THE EFFECTS OF FEATHER TYPE AND COLOUR ON EGG PRODUCTION AND QUALITY CHARACTERISTICS OF LOCAL-EXOTIC CROSSBRED LAYERS

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ABSTRACT
The study was conducted to evaluate the production and quality of eggs from two experimental crossbred layer lines (brown and white) and two feathering types (naked neck and normal feathered). Egg production was studied from age at first egg to peak production. Egg production parameters studied included age and weight of birds at first lay, weight of first eggs, egg mass, FCR and FCE/dozen eggs, NFEI (%) and rate of lay (hen-day and hen-housed). Egg quality was also assessed (external and internal) at 50% and peak production periods. A total of 300 sixteen-weeks old pullets was sampled for the experiment; 150 per line (brown and white), with 75 normal feathered and 75 naked neck birds under each line in a 2 x 2 factorial design. Data on egg production and egg quality were subjected to analysis of variance (ANOVA) using R software version 5.3.1 and GraphPad Prism 7.04 and means compared at p < 0.05 using Tukeys Studentized Range Test. The white line attained 50% egg production earlier and recorded higher (p < 0.05) hen-day and hen-housed egg production at peak production. Eggs from the white line were heavier and wider (p < 0.05) than eggs from their brown counterparts, whereas those from the brown line were longer than those from their white counterparts. The naked neck hens had heavier eggs at first lay and higher hen-day (%) egg production than the normal feathered birds. In conclusion, white line had superior egg production and quality traits than brown line while the naked neck layers had higher

Keywords: *Normal feathered, layer lines, naked neck, egg quality*

INTRODUCTION

One vital source of protein, patronized globally, regardless of religious background, is poultry. Chicken is the most consumed meat, and it contributes approximately 30% of animal protein worldwide (FAOSTAT, 2022). Kabir and Haque (2010) reported that the production of eggs as well as poultry meat on a commercial scale plays a significant role in meeting protein demand worldwide. Poultry populations in many parts of the world are made up of indigenous and improved breeds. The industry's activities are highly influenced by a wide range of factors, particularly, agro-ecology, level of production, housing systems, and the overall environmental conditions. High ambient temperature as a result of climate change is one of the key stressors in poultry farming (Selye, 1976; Nienaber and Hahn, 2007), and it adversely influences reproductive and laying performance of laying hens and reduces their general welfare (Mathur, 2003).

The main challenge associated with indigenous chickens, in the tropics, is their small number of egg and meat production (Alemu, 1995; Fassill *et al*., 2010; Guèye, 1998; Tadelle *et al*., 2000). They are, however, hardy and able to withstand adverse conditions, such as irregular supply of feed, water, and inadequate healthcare. On the contrary, the improved exotic chickens, which produce higher numbers of eggs per year and more meat than the indigenous breeds, are susceptible to harsh tropical environmental conditions, such as high temperatures, diseases and inadequate feed and/or feed ingredients (Barua *et al*., 1998; Ali *et al*., 2000; Islam and Nishibori, 2009). There are mutant traits, within indigenous chickens in tropical environments, which have the genetic potential to improve the productivity of indigenous chickens. Among these is the indigenous naked neck trait, well-known for its positive influence on egg and meat production (Mwacharo *et al*., 2007; Adomako, 2009). The exploitation of genetically diverse stocks for the enhancement of economic traits, such as body weight and annual egg production is one key aspect of breeding programmes.

In an assessment of the egg production performance of local and exotic birds and their crosses, conducted by different research and development organizations in Ethiopia, it was shown that the overall performance of the crossbreds was better than either the native or exotic parents under the prevailing production conditions (Alemu, 1995; Tadelle *et a*l., 1999). The genetic diversity among indigenous and exotic breeds, pure lines and strains of chicken could be utilized in cross breeding schemes. The ultimate goal is obtaining a new breed, hybrid, strain or line that will be well adapted to the vagaries of the tropical climate and environment, and at the same time, increase productivity in terms of production and quality of eggs and meat (Barua *et al*., 1998; Iraqi *et al*., 2005; Mekki *et al*., 2005). The objective of this study was to evaluate the egg production and egg quality performance of two local-exotic crossbred layer lines (White and Brown) and two feathering-types (Naked neck and Normal feathered) raised under humid-tropical conditions.

MATERIALS AND METHODS

Location and duration of study

The experiment was conducted at the Department of Animal Science, Kwame Nkrumah University of Science and Technology (KNUST)-Kumasi (Altitude 261.4 MSL, Latitude 06^{o} 41'N and Longitude 01^{o}33'W- https://www.latlong.net/place/kumasi-south-ghana-1926.htm). The monthly average rainfall, ambient temperature and relative humidity at the experimental site during the experiment were 183.84mm, 27.3^{o}C and 62.9% respectively. The experiment lasted for 11 months, from November to August in the following year.

Background of birds

The birds used for the study were from a cross between indigenous heterozygous naked-neck (*Nana*) males from Ghana and normal feathered (*nana*) exotic commercial females. Males from F_1, F_2, F_3, F_4, F_5, F_6 generations were back-crossed to the exotic commercial female chickens. The two lines of naked neck birds (white and brown) and two lines of normal feathered birds (white and brown) were full-sibs and half-sibs at the same age from a cross between F_6 generation males and the exotic commercial females.

Sampling and experimental design

Three hundred (300) 16-week-old pullets were sampled from the F_7 generation of the cross-breeding programme described above, for the experiment. They were made up of 150 white birds (75 naked neck and 75 normal feathered) and 150 brown birds (75 naked neck and 75 normal feathered). A 2 x 2 factorial experiment arranged in a Completely Randomized Design (CRD) was used for the study. Two factors were considered; factor one (1) comprised two lines (Brown and White), and factor two (2), the feathering-types (Naked neck and Normal feathered). Each factor was replicated thrice, with 25 birds per replicate.

Management of the experimental birds

The birds were raised in an open-sided deep litter pens with the floor space per bird of 0.25 m^2. Each pen had a laying nest at the fourteenth week. The chicks were fed with a commercial chick mash from AGRICARE Ghana Ltd., containing 19% CP, 2800 kcal of ME/kg, 1% Ca and 0.45% available P for the first 6 weeks. Grower mash containing 15% CP, 2650 kcal of ME/kg, 1% Ca and 0.45% available P was fed to the birds from 7 to 18 weeks; pre layer ration containing 16.5% CP, 2650 kcal of ME/kg, 3.1% Ca and 0.25% available P after 18 weeks and layer ration containing 17% CP, 2700 kcal of ME/kg, 3.50% Ca, and 0.45% available P after 22 weeks till the end of the experiment. Feed and clean water were given *ad libitum*. The birds were vaccinated against Marek's disease, Newcastle disease (Hitchner B1, LaSota and Newcavac), Infectious Bursal disease and fowl pox disease. Coccidiostat were administered via drinking water during the chick and grower stage to prevent coccidiosis. They were also dewormed (Kepro, Netherlands) after every three months via their drinking water. Multivitamins were provided intermittently via drinking water.

Data on egg production performance

The age at first egg was measured as the age at which pullets from treatment factors laid their first egg. At this age, pullets and eggs were weighed to obtain their body weight and weight of the first egg. All the eggs laid were recorded daily for five successive months for the evaluation of egg production performance. The daily egg production records were converted to weekly basis from the onset of lay (16^{th} week) till the 33^{rd} week. Evaluation of laying performance was conducted on age at first egg and 50% production and peak production level. The production indices determined were calculated as rate of lay in terms of hen-day egg production (HDEP) and hen-housed egg production (HHEP), egg mass (EM), feed conversion ratio (FCR) per kg egg mass, feed conversion efficiency (FCE) per dozen eggs, and net feed efficiency index (NFEI) at 50% and peak periods as presented in equations 1– 6.

$$HDEP = \frac{\text{Total number of eggs produced on a day}}{\text{Total number of hens present on the day}} \times 100 \quad (1)$$

$$HDEP = \frac{\text{Total number of eggs laid on a day}}{\text{Total No. of hens housed at the onset of lay}} \times 100 \quad (2)$$

$$EM = \text{Hen day} \times \text{Average weight of eggs (g)} \quad (3)$$

$$FCR = \frac{\text{Weight of feed intake (kg)}}{\text{Egg mass (kg)}} \times 100 \quad (4)$$

$$FCE\ (per \quad \frac{\text{Weight of feed intake (kg)}}{\text{Total number of eggs}} \times 12 \quad (5)$$

$$NFEI = \frac{\text{Mean egg mas + Body weight gain}}{} \times 12 \quad (6)$$

$$\text{Yolk index} = \frac{\text{Yolk height (cm)}}{\text{Yolk diameter (cm)}}$$

$$\text{Ibumen index} = \frac{\text{Albumen height (cm)}}{\text{Albumen diameter (cm)}}$$

Egg quality performance

Whole egg weights (in grams) were determined with an electronic digital balance. Egg lengths and diameters (in centimeters) were measured using a Vernier caliper. Yolk and albumen heights (in centimeters) were measured using a spherometer. The average of measurements taken from three different areas on the albumen was

$$Y_{ijk} = \mu + \alpha_i + \beta_j + \alpha_i\beta_j + \varepsilon_{ijkl}$$

Where;
Y_{ijk} = parameter measured;
μ = overall mean; α_i = main effect of lines;
β_j = main effect of feathering-types;
$\alpha_i\beta_j$ = interaction of line and feathering-types;
ε_{ijkl} = residual error term.

RESULTS

Egg production performance

The layer lines did not differ significantly ($p > 0.05$) with regard to age at first egg, and the average weight of birds and eggs at first lay (Table 1). Similarly, the feathering-types had no significant effects ($p > 0.05$) on age at first egg and weight of bird at first lay. However, the *Nana* (Naked neck) birds laid significantly ($p < 0.05$) heavier eggs (44.40 g) at first lay than the *nana* (normal feathered) birds (39.09 g). The effect of lines and feathering-type interactions were not significant ($p > 0.05$) on age at first egg, body weight and egg weight.

Egg production profile

The white layer line laid at a faster rate and attained 50% egg production at 21 weeks of age, whereas the brown line attained 50% egg production at 24 weeks of age. From the study, peak production was attained by both lines at 27 weeks of age. However, the white layer line peaked at a higher rate of lay 92.8%, compared with the brown line's 70.07% (Figure 1a). Regarding the feather-types, both the naked neck hens (*Nana)* and the normal feathered birds (n*ana)* attained 50% egg production at 22 weeks of age and peaked at 27 weeks of age (Figure 1b).

Rate of lay

Table 2 presents a summary of the peak laying rates for both layer lines and feather-types. It was observed that the white line peaked at a significantly higher level ($p < 0.05$) in terms of both hen-housed (90.38%) and hen day (94.93%) egg production compared to the brown line. Additionally, the naked neck (*Nana)* layers performed better in terms of hen-day egg production than the normal feathered (*nana)* hens.

Egg production indices

Results on egg mass (EM) and feed conversion ratio per egg mass (FCR/EM) did not differ significantly ($p > 0.05$) at 50% egg production in both lines and feathering-types. However, significant differences ($p < 0.05$) were observed in feed conversion efficiency per dozen eggs (FCE/12 eggs) and NFEI. The white lines were superior in terms of FCE/12 eggs. On the contrary, the brown lines efficiently utilized better the net feed consumed at 50% lay (64.58%) com-

Table 1: Effects of Lines and Feathering-types on age at first egg, bird weight

Effect	Age at first egg (days)	Weight of birds (kg)	Egg weight (g)
Lines			
White	114	1.50	40.43
Brown	115	1.40	42.08
Feathering-types			
Nana	114	1.50	44.40[a]
nana	115	1.40	39.09[b]
FPr			
Lines	0.07	0.11	0.12
Feathering-types	0.10	0.09	0.02
Lines x Feathering-types	0.09	0.12	0.07

Nana = Naked neck; *nana* = Normal feathered; *FPr* = Fisher's probability level; [a,b] Means within a column with no common superscript differ significantly.

pared to the white lines (58.93%). At peak production, significant differences ($p < 0.05$) were observed in all the indices except for the NFEI; with the white line recording a heavier EM than the brown line. Additionally, the white line was more efficient in terms of per dozen eggs produced and also recorded a lower FCR value per kg EM compared to the brown line. With regards to the feathering-types, the *Nana* layers were significantly ($p < 0.05$) more economical and more efficient (FCE/dozen eggs, NFEI) at 50% lay than the *nana* layers (Table 3).

Egg quality

External quality parameters

The white layer line laid significantly ($p < 0.05$) heavier (54.89 g) and wider eggs (4.34 cm) at 50% lay than the brown line (52.79 g) and (4.15

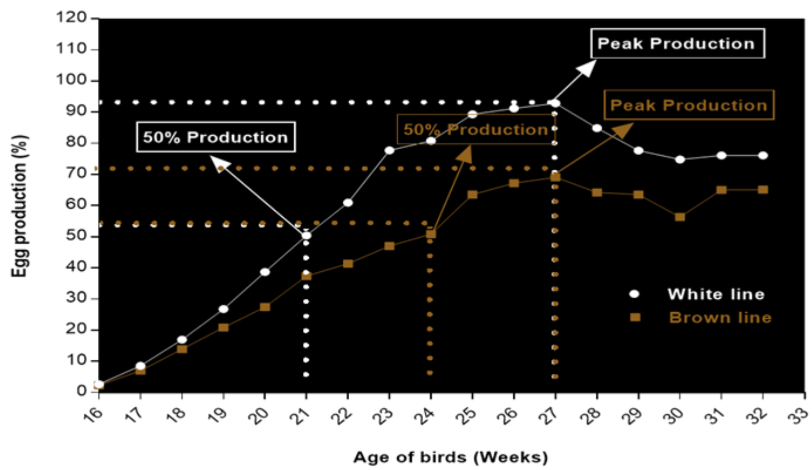

Fig. 1a: Egg production profiles of the white and brown layer lines

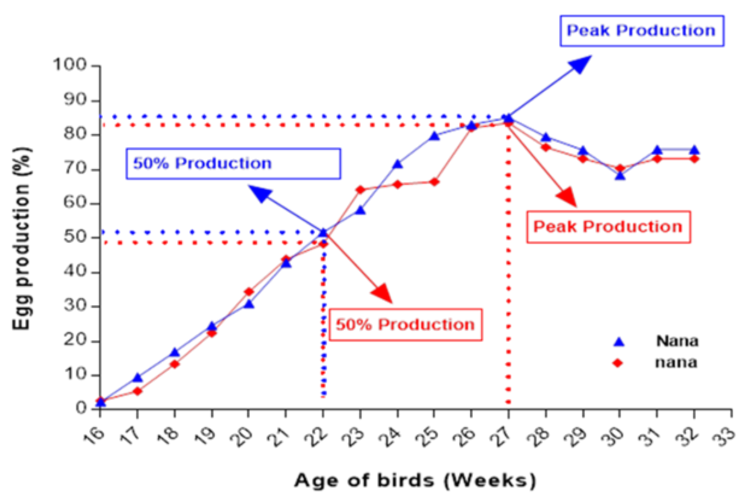

Fig. 1b: Egg production profiles of *Nana* and *nana* feather-types

Table 3: Egg production indices of two layer lines and feathering-types

Effect	50% lay				Peak lay			
	EM (g)	FCR	FCE	NFEI (%)	EM (g)	FCR	FCE	NFEI (%)
Lines								
White	23.73	0.55	0.56[b]	58.93[b]	53.40[a]	0.25[b]	0.69[b]	80.96
Brown	23.03	0.54	0.79[a]	64.58[a]	36.00[b]	0.35[a]	1.00[a]	80.27
Feather-types								
Nana	24.04	0.53	0.65[b]	64.54[a]	44.11	0.29	0.82	84.55
nana	23.04	0.55	0.80[a]	58.52[b]	44.74	0.28	0.84	83.07
FPr								
Lines	0.09	0.28	0.002	0.01	0.02	0.02	<0.001	0.09
Feather-types	0.07	0.11	0.01	0.02	0.102	0.09	0.07	0.08
Line x Feather-types	0.17	0.9	0.002	<0.001	0.13	0.07	0.09	0.09

Nana = Naked neck; nana = Normal feathered; EM = Egg mass; FCR = Feed conversion ratio per kg egg mass; FCE/12 = Feed conversion efficiency per dozen eggs; NFEI = Net feed efficiency index; FPr = Fisher's probability level; [a,b]Means within a

cm) respectively. Egg weights and widths with regard to feathering-types (i.e., *Nana* and *nana*) did not show significant differences ($p > 0.05$) at 50% and at peak production (Table 4). The interaction effects between lines and feathering-types did not influence egg weights and width ($p > 0.05$). At peak lay, the average egg weight and egg width were not significantly ($p > 0.05$) influenced by the lines and feathering-types. The length of eggs observed at 50% lay were found to be statistically non-significant between the lines ($p > 0.05$), although the brown lines produced slightly longer eggs than the white lines. The same observation was made on eggs at peak production. The brown line laid significantly ($p < 0.05$) longer eggs (7.72 cm) than the white line (5.54 cm). With regard to the feathering-types (i.e., *Nana* and *nana*), no significant difference was seen in the lengths of eggs.

Internal quality parameters

Albumen height (AH) did not differ significantly at 50% lay between lines. However, at peak lay, AH was statistically higher ($p < 0.05$) in the white line (0.67 cm) compared to the brown line (0.62 cm). Albumen index (AI) did not differ significantly between the lines and feathering-types at 50% lay, however at peak period, significant differences were observed in the lines but not in the feathering-types ($p < 0.05$). The white line had higher average albumen index value (9.02) than the brown line (8.67). Yolk pH showed significant differences at both 50% and peak production. Significant differences ($p < 0.05$) were observed in the yolk colour score at peak production with the brown line having deeper yellow yolk colour (7.00) compared to the white line (6.08). Regarding the feathering-types, (i.e., *Nana* and *nana)*, the normal feathered layers (6.83) had a higher mean colour score ($p < 0.05$) value compared to the naked neck layers (6.23).

DISCUSSION

The attainment of sexual maturity at 114 and 115 days with average body weights of 1.40 and 1.50 kg agrees with the study of Mussawar *et al.* (2004) who found similar results when they studied local chickens in Paskistan. On the contrary, Ayorinde and Oke (1995) reported sexual maturity ages of 151 and 175 days in black Olympian pullets; Ayorinde *et al.* (1999) also reported sexual maturity ages at 132 and 210 days for Shika Brown commercial layers. Khan *et al.* (2006) reported maturity age of 163 days in Fayoumi layers with an average body weight of

Table 4: External whole egg parameters of two lines and two feathering-types

Effect	50% lay			Peak lay		
	Width (cm)	Length (cm)	Weight (g)	Width (cm)	Length (cm)	Weight (g)
Lines						
White	4.34[a]	5.29	54.89[a]	4.34	5.54[b]	59.08
Brown	4.15[b]	5.44	52.79[b]	4.40	7.72[a]	60.36
Feather-type						
Nana	4.27	5.38	53.07	4.37	5.68	60.06
nana	4.21	5.35	54.61	4.37	5.58	59.38
FPr						
Lines	0.02	0.06	0.04	0.06	0.01	0.20
Feather-types	0.37	0.62	0.13	0.62	0.11	0.50
Line x Feather-types	0.99	0.59	0.07	0.59	0.76	0.96

Nana = Naked neck; nana = Normal feathered; FPr = Fisher's probability level;
[a,b]Means within a column with different superscripts differ significantly ($p < 0.05$).

Table 5: Internal egg quality parameters of two layer lines and two

Effect	50% lay					Peak lay				
	AH (cm)	AI (%)	Alb. pH	Yolk pH	Yolk colour	AH (cm)	AI (%)	Alb. pH	Yolk pH	Yolk colour
Lines:										
White	0.67	8.00	8.57[b]	5.97[b]	4.00	0.67[a]	9.02[a]	8.72[b]	5.88	6.08[b]
Brown	0.72	7.50	9.21[a]	6.33[a]	3.94	0.62[b]	8.67[b]	8.21[a]	5.93	7.00[a]
Feather-type:										
Nana	0.68	8.50	8.63[b]	6.06	4.06	0.64	8.91	8.96[a]	6.28	6.28[b]
nana	0.71	7.00	9.13[a]	6.21	3.91	0.65	8.76	8.83[b]	6.31	6.83[a]
FPr:										
Lines	0.17	0.27	<0.001	0.00	0.83	0.02	0.04	<0.001	0.15	<0.001
Feather-types	0.59	0.31	<0.001	0.15	0.62	0.60	0.38	<0.001	0.22	<0.001
Line x Feather-types	0.02	0.19	<0.001	0.04	0.42	0.51	0.27	<0.001	0.06	0.002

AH=Albumen height; AI=Albumen Index; Nana = Naked neck; nana = Normal feathered;
FPr = Fisher's probability level; [a,b] Means within a column with different superscripts differ significantly ($p < 0.05$)

1.25 kg and average first-egg weight of 45.79 g. The early sexual maturity attained by the birds in this study could be a direct effect of their relatively heavier body weights in addition to the genetic potential of the birds in terms of egg laying.

The superiority of the white layer line over their brown counterparts in egg production indices agrees with the report by Duodu (2013) that the birds with white plumage had higher hen-day egg production and egg mass than their brown feathered counterparts; however, the brown line attained 50% egg production earlier than the white one in his study contrary to the findings of the current study. The higher productivity of the white layer hens also agrees with the report by Küçükyılmaz *et al*. (2012) who found a higher egg production rate in white hens relative to brown hens in both conventional and organic rearing systems.

The white feather plumage in the white line enabled them to reflect large amounts of incoming short-wave emission and outgoing long-wave radiation, therefore reducing the levels of heat stress, and the tendency to peck. This also increased their feed consumption and thereby made more nutrients available for egg production (Bright, 2007).

The naked neck chicken phenotype has been reported in several studies to greatly influence egg production and quality compared to other phenotypes (Singh *et al*., 1996; Mohammed *et al*., 2005; Njenga, 2005; Sharifi, 2006, Adomako, 2009). The superior performance of naked neck birds (*Nana*) in egg production found in this study was contrary to the results of Singh *et al*. (1996) and Mohammed *et al*. (2005), where the laying performance of indigenous chicken phenotypes (viz., naked neck, frizzle and normal feathered) were investigated, they reported that annual egg production, hen-housed and hen-day egg production did not differ significantly.

The heavier average egg weight of the *Nana* hens could be due to the fact that the *Na* gene, which is situated on chromosome three in chickens may be linked to some genes that influence egg production and quality (Mathur, 2003; Adomako, 2009; Dunga, 2013). Additionally, the 20 – 40% reduction in feather cover in the *Nana* birds permits them to preserve more proteins for heavier body weight which manifest in egg production and egg weight as reported by Njenga (2005), Yoshimura (2008) and Adomako (2009).

The mean egg weights in this study at 50% and peak production ranged from 52.79 to 60.36 g, which were described by Zeidler (2002) as large and extra-large. Egg weight was heavier at peak production than at 50% production, indicating a progressive effect of age on egg weight. This agrees with the reports by Johnston and Gous (2007), and Zita *et al*. (2009), who concluded that egg weight increases with the age of hens. The heavier and wider eggs from the white layer line could have resulted from the white layers possessing genes for higher egg quality traits. Küçükyılmaz *et al*. (2012) also observed that eggs from white layer hens (White Lohmann LSL) were heavier than those from brown layer hens (Brown ATAK-S).

The results from this study, however, contradict reports by Singh *et al*. (2009) and Scott and Silversides (2000) who reported that, eggs from brown egg laying hens (Lohmann Brown) were larger and heavier than those from white laying hens (Lohmann white, *H* & *N* white). The differences in the reports may be due to the breed type used, the prevailing environmental conditions, nutritional factors as well as the overall management of the birds.

The height of the albumen varies between 1.5 mm for low quality eggs and 11.5 mm for good and fresh eggs (TSS, 1980). According to the TSS (1980) classification, the albumen quality in the present study could be described as moderate. Zeidler (2002) reported albumen heights between 0.8 – 1.0 cm and concluded that high albumen height may be due to the freshness of eggs and young age of hens. Although the birds used in the current study were young (36 wks) and the eggs were fresh, the albumen heights were moderate compared to that of Zeidler (2002), and this may be due to the genetic differences between the breeds used. The albumen pH values reported here were in accordance with values obtained by Scott and Silversides (2000), Samli *et al*. (2005), Akyurek and Okur (2009), and Jin *et al*. (2011), who observed in their studies that variations in the pH values were within the range of 7.34 and 9.77.

Yolk colour is the most common characteristic easily observed by the consumer. Although preferences differ, consumers in most countries prefer an egg yolk colour with a DSM Yolk Fan TM value of 12 or more (DSM, 2016). The colour of the yolk in this study ranged from pale yellow to dark orange with a score ranging from 1 – 15. The higher the colour score, the better the quality of the eggs. The yolk colour score values for both layer lines and feather-types were not different and according to Garba *et al*. (2010) this could have been the result of the birds being fed on the same diet in the study, since yolk colour of an egg depends on the type of diet. The slight yolk colour changes during the peak laying period might be due to the genetic variation between the two lines which caused the brown line and the normal feathered birds to absorb higher dietary carotenoid in the feed, and deposited efficiently in the egg yolk.

The pH of a fresh egg yolk is generally close to 6.0 and it increases to about 6.4 to 6.9 during storage (Brown, 2011). The yolk pH obtained in this study was slightly acidic i.e. it ranged from 5.88 – 6.33 which fell within the same range as reported by Samli *et al.* (2005) who found that yolk pH differed from 5.75 to 6.08 during 10 day of storage at 29°C.

CONCLUSION

White lines (white feathered local-exotic crossbred birds) were found to be superior to the brown lines (brown feathered local-exotic crossbred birds) in egg production and egg quality traits at 50% lay and peak production. Whilst naked neck and normal feathered layers performed similarly in egg production and egg quality parameters at 50% lay and peak production.

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