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REGULAR ARTICLES

Effect of incorporation of thermo-regulatory genes into exotic layers on egg production and quality under tropical environment

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Abstract A breed development strategy aimed at making exotic layers (Lohmann Brown) more productive under tropical environment using thermo-regulatory genes is underway at Akate Farms in Kumasi, Ghana. The present experiment was carried out to find out the effect of the genes on egg production in hot and humid environments. Three genetic groups comprising naked-neck, frizzle and their normally feathered sibs were obtained after successive generations of crossing between naked-neck and frizzle cocks and Lohmann brown hens. A total of 270 18-week-old pullets, 90 each of the 3 groups, were selected randomly and assigned to a completely randomized design experiment with 3 replicates, with 30 birds in each replicate group and kept up to a period of 72 weeks. The birds were kept in a partitioned open-sided deep-litter house constructed with sandcrete blocks with 30 pullets in each compartment. They were fed ad libitum with layer diets containing 18 % crude protein and 2,800 kcal ME/kg. Results obtained showed that the crossbred naked-neck and frizzle phenotypes produced eggs at a significantly ($P<0.05$) higher rates than their normally feathered sibs and also out-performed their normally feathered sibs in other egg production parameters measured, even though they all segregated from similar parents. This is an indication of the favourable effect of the genes on egg production under hot and humid environments.

Keywords Naked-neck · Frizzle · Phenotypes · Lohmann brown · Crossbred · Normally feathered

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Introduction

According to Hagan et al. (2013) under hot and humid conditions, normally feathered birds do not realize their full genetic potential for growth, meat yield and egg production and quality because according to Azoulay et al. (2011), dissipation of their excessively produced internal heat is hindered by the feathers. Again, according to Rajkumar et al. (2011), high environmental temperatures constrain the birds' performance under intensive production systems, albeit reduced egg production. Exotic layer stocks raised in Ghana produce between 230 and 270 eggs annually, far below the 300 or more produced by these exotic layers at their place of origin (temperate) (Koney 2004 and MoFA 2012). This according to Cahaner et al. (2008) has necessitated the use of major heat-tolerant genes like naked-neck (*Na*) and frizzle (*F*) in breed improvement programmes to improve the birds' productivity especially in the tropics.

These genes diminish the insulating power of the bird's plumage and thus are associated with increased heat loss. The naked-neck condition is characterized by complete absence or reduced feathers in the neck region of chickens controlled by an autosomal dominant gene (Rajkumar et al. 2010). The heterozygotes have a tuft of feathers on the ventral side of the neck, whereas homozygotes have no plumage on the neck. The frizzle gene (F) curls the feathers and reduces their size, thus increasing the heat conductivity of the feather coverage. Birds with the naked-neck and frizzle traits have been found to be thermal stress tolerant as compared to their normally feathered counterparts (Mahrous et al. 2008). The effects of frizzled feathers on the performance of layers were reported by Hagan et al. (2011). Due to the great potential of these genes, crossbreeding between local chickens with the heat-tolerant genes and exotic breeds would allow for the exploitation of the rusticity of the former and high productive performance of the latter in tropical environment so as to produce highly adaptable and superior genetic types.

In pursuance of this, a crossbreeding programme involving the use of local chickens with the naked-neck and frizzle traits and Lohmann brown layers noted for their high egg production potential is underway. This is aimed at complementing the rusticity of the former with that of the high productivity of the latter. The ultimate aim is to make exotic layers more adaptable to the tropical environments so they can produce the number of eggs similar to their countries of origin. The present study was therefore to assess the egg production performance of these crossbred naked-neck and frizzle phenotypes and their normally feathered counterparts under hot and humid environments.

Methodology

Experimental population

The base population used in this experiment were offspring of a cross involving local chicken male lines heterozygous for the *Na* and *F* genes and a Lohmann brown female line homozygous for the normal alleles of the two genes (Hagan et al. 2013). Due to multi-coloured nature of the male lines, colour sexing at day-old was not possible; therefore, the birds were sexed using secondary sexual characteristics. Four different combinations of genes for feather distribution and morphology constituting four different phenotypic groups were segregated. These were combined naked-neck frizzle (Nana Ff), naked-neck only (Nana ff), frizzle only (nana Ff) and their normally feathered (nana ff) sibs. This population has been maintained under intense selection pressure for egg production and kept at Akate Farms, Kumasi, Ghana. The small numbers obtained for the combined naked-neck and frizzle birds at the end of the fifth generation did not permit their use for this experiment.

Study site and management of experimental birds

Ghana is a tropical country with its northern savannah zone between latitudes 8°30′N and 11°00′N of the equator and longitudes 2°30′W and 0°30′E of the Greenwich Meridian. The experiment was carried out at Akate Farms located at Saaman within the Kwabre district in the Ashanti region of Ghana. The experimental area lies in the transitional forest zone and is between latitude 6.35 and 6.40° and longitude 1.30 to 1.35°, an elevation which ranges between 250 and 300 m above sea level. The average minimum temperature is about 21.5 °C and a maximum average temperature of about 36.5 °C. The average humidity is about 84.16 % at 0900 GMT and 60 % at 1500 GMT. The double maximum rainfall is about 214.3 mm in June and 165.2 mm in September. The birds were kept in a partitioned open-sided deep-litter house constructed with sandcrete blocks with 30 pullets in each compartment. They were housed in partitioned deep litter pens with stock density of 0.15 m^2/bird. The feed and water were supplied in 2.5 kg capacity hanging feeders and 10 L capacity plastic fountain drinkers, respectively. The birds were fed layer diets containing 18 % crude protein and 2,800 kcal ME/kg from the 18 weeks on. Feed and water were provided ad libitum. The plastic drinkers were cleaned daily throughout the experimental period. The house was constructed in such a way that there was adequate ventilation. There were eight nests (measuring 30 cm×30 cm×35 cm each) in each pen. Egg collection was done twice a day, at 0900 and 1500 GMT.

The maximum and minimum daily temperatures during the study period ranged between 26.5 to 35.5 and 20.1 to 25.3 °C, respectively, while the relative humidity ranged between 55 and 80 %. There were 12 h of natural light which was supplemented with 4 h of artificial lighting throughout the experimental period. This was achieved by providing 60 W electric bulbs. This did not only enable the pullets to eat during the night but also stimulated the hypothalamus for proper endocrine communication resulting in continuous ovulation, which enhanced egg production. Fowl pox and 3rd Newcastle vaccinations were carried out at 12 and 16 weeks of age, respectively. A coccidiostat, amprolium, was added to their drinking water fortnightly to control coccidiosis. Treatment for worms and lice were done monthly using levasole (water medication) and ectomin (dipping). Miramed was given to them as a prophylactic treatment for chronic respiratory disease. Vitamin supplements (mixture) like Vitalytes was given to the birds after debeaking, transferring and weighing. All the birds were reared under the same environmental management and hygienic conditions.

Data collection and parameter estimation

Egg production

Data on daily egg production were kept throughout the laying period on pen basis. In terms of egg production, the parameters taken were age at sexual maturity, rate of lay (hen-day), egg mass, egg weight, internal and external egg characteristics. Rate of lay was calculated as the number of eggs produced divided by the total laying period in days (from start of lay to end of experimental period) multiplied by 100. Age at sexual maturity was estimated as the age at which the birds laid their first egg. Egg mass was calculated as the product of egg weight (in grams) and hen-day egg production. Feed conversion ratio was calculated as the ratio of kilogram feed intake to the kilogram egg produced.

Egg quality estimation

At 30 weeks of age, 15 samples of fresh eggs were collected from each of the phenotypes for internal and external egg quality test. This was done at the Department of Physics of the University of Cape Coast. Egg eggshell thickness, albumen height, yolk height, Haugh unit and yolk colour score were considered as determinants for egg quality. Fresh eggs were collected separately for the different groups and weighed using a 0.01 g precision top-loading electronic balance. Albumen height was measured using a tripod micrometre. The eggs were broken on a metal plate, and the height of the albumen was measured as the distance between the metal plate and the electrode placed on top of the thick egg white of the broken egg. In order to correct for difference in egg weight, the albumen height was converted into Haugh unit (HU). The Haugh unit was therefore estimated based on the formula below:

$$HU = \log10\left(-1.7xe^{0.37}x\mathrm{In}(eggweight, g) + 7.6 + albumen\,height, mm\right)x100$$

The same tripod micrometre, which was used for albumen height, measured the yolk height, which was estimated as the distance between the metal plate and the electrode placed on top of the yolk of the broken egg. Shell thickness was measured by using a micrometre screw gauge. The shell was cleaned, washed and air dried at room temperature until constant weight was obtained and then thickness was measured along the equator lines. The egg quality tests determination was done following the procedure by Nonga et al. (2010).

Experimental design and statistical analysis

A total of 270 18-weeks-old pullets, 90 each of naked-neck, frizzle and their normally feathered sibs, were selected randomly and assigned to a completely randomized design experiment with three replicates with 30 birds in each replicate group. The data obtained were subjected to one-way analysis of variance with phenotype effect using general linear model procedure of GenStat (Discovery Edition). Where significant differences among means were found, means were separated using least significant difference test at 5 % level of significance.

The linear model below was used for the data analysis.

$$\mathrm{Yij} = \mu + \mathrm{gi} + \varepsilon\mathrm{ij}$$

Where

Yij	Performance of the *j*th pullet of the *i*th phenotypic group
μ	Overall general mean common to all observations
gi	Fixed effect due to ith phenotype ($i=1, 2, 3$)
εij	Random error effects peculiar to each observation

Results and discussion

The egg production performance of the naked-neck, frizzle and their normally feathered counterparts are presented in Table 1. The average rate of lay for the entire laying period showed the crossbred layers with the heat-tolerant genes laid significantly at a higher rate ($P<0.05$) than their normally feathered sibs, even though they all segregated from the same flock. This confirms the observation by Galal (2008), Mahrous et al. (2008) and Islam and Nishibor (2009) that when reared under hot and humid environments, naked-neck and frizzle layers outperformed their normally feathered sibs in terms of egg production and feed efficiency. The present results, however, disagree with that of Rajkumar et al. (2011) who recorded no significant differences ($P>0.05$) in part period egg production up to 40 weeks of age. The annual egg production recorded for the naked-neck and frizzle phenotypes is an improvement over annual egg production of 230–250 recorded for commercial layers (Koney 2004 and MoFA 2012) in Ghana. There was also a significant difference ($P<0.05$) in terms of mortality with the naked-neck and normally feathered phenotypes recording the higher deaths as compared to the frizzled phenotypes. One of the problems with the rearing of naked-neck birds is the incidence of pecking due to their exposed skin (Hagan et al. 2011), and this present work confirms the observation. The naked-neck and frizzle phenotypes consumed significantly ($P<0.05$) less feed and produced more eggs per kilogram of feed, confirming the observation by Mahrous et al. (2008) that the naked-neck and frizzle genes are associated with superior feed efficiency especially under stressful (high and humid) environments. The egg production performance of the normally feathered phenotypes is a reflection

Table 1 Mean egg production performance of the crossbred naked-neck and frizzle phenotypes

Parameters	Phenotypes			
	Naked-neck	Frizzle	Normal	±SEM
Egg production (no)	292.2^{a}	287.4^{b}	255.4^{b}	3.7
Egg mass (g/HD)	43.0^{a}	42.8^{a}	37.9^{b}	1.2
Feed intake (g/day)	116^{a}	117^{a}	120^{b}	2.0
FCR	2.2^{a}	2.3^{a}	2.6^{b}	0.1
Rate of lay (%)	79.9^{a}	78.9^{a}	70.7^{b}	2.6
Age @ 1st lay (days)	128.3^{a}	127.0^{a}	14.0^{b}	1.4
Egg weight (g)	59.7^{a}	58.4^{a}	55.4^{b}	2.3
Mortality (%)	4.4^{a}	3.5^{b}	4.8^{a}	0.21

^{abc} Means in a row with different letters are significantly different at the 5 % level. *HDA* is hen-day average, *FCR* is feed conversion ratio of the performance of commercial layers in the country. Therefore, the increased egg production for the naked-neck and frizzle phenotypes over their normally feathered sibs is an indication of improvement in performance of layers in the country.

The superior performance of the naked-neck and frizzle phenotypes as compared to their normally feathered sibs is as a result of their reduced feathers, which provided a larger surface area for heat dissipation during periods of heat stress. Again, during periods of high temperature, because naked-neck or frizzle feathered birds are able to dissipate heat better, they tend to preserve more nutrient and energy that could otherwise have been used for heat dissipation, for other productive functions like egg production (Mahrous et al. 2008; Islam and Nishibor 2009; Rajkumar et al. 2011). This makes naked-neck and frizzle birds better able to tolerate low dietary protein as compared to the fully feathered counterparts. This is because normal birds use part of the protein for feather growth and development.

The egg quality characteristics of the phenotypes are presented and discussed under external and internal parameters (Table 2). It was observed that internal and external egg qualities of the three phenotypes were significantly ($P<0.05$) different, with naked-neck and frizzle phenotypes laying eggs with superior qualities (shell, albumen and yolk weights and haugh units) compared to their normally feathered sibs, even though they all segregated from the same flock. The results confirm the observations by Islam and Nishibor (2009), Rajkumar et al. (2011) and Hagan et al. (2013) that under tropical environments, birds with thermo-regulatory genes (naked-neck and frizzle) laid eggs with superior qualities as compared to their fully feathered sibs. This observation also confirms the results by Younis and Galal (2006), Yakubu et al. (2008) and Haunshi et al. (2011) that the presence of the naked-neck or frizzle genes in chickens resulted in bigger egg weights, better haugh units and thicker shells in layers reared under tropical conditions as compared with their normally feathered sibs.

Table 2 Mean egg quality characteristics of the crossbred naked-neck and frizzle phenotypes

Parameters	Phenotypes			
	Naked-neck	Frizzle	Normal	±SEM
Shell weight (g)	6.2	6.5	6.3	0.4
Egg height (mm)	50.4	50.4	50.4	0.1
Egg width (mm)	40.2	40.3	40.4	0.1
Shell thickness (mm)	0.4^a	0.4^a	0.3^b	0.01
Albumen weight (g)	27.5^a	27.2^a	21.0^b	2.4
Albumen height (mm)	9.6^a	9.8^a	8.6^b	0.5
Yolk weight (g)	18.6^a	18.2^a	14.9^b	1.5
Yolk height (mm)	6.9^b	7.9^a	6.4^b	0.6
Haugh Unit (%)	86.6^a	87.0^a	81.5^b	5.1

[abc] Means in a row with different letters are significantly different at the 5 % level

Albumen and yolk weight are directly related to the weight of the egg, hence the bigger the egg, the higher the albumen and yolk weight. In this present study, albumen weight was significantly affected by phenotype with the naked-neck and frizzle phenotypes laying eggs of better albumen weight (Table 2) than the normally feathered phenotypes. The albumen weights and yolk weight values obtained for the naked-neck and frizzle phenotypes were comparable to those obtained by Chatterjee et al. (2006) and Yakubu et al. (2008) for crossbred naked-neck birds reared under hot and humid environments.

Haugh unit is the measure of albumen quality which determines the quality of the egg. Albumen quality, which is the most important egg quality criterion, is determined by its height. Hence, the larger the albumen height, the better the albumen quality would be. Albumen height varied between 1.5 mm for low quality eggs and 11.5 mm for good and fresh eggs (Holt et al. 2011). Again, according to Haugh (1937), Haugh unit values of 70 % and above represent good quality eggs; hence the crossbred phenotypes in this present study produced high-quality eggs. According to Hagan et al. (2013), albumen quality is influenced by both genetic and non-genetic factors such as breed, age of hen, length of storage and season of lay. The naked-neck and frizzle phenotypes producing eggs with better Haugh units as compared to the normal phenotypes was a confirmation of the observation by Yakubu et al. (2008), and that Na/na and F/f genotypes are found to produce high-quality eggs due to the association of the genes with heat tolerance (Rajkumar et al. 2011).

According to Caglayan et al. (2009), the thicker shell helps in preventing the damage during handling and also improves the keeping quality of the eggs. The mean shell thickness obtained in this present study was higher than values of 0.30–0.34 in crosses involving naked-neck, frizzle and normal birds by Nwachukwu et al. (2006) and 0.35 in crossbred naked-neck and frizzle genotypes by Hagan et al. (2011) but lower than that obtained by Hagan et al. (2013) for fourth generation crossbred naked-neck and frizzle phenotypes in Ghana. The phenotypes with the Na/na and F/f genotypes laid eggs with significantly ($P<0.05$) thicker shells than their normally feathered sibs, confirming the observation by Islam and Nishibor (2009). Again, due to frequent handling of eggs, thick-shelled eggs are likely to survive poor handling; hence the developed naked-neck and frizzle birds could be a good replacement for exotic breeds in the future.

Conclusion

The introgression of the *Na* and *F* genes has resulted in the improvement of egg production performance and egg quality of commercial layers in the country. This was evidenced by the superior egg production performance of the naked-neck and frizzle phenotypes even under moderately warm environments, as compared to their sibs which were normally feathered. It is therefore suggested that future breed development strategies should involve the incorporation of the naked-neck and frizzle genes for high egg production and quality.

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