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Original article

Egg production and egg quality characteristics of Yoruba, Sussex, and Goliath chickens and their crossbred progenies under humid tropical climate

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ABSTRACT

Yoruba Ecotype Chicken (YEC) is characterized by hardiness and better adaptation to the prevailing tropical environment. However, its poor egg production has hindered its utilization for commercial production. Crossbreeding is a major tool used in improving desired traits in animals. The study aimed to evaluate egg production and quality characteristics in YEC and its crosses with Goliath (GG) and Sussex (SS). The study investigated egg production and quality characteristics using 120 sixteen-week-old YEC and its crosses. The findings of the study showed that egg parameters were significantly higher ($p < 0.05$) and maturity occurred earlier (154 days) in YECxSS than in YECxYEC (146 days), and other YEC crosses. The study concluded that crossbreeding improved the egg production of YEC. Crossbred YECxSS is therefore recommended for egg production in Nigeria.

Keywords: Crossbreeding, Goliath, Sussex, Yoruba Ecotype chicken

INTRODUCTION

Poultry eggs constitute one of the cheapest valuable animal protein sources recommended for human consumption. The Nigerian indigenous chickens are suitable for developing layer strains for the tropical environment (Ayorinde, 1986). Birds with good production can result from the combining ability of the best performing exotic and indigenous chicken lines; the laying performance of Nigerian indigenous chickens has been evaluated and reported. Nwosu and Omeje (1985) reported an egg number of 146 per year under a battery cage system and 80 to 112 per year under a semi-intensive system by Momoh *et al.* (2010) obtained 144 and 136 eggs per year for light and heavy ecotypes of Nigeria local chicken. Also, Fulani Ecotypes produced 78 to 144 eggs per year, while Yoruba ecotypes produced 58 to 128 eggs per year (Sola-Ojo *et al.*, 2013). However, the laying performance of some exotic breeds has also been reported; Rhode Island Red was known to be an excellent egg producer; they could produce 250 to 300 large light brown eggs per year, while Croadlang Shan hens laid 140-150 eggs annually and are characterized as excellent sitters and mothers (Lesley, 2020). Broiler chickens are bred and raised for meat production, but there are some hybrids of egg-

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laying chicken; they lay fewer eggs than other breeds, usually about 140 eggs per year (Lesley, 2020). Also, Sussex hens lay approximately 240-260 eggs per year which are large and cream to light brown, while Goliath lay between 110 and 160 eggs per year (Citrus County Poultry Skill-A-Thon, 2010). Among poultry's most important production traits are live body weight and egg weight. Egg quality is important for consumer acceptance, and the economic success of egg producers is directly proportional to the total number of eggs sold. Silversides *et al*. (2006) and Akintunde and Toye (2022) reported that the quality of eggs has a genetic basis, and this quality varies between strains of hens. Egg quality encompasses egg weight, egg length, egg width, shell weight, shell thickness (external quality), albumen weight, height, Haugh unit, and yolk weight (internal quality). These external qualities represent one of the important phenotypic traits that influence egg quality and reproductive fitness of chicken parents (Islam and Dulta, 2010). The relationship between external and internal egg quality traits contributed to increased egg weight with the age of the hen and reaching an apex by the end of the laying cycle (Danilov, 2000). The length of daylight and climate temperature affected reproductive endocrine followed by the egg quality and productivity trait of hens (Khan *et al*., 2018). Therefore, the work aims to evaluate egg production and quality traits in pure and crossbred hens under humid tropical climates.

MATERIALS AND METHODS

Location of the Study

The study was conducted on a private farm located at Oyan (Osun state, South-West, Nigeria). The coordinates of the experimental site are latitude 8.05 and longitude 4.77, and an elevation of 422 meters above sea level.

Experimental Animals

A total of 120 sixteen weeks old lay points comprising seven strains were randomly selected. The selected birds comprised 30 pure breeds YEC, 20 purebred GG, 20 purebred SS, 15 crossbred (YECxGG), 15 crossbred (YECxSS), ten crossbred (GGxYEC), and ten crossbred (SSxYEC) pullets were transferred to an individual battery cage. Egg production and egg quality traits measured were recorded for 24 weeks.

Data Collection

Laying Performance

Age at First Egg (AFE): This was the age at which each hen started laying and was recorded for each hen. Hen Body Weight at first egg (HBW): This was obtained by weighing the individual hen using a 10 kg Camry measuring scale to record the hen's body weight at first egg. Egg Weight (EW): The egg laid by each hen was weighed daily. Egg Number (EN): This was recorded as the total number of eggs laid by each hen per strain for 24 weeks. Egg Mass (EM): This was obtained as the product of average weight and egg number. Hen Day Production (HDP %): This was taken for each strain as the number of eggs laid per bird alive at the end of the week (Fairful and Gowe, 1990). Feed per Dozen Egg (FDE): Amount of feed consumed divided by dozens of eggs produced.

Egg external quality traits

Two egg samples were selected weekly per genetic group to estimate external egg quality traits. The external egg quality traits considered in this study include Egg length (EL): This was measured as the distance between the tip of narrow and broad ends of an egg with the aid of a pair of vernier calipers (calibrated in mm). Egg width (EWD): Measured with a pair of vernier calipers (calibrated in mm). Egg index (EI): This was taken as the egg length and width ratio. Shell Weight (SW): This was taken as the weight of the shell after the content had been removed. The shell is rinsed in warm water and air dried for 48hrs before taking the weight with a digital scale (the value obtained was recorded in % of EW). Egg Shell Thickness (ST): This was determined as the average of measurements of selected egg shells taken at the broad end, middle portion, and narrow end of the shell using a micrometer screw gauge (calibrated in mm) after removing the egg membrane.

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Egg internal quality traits

Weekly, two eggs were randomly chosen from each genetic group, weighed, broken, and the content poured into a petri dish to determine the egg's internal quality traits. The internal egg quality traits considered in this study include albumen weight (AW) and yolk weight (YW): Albumen and yolk were carefully detached with the aid of a spatula and kept separately for weighing with a digital scale. Albumen height (AH) and yolk height (YH) were measured using a spherometer, while albumen width (AWD) and yolk width (YWD) were measured with the aid of the vernier caliper. Yolk index (YI) is a measure of the standing-up quality of the yolk; this was taken as the ratio of yolk height to yolk width. Haugh unit (HU) values were obtained using the formula: HU = 100Log ($H \pm 7.57-1.7W^{0.37}$) (Novita *et al.*, 2021). Where, HU= Haugh Unit, H= height of thick albumen (mm), W= weight of eggs in grams. The mean of the data obtained was evaluated to represent the average performance of the population for 24 weeks.

Statistical analysis

Data collected were subjected to a one-way analysis of variance using the general linear model (GLM) procedure of the statistical analysis system (SAS, 2009). Duncan multiple range tests were used to separate significant means. The statistical model used to fix the effect of strain on egg production and quality characteristics is $Y_{ij} = \mu \pm g_i \pm e_{ij}$. Where, Y_{ij} = performance of j^{th} individual of i^{th} strain, μ = the overall mean for each of the egg production and egg quality traits, and g_i = fixed effect of the i^{th} strain.(i= 1,2,...10), e_{ij} = residual error.

RESULTS

Egg production traits

The egg production traits in YEC, Goliath, Sussex and their crossbred are presented in Table 1. There was a significant difference ($p < 0.05$) among strains in egg number, with purebred SS and crossbred YECxSS having the highest, while crossbred GGxYEC had the lowest.

AFE was significantly ($p < 0.05$) influenced by strain, with GG and SS reaching sexual maturity earlier than others. The difference in AFE compared to the exotic GG was ten days for YECxGG, 35 days for GGxYEC, and with exotic SS was eight days for YECxSS and 23 days for SSxYEC, while the difference compared to YEC were 11 days for GGxYEC and one day for SSxYEC. The result implies that crossbreeding with YEC extends sexual maturity in exotic hens. Hen body weight at first egg differed significantly ($p < 0.05$) in all the genotypic groups, with YECxGG having the highest value (1715g) and YEC having the least (1310 g) with a difference of (405 g). Egg mass was significant ($p < 0.05$) in all the strains, with values ranging (from 5882 g - 2040 g) for SS and GGxYEC. Also, a significant difference ($p < 0.05$) exists between all the strains in HDP, with purebred SS having the highest (25.19%) while crossbred GGxYEC had the least (14.39%). There was a significant difference ($p < 0.05$) between all the strains generally for feed per dozen eggs, with purebred GG having the highest while crossbred SSxYEC recorded the lowest value.

Effect of strain on egg quality traits

The result of external egg quality traits in YEC, Goliath, Sussex, and their crossbreds are presented in Table 2, while that of internal egg quality traits is shown in Table 3. There were significant differences ($p < 0.05$) among the strains for egg weight (EW) except purebred GG, SS, and YEC, GGxYEC, and SSxYEC that did not differ significantly ($p > 0.05$) from each other. Significantly ($p < 0.05$) bigger eggs (64.89 g and 64.85 g) were obtained in purebred GG and SS, while the eggs laid by purebred YEC, GGxYEC, and SSxYEC (39.12 to 39.38) were small ($p < 0.05$) in weight.

Also, there were significant differences ($p < 0.05$) among strains in the length and width egg. Purebred SS had the highest value, while YEC had the least. Significantly higher ($p < 0.05$) EI values were obtained for YEC, GGxYEC, and SSxYEC, while YECxSS recorded the least value. There were significant differences ($p < 0.05$) in all the strains for SW, with YEC having the highest (13.13%) and SS recording the lowest (8.65%). Shell thickness was significantly higher in YEC (0.61mm) and lower in SS (0.37mm) for this trait.

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Table 1 Egg production traits (Means ± SE) in pure and cross bred hens

traits	YEC	GG	SS	YEC x GG	YEC x SS	GG x YEC	SS x YEC
EN	63.45 ± 1.34 [c]	68.70 ± 0.60 [b]	90.7 ± 0.49 [a]	60.00 ± 0.69 [d]	90.00 ± 0.61 [a]	51.8 ± 0.36 [e]	65.80 ± 052 [c]
AFE (days)	168 ± 0.503 [c]	147 ± 0.21 [f]	146 ± 0.29 [f]	157.90 ± 0.17 [d]	154.10 ± 0.23 [e]	182.07 ± 0.31[a]	169.93 ± 0.15 [b]
HBW(g)	1310 ± 3.76 [f]	1662 ± 18.7 [b]	1575 ± 21.14 [c]	1715 ± 16.81[a]	1499 ± 12.15 [d]	1377±12.93 [e]	1056 ± 10.03 [g]
EM(g)	2482 ± 53.7 [f]	4458 ± 33.9 [c]	5882 ± 46.4 [a]	3521 ± 56.3 [d]	4954 ± 33.11 [b]	2040 ± 16.3 [g]	2576 ± 23.38 [e]
HDP %	17.63 ± 0.37 [de]	19.08 ± 0.15 [c]	25.19 ± 0.13 [a]	17.14 ± 0.19 [e]	22.5 ± 0.8 [b]	14.39 ± 0.10 [g]	18.23 ± 0.14 [d]
FPD (g/egg)	4.87 ± 0.11 [f]	7.57 ± 0.06 [a]	6.07 ± 0.03 [c]	7.34 ± 0.08 [b]	5.00 ± 0.33 [e]	5.84 ± 0.04 [cd]	4.71 ± 0.03 [e]

[a-g] Means with different superscripts across the strains are significantly ($p < 0.05$) different; YEC: Yoruba ecotype chickens; GG: Goliath chickens; SS: Sussex chickens; EN: egg number; AFE: age at first egg; HBW: hen body weight; EM: egg mass; HDP: hen day production; FPE: feed per dozen egg.

Table 2 External egg quality traits (Means ± SE) in pure and cross bred hens

traits	YEC	GG	SS	YEC x GG	YEC x SS	GG x YEC	SS x YEC
EW(g)	39.12 ± 0.07 [d]	64.89 ± 0.26 [a]	64.85 ± 0.25 [a]	58.67 ± 0.41 [b]	55.04 ± 0.01 [c]	39.38 ± 0.08 [d]	39.15 ± 0.09 [d]
EL (mm)	2.91 ± 0.09 [f]	4.30 ± 0.01 [b]	4.42 ± 0.01 [a]	3.86 ± 0.01 [c]	3.67 ± 0.01 [d]	3.09 ± 0.04 [e]	2.94 ± 0.01 [f]
EWD (mm)	2.12 ± 0.01 [e]	3.34 ± 0.05 [b]	3.40 ± 0.01 [a]	3.12 ± 0.01 [c]	3.04 ± 0.01 [d]	2.14 ± 0.06 [e]	2.13 ± 0.01 [e]
EI (%)	1.38 ± 0.07 [a]	1.28 ± 0.03 [b]	1.30 ± 0.02 [b]	1.24 ± 0.01 [c]	1.21 ± 0.01 [d]	1.45 ± 0.02 [a]	1.37 ± 0.01 [a]
SW (%)	13.13 ± 0.07 [a]	9.29 ± 0.03 [e]	8.65 ± 0.04 [f]	9.85 ± 0.03 [d]	10.16 ± 0.07 [d]	13.10 ± 0.01 [b]	13.10 ± 0.01 [b]
ST (mm)	0.61 ± 0.03 [a]	0.38 ± 0.01 [c]	0.37 ± 0.01 [d]	0.35 ± 0.01 [e]	0.37 ± 0.06 [d]	0.52 ± 0.01 [b]	0.52 ± 0.01 [b]

[a-f] Means with different superscripts across the strains are significantly ($p < 0.05$) different; YEC: Yoruba ecotype chickens; GG: Goliath chickens; SS: Sussex chickens; EW: egg weight; EL: egg length; EWD: egg width; EI: egg index; SW: shell weight; ST: shell thickness.

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Table 3 Internal egg quality traits (Means ± SE) in pure and cross bred hens

traits	YEC	GG	SS	YEC x GG	YEC x SS	GG x YEC	SS x YEC
AW (%)	52.15 ± 0.07 [e]	65.53 ± 0.14 [b]	61.84 ± 0.05 [c]	65.91 ± 0.25 [b]	66.47 ± 0.07 [a]	53.50 ± 0.06 [d]	52.43 ± 0.08 [e]
AHT (mm)	6.31 ± 0.04 [f]	7.07 ± 0.03 [b]	7.13 ± 0.02 [a]	6.89 ± 0.019 [c]	6.53 ± 0.02 [d]	6.42 ± 0.04 [e]	6.37 ± 0.04 [f]
AWD (mm)	0.53 ± 0.05 [d]	0.65 ± 0.07 [a]	0.61 ± 0.06 [b]	0.63 ± 0.01 [b]	0.61 ± 0.01 [b]	0.56 ± 0.01 [c]	0.54 ± 0.01 [c]
YW (%)	28.09 ± 0.09 [b]	27.35 ± 0.14 [d]	26.68 ± 0.09 [e]	26.03 ± 0.15 [f]	26.42 ± 0.07 [e]	28.26 ± 0.01 [a]	27.84 ± 0.09 [c]
YH (mm)	15.98 ± 0.04 [c]	18.28 ± 0.03 [a]	18.25 ± 0.02 [a]	18.24 ± 0.27 [a]	15.99 ± 0.03 [c]	16.52 ± 0.02 [b]	15.90 ± 0.05 [c]
YWD (mm)	3.62 ± 0.01 [d]	3.75 ± 0.01 [a]	3.70 ± 0.08 [b]	3.61 ± 0.01 [d]	3.59 ± 0.011 [e]	3.66 ± 0.01 [c]	3.63 ± 0.01 [d]
YI (%)	4.40 ± 0.19 [e]	4.87 ± 0.02 [c]	4.93 ± 0.03 [b]	5.05 ± 0.015 [a]	4.50 ± 0.01 [d]	4.87 ± 0.06 [c]	4.39 ± 0.02 [e]
HU	86.22 ± 0.22 [a]	82.47 ± 0.22 [cd]	82.56 ± 0.14 [bc]	83.23 ± 0.20 [b]	82.01 ± 0.13 [d]	86.76 ± 0.22 [a]	86.56 ± 0.21 [a]

[a-f] Means with different superscripts among strains are significantly ($p < 0.05$) different; YEC: Yoruba ecotype chicken; GG: Goliath chicken; SS: Sussex chickens; AW: albumen weight; AHT: albumen height; AWD: albumen width; YW: yolk weight; YH: yolk height; YWD: yolk width; YI: yolk index; HU: Haugh unit.

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Strains differed significantly (p <0.05) in albumen weight, height, and width; yolk weight, height, width, index, and HU. The crossbred YECxSS had significantly higher (p <0.05) values for albumen weight, height, and width, while purebred YECxYEC had the lowest value for these traits.

Also, purebred GGxYEC had significantly higher values (p <0.05) for relative yolk weight, and crossbred YECxGG had the lowest while purebred GG, SS, and YECxGG had high values but which were not significantly different (p >0.05) for yolk height. However, crossbred SSxYEC had the lowest value for this trait. Significantly higher (p <0.05) values for yolk width and yolk index were obtained in purebred GG, while crossbred YECxSS recorded the lowest value for yolk width and crossbred SSxYEC for yolk index, respectively. Significant differences (p <0.05) also exist among the strains for Haugh Unit except for purebred YEC, GG, and crossbred GGxYEC, SSxYEC, which were not significantly different from each other. The highest values were obtained for crossbred GGxYEC, while crossbred YECxSS had the lowest value for these traits.

DISCUSSION

The genetic difference among the strains for age at first egg (AFE), hen bodyweight (HBW), egg number (EN), and other egg production traits revealed that strains affect egg production traits; this was in line with the report of Amin (2008), Isidahomen *et al*. (2014), Akintunde and Toye (2021), and Akintunde and Toye (2022). The total number of eggs laid was higher in purebred SS and crossbred YECxSS than their counterparts, and this corresponds with the findings of Sola-Ojo and Ayorinde (2011), who reported that crossbred FExDB and DBxFE laid the highest number of eggs than their purebred during early egg production period, while Omeje and Nwosu (1983) had earlier reported high egg production in GLxLC and their reciprocal cross LCxGL than the local chicken. Goliath and Sussex hens gained weight faster, and the development of reproductive traits was early, contributing to their early attainment of age at first egg compared to YEC hen. The body weight of the first egg obtained in this study for GG and SS was higher than that of the Yoruba Ecotype hen (YEC). This corresponds with the findings of Singh *et al*. (1982) but higher than 140 days reported by Sola-Ojo and Ayorinde (2011) for pure purebred Dominant black strain. However, the age obtained for YECxGG and YECxSS corroborates with 22 weeks reported for local chicken by Nwagu *et al*. (1994), Oni *et al.* (1991), Fayeye *et al.* (2005), Yahaya (2008), Sola-Ojo and Ayorinde (2009) and Sola-Ojo and Ayorinde (2011). The results of the hen's body weight at the first egg in SSxYEC were lower than the findings of Khan *et al*. (2006), who reported weight at the first egg in Fayoumi chicken with an average body weight of 1253.53 ± 16.43 g and first egg weighing 45.79 g under intensive management. Meanwhile, Chineke (2001) reported that the association between body weight and selected egg traits (egg length, egg breadth, egg index, egg weight, albumen weight, yolk weight, shell weight, shell thickness, and hen-day production) was non-linear. He recommended maintenance of an optimum body weight range of 1.72 to 1.80 kg, following the report of Akanni *et al*. (2008) on a black Nera pullet, which attained sexual maturity at 188 days and a body weight of 1421.59 g/bird. In this study, YECxGG, YECxSS, SSxYEC, and YEC had age at the first egg that was in close agreement with the report of Ayorinde and Oke (1995), who reported age at the first egg in Black Olympian pullets to be between 151 and 175 days, 132 days and 210 days for Shika brown commercial strain raised on deep litter (Ayorinde *et al*., 1999). The difference in body weight between Goliath and Sussex and their crossbred with YEC hens may be due to the adaptation of these exotic breeds in Nigeria's humid tropical environment. However, the result obtained

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concerning their reciprocal crossbred with YEC hen could result from gene interaction between Goliath and Sussex cork and YEC hen involved in the study. Also, from this present study, the highest age at first egg and hen body weight obtained for crossbred GGxYEC was following the report of Akanni *et al*. (2008) on Black Nera pullet, which attains sexual maturity at 188 days and a body weight of 1421.59 g/bird.

Generally, light strains of poultry perform better than heavy strains in laying performance characteristics. Consequently, the higher egg number produced by SS and YECxSS than others may be due to the maternal effect of Sussex hens. Hence the superiority of purebred SSxSS and YECxSS hen suggests that using Sussex or YEC as a terminal sire strain in a crossbreeding program using Sussex hen will be beneficial for improving egg number. Also, high feed per dozen eggs obtained for GG and YECxGG suggests that they eat more to satisfy their desired appetite because heavy-strain birds consume more muscle-building feed than egg production. The mean egg weight obtained in the present study for YEC and its reciprocal crossed breed is higher than values reported for Sudanese indigenous chicken type and Yoruba Ecotype Nigerian local chickens by Akintunde and Toye (2022), respectively, except for purebred YEC and GGxYEC and SSxYEC. Also, the results obtained in this study agreed with the report of Olawumi and Ogunlade (2009), who reported a significant effect on egg quality traits in some exotic breeds of chicken. The highest egg weight recorded by purebred GG and SS and the lowest by YEC reveals that the body weight of a hen is directly proportional to egg weight. Also, the exotic strain had been known to attain high body weight under favorable environmental and feeding conditions, and this will reflect on the egg quality.

Egg weight is directly proportional to the weight of albumen, yolk, and shell contained in the egg, which varies significantly between strains of the hen. YEC and its reciprocal crossbred had the lowest egg weight, and the values fall within the range of values reported by Fayeye *et al*. (2005) for the Fulani ecotype chicken and Yoruba ecotype chicken by Peters *et al*. (2008). The egg length obtained in this present study was within the range of values reported by Fayeye *et al.* (2005), who opined that the Normal feather Nigeria local chicken had a higher egg length than the Fulani ecotype chicken. The higher egg width for Sussex purebred chicken in this study could be attributed to genetic differences among the strains used in this study.

The egg index is a good indicator of external egg quality, the egg index obtained in this study was higher for purebred YEC and its crossbred (GGxYEC, SSxYEC), which implies a good external quality of the egg. The lower relative shell weight obtained for Goliath and Sussex breeds suggest that a high proportion of the egg is made up of internal content, which explains their significance for high body weight in Nigeria's humid tropical environment. The result for shell thickness in the present study showed that purebred YEC and its crossbred GGxYEC, and SSxYEC, had the best shell thickness. Also, the values obtained for shell thickness were higher than those recorded by Fayeye *et al*. (2005) for Fulani ecotype chickens. The high shell thickness obtained could be attributed to the crossbreeding effects and the effect of feed supplied to the chickens since shell thickness is a vital bio-economic trait that the egg breeder should consider to reduce eggshell breakage.

The mean Albumen characteristics (weight, height, and width) were higher for Goliath and Sussex purebred chickens than YEC and its crossbred chicken. Also, the mean albumen weight obtained in this study showed the proportion of albumen that contributed to the egg weight. The result obtained for YEC and reciprocally crossbred were similar to the reports of Sola-Ojo and Ayorinde (2011), who obtained 21.34 and 22.42 g for Fulani and Yoruba ecotype chicken but higher than 19.86 g for South

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Eastern Nigeria Chicken. The lower values obtained for purebred YEC for internal egg quality traits and reciprocally crossbred were similar to the findings of Fayeye *et al*. (2005) for Fulani ecotype chicken. Purebred Goliath outperformed their other purebred counterparts in yolk weight, yolk index, and haugh unit. These traits have been reported to be the best indicators of internal egg quality. The present study showed that the yolk index favored purebred YEC and crossbred with exotic cork (GGxYEC, SSxYEC). The Haugh unit values obtained for the pure and crossbred were above 80%, which indicates good albumen quality. Hence, the present values suggest that eggs of purebred YEC and Cross-bred GGxYEC and SSxYEC are of good quality because they combine favorably in the eggs they produce.

The main endocrine factors that regulate egg production are the hypothalamus, pituitary, and ovary axis. The hypothalamus produces gonadotropin-releasing hormone (GnRH), which stimulates the release of gonadotropin hormones, namely follicle-stimulating hormone (FSH) and luteinizing hormone (LH) (Du *et al*., 2020). Meanwhile, the ovaries produce estradiol and progesterone hormones in response to gonadotropin hormones. Estradiol regulates folliculogenesis, yolk accumulation in the follicle, ovulation, oviduct development, gland development, and the expression of genes that produce egg white. Progesterone induces ovulation and oviductal gland development (Mishra *et al*., 2019). Therefore, several studies of giving exogenous reproductive hormones affect the quantity and quality of egg production. Injection of Testosterone and Growth Hormone can improve egg quality and production performance of old laying hens (Mohammadi *et al*., 2015). Injection of high doses of progesterone increased the concentration of LH in plasma blood (Iswati *et al*., 2021). Phytoestrogens addition to the laying hen, increased plasma LH and FSH concentrations, steroidogenesis, egg quality, and egg laying rate (Saleh *et al*., 2021).

Stress due to climate has implications for cortisol secretion, which resulted in increased feed consumption and decreased egg production. Corticosterone increased protein breakdown, kidney dysfunction, and pancreatitis (Kim *et al*., 2015). The high-temperature environment caused lower estradiol and impacted egg quality by decreasing the thickness of the eggshell (Sartsoongnoen *et al*., 2018). A more extended photoperiod (16 hours light and 8 hours dark) increased egg production and stimulates plasma LH, FSH, estradiol, and progesterone (Wang *et al*., 2019). This study is limited to egg production and egg quality. Further studies are needed to evaluate reproductive hormone levels to reach a more comprehensive knowledge of native chickens concerning developing strain layers for tropical environments.

CONCLUSION

Crossbreeding improved the hen body weight of exotic chicken and crossbred with YEC cock, while the age at first egg was moderate for these strains but increased for their reciprocal crossbred hens.

Purebred Sussex and crossbred YECxSS hens laid the highest number of eggs during this trial period. Purebred Goliath consumed the highest feed to produce a reasonably high number of eggs and had the highest egg weight, while purebred YEC had the lowest. Albumen weight, height, and width were higher in purebred Goliath, Sussex, and YECxSS chickens than in their other counterparts. Crossbreeding favors the crosses between the YEC cock and the exotic chicken hens for body weight, egg production traits, and external and internal egg quality traits than their reciprocal crossbreeding. The use of egg type (YEC and SS cock) as sire and meat type (MM, GG hens) as dam gives us the highest body weight (weeks 8, 12, 14, and 20), egg number, and AFE. Therefore, this study

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concludes that the superiority of purebred SSxSS and YECxSS hen suggests that using Sussex or YEC as a terminal sire strain in crossbreeding programs will improve egg number.

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