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# Egg Production and Quality Indices of Quails Fed Tumeric-Garlic Supplemented Sorghum Diets

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**ABSTRACT**
The present study was set up to investigate the replacement of maize with sorghum and its fortification by garlic and turmeric in quail diets to observe its effect on egg production and its qualities. A total of 640, six-weeks old adult quails comprising 40 quails per group were used at this phase in a mating ratio of 1:4 (4 cocks to 32 hens). They were arranged in a randomized complete block design in a 3 × 5+1 factorial experiment. To fortify the sorghum-based diets, turmeric and garlic meals were combined at five (5) different levels of: 0, 0.25, 0.50, 0.75 and 1.00 %) and three (3) (0, 0.50 and 1.00%) levels, respectively, and added with the sorghum diet consisting of 15 combination groups. Data were collected on egg laid per day, feed intake, feed conversion ratio, egg mass, hen day production, egg external qualities and internal qualities. The result showed that maize was superior to sorghum in total eggs laid, total egg weight, eggs laid/day, hen day egg % and egg mass. However, garlic, turmeric and their interactions were significant ($p<0.05$) for total feed intake, total eggs laid, total egg weight and egg laid per day. Birds fed 0.25 % turmeric plus 0.50 % garlic performed poorly for most of the parameters under egg performance. Results for both internal and external egg quality parameters were not significantly ($p>0.05$) influenced by the energy source neither the turmeric and garlic supplementation. Eggs performance of quails fed 0.50 % garlic and 1.00 % turmeric sorghum-based diet (T10) compared favourably with those given maize. Apart from in shell weight and thickness, egg quality parameters were better in eggs fed sorghum, and sorghum supplemented with garlic and turmeric diets than in eggs of quails fed Maize (control) diet. Thus, sorghum bio-fortified with turmeric-garlic can replace maize in quail diets with no deleterious effect on egg production and qualitative traits.

**KEYWORDS:** Quails, maize, sorghum, turmeric, garlic, egg production, egg quality.

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## INTRODUCTION

Quails are noted to possess several benefits over other poultry such as early maturity, excellent laying capacity, low feed consumption, low floor space requirements, high immunity against diseases, relatively low meat fat content, and a high nutritive and medicinal value of the eggs (Shanaway, 2008) and this has led to its popularity amongst consumers.

However, sustainable intensification of the quail relies on the cost of dietary ingredients used during feed formulations (Mnisi *et al.*, 2023). Maize constitutes the largest component in conventional poultry diets formulated and is usually over-relied upon. The utilization of less expensive energy feedstuffs such as millet or sorghum would reduce this over-reliance and competition with man which in turn lowers feed costs. Sorghum has been touted to be a good source of energy, vitamins, minerals, secondary plant compounds (phytosterols), and antioxidant phenolic compounds (Okarter and Liu, 2010). Desirable results have been reported by some authors regarding the incorporation of sorghum in the diets of other poultry species (Odo and Nnadi, 2013; Almeida *et al.*, 2020). Unfortunately, their feed value is largely unknown for the quail when fortified with additives.

The reproductive indices of laying birds include egg performance (number of eggs laid); external characteristics (egg weight, egg length, shell weight, shell thickness and shell diameter) and internal characteristics (albumin weight, albumin width, albumin height, yolk weight, yolk length and yolk width) of eggs (Sathya and Murugaian, 2015). Egg quality is of high economic value to the poultry industry. This is because poor egg quality decreases the value, production, and consumer acceptance of eggs, and reduces hatchability, quantity and quality of processed egg and egg products (Abdelqader *et al.*, 2013). According to Sari *et al.* (2016), nutrition is a major factor that affects egg production and quality, especially the hatchability and fertility of eggs, quality of the chicks hatched and their growth and survival rates (Zaheer, 2015).

The egg is a major source of protein for humans. They contain many essential nutrients which make them an important part of human diet (Forson *et al.*, 2011). This high nutrient content, low caloric value and easy digestion make them valuable in many therapeutic diets for adults (Okonko *et al.*, 2019). Japanese quail eggs are rich sources of anti-oxidants, vitamins and minerals and their nutritional value is much higher than those of other egg-types regardless of size (Tunsaringkarn *et al.*, 2013).

Fafiolu *et al.* (2006) reported an average hen-day production of 84.39 percent while Emenalom *et al.* (2007) reported an average percentage production of 76.38 percent for laying hens fed graded level of brewers' dry grain. Behnamifar *et al*. (2015) also reported hen-day production ranging from 66.10-69.25 percent for Japanese quails fed herbal mixtures.

Egg production increased when Japanese quails were fed different concentrations of treated probiotic and medicinal plant powder (Sathya and Murugaian, 2015). Gumus *et al*. (2018) also reported improved egg production on 0.50 percent turmeric inclusion in the diet of laying hens. Feed intake, final live body weight and body weight changes of laying Japanese quails increased significantly with increasing ginger root meal levels over control (Abd El-Galil and Mahmoud, 2015) and when fed diets of mixed probiotic and medicinal plant (Sathya and Murugaian, 2015). Behnamifar *et al*. (2015) reported increased feed intake and egg mass in Japanese quails fed herbal mixture of thyme, caraway and garlic, with garlic having the highest level. Dhalal *et al.* (2018) also reported that addition of turmeric at 0.50 or 1 % significantly increased the egg mass when compared with the control diets.

The efficiency of conversion of feeds to eggs is associated with egg production and size which is expressed in kilogram of feed per dozen eggs or as a ratio of the kilogram of feed to kilogram of eggs (Oluyemi and Roberts, 2000). Efficient utilization of feed is the key factor affecting profitability of egg production and has significant positive relationship with the hen-day production. The standard of this measurement according to Oluyemi and Roberts (2000) is 1.8 kg of feed per dozen eggs. Laying Japanese quails fed 0.50 g/kg ginger root meal recorded the best feed conversion ratio over the control diet (Abd El-Galil and Mahmoud, 2015), while Sathya and Murugaian (2015) reported decreased feed conversion ratio when Japanese quails were fed a mixture of probiotic and medicinal plant.

According to Ogunwole *et al.* (2015), the external and internal characteristics of eggs are reflected both in the quality and size of the egg. The quality of an egg affects its acceptability to consumers and management and other factors influence egg quality parameters (King'ori, 2012). Abd El-Galil and Mahmoud (2015) recorded a non-significant effect of ginger root meal on egg yolk and shell thickness percentage; decreased levels of albumen and yolk index as ginger root meal increased and increased eggshell percentage and egg shape index as ginger root meal increased. Behnamifar *et al*. (2015) reported that supplementation of herbal extracts in Japanese quails' diets had no significant effect on shell thickness, Haugh unit, yolk weight and shell strength.

Literature is evident on the effect of these plant sources utilized singly and their effects have been varied, therefore the combination of, turmeric and garlic, the two necessitated this research. This study aims to evaluate the effect of replacing maize with sorghum, as an energy source, in the diets of quails, fortified with garlic and/or turmeric, on their egg production performance. By exploring the synergistic benefits of these feed components, the research seeks to provide insights into sustainable and effective quail nutrition strategies of utilizing both phytobiotic sources.

## MATERIALS AND METHODS

### Location of the study

The field study was carried out at the Poultry Unit of the Teaching and Research Farm, University of Calabar, Calabar, Cross River State, Nigeria. Calabar is located within the tropical rain forest zone of Nigeria and has a land area of 406m$^2$. Calabar lies between latitude 4.96$^0$N of the Equator and longitude 8.34$^0$E of the Greenwich meridian. Its relative humidity is between 55 and 90 % with an elevation above sea level of 62.30 meters (Google Earth, 2020; Ewona and Udo, 2011). The annual temperature and rainfall ranges between 25$^0$ and 30$^0$C and 1260 and 3500 mm respectively (Okon and Njoku, 2017).

### Sourcing, processing of test ingredients and experimental diets

Turmeric (*Curcuma longa*) rhizomes and garlic (*Allium sativum*) bulbs were purchased from Watt market in Calabar South Local Government Area of Cross River State, Nigeria. Turmeric rhizomes were washed, cut into pieces and sun dried till they became crispy. Subsequently, they were milled using a manual grinder and sieved with a 1mm mesh to obtain turmeric rhizome powder.

Garlic bulbs were cut into very thin pieces and sun dried to constant weight for three days. They were thereafter oven dried at 180 $^0$C (SAISHO S-196 model hot oven) until very crispy and then milled immediately using a manual grinder while still hot to enable grinding due to its sticky nature, to form the garlic powder. The milled samples of turmeric and garlic meals were then stored in dry, airtight containers to avoid contamination and infestation by molds until needed for feed formulation. The proximate composition of turmeric and garlic were determined using AOAC (2006) methods.

Experimental diets were formulated to meet the nutrient requirements of Japanese quails, such that:

i. Two basal diets were formulated: Maize diet as positive control and Sorghum diet as test diet (Table 1) to compare the replacement value of maize by sorghum at 100% level.
ii. To fortify the sorghum-based diet for improved utilization, and determine its efficacy in quails, turmeric and garlic meals were combined at five (5) different levels such as 0, 0.25, 0.50, 0.75 and 1.00 %) and three (3) (0, 0.50 and 1.00%) levels, respectively, and added with the sorghum diet consisting of 15 combination groups as follows:

Ma: Positive control basal diet (Maize);
T1: Negative control basal diet (Sorghum)
T2: T1 Diet + 0.25% turmeric
T3: T1 Diet + 0.50% turmeric
T4: T1 Diet + 0.75% turmeric
T5: T1 Diet + 1.00% turmeric
T6: T1 Diet + 0.50% garlic
T7: T1 Diet + 0.50% garlic and 0.25% turmeric
T8: T1 Diet + 0.50% garlic and 0.50% turmeric
T9: T1 Diet + 0.50% garlic and 0.75% turmeric
T10: T1 Diet + 0.50% garlic and 1.00% turmeric
T11: T1 Diet + 1.00% garlic
T12: T1 Diet + 1.00% garlic and 0.25% turmeric
T13: T1 Diet + 1.00% garlic and 0.50% turmeric
T14: T1 Diet + 1.00% garlic and 0.75% turmeric
T15: T1 Diet + 1.00% garlic and 1.00% turmeric

Therefore, a total of 16 dietary groups were studied. The experimental diets were formulated to meet the nutrient requirement of Japanese quails during the growth and laying phases according to NRC (1994). Feed and water were offered *ad libitum.*

**Experimental animals and management**

Nine hundred and sixty (960), one-week old unsexed Japanese quail chicks purchased from the National Veterinary Research Institute (NVRI), Vom in Plateau State, Nigeria were used in the study which lasted for a period of sixteen (16) weeks. The birds were managed on deep litter system according to the Federation of Animal Science Societies' Principles of Animal Care in experimentation set (Craig *et al*., 1999) and no prophylactic therapy was administered throughout the research period. For the feeding trial, during the growth phase, there were sixteen (16) groups of sixty (60) birds each. Each group was sub-divided into three (3) replicates of twenty (20) birds each.

A total of 640, six-weeks old adult quails comprising 40 quails per group were used at the laying phase. At the end of the growth phase, sex identification within groups was conducted by vent examination technique (Ottinger, 2005) such that a mating ratio of 1:4, as recommended by Narinc *et al*. (2013) was maintained. Therefore, thirty-two (32) hens and eight (8) cockerels were selected from each treatment population. The birds were fed layer diets (Table 1) and managed under similar experimental protocol as at the growing period. To investigate the efficacy of turmeric and garlic in laying quails, some reproductive fitness and physiological endpoints were assayed.

**Table 1: Gross composition of sorghum and maize basal diets for Japanese quails**

| | Chick diet | | Grower diet | | Layer diet | |
|---|---|---|---|---|---|---|
| Ingredient (%) | Maize | Sorghum | Maize | Sorghum | Maize | Sorghum |
| Maize | 41.00 | 0.00 | 40.00 | 0.00 | 42.00 | 0.00 |
| Sorghum | 0.00 | 41.00 | 0.00 | 40.00 | 0.00 | 42.00 |
| Soya bean | 42.00 | 42.00 | 38.00 | 38.00 | 40.00 | 40.00 |
| Wheat offal | 6.00 | 6.00 | 7.00 | 7.00 | 5.00 | 5.00 |
| Crayfish dust | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| PKC | 4.00 | 4.00 | 8.00 | 8.00 | 4.00 | 4.00 |
| Palm oil | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| DCP | 3.00 | 3.00 | 3.00 | 3.00 | 3.50 | 3.50 |
| Limestone | 0.00 | 0.00 | 0.00 | 0.00 | 1.50 | 1.50 |
| Methionine | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| Lysine | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| Salt | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| Premix* | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Total | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| **Calculated nutrients (%)** | | | | | | |
| Crude protein | 25.05 | 25.87 | 24.08 | 24.88 | 24.10 | 24.94 |
| Crude Fibre | 5.94 | 3.89 | 6.22 | 4.22 | 5.75 | 3.65 |
| Calcium | 1.24 | 1.25 | 1.24 | 1.25 | 1.93 | 1.94 |
| Energy (Kcal/Kg) | 3116.20 | 3075.20 | 3056.90 | 3016.90 | 3065.50 | 3023.50 |

*Premix=Vitamin A 12,000,000 i.u., Vitamin D3 2,500,000 i.u., Vitamin E 30,000 i.u., Vitamin K 2,000mg, Vitamin B1 2,250mg Vitamin B2 6,000mg, Vitamin B6 4,500mg, Vitamin B12 15mg, Niacin 40,000mg, Pantothenic Acid 15,000mg, Folic Acid 1,500mg, Biotin 50mg, Choline chloride 300,000mg, Manganese 80,000mg, Zinc 50,000mg, Iron 20,000mg, Copper 5,000mg, Iodine 1,000mg, Selenium 200mg, Cobalt 500mg and Antioxidants 125,500mg. PKC=Palm Kernel Cake, DCP=Dicalcium Phosphate.

**Feed intake**

A weighed amount of feed was offered to each group of birds in the morning (07:00 – 08:00) and evening (17:00 – 18:00) hours daily. Daily feed intake per group was determined by weighing of the feed offered (g) and the leftover (g) the next morning and finding the difference. Water was given *ad libitum*. Feed intake (g/b/d) = feed supplied – feed refused or leftover.

**Egg collection**

Eggs collected daily were counted, weighed and used to determine total eggs laid and egg weight for each group.

**Hen-Day egg production (%)**

Hen-day production was calculated as $\frac{\text{Total No. of eggs laid}}{\text{No. of birds} \times \text{days}} \times 100$

**Egg mass (g)**

Egg mass was calculated as % hen-day egg production (HDEP) × egg weight (g)

**Feed/dozen eggs (g)**

This was calculated weekly as feed conversion ratio (FCR) (per dozen eggs) =

$$\frac{\text{Kg of feed consumed}}{\text{Total eggs produced}} \times 12$$

**Feed conversion ratio (FCR)**

Feed conversion ratio (FCR) = $\frac{\text{Feed consumed}}{\text{Eggs produced}}$

**Egg quality traits**

At 15 weeks of age, 20 eggs were randomly taken from each group and used to evaluate egg quality. Internal and external egg qualities were measured by methods described by (Adikari *et al.,* 2016).

**External egg qualities**

Egg weight: Each egg was weighed using an electronic sensitive scale. Egg diameter and length were measured using a Venier Caliper. Egg diameter was measured at three points; on the blunt end, equatorial region and at the pointed end.

Egg Shell weight: Eggs were broken; shells washed and cleaned of clinging albumin and dried in room temperature and weighed. Shell weight (with membrane) was measured using a laboratory scale and the percentage proportion of the shell in the egg was determined (Hanusova *et al.,* 2015).

Egg shell thickness: egg shell thickness including shell membrane were measured at three points; on the end, equatorial region and at the pointed end using a Micrometer Screw Guage (PM 025, Draper Tools Ltd., Eastleigh, UK). These measurements were recorded as mean of pooled values (Oke *et al.,* 2014).

**Internal egg qualities**

For studying the effect of diet on internal egg quality (following external quality assessment), the 20 representative eggs per treatment were individualy broken into flat plates and seperated into albumen, yolk and egg shell. Albumen weight and yolk weight were measured using an electronic scale. Yolk height and width were measured using a Venier Caliper.

**Statistical design and analysis**

The design was a randomized complete block design in a factorial arrangement. Data collected were subjected to a two-way analysis of variance (ANOVA). Analyses were performed using the Genstat (2011) software. Where significant, Duncan multiple range test was used to separate means.

## RESULTS AND DISCUSSION

The egg performance of quails fed turmeric-garlic sorghum diets is summarized in Table 2. Results showed that total feed intake, total eggs laid, average egg weight, total egg weight, eggs laid daily, hen day egg, egg mass and feed/dozen eggs were significantly influenced (P<0.05) by turmeric and garlic supplementation either individually or in their interactions. Layers on the maize diet had higher total feed intake (1729.00g) compared to feed intake of 1696.88g from layers fed sorghum diet. The highest total feed intake was recorded by layers on T11 fed sorghum supplemented with 1.00 percent garlic while layers on T14 fed sorghum supplemented with 1.00 percent garlic and 0.75 percent turmeric had the lowest feed intake. Feed intake may have increased due to the enhanced taste or aroma by the addition of garlic. This submission agreed with that of Gumus *et al*. (2018) who had reported that increased feed intake in laying hens fed turmeric and sumac may have been as a result of turmeric's special aroma. This aroma resulted from volatile essential oils found in turmeric. Apparently, sorghum was capable of replacing maize in quail diets favourably as observed in its feed intake. The synergistic profound effect of garlic and turmeric in feed intake cannot be wished away as seen in diets T10 and T12 (1697.50 g) of sorghum based diet with garlic at 0.50 % and 1.00% fortification together with turmeric at 1.00% and 0.25% respectively. Profound effect was however not felt at the fortification mixture of 0.75% turmeric and 1.00% garlic. This observation agreed with the findings of Kroismay *et al*. (2006) who attributed the increase in voluntary feed intake resulting in improved weight gain to the flavour and palatability of feed which could have been enhanced by the synergistic effect of the combined aromatic essential oils. The significant decreased in feed intake as observed for turmeric fortified diets could be attributed to the active ingredients present in the turmeric (curcumin), resulting in the change of aroma, palatability, and taste of feed (Suwarta and Suryani, 2019).

**Table 2: Egg performance of quails fed turmeric–garlic sorghum diets**

| Parameters | MA | T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 | T9 | T10 | T11 | T12 | T13 | T14 | T15 | P values | | | SEM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | | G eff. x T | T eff. | G | |
| Daily FI (g/d) | 24.70 | 24.24 | 20.27 | 24.67 | 24.52 | 23.87 | 22.33 | 22.12 | 21.11 | 23.49 | 24.25 | 26.23 | 24.25 | 23.67 | 20.05 | 21.56 | 0.6432 | 0.9592 | 0.9133 | 1.41 |
| Total FI (g) | 1729.00 | 1696.80 | 1418.90 | 1726.90 | 1716.90 | 1670.90 | 1563.10 | 1548.40 | 1477.70 | 1644.30 | 1697.50 | 1836.10 | 1697.50 | 1656.90 | 1403.50 | 1509.20 | 0.0015* | 0.0008* | 0.0038* | 21.23 |
| Tot eggs laid | 719.00 | 525.00 | 470.00 | 492.00 | 468.00 | 397.00 | 374.00 | 225.00 | 379.00 | 570.00 | 615.00 | 615.00 | 554.00 | 498.00 | 406.00 | 379.00 | 0.0055* | 0.0018* | 0.0013* | 1.25 |
| Ave Egg Wt (g) | 10.84 | 12.33 | 11.33 | 9.83 | 10.67 | 10.33 | 11.00 | 10.50 | 10.33 | 10.67 | 10.67 | 10.83 | 10.50 | 12.00 | 10.17 | 9.50 | 0.0383* | 0.0026* | 0.0009* | 1.02 |
| Tot egg wt (g) | 259.80 | 215.78 | 177.50 | 161.21 | 166.45 | 136.70 | 137.13 | 78.75 | 130.50 | 202.30 | 218.74 | 222.02 | 193.90 | 199.20 | 137.63 | 119.07 | 0.0032* | 0.0142* | 0.0002* | 1.36 |
| Eggs laid /day | 17.00 | 13.00 | 12.00 | 13.00 | 13.00 | 13.00 | 11.00 | 9.00 | 13.00 | 15.00 | 17.00 | 15.00 | 15.00 | 14.00 | 11.00 | 10.00 | 0.0001* | 0.0410* | 0.0004* | 0.25 |
| Hen Day Egg (%) | 56.67 | 43.33 | 40.00 | 43.33 | 43.33 | 43.33 | 36.67 | 30.00 | 43.33 | 50.00 | 56.67 | 50.00 | 50.00 | 46.67 | 36.67 | 33.33 | 0.0023* | 0.4225 | 0.0211* | 1.54 |
| Egg Mass (g) | 6.14 | 5.34 | 4.53 | 4.26 | 4.62 | 4.48 | 4.03 | 3.15 | 4.48 | 5.34 | 6.05 | 5.42 | 5.25 | 5.60 | 3.73 | 3.17 | 0.1423 | 0.2111 | 0.0321* | 0.06 |
| Feed/ Dozen eggs (g) | 28.86 | 38.78 | 36.23 | 42.12 | 44.01 | 50.51 | 50.15 | 82.58 | 46.79 | 34.62 | 33.12 | 35.83 | 36.77 | 39.93 | 41.48 | 48.17 | 0.0021* | 0.1111 | 0.0011* | 1.58 |
| Feed Efficiency | 2.40 | 3.23 | 3.02 | 3.51 | 3.51 | 4.21 | 4.18 | 6.88 | 3.90 | 2.88 | 2.76 | 2.99 | 3.06 | 3.33 | 3.46 | 4.01 | 0.4111 | 0.2365 | 0.0933 | 1.54 |

* Significant (p< 0.05) differences between treatments. SEM = Standard error of mean.

Ma: Positive control basal diet (Maize); T1: Negative control basal diet (Sorghum); T2: T1 Diet + 0.25% turmeric; T3: T1 Diet + 0.50% turmeric; T4: T1 Diet + 0.75% turmeric T5: T1 Diet + 1.00% turmeric; T6: T1 Diet + 0.50% garlic; T7: T1 Diet + 0.50% garlic and 0.25% turmeric; T8: T1 Diet + 0.50% garlic and 0.50% turmeric; T9: T1 Diet + 0.50% garlic and 0.75% turmeric; T10: T1 Diet + 0.50% garlic and 1.00% turmeric; T11: T1 Diet + 1.00% garlic; T12: T1 Diet + 1.00% garlic and 0.25% turmeric; T13: T1 Diet + 1.00% garlic and 0.50% turmeric; T14: T1 Diet + 1.00% garlic and 0.75% turmeric; T15: T1 Diet + 1.00% garlic and 1.00% turmeric.

Total FI – Total Feed Intake; Tot eggs laid – Total eggs laid; Ave Egg Wt – Average Egg Weight; Tot eggs wt – Total eggs weight.

Quails on Maize diet recorded a higher total eggs laid (719) when compared with Sorghum (T1) diet of 525 eggs laid. The fortified sorghum diets (T10 and T11) could not compare with Maize diet fed Quails (719 vs 615) on total eggs laid but was higher than that of diet T7 (225). At a higher garlic inclusion (1%), increased levels of turmeric (T12-T15) resulted in reduction of total eggs laid while at 0.50% garlic increased turmeric levels elicited an increase in eggs laid. Garlic effect was felt in diet T11 and was similar with that of T10. Garlic effect could be attributed to the increased feed intake which in-turn boosted the egg laying ability. Quails fed maize diet laid 17 eggs daily while quails fed sorghum diet laid 13 eggs daily. T10 birds fed sorghum supplemented with 0.50 percent garlic and 1.00 percent turmeric laid the highest number of eggs daily (17) while birds on T7 fed sorghum supplemented with 0.50 percent garlic and 0.25 percent turmeric laid the lowest number of eggs daily (9.00).

The findings from this study disagrees with those of several authors who reported an increase in egg production in different levels of turmeric supplementation (Gumus *et al.*, 2018; Liu *et al.*, 2020) and that the increasing levels of turmeric extract in the drinking water increased the hen-day egg production of laying quail. Apparently, the decrease in egg production in laying quails supplemented with turmeric rhizome powder is most likely due to reduced feed consumption. It has been stated that higher feed intake of laying quail increases nutrient consumption, particularly protein intake (Mirzah and Djulardi, 2019). Hence, reduced feed consumption will also reduce the available nutrients for egg production (Liu *et al.*, 2020). However, the result of this study is similar to the investigation of Liu *et al.* (2020) that supplementation of turmeric at higher levels decreased the egg production of the layer chicken.

Birds on the maize diet and those on T10 (sorghum diet supplemented with 0.50 percent garlic and 1.00 percent turmeric) had the highest hen day egg production (56.67%) while T7 birds fed sorghum supplemented with 0.50 percent garlic and 0.25 percent turmeric had the lowest hen day egg production of 30.00 percent. Radwan *et al.* (2008) reported that supplementation of layer diets with turmeric meal at 5g/kg increased percentage hen day production. Gumus *et al.* (2018) reported that inclusion of at least 0.50 percent turmeric in laying hens' diet improved egg production. However, the egg production percentage of the current study is lower than the report of Mirzah and Djulardi (2019) that quails supplemented with turmeric extract have 79.99% hen-day egg production. Turmeric had no effect on hen day percentage but garlic and the interaction of garlic and turmeric altered the means. The lowered total eggs laid affected the hen day production as a result of phytobiotic effect on feed intake, available nutrients (Liu *et al.*, 2020) and probably the stimulatory egg laying ability in the quails. A heightened combined effect was noted for birds on T10.

Reddy *et al.* 1991; Lim *et al.* 2006) found that garlic products had no effect on egg weight. These differences may be due to the use of different commercial garlic products and the preparation methods of garlic powder.

The highest egg mass (6.05 g) was from T10 birds fed sorghum supplemented with 0.50 percent garlic and 1.00 percent turmeric, though similar with those of Maize based diet (6.14g). Yalcin *et al.* (2006) reported that egg weight increased significantly ($p<0.01$) when laying hens were fed 5 and 10 g/kg garlic powder supplementation. This study however shows significant decrease in egg weight and is in line with findings of Park *et al*. (2012). These different results could arise from the use of different garlic sources, methods of preparation of garlic powder, and strains or age of layers used in the experiments. The interaction effect was felt at 0.50 % inclusion of garlic, whereby increased levels of turmeric resulted in increase of the egg mass. Pradikta *et al*. (2018) had reported that the value of egg mass increases as the amount of probiotics for laying hens increases. Probiotics acts in the small and large intestines to suppress pathogenic bacteria and stimulate the growth and activity of beneficial bacteria in the intestine, which can increase nutrient absorption (Mas'ad *et al.*, 2020). In this study, garlic seemed to perform the role of a probiotics in improving the egg mass.

The average egg weight was affected by garlic, turmeric and their interactions. However, the average egg weight observed in this study was slightly above the value of 9.75g/egg observed by Tuleum *et al*. (2013) for laying quails fed with a diet consisting of 20%crude protein was 9.75g/egg. This result is also similar to that obtained by Al-Daradji *et al*. (2010), who showed that laying quails supplemented with up to 6% linseed in the diet produced an average egg weight ranging from 9.40 - 11.13 g/egg. Sorghum diet seemed to increase the weight when compared with Maize based diet (12.33 vs 10.84 g).

The feed efficiency was not significantly affected by dietary treatments over the 21 weeks period. These results demonstrated that the strong odour of garlic does not act as a deterrent to feeding. In agreement with the present study, some researchers (Reddy *et al.*, 1991; Yalçın *et al.*, 2006) reported that egg production and feed efficiency of laying hens were not significantly affected by dietary garlic supplementation. The feed conversion ratio was computed based on the feed consumed per weight of eggs laid. Maize (control) fed birds had the best feed efficiency compared to other treatments while birds on T7 recorded the worst. The result from this study disagreed with the submission of Radwan *et al*. (2008) and Durrani *et al*. (2006) who reported that 2g per kg and 5g/kg of turmeric powder in the diet had a beneficial effect on egg mass production and it improved the feed conversion ratio. These results may be due to differences in feed consumption and egg mass caused by the phytobiotic fortification of the diet, which might have improved feed utilization efficiency (Suwarta and Suryani, 2019) numerically. Further, the relationship between feed consumption and egg mass is determined by feed conversion, and low feed conversion values indicate better feed use efficiency.

**Egg quality parameters of quails fed turmeric-garlic sorghum diets**

The result of egg quality of quails fed turmeric – garlic sorghum diets is summarized on Table 3. Results showed that both internal and external egg quality parameters were not significantly ($p>0.05$) influenced by turmeric and garlic supplementation. A study by Freitas *et al.* (2014) observed that feeding Japanese quails with either white or red sorghum as replacements for maize grain, did not influence egg production, egg mass and egg yolk colour. Abd El-Galil and Mahmoud (2015) recorded a non-significant effect of ginger root meal on egg yolk and shell thickness percentage while Saraswati and Tana, (2016) observed no significance on physical qualities of both interior and exterior Quail eggs fed turmeric at 54 and 108 mg/bird/day. Behnamifar *et al*. (2015) reported that supplementation of herbal extracts in Japanese quails' diets had no significant effect on shell thickness, Haugh unit, yolk weight and shell strength. On the contrary, Suwarta and Suryani (2019) claimed that supplementation of 40g/kg of turmeric + 40g/kg of cinnamon in the Japanese quail diets significantly improved the eggshell weight. Contradicting results in the Japanese quails' eggshell weight might be due to the different doses of turmeric rhizome powder supplemented in the diet, duration of the experiment period, and animal age.

Eggs from T1 fed sorghum without garlic and turmeric had the heaviest eggs (12.33g) numerically when compared to 10.84g from eggs fed maize diet and other treatments. Egg diameter (24.27mm) and length (33.20 cm) were also higher in eggs of birds fed T1 diet numerically when compared to those fed maize diet (23.82mm and 31.67 cm respectively).

Aminu *et al.* (2021) also revealed that the daily egg production of Japanese quail hens was not affected by complete replacement of dietary maize by either millet or sorghum. Abu and Judah (2019) evaluated the comparative effect of millet, sorghum, and cassava flours as alternative energy sources for the Japanese quails in place of maize and found that while egg weight, yolk weight and height were highest in quails fed with the sorghum-based diet, quails fed with millet had the highest yolk and egg shape indices compared to those that had received the maize and cassava-based diets.

The most important traits of the eggshell are its strength and thickness. Shell thickness ranged from 0.62 – 1.00 mm with eggs on the maize (control) diet having the thickest shells. These values were higher than values of 0.33 – 0.41 mm and 0.37 – 0.38 mm reported by Abd El-Moneim and Sabic (2019) and Hanusova *et al*. (2015) respectively. The shell weight and thickness were not affected by dietary treatments, indicating that supplementation of sorghum diet with garlic and turmeric had no negative interface with calcium metabolism. The values for albumin weight ranged between 4.54 – 6.00 g with eggs of T1 birds having the best weight when compared to albumin weight of eggs on other treatments.

The yolk length and yolk width ranged between 21.37 – 24.52 g and 21.13 – 23.34 g respectively with eggs from T1 having the best yolk length and width of 24.52 g and 23.34 g respectively. Egg quality parameters were better in eggs fed sorghum, and sorghum supplemented with garlic and turmeric diets than in eggs fed maize (control) diet. The results observed for internal parameters of eggs could be attributed to turmeric powder supplementation which might have elicited the numerical increase. The increased diameter and height of yolk indicated an increase in vitellogenin synthesis by hepatocytes and deposited into the ovarian follicles. Increase in albumen showed that active substances in the turmeric powder stimulated the growth of the epithelial cells and tubular gland cells in the magnum to synthesize and secrete albumen (Saraswati *et al.*, 2013).

**Table 3: Egg qualities of quails fed turmeric–garlic sorghum diets**

| Parameters | MA | T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 | T9 | T10 | T11 | T12 | T13 | T14 | T15 | P-values | | | SEM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | | G eff. | T eff. | G x T | |
| EXTERNAL PARAMETERS | | | | | | | | | | | | | | | | | | | | |
| Egg Weight (g) | 10.84 | 12.33 | 11.33 | 9.83 | 10.67 | 10.33 | 11.00 | 10.50 | 10.33 | 10.67 | 10.67 | 10.83 | 10.50 | 12.00 | 10.17 | 9.50 | 0.413 | 0.477 | 0.411 | 1.53 |
| Egg Diameter (mm) | 23.82 | 24.27 | 23.44 | 22.68 | 22.74 | 23.85 | 23.32 | 23.00 | 22.25 | 22.41 | 22.69 | 22.91 | 22.68 | 23.49 | 22.13 | 21.74 | 0.711 | 0.888 | 0.885 | 1.53 |
| Egg Length (cm) | 31.67 | 33.20 | 32.44 | 31.40 | 32.05 | 31.30 | 32.13 | 30.05 | 31.25 | 31.68 | 33.12 | 32.88 | 32.21 | 32.64 | 31.90 | 30.83 | 0.366 | 0.963 | 0.333 | 1.36 |
| Shell Wt. (g) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.06 |

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Shell Thickness (mm) | 1.00 | 0.70 | 0.74 | 0.62 | 0.74 | 0.73 | 0.74 | 0.69 | 0.73 | 0.75 | 0.68 | 0.69 | 0.69 | 0.77 | 0.66 | 0.67 | 0.423 | 0.999 | 0.155 | 0.03 |
| INTERNAL PARAMETERS | | | | | | | | | | | | | | | | | | | | |
| Albumin Wt. (g) | 5.17 | 6.00 | 5.34 | 4.58 | 5.50 | 5.33 | 5.83 | 5.17 | 5.42 | 5.70 | 5.28 | 5.53 | 5.32 | 5.93 | 5.53 | 4.83 | 0.411 | 0.663 | 0.712 | 0.52 |
| Yolk Weight (g) | 3.00 | 3.83 | 3.50 | 3.00 | 3.67 | 3.33 | 3.50 | 3.17 | 3.67 | 3.67 | 3.33 | 3.45 | 3.67 | 4.03 | 3.67 | 3.00 | 0.777 | 0.999 | 0.223 | 0.22 |
| Yolk Length (cm) | 23.37 | 24.52 | 23.85 | 23.07 | 23.52 | 21.93 | 23.57 | 21.98 | 23.72 | 22.55 | 22.93 | 22.97 | 22.95 | 23.92 | 22.43 | 21.37 | 0.963 | 0.233 | 0.142 | 1.56 |
| Yolk Width (cm) | 22.13 | 23.34 | 21.99 | 22.97 | 22.22 | 22.10 | 21.90 | 21.58 | 22.07 | 22.8 | 22.35 | 22.37 | 22.52 | 22.95 | 23.17 | 22.48 | 0.321 | 0.224 | 0.789 | 9.63 |
| Alb. Width (cm) | 31.31 | 32.17 | 33.04 | 30.75 | 32.53 | 31.85 | 32.32 | 31.3 | 31.47 | 32.17 | 30.35 | 31.49 | 31.42 | 32.15 | 31.34 | 29.94 | 0.411 | 0.111 | 0.366 | 8.52 |
| Alb. Ht. (cm) | 41.18 | 44.35 | 44.90 | 41.50 | 46.28 | 43.29 | 45.52 | 41.37 | 43.60 | 46.18 | 41.72 | 43.57 | 45.17 | 46.38 | 44.07 | 41.60 | 0.663 | 0.366 | 0.411 | 12.2 |

Ma: Positive control basal diet (Maize); T1: Negative control basal diet (Sorghum); T2: T1 Diet + 0.25% turmeric; T3: T1 Diet + 0.50% turmeric; T4: T1 Diet + 0.75% turmeric T5: T1 Diet + 1.00% turmeric; T6: T1 Diet + 0.50% garlic; T7: T1 Diet + 0.50% garlic and 0.25% turmeric; T8: T1 Diet + 0.50% garlic and 0.50% turmeric; T9: T1 Diet + 0.50% garlic and 0.75% turmeric; T10: T1 Diet + 0.50% garlic and 1.00% turmeric; T11: T1 Diet + 1.00% garlic; T12: T1 Diet + 1.00% garlic and 0.25% turmeric; T13: T1 Diet + 1.00% garlic and 0.50% turmeric; T14: T1 Diet + 1.00% garlic and 0.75% turmeric; T15: T1 Diet + 1.00% garlic and 1.00% turmeric.

SEM = Standard error of mean. Shell Thick. - Shell Thickness Alb. Width - Albumin Width Alb. Ht. - Albumin Height Albumin Wt. - Albumin Weight

## CONCLUSION

Egg performance of quail layers fed turmeric-garlic sorghum-based diets recorded profound improvements on feed intake, total eggs laid and hen day production. Daily eggs laid compared favourably with those of maize at 0.50 % garlic and 1.00 % turmeric sorghum diet T10). Hen day production of birds fed sorghum diets was comparable to birds on maize diet but higher than those on sorghum diets at 0.50 % garlic-1.00 % turmeric. Egg quality parameters were better in eggs fed sorghum, and sorghum supplemented with garlic and turmeric diets than in eggs of quails fed maize (control) diet.

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