Laying performance and egg characteristics of Japanese quail fed rations containing different levels of Maxigrain as a feed additive

O. E. Negedu* | Celestine Ezenwosu* | A. E. Onyimonyi*

Abstract The performance, egg characteristics and lipid profile of Japanese quail (Coturnix japonica) fed diets containing different levels of Maxigrain as a feed additive were investigated. A total of 225 (7 weeks) old Japanese quails weighing 235-248 g at the point of lay were allotted to 5 dietary treatments in a completely randomized experimental design with 5 replicates of 9 birds each. Dietary treatments for the entire 56 of days the feeding trial included: T1: 0 g of Maxigrain kg⁻¹ diet, T2: 0.5 g Maxigrain kg⁻¹ diet, T3: 1 g Maxigrain kg⁻¹ diet, T4: 1.5 g Maxigrain kg⁻¹ diet and T5: 2 g Maxigrain kg⁻¹ diet. The results of the study showed that values for average daily feed intake, egg length, egg diameter, egg shape index, cholesterol, high density lipoprotein, low density lipoprotein, triglyceride, albumen weight, albumen height and yolk height were not affected by the treatment (P > 0.05), while dietary treatment significantly (P < 0.05) affected the values for the average daily weight gain, egg weight, egg mass, egg yolk weight and shell thickness among the treatments with T4 and T5 having the highest values of the above variables. It was concluded that T4 and T5 treatment could be safely included in the diet for improved performance in laying quail.

Keywords: Coturnix coturnix japonica, egg, Japanese quail, laying performance, Maxigrain

1. Introduction

Poor protein consumption has a severe impact on developing nations such as Nigeria, contributing to poor physical condition and low energy output (Adekunmi et al 2017). According to the Food and Agriculture Organization (FAO), animal products should provide 35 g of the minimum required 65–72 g of the reference protein.

However, the production of all classes of poultry meat, such as quail eggs and meat, is required to provide a sustainable source of farm animal protein to fulfill the protein demands of the growing global human population and achieve self-sufficiency in the supply of animal protein. Japanese quails are described as robust, easy to handle, small-sized, rapidly growing, and prolific egg producers by Moraea et al (2016) and Weslane et al (2017). The meat and eggs of quails are the main reasons they are raised. It contains protein and only a small amount of unhealthy saturated fat in terms of lipid content (Ani and Emeh 2009). However, it also contains more beneficial polyunsaturated fatty acids. Therefore, quail eggs are beneficial for those with problems of stress, hypertension, digestive disturbance, gastric ulcer, liver problems, blood pressure, migraine, asthma, anemia, various heart issues, depression, eczema, panic and anxiety.

Although poultry such as quail can help in supplying the increasing human population with quality protein, but due to their monogastric nature, they still have problems with feed digestion because of antinutritional elements and fibrous materials that may be present in the feed as a result of the use of nonconventional plant-based feed ingredients such as palm kernel cake. These elements cause a decrease in performance by decreasing the use of other dietary nutrients. Due to a lack or insufficiency in endogenous enzyme production in their bodies, many elements of feed materials of plant origin and their byproducts are resistant to the digestive enzymes of monogastric animals such as chickens (Ravindran et al 1999). Although dietary fibre is a key nutrient component used in the formulation of poultry feed (Tejeda and Kim, 2021), it may have negative effects on feed consumption and nutrient digestibility despite having positive effects on organ development, microflora intestinal modulation, and intestine morphology (Sittiya et al 2020; Singh and Kim 2021; Jha and Mishra 2021). Additionally, the anti-nutritional activity of NSPs' cell walls has a negative impact on feed efficiency and growth rate (Kalantar et al 2015).

However, numerous nonsynthesized-antibiotic dietary supplements have been used as growth promoters in farm animal production since the European Union banned the utilization of antibiotics in poultry production due to the amplified issues related to their use such as formation of resistance in birds and residues in meat (Carvalho and Santos 2016). These supplements include prebiotics, probiotics, organic acids, amino acids, immunostimulants, and phytogetic feed additives (Ahsan et al 2016; Mashayekhi et al 2018; Abouelezz et al 2019).
The use of enzymes is another nonantibiotic supplement that has been utilized to improve feed digestion and utilization in chickens. Reducing losses through improved feed digestibility and effective nutrient use is one of the poultry industry's biggest challenges. Exogenous enzymes added to feed before it is given to poultry is one of the best approaches that can be used to address this issue. By enhancing the coefficient of nutrient digestibility, the addition of enzymes to animal feeds, such as poultry, helps to inactivate antinutrients in the feeds (Lavrentev, 2016; Ivanova and Lavrentev, 2014). It has been discovered that adding enzyme supplements can increase how effectively high-fibre or low-quality feed ingredients are incorporated into poultry production. Multienzyme supplementation improved energy utilization and reduced the negative effects of nonstarch polysaccharides (NSPs) in poultry by promoting the dissolution of starch, cell walls, and endogenous proteins (Suresh et al 2019; Attia et al 2020). The digestibility of NSPs is very small in poultry, and a huge quantity is emptied through the excreta. The NSPs' capacity to bind enormous amounts of water results in an increase in the viscosity of fluid in the intestines. A rise in viscosity could result in certain difficulties with the digestion of protein, carbohydrate and fat.

Maxigrain is one such enzyme that has been utilized to improve feed digestion and utilization. Maxigrain, a complex blend of enzymes that can be used in chicken nutrition. It contains amylase, xylanase, glucanase, cellulase, pectinase, protease, phytase, and lipase (Agyekum et al 2012). Maxigrain® has a reputation for maximizing the use of nontraditional feed ingredients by improving broiler weight gain and feed conversion ratio, as well as litter quality, egg output, and shell quality. Additionally, it dramatically lowers the levels of dicalcium phosphate incorporation in the feed (Polchem Innovative Solution 2013). Since increasing egg production and quality features through affordable nutritional solutions is essential to supplying high-quality protein for the world’s burgeoning human population, the current study was intended to determine the laying performance, internal egg characteristics, external egg characteristics and lipid profile of Japanese quail (Coturnix japonica) fed diets containing different levels of Maxigrain enzyme as feed additive.

2. Materials and Methods

2.1. Study site

The study took place at the Department of Animal Science Teaching and Experimental Farm Poultry Section of the University of Nigeria, Nsukka. Nsukka lies within longitude 6° 45′E and 7° E and latitude 7° 12.5′N and at an altitude of 447 m above sea level. The annual rainfall ranges from 1567.05 mm-1846.98 mm (Metrological Center, Department of Crop Science, University of Nigeria, Nsukka). The climate of the study region is naturally tropical with relative humidity ranging from 65 to 80% and mean daily temperature of 26.8 °C (Okonkwo and Akubuo, 2007). The study lasted for a period of 10 weeks.

2.2. Characteristics of Maxigrain

The tested Maxigrain was purchased at Peace Ugwu Feed Venture Limited in Nsukka Enugu State Nigeria. Each gram of Maxigrain® is composed of 10,000 IU Cellulase, 200 IU Beta-glucanase, 10,000 IU Xylanase and 2500 FTU Phytase. Maxigrain® used in the study was produced by Polchem Hygiene Laboratories, India.

2.3. Experimental birds and management

A total of 225 Japanese quails (7 weeks old) weighing 235-248 g were purchased from Jos, Plateau, Nigeria. They were divided into five dietary treatment groups in a fully randomized experimental design, with 45 Quails per treatment, after stabilizing them together for one week. The birds were kept in a deep litter system with clearly defined boundaries and wire gauze protection. Additionally, feeding troughs and drinks were bought, cleaned, and placed in ideal locations. According to the manufacturer’s instructions, a stress pack was given to the birds by drinking water at a dosage of 100 g/50 liters to increase appetite and vigor. Throughout the experiments, food and fresh water were freely available. Feed and clean water were made available ad libitum during the entire period of the study. The room temperature was monitored using a thermometer, and lighting was provided using a 200v watt bulb. Birds were checked twice daily for mortality.

2.4. Experimental diets

An 8-week feeding study was conducted. According to the Nutrition Research Council (1994) the diets were formulated to satisfy the nutrient needs of laying quail. The experimental diet and its approximate components are shown in Table 1 and, in addition, the Association of Official Agricultural Chemists’ methodologies were used to analyze the chemical (proximate) components of the experimental meals (AOAC 2011).

2.5. Data collection

2.5.1. Growth performance parameters

Birds were weighed at the start of the experiment and then every 7 days after that using a 10.1 kg precision aptitude balance. On a daily basis, hen-day egg production (%) was recorded and computed as follows: total eggs collected divided by total live hens per day in each replicate per treatment. A digital balance with a precision of 0.01 g was used to weigh the
average weight of all the eggs laid by birds in each replicate, which was recorded weekly to determine egg weights. From the first day of the study to the last, feed intake was recorded. Weighing the meal before giving it to the birds allowed us to determine how much was consumed. Second, the variation between the feed given the day before and leftover feed in the feeding trough the next morning was divided by the number of birds in each replicate to obtain the daily feed intake per bird for each replicate. Average daily feed intake (ADFI) was obtained by dividing the daily feed intake of birds by the number of days the feeding trial lasted. Average daily weight gain (ADWG) was obtained by dividing the weight gained by birds by the number of days the feeding trial lasted.

Table 1 Ingredients (%) and chemical composition (g/kg DM) of experimental diets.

<table>
<thead>
<tr>
<th>Ingredients (%)</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
<th>T5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>40.00</td>
<td>40.00</td>
<td>40.00</td>
<td>40.00</td>
<td>40.00</td>
</tr>
<tr>
<td>Soya bean meal</td>
<td>28.00</td>
<td>28.00</td>
<td>28.00</td>
<td>28.00</td>
<td>28.00</td>
</tr>
<tr>
<td>Palm kernel cake</td>
<td>15.00</td>
<td>15.00</td>
<td>15.00</td>
<td>15.00</td>
<td>15.00</td>
</tr>
<tr>
<td>Wheat offal</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
</tr>
<tr>
<td>Fish meal</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Bone meal</td>
<td>4.00</td>
<td>4.00</td>
<td>4.00</td>
<td>4.00</td>
<td>4.00</td>
</tr>
<tr>
<td>Cassava peel meal</td>
<td>6.00</td>
<td>6.00</td>
<td>6.00</td>
<td>6.00</td>
<td>6.00</td>
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<td>Lime stone</td>
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<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
</tr>
<tr>
<td>Palm oil</td>
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<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Salt</td>
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<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
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</tr>
<tr>
<td>Methionine</td>
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<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
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<tr>
<td>Lysine</td>
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<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
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<tr>
<td>Vitamin premix</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Maxigrain (g/kg diet)</td>
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<td>0.05</td>
<td>1.00</td>
<td>1.50</td>
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<tr>
<td>Calculated composition (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crude protein (%)</td>
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<td>19.80</td>
<td>19.80</td>
<td>19.80</td>
<td>19.80</td>
</tr>
<tr>
<td>Metabolizable Energy (Mcal/KgME)</td>
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<td>2800.00</td>
<td>2800.00</td>
<td>2800.00</td>
<td>2800.00</td>
</tr>
<tr>
<td>Crude fibre (%)</td>
<td>5.98</td>
<td>5.98</td>
<td>5.98</td>
<td>5.98</td>
<td>5.98</td>
</tr>
<tr>
<td>Crude fat (%)</td>
<td>3.28</td>
<td>3.28</td>
<td>3.28</td>
<td>3.28</td>
<td>3.28</td>
</tr>
<tr>
<td>Chemical compositions (%)</td>
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<td></td>
<td></td>
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<tr>
<td>Crude matter</td>
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<td>90.66</td>
<td>90.68</td>
<td>90.64</td>
<td>90.56</td>
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<tr>
<td>Crude fibre</td>
<td>5.81</td>
<td>5.41</td>
<td>5.81</td>
<td>5.81</td>
<td>5.83</td>
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<td>Crude protein</td>
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<td>20.20</td>
<td>20.19</td>
<td>20.41</td>
<td>20.22</td>
</tr>
<tr>
<td>Moisture</td>
<td>10.12</td>
<td>9.34</td>
<td>9.32</td>
<td>9.36</td>
<td>9.44</td>
</tr>
<tr>
<td>Crude fat</td>
<td>4.23</td>
<td>3.99</td>
<td>4.00</td>
<td>4.51</td>
<td>4.22</td>
</tr>
<tr>
<td>Crude ash</td>
<td>7.90</td>
<td>8.00</td>
<td>7.97</td>
<td>8.11</td>
<td>7.99</td>
</tr>
<tr>
<td>Nitrogen Free extract</td>
<td>51.64</td>
<td>53.06</td>
<td>52.71</td>
<td>52.00</td>
<td>52.30</td>
</tr>
</tbody>
</table>

*Each 2 kg of vitamin premix contains: vitamin A: 1000000 IU; vitamin D3: 2,200000 mg; vitamin B1: 1500 mg; vitamin B2: 5000 mg; vitamin K3:2000 mg, vitamin B12: 10 mg; vitamin B6:1500 mg, vitamin E: 10000 mg; Biotin: 20 mg; Niacin: 15,000 mg, Folic acid: 500 mg and 5000 mg calpan.

2.5.2. Determination of external egg characteristics

To calculate the average egg weight, all eggs laid in each replicate on a weekly basis were collected. In addition, 10 eggs were randomly chosen from the already laid eggs in each replicate to determine the average egg length, egg diameter, shell weight, and egg shape index. A digital caliper was used to measure the egg’s length, width and diameter. Before being weighed with a delicate weighing scale, the shells were oven dried. Using the equation: width/length x 100 egg shape index was calculated. Egg mass was calculated using the formula: Percentage HDEP x average egg weight in grams /100

The eggs shell thickness was also determined by using a micrometer which was obtained as an average value of the measurements taken at 3 points of the egg shell that is: the equator, air cell and sharp end which is a method by Abd El-Hack et al 2017).

2.5.3. Lipid profile determination
To examine the lipid profile, 3 to 5 mls of the mixed egg were sampled using a syringe and placed in bottles containing the anticoagulant ethylene diamine tetra-acetic acid. The samples were centrifuged at 1800 rpm, and the Hitachi 902: Auto Analyser was used to determine the levels of total cholesterol, triglycerides, HDL, and LDL.

2.5.4. Internal egg characteristic determination

The method outlined by Ratriyanto et al (2017) was used to determine the weights of albumen and yolk. With a 0.01 g precision digital scale, each egg was painstakingly weighed before being broken. Using a yolk separator, the albumen and yolks were separated. Any albumen that had adhered to the eggshell was removed. By deducting the weight of the egg yolk and eggshell from the total egg weight, the weight of the albumen was calculated. After being weighed, each egg was cracked into a flat surface to determine the height of the albumen and yolk using an electronic tripod micrometer.

2.6. Statistical design and analysis

Data produced were subjected to analysis of variance (ANOVA) in CRD using the statistical package (SPSS 2003) Windows version 8.0. Mean differences were separated using Duncan’s New Multiple Range Test (Duncan, 1955) as outlined by Obi (2002). In the present study, the significance was held at 5% for the entire analysis.

The statistical model used to test the effects of treatments on performance, internal egg characteristics, external egg characteristics and lipid profile parameters are stated below:

$$X_{ij} = \mu + T_i + E_{ij}$$

Where: $X_{ij}$ = individual observation; $\mu$ = population mean; $T_i$ = treatment effect; $E_{ij}$ = experimental error.

3. Results

The performance of laying quails fed diets containing varying levels of Maxigrain for 56 days are shown in Table 2 and Figures 1-3. Values of average daily feed intake and initial body weight were not significant ($P > 0.05$). In contrast, the values of average daily weight gain, hen day egg production, egg mass and egg weights among the treatments were significantly ($P < 0.05$) influenced by the treatments. The average daily weight gains of T1, T2 and T3 were the same ($P > 0.05$) but lower than the values of 27.58 and 27.89 recorded in T5. The values of hen day egg production and egg mass values among the treatments followed the same trend as that observed for average daily weight gain. The egg mass values of T5, T4 and T2 were the same ($P > 0.05$) but lower than the values of 9.55 and 9.21 recorded in T2 and T1, respectively.

Table 2 Performance characteristics of laying quails fed diet containing varying levels of Maxigrain for 56 days.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Treatments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T1</td>
</tr>
<tr>
<td>Initial weight (g/bird)</td>
<td>248.00</td>
</tr>
<tr>
<td>Average daily weight gain (g/bird)</td>
<td>23.23</td>
</tr>
<tr>
<td>Average daily feed intake (g/bird)</td>
<td>31.55</td>
</tr>
<tr>
<td>Hen day egg production (%)</td>
<td>73.80</td>
</tr>
<tr>
<td>Egg mass (g/day)</td>
<td>6.79b</td>
</tr>
<tr>
<td>Egg weight(g)</td>
<td>9.21b</td>
</tr>
</tbody>
</table>

Means on the same row with different superscript are significantly different ($P < 0.05$). T1: 0 g of Maxigrain kg$^{-1}$ diet, T2: 0.5 g Maxigrain kg$^{-1}$ diet, T3: 1 g Maxigrain kg$^{-1}$ diet, T4: 1.5 g Maxigrain kg$^{-1}$ diet, T5: 2 g Maxigrain kg$^{-1}$ diet.

The results of the external egg characteristics of laying quails fed diets containing varying levels of Maxigrain are presented in Table 3 and Figure 4. Values of egg length, diameter and shape index were not significant ($P > 0.05$), while values of egg shell weight and shell thickness were significant ($P < 0.05$). The egg shell values of T5 and T4 were the same ($P > 0.05$) but significantly higher than the values of 0.26, 024 and 0.23 recorded in T3, T2 and T1, respectively. Egg shell thickness values of T1, T2 and T3 were the same ($P > 0.05$) but significantly lower than the values of 9.32 and 0.31 recorded in T4 and T5, respectively.

The results of the lipid profile of laying quail containing varying levels of Maxigrain are shown in Table 4. The values of cholesterol, triglycerides, high-density lipoprotein and low-density lipoprotein were not significant ($P > 0.05$).

The results of the internal egg characteristics of laying quails fed diets containing varying levels of Maxigrain for 56 days are presented in Table 5 and Figure 6. Albumen weight, albumen height and yolk height were not significantly different ($P > 0.05$), while yolk weight was significantly different ($P < 0.05$). The yolk weights of T5 and T4 were the same but higher than the values of 1.47, 1.39 and 1.51 recorded for T3, T2 and T1.
4. Discussion

The results of the performance of laying quails fed varying levels of Maxigrain are presented in Table 2 and Figures 1–3. From the results, values of body weight gain, egg mass, egg weight and hen day egg production were significantly improved in favor of birds on Maxigrain supplementation though relatively higher in T4-T5 when compared to other treatment group, but with exception in egg weight value were T3-T5 group were higher compared to T1 and T2. These results were similar to the findings of Olajide et al (2013), who recorded better hen-day egg production when brewers’ dried grain-based diets were supplemented with Grandizyme® enzyme. This was also similar to Olajide (2022), who studied the influence of Maxigrain® enzyme-supplemented beniseed hull on the performance and haematological parameters of domestic laying hens and observed improvement in egg weight, egg mass and hen-day egg production in favour of the treatment groups, and Alagawany et al (2017), Chimote et al (2009) and Goli and Shahryar (2015), who studied the effect of adding enzyme on the growth performance of quail and observed a significant improvement in body weight gain in favour of the treatment group. Furthermore, Shehata (2000) and Abd El-Maksoud (2006) reported that egg weights were significantly enhanced by enzyme inclusion at the level of 1.0 g/kg diet even though enzyme supplementation in this present study was up to 2 g/kg. Other studies
with laying hens revealed a significant improvement in egg mass among different laying hen strains when diets were supplemented with enzymes (Sohail et al. 2003). Mohammed et al. (2010) observed in their study that phytase (one of the components of Maxigrain) inclusion at levels of 1.0, 1.5, 2.0 and 2.5 g/kg diet significantly enhanced average egg mass during the entire laying egg period by 0.25%, 4.14%, 5.63% and 4.16%, respectively, and this phytase enzyme was also a major component of the tested multienzyme product used in the present study.

Table 3 External egg characteristics of laying quails fed diet containing varying levels of Maxigrain for 56 days.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Treatments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T1</td>
</tr>
<tr>
<td>Egg length (mm)</td>
<td>30.13</td>
</tr>
<tr>
<td>Egg diameter (mm)</td>
<td>11.29</td>
</tr>
<tr>
<td>Egg shape index (%)</td>
<td>77.39</td>
</tr>
<tr>
<td>Egg shell weight (g)</td>
<td>1.25c</td>
</tr>
<tr>
<td>Egg shell thickness (mm)</td>
<td>0.23b</td>
</tr>
</tbody>
</table>

a, b, c Means on the same row with different superscript are significantly different (P < 0.05), T1: 0 g of Maxigrain kg⁻¹ diet, T2: 0.5 g Maxigrain kg⁻¹ diet, T3: 1 g Maxigrain kg⁻¹ diet, T4: 1.5 g Maxigrain kg⁻¹ diet, T5: 2 g Maxigrain kg⁻¹ diet

Table 4 Egg lipid profile laying of quails fed diet containing varying levels of Maxigrain for 56 days.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Treatments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T1</td>
</tr>
<tr>
<td>Cholesterol (mg/dL)</td>
<td>139.07</td>
</tr>
<tr>
<td>Triglycerides (mg/dL)</td>
<td>124.02</td>
</tr>
<tr>
<td>High density lipoprotein (mg/dL)</td>
<td>114.38</td>
</tr>
<tr>
<td>Low density lipoprotein (mg/dL)</td>
<td>0.44</td>
</tr>
</tbody>
</table>

T1: 0 g of Maxigrain kg⁻¹ diet, T2: 0.5 g Maxigrain kg⁻¹ diet, T3: 1 g Maxigrain kg⁻¹ diet, T4: 1.5 g Maxigrain kg⁻¹ diet, T5: 2 g Maxigrain kg⁻¹ diet.

Figure 4 Egg shell weight and thickness of laying quail fed diets containing varying levels of Maxigrain for 56 days.

However, the observed improvement in the average body weight gain, egg weight, egg mass and hen-day egg production in favor of the treatment group could be linked to the positive effect of enzymes on body metabolic processes. Maxigrain® enzymes can digest many substrates for proper utilization and thus support various physiological activities for improved weight gain and egg trait performance. To improve the digestion of nutrients in monogastric animals such as poultry, especially when high-fibre diets are used, enzyme application becomes a significant key to modifying the intestinal microflora and subsequently changing the structural morphology of the intestinal villi (Souza et al. 2014; Yadav and Jha, 2019) for improved nutrient absorption. Enzyme inclusion enhances nutrient digestibility (Kheravii et al. 2018; Zarghi, 2018; Raza et al. 2019) and improves poultry production (Sateri et al. 2017) and egg quality (Ceylan and Cufadar 2018). Therefore, the improvement in the values of egg weight, body weight gain, egg mass and hen-day egg production observed in the present study could be attributed to the beneficial roles of enzymes in feed digestion, nutrient absorption and utilization. Multisubstrate enzymes such as Maxigrain used in this study cause efficient feed utilization for improved egg traits and growth performance. Enzymes...
breakdown NSPs, decrease the viscosity of the intestine, and improve nutrient digestibility by enhancing gut performance (Amerah, 2015). Better gut performance will culminate in better utilization of the digested nutrient with an eventual positive effect on egg performance traits. Enzymes cause the disruption of plant cell wall integrity and the resultant release of encapsulated nutrients by the cell wall (Ravindran, 2013). Values for average daily feed intake in this present study did not differ by Maxigrain supplementation, which was similar to the findings of Ghazalah et al (2011), Chimote et al (2009) and Abd El-Hack et al (2015), who did not record a significant impact on the measured variable when an enzyme complex such as Maxigrain was added to the laying hens' diet as a supplement. In contrast, Abo El-Maaty (2015) found that adding Bio-Feed® Pro enzyme to the diet considerably boosted the overall feed intake of quail. This variation may be due to the different enzyme mixes and combinations of feed items employed by both authors. Additionally, it is well known that the performance responses to exogenous enzymes in many chicken species have been inconsistent and depend on a variety of circumstances, including the age of the birds and the quality or kind of feed employed (Tufarelli et al 2007; Lee et al 2014; Sateri et al 2017). Egg quality traits recorded in control (T1) and in T2 with the least amount of enzyme supplementation could be linked to increased viscosity in the intestine and poor digestibility of feed as a result of absence or poor enzyme supplementation that was not capable enough to trigger proper feed digestibility, absorption and utilization of various components of feed for improved egg trait performance.

Table 3 and Figure 4 show the outcomes of the exterior egg features of laying quails fed diets containing various amounts of Maxigrain for 56 days. Only the values for shell weight and shell thickness within the treatment groups were significant (P < 0.05) among all the exterior egg variables assessed. In keeping with the present research findings, other researchers found that feeding laying chickens an enzyme complex increased the weight and thickness of their egg shells (Attia et al 2012). Additionally, it has been found that Maxigrain can maximize the usage of some unusual feed ingredients, including cassava peel meal, by promoting weight increase, litter quality, feed conversion ratio, egg production, and shell quality (Duru and Dafwang, 2010; Ademola et al 2012). The increase in egg shell weight and thickness resulting from the increased level Maxigrain (T4-T5) in the diet could be related to the amplified accessibility and use of nutrients, especially energy, calcium and phosphorus, by enhancing the digestibility of consumed diets, as observed by earlier researchers (Abudabos 2012; Nourmohammadi et al 2012; Sun and Kim, 2019).

The results of the exter nal egg characteristics of laying quail fed diets containing varying levels of Maxigrain for 56 days are shown in Table 3 and Figure 4. Among all the external egg variables measured, only the shell weight and shell thickness values were significant (P < 0.05) among the treatment groups. In agreement with the present study, some researchers revealed that the eggshell thickness and weight of laying hens were improved due to feeding with an enzyme complex (Attia et al 2012). Furthermore, Maxigrain has been identified to optimize the use of some unconventional feed ingredients, such as cassava peel meal, by enhancing weight gain, litter quality, feed conversion ratio and egg production as well as shell quality (Duru and Dafwang, 2010; Ademola et al 2012).

Additionally, the presence of exogenous phytase (a significant enzyme component of Maxigrain) in the diet may have had a direct impact on the strength and thickness of egg shells in laying chickens through enhanced utilization of calcium and phosphorus in this study's increase in egg shell quality (Lima et al 2011; Rossetto et al 2019). Additionally, Shet et al (2018) found that better phosphorus and calcium availability resulted from increased bioavailability of phosphorus caused by phytate-phosphorus release as a result of phytase activity in the gastrointestinal tract, supporting the increase in egg shell quality in favor of the treatment group by revealing that egg-producing birds' egg weight, shell weight, and shell thickness were maintained. In contrast with the findings of this research, Abd El-Maksoud (2006) reported that Kemzyme® supplementation did not significantly affect the relative shell weight in laying hens. Additionally, Aderemi et al (2006) and Abd El-Maksoud (2006) stated that enzyme inclusion did not affect egg shell thickness.

Table 4 and figure 5 demonstrate the outcomes of the egg lipid profile of laying quail fed diets containing various amounts of Maxigrain for 56 days. Many people today are concerned about their health and actively seek balanced diets to prevent and treat health issues (Cherian, 2015; Lee et al 2019). Demand from consumers for meat and egg products that prioritize animal welfare during production as well as product safety and quality has increased over the past ten years (Hammershoj and Johansen, 2016). Because it greatly enhances overall chicken productivity and performance and protects the health of birds, suitable supplementation of poultry diets with beneficial feed additives is becoming more important. as it significantly improves overall poultry production and performance and safeguards the health of birds (Dhama et al 2015; Laudadio et al 2015). Manipulating the diet of laying hens by including diverse additives that can modify the lipid profile of eggs is of paramount importance. In this research, dietary treatment did not have an effect on the lipid variables measured.

The results of the internal egg characteristics of quail fed a diet containing various levels of Maxigrain for 56 days are shown in Table 5 and Figure 5. Yolk weight values significantly increased after the treatment. In contrast, research by Kaankuka et al (2012), Deniz et al (2013), and Yaşlan et al (2015) found that the internal and exterior egg quality features of laying birds were unaffected by dietary enzyme complexes. However, the increased yolk weight observed in this study could be attributed to the addition of enzymes, which helped in nutrient digestion, absorption, and utilization. When Maxigrain is consumed, the weight of egg yolks increases, which may be related to the increased availability and use of nutrients, particularly energy,
calcium, and phosphorus. by improving the digestibility of ingested diets, as revealed by some researchers (Abudabos 2012; Kim 2019).

5. Conclusions

From the results of this study, the utilization of Maxigrain® had a positive effect on bird performance and egg quality characteristics. Supplementation of multienzymes at 2 g/kg diet had the highest improvement in the entire variable determined in the quail and therefore was recommended for use by quail-producing farmers for improved egg quality.

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Ethical Considerations

The experiment was carried out according to the provisions of the Ethical Committee on the use of animals and humans for biomedical research of the University of Nigeria, Nsukka, Enugu, Nigeria.

Conflict of Interest

The authors declare no competing interest.

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