Assessment of Production Performance and Egg Quality of Commercial Laying Hens Fed Black Pepper and Red Pepper Additives

Kelvin Uahunoma Aikpitanyi and James Ateka Iamasuen

ABSTRACT

With the increasing demand for poultry products (meat and eggs) worldwide, poultry farmers want to improve the productivity of their flocks. This challenge has necessitated poultry nutritionists to offer specific nutritional strategies for improved productivity. Feed additives are recommended as one of such strategic options, and plant materials, otherwise known as phytocegens, are being extensively investigated. Therefore, the study's objective was to assess the production performance and egg quality of commercial laying hens fed black pepper and red pepper additives. A total of 210 commercial laying hens at 24 weeks of age were allotted into seven dietary treatments in a completely randomized design. Each treatment had thirty (30) birds each, replicated three times to give ten (10) birds per replicate in a study that lasted 12 weeks. The formulated diets included: a control diet with no additives; Treatments 2 and 3 had 1% and 1.5% black pepper powder; Treatments 4 and 5 had 1% and 1.5% red pepper powder; Treatment 6 had a mixture of 0.5% each of black pepper and red pepper, while treatment 7 had a mixture of 0.75% each of black pepper and red pepper. All data collected were subjected to a one-way analysis of variance using the general linear model procedure of SAS (2012). From the results obtained, the hen day production (%) was significantly highest in hens fed the diet with 1% red pepper (83.40%) and the least from hens in the control (65.56%). The control treatment also recorded the least performances in egg mass (48.76g/bird/day) and feed conversion ratios (2.58 and 2.30). Shell thickness was least (0.43mm) in hens fed the diet with 1.5% red pepper, while the thickest shell measurement of 0.50mm was recorded in Treatment 6. The highest Haugh unit of 103.77 was obtained from Treatment 4, while the least value of 96.66 was obtained from the control. Yolk colour was significantly improved in the treated groups as against what was obtained from the control group. From the results, it can be concluded that black pepper and red pepper, having improved production performance and some egg quality characteristics in the treated groups compared to the control hold great potential as dietary additives.

Keywords: Black pepper, egg quality, laying hens, production performance, red pepper.

I. INTRODUCTION

The ISA Brown breed has proven for 35 years to have an excellent egg-laying performance over other strains in the world [1]. It is well known for its solid and reliable results, renowned as a global superstar in performance. ISA Brown adapts well to different climates, management systems and housing systems. All this, combined with an excellent feed conversion ratio, results in reliable performance for commercial egg Producers [2]. The interaction between nutrition and health is essential in an animal production system. However, stress factors, including climate, environment, and management practices, also influence the herd's productive performance [3]. Many additives are recently being used in poultry diet to enhance production performance and immune response of the birds. Apart from the vital role of medicinal herbs, aromatic plants and spices in daily human nutrition for enhancement of taste, aroma and colour of food, these additives have also been efficiently used in animal nutrition to improve animal health and wellbeing. In particular, these additives are primarily included in poultry diet to improve the feed utilization, growth and laying capacity. The plant-derived additives used in animal nutrition which improve performance, are referred to as "zootechnical feed additives" [4]. This form of feed additives has recently become of particular interest for use in poultry production and there have been an increasing number of scientific discoveries.
Known worldwide, black pepper is commonly used as a seasoning or ingredient in alternative medicine because of its active ingredient called piperine. Piperine, its active ingredient, has a potential application as a natural additive in animal production. It has several biological and physiological advantages such as enhancing immune system, anti-tumour influences, reduction of inflammation and improved digestion in animals [5]. In addition, its metabolism leaves no residue in the final products of the animals [6].

Red pepper is one of the most widely used spice and condiments in the world and is remarkably priced for its pungency and adds a unique flavour to many cuisines worldwide. Red pepper (capsicum annum) plays an essential role in increasing cholesterol and fat deposition in the body. Red pepper is rich in vitamin C, which considerably improves production by contributing to the reduction of heat stress in animals [7]. Consumption of red pepper induces a considerable change in energy balance in birds when individuals are given free access to feed [8]. Recent studies on poultry performance have shown that a blend of active compounds from red pepper has chemopreventive and chemotherapeutic effects which may curb appetite, speed up metabolism and help burn calories. Capsaicin, its active ingredient, is used as an analgesic in topical ointments, and dermal patches to relieve pain [9], [10].

Considering the above, the present study aimed to evaluate the effects of varying levels of black and red pepper and their combinations on performance and egg quality of Isa Brown laying hens.

II. MATERIALS AND METHODS

A. Experimental Location

The research was carried out at the poultry unit of the Teaching and Research Farm of the Faculty of Agriculture, University of Benin, Benin City, Edo State, Nigeria. The farm lies within latitude 6°20’1.32” N of the equator and longitude 5°36’0.53” E of Greenwich meridian, with a mean annual temperature of 34°C. The area has an average annual rainfall and relative humidity of 2000 mm and 72.5%, respectively [11].

B. Preparation of Test Ingredients

The dried test ingredients for the research were obtained from the local market in Benin City. After inspecting that they were evenly dried and not rotten, the red pepper was ground into a fine powder and stored in airtight containers until incorporated into the experimental diets. The black pepper was ground intermittently in small batches sufficient for the proposed feed quantity to be formulated. This procedure was essential to retain the aromatic smell of the pepper in the formulated diets.

C. Experimental Diets

Standard layer diets were formulated according to the recommendations of [12], [13]. The calculated crude protein level was 16%, while metabolizable energy was 2600 Kcal/kg. The chemical composition of the diets is given in Table I. Each diet had varying levels of either black pepper, or red pepper and their combinations, as outlined below.

1. Diet 1 0% black pepper and red pepper (control diet)
2. Diet 2 1% black pepper (10 g/kg feed)
3. Diet 3 1.5% black pepper (15 g/kg feed)
4. Diet 4 1% red pepper (10 g/kg feed)
5. Diet 5 1.5% red pepper (15 g/kg feed)
6. Diet 6 0.5% black pepper + 0.5% red pepper (5 g BP + 5 g RP/kg feed)
7. Diet 7 0.75% black pepper + 0.75% red pepper (7.5 g RP + 7.5 g/kg feed)

*RP = red pepper, BP = black pepper

The calculated nutrient compositions were derived using the following values: maize 9% crude protein and 3520 kcal/kg ME, soybean meal 48% crude protein and 3400 kcal/kg ME, palm kernel meal 21% crude protein and 2500 kcal/kg ME, fish meal with 70% crude protein and 3000 kcal/kg ME. Source [13].

Premix supplied per kilogram of feed: vit. A, 8,800 IU; vit. D3, 1,600 IU; vit. E, 12.8 mg; folic acid, 0.32 mg; pantothenic acid, 8 mg; biotin, 0.048 mg; niacin, 28 mg; vit. B6, 1.6 mg; riboflavin, 3.6 mg; thiamine, 0.96 mg; vit. B12, 12.8 μg; Vit. K3, 1.2 mg; copper, 9 mg; zinc, 60 mg; iodine, 1 mg; iron, 30 mg; manganese, 60 mg; selenium, 0.25 mg.

D. Experimental Animals and Design

The study was laid out in a completely randomized design. A total of 252 twenty weeks old laying hens were purchased from a reliable farm and used for the study. They were randomly allotted into seven treatments of 36 birds/treatment, each of which was further divided into three replicates of 12 birds per replicate.

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>56.85</td>
<td>56.85</td>
<td>56.85</td>
<td>56.85</td>
<td>56.85</td>
<td>56.85</td>
<td>56.85</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>18.00</td>
<td>18.00</td>
<td>18.00</td>
<td>18.00</td>
<td>18.00</td>
<td>18.00</td>
<td>18.00</td>
</tr>
<tr>
<td>Wheat bran</td>
<td>15.00</td>
<td>14.00</td>
<td>13.50</td>
<td>14.00</td>
<td>13.50</td>
<td>14.00</td>
<td>13.50</td>
</tr>
<tr>
<td>Bone meal</td>
<td>2.65</td>
<td>2.65</td>
<td>2.65</td>
<td>2.65</td>
<td>2.65</td>
<td>2.65</td>
<td>2.65</td>
</tr>
<tr>
<td>Limestone</td>
<td>7.00</td>
<td>7.00</td>
<td>7.00</td>
<td>7.00</td>
<td>7.00</td>
<td>7.00</td>
<td>7.00</td>
</tr>
<tr>
<td>Common salt</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
</tr>
<tr>
<td>Premix</td>
<td>0.15</td>
<td>0.15</td>
<td>0.15</td>
<td>0.15</td>
<td>0.15</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>Black pepper</td>
<td>1.00</td>
<td>1.00</td>
<td>1.50</td>
<td>-</td>
<td>-</td>
<td>0.50</td>
<td>0.75</td>
</tr>
<tr>
<td>Red pepper</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1.00</td>
<td>1.50</td>
<td>0.50</td>
<td>0.75</td>
</tr>
<tr>
<td>Total (%)</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Crude protein (%)</td>
<td>16.10</td>
<td>16.06</td>
<td>16.05</td>
<td>16.05</td>
<td>16.05</td>
<td>16.06</td>
<td>16.05</td>
</tr>
<tr>
<td>Metabolizable energy (Kcal/Kg)</td>
<td>2610.00</td>
<td>2607.53</td>
<td>2600.75</td>
<td>2607.53</td>
<td>2600.75</td>
<td>2607.53</td>
<td>2600.75</td>
</tr>
</tbody>
</table>
E. Management of Animals

Before the arrival of the birds, the pens were thoroughly cleaned and disinfected. All materials used during the study were also thoroughly cleaned and disinfected. The experimental birds were housed in a deep litter system of management with wood shavings as litter material. Adequate drinkers and feeders were provided to prevent aggressive competition for feed and water. Birds had access to feed and water ad libitum. All daily and routine management practices related to feeding, watering, litter management and medication were diligently observed. The lighting program during the study period was 16 hours of light and 8 hours of darkness.

F. Determination of Production Performance of Layers

For production performance, the following parameters were evaluated; feed intake (g/bird/day), hen day production (%), egg mass (g), feed conversion (kg feed/kg egg produced) and feed conversion ratio (kg feed/dozen eggs). Eggs were collected twice daily, pooled on a replicate basis, and carefully labelled. Percentage hen day production was calculated as the percentage of the ratio of the total number of eggs and the total number of days by the number of hens:

\[
\text{Percentage hen day production} = \frac{\text{Total number of eggs}}{\text{Total number of days} \times \text{number of hens}} \times 100
\]

Feed and water intake were determined by weighing and measuring the quantity of feed and water offered for specific periods (day, week and month) and subtracting the leftover at the end of the period. Egg mass was calculated as the ratio between egg production and egg weight. Feed conversion ratio was calculated as stated in the formulae below.

\[
\text{FCR (feed/egg produced)} = \frac{\text{Feed intake}}{\text{Egg mass}}
\]

\[
\text{FCR (feed/dozen eggs)} = \frac{\text{Feed intake}}{\text{Dozen eggs}}
\]

All evaluations were assessed on a fortnight basis. The equipment used to carry out these assessmentsmeasurements included the calibrated bucket, measuring scale, calibrated measuring glass, and a sensitive scale.

G. Determination of Egg Traits

At the end of each week, four eggs (n: 12 eggs/treatment) were randomly collected from each replicate and used to determine egg quality (egg weight (g), albumen weight (%), yolk weight (%), albumen height (mm), yolk height (mm), shell weight (%), shell thickness (μm) and yolk colour). Eggs were weighed on an electronic scale accurate to 0.01 g. Albumin index was determined as albumen height/albumen diameter × 100. The same principle as used in the albumin index was applied to determine the yolk index (yolk height/yolk diameter × 100). For the analysis of albumen and yolk weight, a manual yolk separator was used. The separated albumen and yolk were placed in plastic cups and weighed separately in an analytical balance. The height of the albumen and yolk was determined by placing them on a flat glass plate, and a digital calliper was used to measure their elevation off the flat surface. The weight of the eggshells was obtained after they were washed, dried at room temperature, and weighed using a sensitive scale. Shell thickness was determined with dried shells with the aid of a digital micrometer. The measurements were taken from three regions of the shell: basal, meridional, and apical. From the values obtained from the three regions, the average thickness of the eggshell was calculated in micrometres.

The Haugh unit is one of the measures of the internal quality of an egg. The test was introduced by Raymond Haugh in 1937 and is considered one of the most significant measures of egg quality. The measured height of the thick albumen was correlated with the egg weight to get the Haugh unit as given in the formula:

\[
\text{HU} = 100 \times \log_{10} (h - 1.7w^{0.37} + 7.6)
\]

where HU = Haugh unit, H = albumin height in millimetres, W = weight of egg in grams.

The egg yolk colour (n = 12 eggs per treatment group) was assessed visually with a Roche egg yolk colour fan (Roche Ltd., Switzerland). Pigmentation of the yolk was determined by comparing yolk colour against the range of the yolk colour fan (colours 1-15).

H. Statistical Analysis

All data collected was subjected to a one-way analysis of variance (ANOVA) using SAS’s general linear model procedure [14]. The differences in treatment means were compared by Duncan’s multiple range test as outlined by [15]. The level of statistical significance was preset at p<0.05.

III. RESULTS

A. Production Performance of Laying Hens

The results from assessing the production performance of the laying hens for the 12 weeks period of the study is given in Table II.

![Table II: Production Performance of Laying Hens Fed Varying Levels of Black Pepper, Red Pepper and Their Combinations](image)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
<th>T5</th>
<th>T6</th>
<th>T7</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hen day (%)</td>
<td>65.56ab</td>
<td>79.22ab</td>
<td>69.26ab</td>
<td>83.40ab</td>
<td>72.73ab</td>
<td>71.28ab</td>
<td>71.65ab</td>
<td>2.85ab</td>
</tr>
<tr>
<td>Egg weight (g/day)</td>
<td>54.70</td>
<td>55.71</td>
<td>58.05</td>
<td>55.35</td>
<td>56.10</td>
<td>58.35</td>
<td>58.95</td>
<td>1.03NS</td>
</tr>
<tr>
<td>Egg mass (g/bird/day)</td>
<td>35.86</td>
<td>44.06a</td>
<td>40.06ab</td>
<td>46.03ab</td>
<td>40.82ab</td>
<td>41.44ab</td>
<td>42.25ab</td>
<td>1.44ab</td>
</tr>
<tr>
<td>Feed intake (g/bird/day)</td>
<td>125.87</td>
<td>118.47bc</td>
<td>108.80bc</td>
<td>118.76bc</td>
<td>119.91bc</td>
<td>116.45bc</td>
<td>112.70bc</td>
<td>1.90bc</td>
</tr>
<tr>
<td>FCR (feed/egg mass)</td>
<td>3.34</td>
<td>2.69</td>
<td>2.88</td>
<td>2.74</td>
<td>2.96</td>
<td>2.94</td>
<td>2.75</td>
<td>0.14NS</td>
</tr>
<tr>
<td>FCR (feed/dozen eggs)</td>
<td>2.30ab</td>
<td>1.80b</td>
<td>1.89b</td>
<td>1.72b</td>
<td>1.99b</td>
<td>1.99b</td>
<td>1.94b</td>
<td>0.09ab</td>
</tr>
<tr>
<td>Water intake (ml/bird/day)</td>
<td>250.56</td>
<td>257.46</td>
<td>236.77</td>
<td>256.92</td>
<td>271.31</td>
<td>256.70</td>
<td>260.71</td>
<td>5.20ab</td>
</tr>
</tbody>
</table>

1 = Treatment, wk = week, SEM = standard error of mean, FCR = feed conversion ratio, BP = black pepper, RP = red pepper, * = significant (p<0.05), NS = not significant. a,b,c,d = means in the same row with different superscript are significantly different (p<0.05). T1 = Control, T2 = 1% BP, T3 = 1.5% BP, T4 = 1% RP, T5 = 1.5% RP, T6 = 0.5% each of BP and RP, T7 = 0.75% each of BP and RP.
Hen day production was influenced by the inclusion of black pepper, red pepper, and their combinations, with significantly higher readings in Treatment 4 (83.40%) and Treatment 2 (79.22%) compared to the control. However, the rest treated groups were not significantly different (P<0.05) from the control, which recorded the least hen day production of 65.56%.

The treated groups had significantly higher egg mass than what was recorded in the control, except for Treatment 3, which had no significant (P<0.05) difference from the control. The highest egg mass of 46.03g/bird/day was obtained from Treatment 2, while 35.86g/bird/day was the least and obtained from the control.

The control had the highest feed consumption of 125.87 g/bird/day and was significantly different (P<0.05) from the treated groups. Treatment 3 (1.5% black pepper) had the least feed consumption of 108.80g/bird/day. Feed conversion ratio (feed/dozen eggs) was influenced by the application of the treatment, as the treated groups gave better and significantly different (P<0.05) performance than what was obtained from the control. In this instance, the value was between 1.72 in Treatment 4 (1% red pepper), 1.99 in Treatments 5 and 6, and 2.30 in the control.

Water intake was highest in Treatment 5 (271.31 ml/bird/day), and the least was recorded in Treatment 3 (236.77 ml/bird/day). All treatments apart from treatment 5 had no significant difference from the control.

No significant difference was observed in recorded values in egg weight and feed conversion ratio (feed/egg mass) despite numerical differences. Improved values were noted in the treated groups compared to the control in both instances.

### B. Egg quality of Laying Hens

Table III shows the result of the assessment of egg weight, relative albumen weight, relative yolk weight, relative shell weight, shell thickness, albumen index, yolk index, Haugh unit and yolk colour of laying hens fed black pepper, red pepper and their combinations. On average, egg weights for the duration of the study were significantly high in Treatment 6 (61.18 g), Treatment 5 (61.01 g) and Treatment 3 (59.25 g). The least egg weight (53.63 g) with a significant (P<0.05) difference from the treated groups was obtained from the control.

The use of the spices and their combinations as additives in this study did not influence relative yolk weight, relative yolk weight, and relative shell weight. The numerical differences between treatments could not be attributed to the additives, as the control treatment shared statistical similarities with the treated groups. Shell thickness grew increasingly thinner as the assessment progressed. On average, Treatments 6 and 7 had a more significant influence on shell thickness as they both had significantly higher values of 0.50mm and 0.49mm, respectively, as against the 0.44mm obtained from the control. However, the average thickness of 0.43mm was the least obtained in the study and was from the birds fed the 1.5% red pepper diet (Treatment 5).

Albumen index percentage was improved with the addition of the spices, as reflected in the significantly higher values in the treated groups, except Treatment 3 (1.5% black pepper), which had no significant difference from the control. Treatment 4 had the highest albumen index of 17.25%, while the control had the least (13.66%).

Significant (P<0.05) difference was recorded in yolk index between the control and the treated group, with 50.02% in Treatment 2 and 46.26% in the control. The other treated groups, except for Treatment 3 (47%), had statistical similarities with Treatment 2, thus suggesting that the additives had a possible influence on yolk index. On average, the computed Haugh unit was highest in Treatment 4 (103.77) but not significantly different from the rest of the treated group except for Treatment 3, which was statistically like the control with a value of 96.66. The yolk colour score was much improved in the treated group compared to the control, with the treated groups having a score between 9.00-9.89. This range for the treated group was significantly different from the least score of 8.44 obtained in the control.

### IV. DISCUSSION

As observed in the present study, hen day production was influenced by the treatment, with the highest values obtained in Treatment 4 (83.40%) and Treatment 2 (79.22%) with a significant difference (P< 0.05) from the control (65.56%). The control, however, shared statistical similarities with the other treated groups despite being the least. These findings are in agreement with other studies where dietary inclusion of phytogenic feed additives (fennel, black cumin and hot red pepper) led to significant (P < 0.05) differences in egg production [16]-[18]. However, some studies with red pepper contradict these findings and report a non-significant effect on egg-laying performance [19]-[21]. The beneficial impact of the spices on the productive performance of the laying hens can be attributed to their bioactive compounds.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
<th>T5</th>
<th>T6</th>
<th>T7</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg weight (g)</td>
<td>53.62</td>
<td>57.65</td>
<td>59.25</td>
<td>58.35</td>
<td>61.01abd</td>
<td>61.18</td>
<td>58.06</td>
<td>0.82</td>
</tr>
<tr>
<td>Relative albumen weight (%)</td>
<td>52.68</td>
<td>53.31</td>
<td>54.49</td>
<td>54.58</td>
<td>55.56</td>
<td>55.43</td>
<td>54.41</td>
<td>0.76NS</td>
</tr>
<tr>
<td>Relative yolk weight (%)</td>
<td>24.95</td>
<td>24.74</td>
<td>23.58</td>
<td>23.53</td>
<td>24.03</td>
<td>23.55</td>
<td>24.10</td>
<td>0.55NS</td>
</tr>
<tr>
<td>Relative shell weight (%)</td>
<td>12.67</td>
<td>12.59</td>
<td>12.24</td>
<td>12.43</td>
<td>12.09</td>
<td>12.66</td>
<td>12.36</td>
<td>0.17NS</td>
</tr>
<tr>
<td>Shell thickness (mm)</td>
<td>0.44</td>
<td>0.46*</td>
<td>0.47*</td>
<td>0.45*</td>
<td>0.43*</td>
<td>0.50*</td>
<td>0.49*</td>
<td>0.01*</td>
</tr>
<tr>
<td>Albumen index (%)</td>
<td>13.66</td>
<td>16.54</td>
<td>14.90</td>
<td>17.25*</td>
<td>16.44b</td>
<td>16.94*</td>
<td>16.35*</td>
<td>0.01*</td>
</tr>
<tr>
<td>Yolk index (%)</td>
<td>46.26</td>
<td>50.02*</td>
<td>47.00</td>
<td>49.68*</td>
<td>49.45*</td>
<td>49.77*</td>
<td>49.69*</td>
<td>0.01*</td>
</tr>
<tr>
<td>Haugh unit</td>
<td>96.66</td>
<td>102.88*</td>
<td>97.34</td>
<td>103.77*</td>
<td>102.30</td>
<td>102.95*</td>
<td>102.65*</td>
<td>1.28*</td>
</tr>
<tr>
<td>Yolk colour</td>
<td>8.44</td>
<td>9.67*</td>
<td>9.00</td>
<td>9.00*</td>
<td>9.33*</td>
<td>9.89*</td>
<td>9.22*</td>
<td>0.15*</td>
</tr>
</tbody>
</table>

T1 = Control, T2 = 1% BP, T3 = 1.5% BP, T4 = 1% RP, T5 = 1.5% RP, T6 = 0.5% each of BP and RP, T7 = 0.75% each of BP and RP, T = Treatment, SEM = standard error of mean, BP = black pepper, RP = red pepper, * = significant (p<0.05), NS = Not significant a,b,c,d; means in the same row with different superscript are significantly different (p<0.05).
For example, capsaicin, the active component of hot red pepper, is efficient in augmenting nutrients and energy metabolism by enhancing glucose-6- phosphate dehydrogenase, lipoprotein lipase in adipose tissue, and pancreatic and intestinal enzymes [22, 23]. The active biomolecular compounds in herbs and spices can also aid in regulating various metabolic functions and therefore increase the production performance of layers [24]. These compounds can dramatically increase the absorption of selenium, vitamin B complex, beta-carotene, curcumin and other nutrients [25]. The significant impact of phytogenic feed additives on laying performance can also be attributed to the positive effects of these additives in modulating gut microbiota, enhancing nutrient digestibility and absorption, and improving ovarian characteristics [26, 27].

Some studies with red pepper reported no significant difference (p>0.05) in the feed conversion ratio of laying hens [20, 21]. This partly agrees with the present study as significant difference was recorded only in feed conversion ratio (feed/dozen egg). In contrast, no significant difference was observed in feed conversion (feed/egg mass) between the treated groups and the control. Contrary to our findings, [18] reported a significant influence of red pepper on feed conversion ratio (feed/egg mass). Additionally, a mixture of red pepper and other phyogenic additives has also been reported to influence egg weight and mass positively in comparison with the non-supplemented control group [20, 24]. These reports agree with the result of egg mass in the present study, with significant differences observed between the treated groups and the control. However, other studies with red pepper reported no significant difference in egg mass [28]-[30].

Eggshell quality parameters have valued economic importance for the egg production chain because a stronger shell structure with higher breaking strength is one of the most crucial quality targets to reduce the breaking and cracks of eggs during handling, storage and transportation [31], [32]. This study revealed that the combination diets (Treatments 6 and 7) significantly improved shell thickness (0.50 mm and 0.49 mm, respectively) compared to the control (0.44 mm). These values are higher than the shell thickness of 0.40-0.47 mm reported by [33] and lower than 0.53mm stated by [34] for indigenous breeds of layers in Nigeria. On the contrary, no significant difference in shell thickness between the experimental group fed a 0.5% red pepper diet and the control [35], [24] reported that varying levels of black pepper (0.1% - 0.6%) reduced shell thickness compared to the control, though no significant difference was observed between them. A similar statistical observation was noted in the present study, but increased numerical values were recorded in the black pepper treatments. The improved shell quality is related to the more efficient utilization of nutrients, especially some minerals that have a critical role in shell formation [23].

The yolk index value is related to yolk height and yolk diameter and is majorly used as an indicator of deterioration. Eggs with a yolk index above 0.38 are considered extra fresh, those ranging from 0.28 to 0.38 are fresh, and those below 0.28 are considered regular [36]. The current study had a range of 0.47-0.50 in most of the treated groups with a significant difference (p<0.05) from the control (0.46) and Treatment 3 (0.47). A reported study recorded a significantly higher yolk index of 0.68 in the red pepper treatment as against 0.66 obtained from the control [16]. Contrary to the other findings, a yolk index value of 0.42 and 0.45 was reported for frizzle and naked neck breeds, respectively [34]. At the same time, a range of 0.39-0.45 was documented as the average yolk index influenced by storage and breed [37]. It has also been established that phytogenic feed additives stimulate the hepatic secretion of egg yolk precursors by protecting hepatocytes from oxidative damage with subsequent enhancement of yolk formation and ovulation [38].

As observed in this study, the lower levels of the additives in Treatments 2, 4 and 6 (1% BP, 1% RP and 0.5% each of BP and RP) significantly influenced the albumen index compared to the control. In contrast to this result, no significant difference in albumin index of 0.10 in the control and 0.11 in the red pepper treatment was reported in a similar study [16]. In support of the result of this study, it is postulated that bioactive compounds in herbal additives protect the magnum and uterus of laying birds which in due course improves albumen secretion [39].

The Haugh unit (HU) score is regarded as an indicator of egg freshness and is related to shelf life [40]. As the Haugh unit and yolk index are the significant indicators of internal egg quality, the higher their values, the more desirable is the egg quality as table eggs or for hatching [41]. Fresh eggs from young flocks will have a HU of 85 and above and decrease with the flock's age, length of storage and temperature [36]. In the current study, the Haugh unit across all treatments was above 85. Despite the high numerical values obtained in the study, significant differences were observed between the control and the treated groups (96.66 in the control and 97.34-103.77 in the treated group). Similar improvement in the Haugh unit as influenced by different phytogenic additives was also reported by [18, 21]. On the contrary, similar studies reported a non-significant difference in Haugh unit between the experimental group and the control [16], [24]. In contrast, the supplementation of pipерine, the active compound in black pepper, at 30 mg/kg body weight in the quail diet increased Haugh unit [29]. This result is consistent with the present study where the black pepper treatment increased the Haugh unit compared to the control. The Haugh unit recorded in this study's treated group is higher than the average reported in frizzle and naked neck [34], and some other indigenous backyard poultry [42, 43].

The colour of egg yolk is another main parameter for assessing egg quality besides shape, weight, eggshell strength, and freshness [44]. Carotenoids affect and improve Yolk colour, and animals can only convert or metabolize carotenoids; they cannot synthesize them [44]. However, the use of artificial colour additives in place of natural carotenoids have been linked to the development of cancer, which has given massive credence to phytogenic feed additive rich in carotenoids [45]. It has also been established that the improved yolk colour in red pepper treatments could linger up to eight days after removing the additive from the diet [20]. Like the current study, other authors have reported yolk colour improvements with phytogenic additive inclusion in laying hens’ diets [16], [35]. In contrast to the
present study, however, a non-significant effect of black pepper on yolk colour is also documented [24]. On average, the present study's combination additives (Treatments 6 and 7) generally improved yolk pigmentation better than the rest treatments. Treatment 6 recorded the highest Roche yolk fan score of 9.89, followed by 9.67 obtained from Treatment 2 (1% black pepper). Both were significantly different from the colour score of 8.44 recorded in the control. [46] determined and reported a high egg yolk colour value of 14.33 in the groups with 2% red pepper supplementation, while the lowest value of 1.58 was observed in the groups that had consumed the basal diet (P <0.05). In addition, [45] observed the highest Roche yolk colour fan values (14.30 and 14.45) in the groups supplemented yellow corn-based diet with 3% and 4% red pepper, respectively. Consumers' egg choice is no longer based on yolk cholesterol content or fatty acids profile alone but also on its colour due to the health benefits associated with the pigment source [47]. Like antioxidants, carotenoids have been found to neutralize excess free radicals and protect the cell against toxic effects [48].

V. CONCLUSION

As observed in this study, black pepper, red pepper, and their combinations had varied effects on the experimental birds, which led to the following conclusions:
1. The 1.5% black pepper and 1% red pepper treatments significantly improved the hen day production, egg mass and feed conversion ratio compared to the control.
2. The additives significantly improved the egg quality characteristics with particular reference to the combination diets (Treatments 6 and 7) which recorded better values in shell thickness, yolk index, Haugh unit, and egg yolk colour.

In general, the conclusions confirm the beneficial role and potential of black pepper, red pepper and their combinations in improving the productivity and egg quality of laying hens.

ACKNOWLEDGMENT

The authors' profound gratitude goes to the Boards of Animal Science Department and Faculty of Agriculture, University of Benin, Nigeria, for their academic input in this research.

CONFICT OF INTEREST

The authors declare no conflict of interest in this research.

REFERENCES


