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Original Contribution

PRODUCTION PERFORMANCE AND EGG QUALITIES OF JAPANESE QUAIL (*Coturnix coturnix japonica*) LAYERS FED DIETS WITH VARYING PROTEIN LEVELS SUPPLEMENTED WITH OR WITHOUT TURMERIC RHIZOME POWDER

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ABSTRACT

This experiment investigated the effects of varying crude protein levels (CPL) supplemented with or without Turmeric Rhizome Powder (TRP) on laying performance and egg quality of Japanese quails. A total of one hundred and ninety two 10-weeks-old laying Japanese quails were randomly distributed into six dietary treatment groups (3 x 2 experimental arrangement) with four replicates per group (8 birds per replicate) in a completely randomized design. Dietary treatments were: A (24%CP), B (21%CP), C (18%CP) without TRP while D, E and F contains 24%CP+0.5%TRP, 21%CP + 0.5%TRP and 18%CP + 0.5%TRP, respectively. Data were taken on productive performance, egg quality and egg proportions for 10 weeks. The main effect showed that quails on 24 and 21% CPL diet had elevated ($P<0.05$) hen egg day production (HDP). Feeding of quails with 18% CPL diet resulted in increased ($P<0.05$) feed cost /kg egg and revenue was higher ($P<0.05$) with the use of 21 and 24% CPL diet. The main effect shows that turmeric supplementation enhanced ($P<0.05$) yolk colour. The interactive effect showed that quails fed diets containing 24 and 21% CPL with or without TRP supplementation had increased ($P<0.05$) HDP. Feed cost/kg egg increased ($P<0.05$) for quails fed diet with 18% CPL diet with or without TRP supplementation. The revenue increased for quails fed 21% CPL diet with TRP supplementation. The feeding of diets containing 21 and 18% CPL with TRP supplementation resulted in enhanced ($P<0.05$) yolk colour (4.36 and 4.43) respectively. Egg proportions were not influenced ($P>0.05$) by CPL or TPL. It was concluded that TRP supplementation influenced HDP, increased revenue with 21% CPL diet and enhanced egg yolk colour.

Key words: protein level, laying performance, egg quality, Japanese quail, turmeric

INTRODUCTION

Japanese quails (*Coturnix coturnix japonica*) have emerged as a low-capital, cheap and alternative source for supplementing protein intake among tropical countries such as Nigeria (1). They are hardy birds and are rarely affected by common poultry diseases (2). They attain maturity in about six weeks and are usually in full egg production by fifty days of age. The hens, with life expectancy of 2 to 2 ½ years under proper management will lay about 200-300 eggs in the first year of production (2). The low maintenance cost of quail is due to its small size, coupled with its short generation interval, resistance to diseases with high egg production

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(3, 4). Quail's egg is higher in protein, vitamins and other nutrients compared to hen's egg (5). These recognised qualities had encouraged commercial quail farming and it has gained popularity with increased promotion recently in Africa (4).

Despite the qualities of quail, the availability of nutrient especially protein should be ensured to achieve optimum performance from quails. It is a known fact that feed constitutes the major cost of poultry production and particularly protein rich feed ingredients are expensive making the cost of feed ingredients as high as 60-70% of the finished feed (6) and therefore, is the major component in changing production and marketing scenario of poultry and poultry products. There is therefore, the need to look into ways of reducing the cost of feeding by reducing the inclusion of high cost feed ingredients and increasing the accessibility and availability of protein in the diet of quails for improved production at an economical rate. Commonly used growth promoters in poultry production which are synthetic antibiotics known to enhance the efficiency of production by reducing the risk of diseases has been rejected due to residual drug contamination of the egg and meat causing drug resistance in human (7). This has led to the search for suitable alternatives to antibiotics such as phyto-additives. Phyto additives are non-antibiotic growth promoters derived from herbs, spices or other medicinal plants (8, 9). Turmeric belongs to this class of phytogenic plants with an active constituent called curcumin which may constitute 2 to 8% of the spice and it is a non-water-soluble polyphenol derived from turmeric (10). They have the potency to promote growth through the inhibition of pathogen proliferation in the chicken gut for improved nutrient availability and absorption (11, 12).

The active component of this plant possesses antifungal, antiprotozoal and antibacterial activities (13) and it is capable of preventing lipid oxidation (14). The turmeric rhizome contains essential oils (artumerine, zingberene borneol) and protein (15). Turmeric powder is widely used as a spice that has different biological activities and medicinal applications (16). Turmeric is used traditionally to improve digestion and intestinal flora (17) and it has also been shown to be a powerful antioxidant (18, 19). Based on this, we hypothesized that the supplementation of turmeric will increase nutrient digestion and availability with reduced dietary protein content for improved performance. In addition, research studies on the effect of dietary supplementation of turmeric for laying quail birds are rare. Therefore, this study investigated the influence of turmeric supplementation on the production performance of Japanese quail fed diets with different protein concentrations.

MATERIALS AND METHODS

Experimental Site

The experiment was carried out at the Quail Research Unit, Faculty of Agricultural Sciences, Ladoke Akintola University of Technology, Ogbomoso, Oyo State. The location falls within the derived savannah Agro-ecological zone of Nigeria, and the geographical positioning coordinates of the area is located on longitude 4°27'E of the Greenwich meridian and latitude 8°17'N of the equator (20)

Source and Preparation of Turmeric Rhizome Powder (TRP)

The turmeric rhizomes used in this study were harvested from LAUTECH Teaching and Research Farm Ogbomoso. The adhering dirt to the rhizomes were removed, washed, air-dried, and the rhizomes were sliced with the use of a knife. It was then parboiled at 60°C and oven dried at 45°C for 48 hours. Boiling enables the starch in the turmeric to gelatinize and also helps in intensifying the color and in uniform distribution of color throughout the rhizome. After oven drying, it was blended into powdery form with the use of an electric blender and stored in an air tight container to avoid absorption of moisture because it is hygroscopic in nature.

Birds and Management

One hundred and ninety-two (192) Japanese quails used for the experiment were purchased from a reputable hatchery in Ibadan. The quails were obtained at 3 weeks of age and were further reared until 10 weeks old before the commencement of the experiment. The birds were housed in quail battery cages designed at the Quail Research Unit. Each cage was equipped with feed and conical water troughs. The quails were offered respective experimental diets and water *ad-libitum* throughout the laying experimental period that lasted 10 weeks. The thermo-hygrometer was used to monitor the temperature and humidity within the experimental pen. The average temperature and relative humidity in the house are 27.8 ± 2◦C and 71.5% ± 3 respectively.

Experimental Design and Diets

The birds were randomly divided into 6 dietary treatments using a 2 by 3 factorial arrangement of turmeric supplementation (with or without) and dietary protein concentration (24, 21 and 18%). Each treatment was subdivided into 4 replicates and each replicate contains 8 birds. Six cages were assigned to each of the six dietary treatments. The diets were formulated such that diets A, B and C had 24% CP, 21%CP and 18% CP without turmeric rhizome powder (TRP) supplementation while D, E and F contains 24%CP+0.5%TRP, 21%CP + 0.5%TRP and 18%CP + 0.5%TRP respectively **(Table 1).** The calculated metabolizable energy values fell within the range recommended by NRC (21). Ingredients used such as maize, soya bean meal, fish meal, wheat offal, dicalcium phosphate (DCP), oyster shell, salt, premix, and methionine were purchased from a reputable feed mill in Ogbomoso.

Table 1. *Composition of Experimental Diets*

	Crude protein levels		
Ingredients (%)	24%	21%	18%
Maize	47.92	54.30	64.00
Soyabean meal	43.38	33.00	23.30
Fish meal (72%)	3.00	3.00	3.00
Wheat offal	1.00	5.00	5.00
Dicalcium phosphate	2.50	2.50	2.50
Oyster shell	1.50	1.50	1.50
Salt (NaCl)	0.20	0.20	0.20
Premix*	0.25	0.25	0.25
Methionine	0.25	0.25	0.25
Total	**100**	**100**	**100**
Feed cost/kg (₦)**	**126.30**	**121.10**	**117.10**
Determined composition (%)			
Crude Protein	23.92	20.91	18.25
Crude Fiber	3.90	4.06	4.20
Fat	5.02	5.50	5.60
Ash	5.00	4.00	4.10
Moisture	9.60	8.55	6.91
Nitrogen free extracts	52.56	56.98	60.94
Metabolizable energy (ME kcal/kg)	2890.60	2910.40	2975.10

*Premix Composition (per kg of diet) : Vitamin A(10,000,000I.U), Vitamin D3 (2,200,000I.U), Vitamin E (10,000mg), Vitamin K3 (2,000mg), Folic acid (500mg), Niacin (15,000mg), Calpan (5000mg), Vitamin B2 (5000mg), Vitamin B12 (10mg), Vitamin B1 (1500mg), Vitamin B6 (1500mg), Biotin (20mg), Antioxidant (125,000mg), Selenium (200mg), Iodine (1000mg), Iron (40,000mg), Cobalt (200mg), Manganese (70,000mg), Copper (4000mg), Zinc (50,000mg), Choline chloride (150,000mg).
₦= Nigerian Naira where 1 US dollar = ₦360
**Diets with turmeric cost ₦127.4, ₦122.2 and ₦118.2 for 24%CPL, 21%CPL and 18%CPL respectively.

DATA COLLECTION

Productive Performance Parameters

Data were collected on performance parameters (percentage hen day production (%HDP), initial body weight, final body weight, daily weight changes, daily feed intake, feed conversion ratio (kg feed/kg egg weight), Cost of feed consumed per kg egg and revenue per tray of egg.

Egg Quality Traits

Sampling of eggs: Four eggs per replicate were sampled at random on the last day of each fortnight for five times. Each egg was assessed separately for internal and external egg quality traits.

For external quality traits, data on egg weight, egg length, egg breadth, egg shape index and shell thickness were collected. Individual egg weight was measured using a sensitive electronic balance while egg length and breadth were measured using a vernier caliper. The egg shape index (ESI) was measured as a ratio of the width and length of the egg multiplied by 100. Shell thickness was measured for individual dry eggshells to the nearest 0.01mm using a micrometer screw gauge.

The interior egg quality traits were measured in terms of Haugh unit, yolk index and yolk colour. The Haugh unit was calculated from egg weight and albumen height according to Haugh (22).

Haugh unit (%):

$$\text{Haugh unit} = 100 \text{ Log } (H + 7.57 - 1.7W^{0.37})$$

Where H = Albumen height (mm)

W = Weight of the egg (g)

The values 7.57 and 1.7 are constant

The yolk index was calculated as the proportion of yolk height to diameter. Yolk height (mm) was measured at the highest point using a tripod micrometer. Yolk width (mm) was measured with the use of digital vernier caliper which was placed across the yolk and the reading was taken through the vernier caliper. Yolk colour was scored for individual egg yolk by comparing the colour of the yolks with the colour of the chips of a Hoffman-La Roche yolk colour fan.

The egg proportions (Yolk %, Albumin% and Shell + membrane %) were determined by carefully breaking each egg, shells separated and air-dried overnight. Eggshells plus the membrane air-dried overnight were weighed, and the relative weight was calculated by expressing the shell + membrane weight as a percentage of the egg weight. The yolk weight was determined by first using an egg separator to separate the yolk from the albumen, the yolk weighed, and the relative yolk weight was calculated by expressing the yolk weight as percentage of egg weight. The albumen weight was calculated by subtracting the yolk and dry shell weights from the whole egg weight. The relative albumen weight was calculated by expressing the albumen weight as a percentage of the egg weight.

Chemical Analysis

Proximate analysis of formulated diets and samples of TRP was carried out according to standard procedures (23).

Statistical design and analysis

The experiment was a 3 x 2 factorial arrangement composed of 3 different levels of protein supplemented with or without turmeric rhizome powder. The data collected were subjected to a two-way analysis of variance in a completely randomized design (CRD) using SAS (24) package to determine the main effects of crude protein level (24, 21 and 18%) and TRP supplementation (with or without)) and interactions of protein level and TRP supplementation. The significant means were separated using the Tukey test of the same package at a 5% level of probability.

RESULTS

The analyzed proximate composition of Turmeric powder showed that it contains 8.05% crude protein, 3.20% ether extract, 4.10% crude fibre, 7.00% ash, 7.88% moisture and 69.77% nitrogen free extract.

Main Effect of CPL and TRP Supplementation on Productive Performance of Japanese Quails

The main effect of CPL and TRP supplementation on the productive performance is shown in **Table 2.** The result shows no significant (P>0.05) effect of TRP supplementation on productive performance of quails. Crude protein level significantly (P<0.05) influenced HDP and FCR. HDP was higher (P<005) for quails fed diets with crude protein of 24 and 21% than those fed diet with 18% CPL. Crude protein level of 24% resulted in the best FCR and CPL of 18% resulted in the worst FCR while that of 21% was intermediate. There was no significant (P>0.05) effect of TRP supplementation on feed cost /kg egg, however, CPL significantly (P<0.05) influenced feed cost /kg egg. Feeding of quails with 18% CPL diet resulted in higher (P<0.05) feed cost /kg egg than those fed diet with 21 and 24 % CPL. There was no significant (P>0.05) difference in revenue with TRP supplementation while revenue was higher (P<0.05) with the use of 21 and 24% CPL diet than that of 18% CPL diet in feeding of quails

Table 2. *Main Effect of Crude Protein Level and Turmeric Powder Supplementation on Productive Performance of Japanese Quails*

	TRP				Varying protein level (%)				
Parameters	*Without*	*With*	**P-value**	**SEM**	*24 CPL*	*21 CPL*	*18 CPL*	**P-value**	**SEM**
Hen day	75.38	76.26	0.385	0.70	77.78^{a}	77.47^{a}	72.21^{b}	0.000	0.86
Feed Intake, g/d	29.19	29.67	0.574	0.59	28.75	29.84	29.70	0.524	0.73
Initial weight, g	152.40	153.60	0.331	77.28	153.10	151.90	154.2	0.391	94.65
Final weight, g	191.60	191.40	0.749	1.18	192.30	191.20	190.6	0.697	1.44
Weight gain, g/d	0.56	0.54	0.623	0.03	0.56	0.56	0.52	0.642	0.04
Egg weight, g	10.09	10.11	0.954	0.16	10.16	10.12	10.01	0.864	0.20
FCR, kg feed/kg egg	3.86	3.85	0.935	0.10	3.64^{b}	3.80^{ab}	4.11^{a}	0.037	0.11
Feed cost/ kg egg, ₦	441.20	443.10	0.289	65.30	440.60^{b}	442.61^{b}	458.20^{a}	0.042	47.10
Revenue, ₦/tray	258.80	256.90	0.301	75.80	259.40^{a}	259.40^{a}	244.80^{b}	0.020	25.90

^{ab}Means on the same row with different superscript are significantly different (P<0.05)
TRP: turmeric root powder, CPL: crude protein level, SEM: pooled standard error of mean

Interactive Effect of CPL and TRP Supplementation on Productive Performance of Japanese Quails

The interactive effect of CPL and TRP supplementation on productive performance is presented in **Table 3**. The result shows a significant (P<0.05) interactive effect only on HDP. The quails fed a diet containing 24 and 21% CPL without or with TRP supplementation had higher (P<0.05) HDP than those fed 18% CPL diet without TRP supplementation while those fed diet containing 18% CP with TRP supplementation was better than 18% CPL diet without TRP. Feed cost/kg egg increased (P<0.05) for quails fed diet with 18% CPL diet with or without TRP supplementation while those fed 21 and 24% CPL diet with or without TRP supplementation had reduced (P<0.05) Feed cost/kg egg. The revenue was higher (P<0.05) for quails fed 24% CPL diet without TRP supplementation and those fed 21% CPL diet with TRP supplementation than other treatments.

Table 3. *Interaction Effect of Crude Protein Level and Turmeric Powder Supplementation on Productive Performance of Japanese Quails*

	Without TRP			With TRP				
Parameters	24% CPL	21% CPL	18% CPL	24% CPL	21% CPL	18% CPL	**P-value**	**SEM**
Hen day Production, %	77.76^{a}	76.94^{a}	71.43^{b}	77.81^{a}	78.00^{a}	72.98^{ab}	0.003	1.22
Feed Intake, g/d	28.36	29.98	29.23	29.14	29.70	30.17	0.810	1.03
Initial weight, g	152.60	152.60	152.50	153.40	150.9	156.40	0.374	133.90
Final weight, g	192.40	191.80	190.80	192.30	190.60	190.50	0.960	2.04
Weight gain, g/d	0.57	0.56	0.55	0.56	0.56	0.49	0.816	0.05
Egg weight, g	10.07	10.13	10.09	10.26	10.12	9.94	0.838	0.28
FCR, kg feed//kg egg	3.64	3.88	4.07	3.66	3.76	4.14	0.840	0.16
Feed cost/kg egg, ₦	457.50^{b}	465.60^{b}	474.40^{a}	464.70^{b}	459.40^{b}	491.40^{a}	0.008	58.90
Revenue, ₦/tray	261.90^{a}	258.40^{b}	256.30^{b}	257.00^{b}	260.40^{a}	253.40^{b}	0.005	37.40

^{ab}Means on the same row with different superscript are significantly different (P<0.05)
TRP: turmeric root powder, CPL: crude protein level, SEM: pooled standard error of mean

Main Effect of CPL and TRP Supplementation on Egg Quality of Japanese Quails

The main effect of CPL and TRP supplementation on egg quality of Japanese quails is shown in **Table 4**. The result showed significant (P<0.05) effect of turmeric supplementation and CPL only on yolk colour. Turmeric supplementation resulted in higher (P<0.05) yolk colour than those without turmeric supplementation. Feeding of quail with 18% CPL, 2975.10 Kcal/kg diet and the 21% CPL, 2910.45 Kcal/kg diet resulted in higher (P<0.05) yolk colour than that of 24% CPL, 2890.60 Kcal/kg diet.

Table 4. *Main Effect of Crude Protein Level and Turmeric Powder Supplementation on Egg Qualities of Japanese Quails*

	TRP				Varying protein level (%)				
Parameters	*Without*	*With*	**P-value**	**SEM**	*24 CPL*	*21 CPL*	*18 CPL*	**P-value**	**SEM**
Haugh unit, %	90.15	90.74	0.257	0.36	90.04	90.83	90.45	0.454	0.44
Albumen height, mm	4.37	4.48	0.938	0.10	4.36	4.50	4.41	0.041	0.11
Yolk index	0.35	0.35	0.946	0.01	0.35	0.35	0.36	0.706	0.01
Yolk colour	2.38[b]	4.05[a]	0.000	0.06	2.37[b]	2.86[a]	2.91[a]	0.000	0.07
Shell thickness, mm	0.28	0.29	0.331	0.01	0.29	0.29	0.29	0.834	0.01
Yolk %	36.76	37.08	0.468	0.31	36.96	37.21	36.59	0.515	0.38
Albumen %	54.31	53.93	0.279	0.24	54.10	53.74	54.51	0.211	0.30
Shell + Membrane %	8.97	9.01	0.876	0.16	8.96	9.10	8.92	0.800	0.20
Egg shape index %	75.10	77.23	0.066	0.01	77.10	75.25	75.32	0.484	0.01

[ab]Means on the same row with different superscript are significantly different (P<0.05)
TRP: turmeric root powder, CPL: crude protein level, SEM: pooled standard error of mean

Interactive Effect of CPL and TRP Supplementation on Egg Quality of Japanese Quails

The interactive effect of CPL and TRP supplementation on egg quality is presented in **Table 5.** The result shows a significant (P<0.05) interactive effect on yolk colour, albumen and shell + membrane. The yolk colour of eggs from quails fed diet containing 21 and 18% CPL with TRP supplementation was higher (P<0.05) compared to other treatments. The albumen percentage was higher (P<0.05) for quails fed diet containing an 18% CPL without TRP supplementation than those fed 18% CPL diet with TRP supplementation while other treatments were intermediate. Quails fed diet containing 24% CPL without TRP and those fed diet containing 18% CPL with TRP supplementation had higher (P<0.05) shell + membrane % than those fed diet containing 18% CPL without TRP supplementation.

Table 5. *Interaction Effect of Crude Protein Level and Turmeric Powder Supplementation on Egg Qualities of Japanese Quails*

	Without TRP			With TRP				
Parameters	24% CPL	21% CPL	18% CPL	24% CPL	21% CPL	18% CPL	**SEM**	**P-value**
Haugh unit, %	89.72	90.41	90.32	90.37	91.26	90.59	0.62	0.892
Albumen height, mm	4.29	4.42	4.40	4.43	4.58	4.43	0.17	0.860
Yolk index	0.35	0.35	0.37	0.35	0.36	0.36	0.02	0.865
Yolk colour	2.38[b]	2.36[b]	2.40[b]	2.37[b]	4.36[a]	4.43[a]	0.10	0.000
Shell thickness, mm	0.28	0.28	0.29	0.29	0.29	0.30	0.01	0.980
Yolk %	36.73	37.13	36.43	37.2	37.30	36.75	0.54	0.962
Albumen %	53.85[ab]	53.60[ab]	55.48[a]	54.35[ab]	53.88[ab]	53.55[b]	0.42	0.018
Shell + Membrane %	9.44[a]	9.35[ab]	8.13[b]	8.48[ab]	8.85[ab]	9.70[a]	0.28	0.001
Egg shape index %	76.43	73.45	75.24	77.15	77.32	76.21	0.01	0.271

[ab]Means on the same row with different superscript are significantly different (P<0.05)
TRP: turmeric root powder, CPL: crude protein level, SEM: pooled standard error of mean

DISCUSSION

The main effect of CP and TRP on productive performance response shows that varying level of protein significantly influenced HDP in which diets with 24 and 21% CP increased HDP than diet with 18% CP. This is in accordance with the findings of Muhammad et al. (25) who reported increase in egg production, and HDP of Japanese quails fed diets with 20 and 25% CP compared to those fed diet with 15% CP. Higher egg production for quails fed diet containing 24% CP compared to those fed diet with 16% CP were also observed by Ri et al. (26). The increase in HDP obtained with diets having higher CP is due to the importance of protein in egg formation and development. The research reports by Gunawardana et al. (27) and Li et al. (28) indicated that dietary crude protein influences laying performance and egg quality while Tuleun et al. (28) concluded that 21% CP is required in the diets of laying Japanese quails under a hot-humid tropical environment. However, the report of Jesuyon et al. (29) (Humid forest environment) is opposite to the result of our study. Ratriyanto et al. (30) (25.40

ºC in the morning, 32.90 ºC in the afternoon and 28.70 ºC in the evening) and Agboola et al. (31) (During the month of August and September) did not observe significant effects of varying protein from 16.5-19.5% or 18-24% on egg production, feed intake, egg weight or feed conversion ratio in Japanese quails. The main effect of CPL shows that the feeding of 18% CPL diet increased feed cost/ kg egg and also resulted in reduced revenue. This is due to the lower CP content of the diet which negatively affected egg weight. Reduced egg weight, although not significant was observed for quails fed 18% CP diet and this can eventually cause overall reduction in revenue. This is similar to the report of Adeyemo et al. (32) who observed reduced egg number and egg weight for layers fed diet with CP content of 13%.

The interactive effect of TRP and CP levels on productive performance shows that HDP increased with dietary CP level of 21 and 24% with or without TRP supplementation. The increase implies that dietary CP is essential for improved laying performance. The main factor limiting animal performance is protein in terms of quantity and quality (33). The HDP of quails fed 18% CP diet supplemented with TRP was intermediate between other treatments. This implies that TRP was able to influence protein utilisation of the diet despite low CP content. Turmeric root powder has been reported to contain active substances such as essential oils (3-7%) and curcuminoids (1-6%) that exhibit digestive and antimicrobial properties and these makes it a potential alternative growth promoter in livestock feed (34) and an immune system booster (35). Stimulation of digestive enzymes and pancreatic lipase can be achieved by dietary supplementation of turmeric (17). Phytoestrogens is also a constituent of turmeric powder which is capable of stimulating the development of ovarian follicles for increased egg production and hatchability (36, 37, and 38). The reduction in CP up to 18% in the diet of quails with or without TRP supplementation resulted in increased feed cost/ kg egg which indicates the adverse effect of reduced CP in the diet of poultry birds. This is in agreement with the report of Zhang et al. (39) who reported reduced egg production and egg mass for ducks fed diets with reduced CP of 13.5%. This is also in agreement with the report of Burley et al. (40) who reported reduced weekly egg income per hen housed when Lohmann LSL Lite laying hens were fed reduced CP diet with balanced amino acid. However, in this study, increased revenue was recorded for quails fed diet with 21% CPL supplemented with TRP and this shows the positive influence of TRP supplementation in the diet which makes the use of 21% CPL economical with TRP supplementation.

The main effect of TRP and CP level on egg qualities revealed that dietary turmeric supplementation resulted in enhanced yolk colour of quail eggs. This is in agreement with Nuraini and Ade (41) who reported increase in yolk colour of quail eggs following inclusion of turmeric extract in drinking water of quails. The present finding also corroborates the reports of Radwan et al. (42) and Hassan (43) who reported increase in egg yolk colour of laying hens fed diet supplemented with 1% turmeric. The increased yolk colour is associated with the rich yellow orange colour of turmeric due to presence of the active constituent called curcumin (44). The report of Park et al. (45) was also similar to the result of this study. The authors observed significantly higher egg yolk colour of laying hens fed diet supplemented with 0.5% turmeric powder than the control group and affirms that the natural yellow-orange substance in turmeric is responsible for the increased yolk colour. Increased supplementation of turmeric-cinnamon powder in the diet of quail resulted in increasing egg yolk colour index (46). However, Liu et al. (47) observed no significant effect of 100, 150 and 200 mg/kg dietary curcumin supplementation on the yolk colour of eggs obtained from heat stressed hens (Ambient temperature was maintained at 34 ± 2°C for 8 hours per day (9:00 am–5:00 pm) and also maintained 22°C to 28°C for 16 hours per day). The non-significant effect observed could be due to the subjection of the hens to heat stress. Poultry production and health is adversely affected by high ambient temperature (48) and it causes a marked decrease in feed intake and egg production in laying hens (49). The discrepancies observed in the studies could be due to differences in dietary constituents and experimental conditions. Supplementation of diets with TRP only numerically increased Haugh unit and albumen height which were the major indices of assessing internal egg quality. In this study, the yolk colour reduced with diet containing 24% CP which establishes the fact that yolk colour is not a function of crude protein level but rather protein is the main nutrient required for egg formation (50). The lower yolk colour obtained with higher CP suggested that the increased protein intake was directed towards increased egg weight (51).

The interactive effect of TRP and CP levels on egg qualities shows that there was enhanced yolk colour in quails fed 21 and 18%CP diet when supplemented with TRP over those fed 24%CP diet which could not be readily explained. However, the improvement of yolk colour due to turmeric supplementation is associated with the influence of yellowish pigments (curcuminoids, curcumin and its related compounds) present in TRP. The rhizome of turmeric is widely used as spice and colouring agent (52). Riasi et al. (53) also observed increased egg yolk colour of old laying hens with dietary supplementation of TRP at 1 and 2g/kg. Lower albumen percentage was observed for 18% CP diet with TRP supplementation compared to 18% diet without TRP supplementation. The shell plus membrane percentages were higher with 24% CP diet without TRP supplementation and 18% diet with TRP supplementation which indicated that TRP supplementation was able to influence calcium accumulation in the shell despite low CP content. Laganá et al. (54) reported no difference in egg shell percentage of white hens fed diets with varying levels of turmeric supplementation while Zacaria and Ampode (55) observed no significant effect of dietary TRP supplementation on egg shell weight of quails. The increase in shell percentage with 18% CP diet and TRP supplementation in this study could be associated with improved nutrient utilisation due to TRP supplementation. Higher levels of turmeric up to 10g/kg may improve the small environment of uterus and consequently increase the shell weight and shell thickness (41).

CONCLUSION

Crude protein level of 24 and 21% in diet increased HDP with better feed conversion ratio. However, Turmeric supplementation improved the HDP of quails with 21% CP diet and also increased egg yolk colour of quail eggs. The supplementation of TRP in the 18% CP diet of quails resulted in a similar HDP with the group of quails fed 24% CP diet supplemented with TRP. Therefore, it is recommended that quails can be fed 18% CP diet with supplementation of turmeric powder for improved egg production and quality for better economic returns.

REFERENCES

1. Jesuyon, O.M.A., Aganga, A.A. Orunmuyi, M. and Falade, G.T., Effect of dietary protein level on egg production and egg-quality characteristics of Japanese quail (*Coturnix coturnix japonica*) in the tropical environment. *Anim. Prod. Sci*., 62: 1430-1438, 2021. https://doi.org/10.1071/AN20399
2. Huss, D., Poynter, G. and Lansford, R., Japanese quail (*Coturnix coturnix japonica*) as a laboratory animal model. *Department of Biology,* Biological Imaging Centre, California Institute of Technology, Pasadena. CA. USA. Laboratory Animal (NY), 37(11): 513-519, 2008.
3. Oguz, I., and Minvielle, F., Effects of genetics and breeding on carcass and meat quality of Japanese quail: A review, XV European symposium on the quality of poultry meat, WPSA, Kusadasi-Turkey. 2001.
4. Vali, N., The Japanese quail: A review. *Int. J. Poult. Sci.,* 7: 925-931, 2008.
5. Khalifa, M.I. and Noseer, E.A., Cholesterol quality of edible eggs produced by quail fed diets containing probiotic and/or ginger (Zingiber officinale). *Livest. Res. Rural Dev.,* 31 (10) Article #165. 2019. http://www.lrrd.org/lrrd31/10/mrwa31165.html
6. Akinfenwa, G., High cost of feeds threaten Southwest poultry farms in Nigeria: Business Agro, The Guardian 24 Jan 2021, www.guardian.ng/features. Accessed on 16/07/2022.
7. Kafi, A., Uddin, M.N., Uddin, M.J., Khan, M.M.H. and Haque, M.E., Effect of Dietary Supplementation of Turmeric (*Curcuma longa*), Ginger (*Zingiber officinale*) and their Combination as Feed Additives on Feed Intake, Growth Performance and Economics of Broiler. *Int. J. Poult. Sci*. 16: 257-265, 2017. DOI: 10.3923/ijps.2017.257.265
8. Abd El-Hack, M.E., Alabdali, A.Y.M., Aldhalmi, A.K., Bassiony, S.S., Selim, S., El-Saadony, M., Reda F.M. and Alagawany, M., Impacts of Purslane (Portulaca oleracea) extract supplementation on growing Japanese quails' growth, carcass traits, blood indices, nutrients digestibility and gut microbiota, *Poult. Sci*., 101(11): 1-12, 2022. doi: https://doi.org/10.1016/j.psj.2022.102166

9. Yitbarek, M.B., Phytogenics as feed additives in poultry production: A review. *Int. J. Extensive Res*., 3: 49-60, 2015.
10. Jarenka, S., Anti-inflammatory properties of curcumin, a major constituent of curcuma longa: A review. *J. Pre-Clin. Clin. Res.*, 23(3): 141-153, 2009.
11. Athanasiadou, S., Githiori, J. and Kyriazakis, I., Medicinal plants for helminthes parasite control: facts and fiction. *Anim.*, 1(9), Pp. 1392–1400, 2007.
12. Ghazalah, A.A., and Ali, A.M., Rosemary leaves as a dietary supplement for growth in broiler chickens. *Int. J. Poult. Sci*., 7: 234-239, 2008.
13. Basavaraj, M., Nagabhushana, V., Prakash, N., Appannavar, M.M., Wagmare, P., Mallikarjunappa, S., Effect of dietary supplementation of curcuma longa on the biochemical profile and meat characteristics of broiler rabbits under summer stress. *Vet. World.*, 4(1): 15-18, 2011.
14. Saraswati, T.R., Manalu, W., Ekastuti, D.R. and Kusumorini, N., The role of turmeric powder in lipid metabolism and its effect on quality of the first quail's egg. *J. Indones. Trop. Anim. Agric*. 38(2): 123-130, 2013. DOI: https://doi.org/10.14710/jitaa.38.2.123-130
15. Li, S.Y., Yuan, W., Yang, P.Y., Antoun, M.D., Balick, M.J. and Cragg, G.M., Pharmaceutical crops: An overview. *Pharm. Crops.*, 1: 1-17, 2010.
16. Akbarian, A., Golian, A., Kermanshahi, H., Gilani A. and Moradi S., Influence of turmeric rhizome and black pepper on blood constituents and performance of broiler chickens. *Afr. J. Biotechnol*., 11: 8606-8611, 2012.
17. Platel, K. and Srinivasan, K., Influence of dietary spices and their active principles on pancreatic digestive enzymes in albino rats. *Food.* 44(1): 42-46, 2000. DOI: https://doi.org/10.1002/(SICI)1521-3803(20000101)44:1<42::AID-FOOD42>3.0.CO;2-D
18. Jayaprakasha, G.K., Jaganmohan, L., and Sakariah, K.K., Antioxidant activities of curcumin, demthoxycurcumin and bisdemethoxycurcumin. *Food chem.* 98: 720-724, 2006.
19. Sumanont, Y., Murakami, Y., Tohda, M. and Vajragupta, O., Evaluation of the nitric oxide radical scavenging activity of manganese complexes of curcumin and its derivative. *Biol. Pharm. Bull*., 27(2): 170-173, 2004.
20. Google Maps Ladoke Akintola University of Technology, Ogbomoso. 2018. Retrieved from https://earth.google.com/web/@8.17135285,4.27002125,364.34348715a,1044.54281127d,35y,0h,0.00000038t,0r/data=CigiJgokCYcDsRBXDTNAEYUDsRBXDTPAGU_30QFp00hAIfoN58gjHEnA
21. NRC, Nutrient Requirements of Poultry. National Research Council, National Academy Press, Washington, D. C., 9th Revised Edition. Pp. 234, 1994.
22. Haugh, R.R., The Haugh unit for measuring egg quality. The U.S. *Egg and Poultry Magazine,* 43: 552-555, 572-573, 1937.
23. AOAC, Official Method of Analysis (15thedn). Association of Analytical Chemist, Washington D. C. 2005.
24. SAS, Statistical Analysis System, Statistical Methods SAS Institute Inc., Cary, NC, USA. 2003.
25. Muhammad, N., Altine, S., Abubakar, A., Chafe, U.M., and Mikailu, M.M., Effect of varying protein levels and preservation methods and duration on egg production performance and external egg qualities of japanese quails in a semi-arid environment. Iran. *J. Appl. Anim. Sci*.**,** 5(4): 941-947, 2015.
26. Ri, E., Sato, K., Oikawa, T., Kunieda, T. and Uchida, H., Effects of dietary protein levels on production characteristics of Japanese quail eggs. *J. Poult. Sci*., 42:130-139. 2005.
27. Gunawardana, P., Roland, D.A., and Bryant, M.M.. Effect of energy and protein performance, egg components, egg solids, egg quality, and profits in molted Hy-line W-36 hens. *J. Appl. Poult. Res*.**,** 17: 432-439, 2008.
28. Li, F., Zhang, L.M. and Wu, X.H., Effects of metabolizable energy and balanced protein on egg production, quality, and components of Lohmann Brown laying hens. *J. Appl. Poult. Res.* 22: 36-46, 2013.
29. Tuleun, C.D., Adenkola, A.Y. and Yenle, F.G., Performance and erythrocyte osmotic membrane stability of laying Japanese quails (Coturnix coturnix japonica) fed varying dietary protein levels in a hot-humid tropic. *Agric. Biol. J. NA.,* 4 (1): 6-13, 2013. DOI:10.5251/abjna.2013.4.1.6.13
30. Ratriyanto, A., Indreswari, R. and Nuhriawangsa, A.M.P., Effects of dietary protein level and betaine supplementation

on nutrient digestibility and performance of Japanese quails. *Braz. J. Poult. Sci.*, 19(3): 445-454. 2017. http://dx.doi.org/10.1590/1806-9061-2016-0442

31. Agboola, A.F., Omidiwura, B.R.O., Ologbosere, D.Y. and Iyayi, E.A., Determination of crude protein and metabolisable energy of Japanese quail (*Coturnix coturnix japonica*) during laying period. *J. World's Poult. Res*., 6(3):131-138, 2016.
32. Adeyemo, G.O., Abioye, S.A. and Aderemi, F.A., The Effect of Varied Dietary Crude Protein Levels with Balanced Amino Acids on Performance and Egg Quality Characteristics of Layers at First Laying Phase. *Food Nutr. Sci*., 3(4):526-529, 2012. DOI:10.4236/fns.2012.3407.
33. Sharifi, M.R., Shams-Shargh, M., Dastar, B. and Hassani, S., The effect of dietary protein levels and symbiotic on performance parameters, blood characteristics and carcass yields of Japanese quail (*Coturnix coturnix japonica). Ital. J. Anim. Sci*., 10(4): 17-21, 2011. https://doi.org/10.4081/ijas.2011.e4
34. Kilany, O.E. and Mahmoud, M.M.A., Turmeric and exogenous supplementation improve growth performance and immune status of Japanese quail. *World's Vet. J.,* 4(3): 20–29, 2014.
35. Qasem, M.A.A., Alhaj, M., Ger El Nabi, A.B. and Al-Mufarrej, S., Effect of high level of turmeric powder as dietary supplement on performance indicators and immune responses in broiler chickens. *J. Anim. Vet. Adv.,* 14: 30–35. 2015.
36. Hamed, A.H.M., Hamid, I.I., Yagoub, Y.M. and Elimam, M.E., Effects of dietary protein level on egg production and hatchability in Japanese quail (Coturnix japonica) in Khartoum State, Sudan. *Asian J. Agric. Food Sci.*, 4(2): 109-116, 2016. Retrieved from https://ajouronline.com/index.php/AJAFS/article/view/3638
37. Saraswati, T.R. and Tana, S. Effect of Turmeric powder supplementation to the age of sexual maturity, physical, and chemical quality of the first Japanese quail's (Coturnix japonica) egg. *Biosaintifika: J. Biol. Biol. Edu*. 8(1): 18-24, 2016.
38. Gumus, H., Oguz, M.N., Bugdayci, K.E. and Oguz, F.K., Effects of sumac and turmeric as feed additives on performance, egg quality traits and blood parameters of laying hens. *Rev. Bras. de Zootec*., 47:e20170114, 2018. DOI: https://doi.org/10.1590/rbz4720170114.
39. Zhang, Y. N., Wang, S.Y., Deng, Z., Huang, X. B., Li, K. C., Chen, W., Ruan, D., Xia, W. G., Wang, S. L. and Zheng, C. T., The application of reduced dietary crude protein levels supplemented with additional amino acids in laying ducks. *Poult. Sci.,* 100(4): 100983 2021. https://doi.org/10.1016/j.psj.2021.01.006
40. Burley, H.K., Patterson, P.H., and M.A. Elliot. Effect of a reduced crude protein, amino acid-balanced diet on hen performance, production costs, and ammonia emissions in a commercial laying hen flock. *J. Appl. Poult. Res.,* 22(2): 217-228. 2013. https://doi.org/10.3382/japr.2012-00609.
41. Nuraini, M. and Ade, D., Effect of turmeric (*Curcuma domestica*, Val) extract as a feed additive on performance and egg quality of quail. *Int. J. Poult. Sci*., 18: 88-92, 2019.
42. Radwan, N.L, Hassan, R.A., Qota, E.M. and Fayek, H.M., Effect of natural antioxidant on oxidative stability of eggs and productive and reproductive performance of laying hens. *Int. J. Poult. Sci.,* 7(2): 134-50, 2008.
43. Hassan, S.M., Effects of adding different dietary levels of Turmeric (*Curcuma longa Linn*) powder on productive performance and egg quality of laying hens. *Int. J. Poult. Sci.*, 15(4): 156-60, 2016.
44. Bermawie, N., Overcoming dengue fever with medicinal plants. *Agric. Res. Dev. News*., 28: 6-8, 2006.
45. Park, S., Kim, J., Kim, E., Kim, H., An, B. and Kang, C., Effects of dietary Turmeric powder on laying performance and egg qualities in laying hens. *Korean J. Poult. Sci.,* 39(1): 27-32, 2012. http://dx.doi.org/10.5536/KJPS.2012.39.1.027
46. Suwarta, F.X. and Suryani, C.L., The effects of supplementation of cinnamon and turmeric powder mixture in ration of quail on performance and quality of eggs. *World's Vet. J.,* 9(4): 249-254, 2019. https://dx.doi.org/10.36380/scil.2019.wvj31
47. Liu, M., Lu, Y., Gao, P., Xie, X., Li, D., Yu, D. and Yu, Mi., Effect of curcumin on laying performance, egg quality, endocrine hormones, and immune activity in heat stressed hens. *Poult. Sci.,* 99: 2196–2202. 2020. https://doi.org/10.1016/j.psj.2019.12.001

48. Lara, L.J. and Rostagno, M.H. Impact of heat stress on poultry production. *Anim.*, (Basel) 3: 356–369, 2013.
49. Mashaly, M.M., Hendricks, G.L., Kalama, M.A., Gehad, A.E., Abbas, A.O. and Patterson, P.H., Effect of heat stress on production parameters and immune responses of commercial laying hens. *Poult. Sci.*, 83: 889–894, 2004.
50. Ding, Y., Bu, X., Zhang, N., Li, L. and Zou, X., Effects of metabolizable energy and crude protein levels on laying performance, egg quality and serum biochemical indices of Fengda-1 layers. *Anim. Nutr.*, 2: 93- 98, 2016.
51. Li, Y.X., Wang, Y.Q., Pang, Y.Z., Li, J.X., Xie, X.H., Guo, T.J. and Li, W.Q. The effect of crude protein level in diets on laying performance, nutrient digestibility of yellow quails. *Int. J. Poult. Sci*., 10: 110–112, 2011.
52. Emadi, M., Kermanshahi, H. and Maroufyan, E., Effect of varying levels of turmeric rhizome powder on some blood parameters of broiler chickens fed corn soybean meal based diets. *Int. J. Poult. Sci*,. 6(5): 345–348, 2007.
53. Riasi, A., Kermanshahi, H. and Mahdavi, A.H., Production performance, egg quality and some serum metabolites of older commercial laying hens fed different levels of turmeric rhizome (Curcuma longa) powder. *J. Med. Plant Res.*, 6(11): 2141-2145, 2012. Available online at http://www.academicjournals.org/JMPR. DOI: 10.5897/JMPR11.1316
54. Laganá, C., Saldanha, E.S.P.B., Sartori, J.R., Gonzales, E., Luciano, R.L., Zanatta, G. and Fascina, V.B., Turmeric and vitamin E on the performance and quality of eggs from white layers. *Agric. Sci*., 10:720-726, 2019. https://doi.org/10.4236/as.2019.106056
55. Zacaria, A.M. and Ampode, K.M.B., Turmeric (*Curcuma longa* Linn.) as phytogenic dietary supplements for the production performance and egg quality traits of laying Japanese quail. *J. Anim. Health Prod.*, 9(3): 285-295, 2021. DOI: http://dx.doi.org/10.17852/journal.jahp/2021/9.3.285.295