-neck and frizzle chickens matured earlier than normal-feathered birds under tropical environments, corroborating the present findings.

The reduced feather coverage in naked-neck and frizzle genotypes enhances thermoregulation by facilitating heat loss, thereby reducing heat stress—a major constraint to poultry production in humid tropics. Heat stress is known to delay sexual maturity and depress egg production (Tadelle et al., 2003). Thus, the superior reproductive performance of Na × E and F × E reciprocal crosses suggests that incorporation of major genes conferring heat tolerance can significantly improve productivity under tropical climatic stress.

Egg weight at first egg also varied significantly among the genetic groups, with F × E recording the highest value (47.55 g). Egg weight is a trait of economic importance, influencing market acceptability and hatchability. The larger egg size in reciprocal crosses indicates possible heterotic effects. Genotype-dependent variation in egg weight has been widely reported (Pandey et al., 1986; Yeasmin&Howlider, 1998; Momoh et al., 2010).

Short-term egg number (90 days) followed a similar pattern, with reciprocal crosses outperforming main crosses. Na × E (40.70) and F × E (41.02) recorded the highest egg numbers, indicating superior early laying intensity. This observation agrees with findings by Adumako (2009) and Fathi et al. (2013), who reported that naked-neck birds generally exhibit enhanced egg production under hot climates. The positive influence of the Na gene on egg production traits is likely associated with improved feed efficiency and reduced maintenance energy requirements under heat stress.

Table 1: Egg Production Characteristics of F_1 Crossbred Normal feathered, Naked neck and Frizzle Chickens

Parameters	E x NF	E x Na	E x F	NF x E	Na x E	F x E
Weight at first egg (g)	900.75±3.09[c]	895±3.12[c]	1000.50±3.00[d]	1494.60±3.08[c]	1604.00±3.12[b]	2000.00±3.8[a]
Age at first egg (days)	158±44.87[b]	150±32.19[b]	170±56.01[a]	149±60.09[c]	148±33.82[d]	146±40.00[c]
Egg weight at first egg (g)	25.03±0.69[d]	25.27±0.04[d]	37.43±0.69[c]	36.64±0.60[c]	38.36±0.09[b]	47.55±0.71[a]
Short term egg number at 90 days	25.06±0.09[c]	29.80±0.85[d]	31.03±0.25[c]	38.58±2.28[b]	40.70±1.13[a]	41.02±0.81[a]

[a–c]Means±Standard Error of mean with different superscripts in the same row are significantly different (P<0.05)

External and Internal Egg Characteristics

External and internal egg quality traits (Table 2) were significantly influenced (P < 0.05) by genotype. Reciprocal crosses consistently demonstrated superior performance, especially F × E and Na × E groups.

Egg weight, egg length, shell weight, and shell thickness were significantly higher in F × E birds, while NF × E exhibited higher egg width and competitive shell thickness values. Egg weight ranged from 36.30 g in E × NF to 39.96 g in F × E. These results reinforce the importance of genotype in determining egg size and structural quality.

Egg weight is primarily a function of albumen, yolk, and shell proportions (Pandey et al., 1986). Variations among genetic groups may reflect differences in nutrient partitioning and metabolic efficiency. Similar genotype effects on specific gravity and shell characteristics have been reported by Yeasmin and Howlider (1998), Nahar et al. (2007), and Onagbesan et al. (2007).

Shell weight values observed in this study fall within ranges reported by Markos et al. (2017) for chickens reared across different Ethiopian agro-ecologies. Adequate shell thickness and weight are essential for reducing breakage losses and improving hatchability.

Internal egg quality parameters further demonstrated the superiority of reciprocal crosses. F × E birds recorded significantly higher albumen weight (21.72 g), yolk weight (15.45 g), albumen height (8.98 mm), yolk height (17.89 mm), and Haugh unit (155.17), indicating superior internal quality. The Haugh unit, a standard indicator of albumen quality, was consistently high across all genetic groups, suggesting good freshness and protein quality.

Albumen and yolk weights are nutritionally important, influencing protein and lipid content (Bain, 2005). Higher albumen weight enhances protein yield, while yolk weight affects energy density and cholesterol content (Sparks, 2006). Comparable internal quality values have been reported in studies conducted in Bangladesh, India, Nigeria, and China (Chatterjee et al., 2007; Olawumi&Ogunlade, 2008; Wang et al., 2009).

The superiority of F × E in both external and internal traits suggests that the frizzle gene may confer adaptive advantages under humid tropical stress conditions. Nwachukwu et al. (2006) similarly reported that birds carrying the frizzle gene outperformed naked-neck and normal-feathered counterparts in several egg quality traits.

Table 2: External and Internal Egg Characteristics of F_1 Crossbred Normal feathered, Naked neck and Frizzle Chickens

	Genetic groups					
	Main crosses →			Reciprocal crosses →		
Parameters	E x NF	E x Na	E x F	NF x E	Na x E	F x E
External egg characteristics						

Egg weight (g)	36.30 ± 0.52^{d}	38.03 ± 2.45^{c}	38.12 ± 1.26^{bc}	38.31 ± 0.87^{b}	38.91 ± 0.95^{ab}	39.96 ± 3.09^{a}
Egg length (mm)	48.39 ± 0.54^{c}	47.01 ± 0.44^{d}	48.12 ± 0.29^{c}	49.03 ± 0.57^{b}	49.25 ± 0.36^{b}	51.64 ± 1.45^{a}
Egg width (cm)	37.09 ± 0.45^{c}	37.48 ± 1.03^{bc}	37.11 ± 2.09^{c}	38.32 ± 3.09^{b}	45.48 ± 5.92^{a}	44.65 ± 3.09^{a}
Shell weight (g)	4.52 ± 0.12^{bc}	4.87 ± 0.25^{b}	4.44 ± 0.30^{c}	4.54 ± 0.73^{b}	5.10 ± 0.23^{a}	^{b}
Shell thickness (mm)	0.26 ± 0.02^{d}	0.31 ± 0.01^{b}	0.27 ± 0.01^{c}	0.35 ± 0.20^{b}	0.37 ± 0.01^{a}	5.52 ± 0.01^{a}
						0.38 ± 0.10^{a}
Internal Egg Characteristics						
Albumin weight (g)	18.02 ± 0.65^{d}	18.56 ± 0.56^{c}	17.77 ± 0.89^{d}	20.11 ± 0.80^{b}	20.36 ± 0.23^{b}	21.72 ± 0.91^{a}
Yolk weight (g)	12.02 ± 0.53^{c}	14.95 ± 0.74^{a}	14.62 ± 0.20^{a}	14.02 ± 0.60^{a}	13.79 ± 0.46^{b}	15.45 ± 0.81^{a}
Albumin height	8.56 ± 0.15^{ab}	7.50 ± 0.32^{c}	8.19 ± 0.41^{b}	8.66 ± 0.50^{b}	8.75 ± 0.25^{b}	8.98 ± 0.11^{a}
(mm)	15.97 ± 0.62^{c}	17.37 ± 0.94^{b}	15.38 ± 0.13^{c}	17.15 ± 0.41^{b}	17.65 ± 0.74^{b}	17.89 ± 0.55^{a}
Yolk height (mm)	35.61 ± 0.54^{d}	39.52 ± 0.88^{b}	39.16 ± 0.28^{c}	39.61 ± 1.55^{b}	42.97 ± 1.06^{a}	41.45 ± 1.27^{a}
Yolk circumference	153.04 ± 1.81^{b}	146.90 ± 3.97^{d}	151.37 ± 2.79^{c}	153.94 ± 2.48^{b}	154.73 ± 1.61^{a}	^{b}
Haugh unit						155.17 ± 1.77^{a}

Means with different superscripts in the same row are significantly different (p<0.05), S.E.M: Standard Error of mean

Correlation between Body Weight at First Egg and Egg Production Parameters

Correlation coefficients between body weight at first egg and selected production traits (Table 3) revealed predominantly positive associations, ranging from low to very high (0.287–0.996). Positive correlations imply that heavier pullets tend to attain sexual maturity earlier or exhibit improved egg production.

Moderate positive correlations between body weight at first egg and age at first egg have been reported by Karabag (2010) and Alkan et al. (2010). However, the highly significant negative correlation ($r = -1.00$; $P < 0.01$) observed in F × E suggests a complex genetic relationship, possibly due to small sample variation or strong genetic linkage between maturity and body weight in this genotype.

Negative correlations between body weight and egg number observed in some crosses indicate potential trade-offs between growth and early egg output. Similar negative relationships have been reported in quail and chicken lines (Farrag, 2011; Lotfi et al., 2012). Such antagonistic relationships are common in selection programs and highlight the need for balanced breeding objectives.

Table 3: Correlation between Body Weight at First Egg and Egg Production Parameters in F_1 Crossbred Chickens

	Genetic groups					
	Main crosses			Reciprocal		
Parameters	**E x NF**	**E x Na**	**E x F**	**NF x E**	**Na x E**	**F x E**
Age at first egg (days)	$.996^{NS}$	$.991^{NS}$	$.287^{NS}$	-1.000**	$.984^{NS}$	$.964^{NS}$
Short term egg number at 90 days	-.447	-.567	-.999*	495^{NS}	-.577	-.153

*Correlation is significant at the 0.05 level

** Correlation is significant at the 0.01 level

^{NS} = Not significant

Correlation between Egg Weight and Egg Quality Traits

Correlation analysis (Table 4) revealed strong and significant ($P < 0.01$) positive associations between egg weight and most external and internal quality traits across genetic groups. Egg weight showed significant positive correlations with egg length, egg width, shell weight, albumen weight, yolk weight, and Haugh unit in most crosses.

These findings agree with earlier reports indicating strong positive relationships between egg weight and albumen and yolk weights (Yousif&Eltayeb, 2011; Yakubu et al., 2008). Strong correlations suggest that selection for increased egg weight will simultaneously improve albumen and yolk yield, enhancing nutritional and economic value.

The positive correlation between egg weight and shell thickness observed in most genetic groups aligns with the report of Chineke (2001). However, the absence of significant correlations in certain crosses indicates genotype-specific relationships, reinforcing the need for tailored breeding strategies.

Overall, the correlation patterns demonstrate that egg weight is a reliable selection criterion for improving overall egg quality in F_1 backcross progenies. The consistent superiority of reciprocal crosses, particularly F × E and Na × E, underscores the importance of maternal effects and adaptive major genes in enhancing productivity under humid tropical conditions.

Table 4: Correlation between Egg weight at 60 days of lay and Egg Quality Traits in F₁ Hybrid Chickens

	Genetic groups					
	Main crosses			Reciprocal		
Parameters	E x NF	E x Na	E x F	NF x E	Na x E	F x E
Egg length	.803**	.731**	.868**	.764**	.745**	.792**
Egg width	.350**	.347**	.273**	.172^{NS}	.307**	.408**
Egg Volume	.760**	.883**	.828**	.862**	.772**	.849**
Shell weight	.581**	.469**	.493**	.394**	.451**	.400**
Shell thickness	.310**	.553**	.080^{NS}	.704**	.153^{NS}	.437**
Albumen weight	.614**	.689**	.516**	.886**	.539**	.607**
Yolk weight	-.180^{NS}	.613**	.085^{NS}	.733**	.009^{NS}	.409**
Albumen height	.802**	.777**	.836**	.780**	.867**	.733**
Yolk height	.582**	.693**	.084^{NS}	.681**	.401**	.854**
Yolk circumference	-.286**	.564**	.129^{NS}	.642**	-.052^{NS}	.139^{NS}
Haugh unit	.598**	.826**	.859**	.831**	.680**	.830**

** Correlation is significant at the 0.01 level
NS = Not significant

General Implications

The present study demonstrates that the incorporation of adaptive major genes (naked-neck and frizzle) into crossbreeding programs significantly improves egg production and egg quality traits under humid tropical conditions. Reciprocal crossing strategies, especially involving frizzle dams, yielded superior reproductive and egg quality performance, likely due to favourable maternal and heterotic effects.

These findings provide strong evidence that strategic utilisation of adaptive genes can enhance productivity, resilience, and profitability of poultry production systems in tropical environments. Future breeding programs should prioritise reciprocal cross evaluation and multi-trait selection indices to optimise both production and adaptive traits.

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