Research Article

Turmeric (*Curcuma longa* Linn.) as Phytogenic Dietary Supplements for the Production Performance and Egg Quality Traits of Laying Japanese Quail

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Abstract | Quail farming is one of the most promising livelihoods due to the high demand for cheap eggs and meat with good protein sources that do not compromise health. In recent years, turmeric (*Curcuma longa* Linn.) has been utilized as a feed additive alternative to synthetic antibiotics in poultry production. This study was conducted to investigate the potential of turmeric rhizome powder (TRP) as dietary supplements on the laying performance, egg quality traits, and return on investment of laying Japanese quails. A total of 150 (110 days old) female quails were used in the feeding trial and arranged in a Completely Randomized Design (CRD) experimental set-up with 5 treatments replicated three times, having 10 birds in every replication. The treatments were: control group fed with commercial quail laying mash (T_1), homemade quail laying mash (HQLM) with 0% TRP (T_2), HQLM + 1% TRP (T_3), HQLM + 3% TRP (T_4), and HQLM + 5% (T_5) turmeric rhizome powder. The results revealed that supplementation of TRP into the diet of Japanese quails significantly influenced ($p<0.05$) the voluntary feed intake, percent egg production, feed conversion ratio, and egg yolk color. Moreover, numerical values on body weight, weight gain, egg weight, egg shape index, shell weight, and return on investment were higher in quails supplemented with TRP than those without TRP supplementation. In conclusion, supplementation of 5% TRP in the diet of laying quails seems potential to improve the egg yolk color, increase egg production, and obtain higher net income.

Keywords | Turmeric, *Coturnix japonica*, Laying performance, Egg production, Egg quality

Editor | Asghar Ali Kamboh, Sindh Agriculture University, Tandojam, Pakistan.
Received | May 31, 2021; **Accepted** | June 30, 2021; **Published** | July 15, 2021
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Citation | Zacaria AM and Ampode KMB (2021). 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.
DOI | http://dx.doi.org/10.17852/journal.jahp/2021/9.3.285.295
ISSN (Online) | 2307-8316; **ISSN (Print)** | 2309-3331

INTRODUCTION

Quail raising is believed to be a business enterprise for those with limited capital but looks for high returns quickly. The Japanese quail (*Coturnix japonica*, Temminck and Schlegel, 1849), often known as pugo, is a small, tailless bird that is widespread throughout Asia and belongs to the order Galliformes, family Phasianidae, and subfamily Phasianinae (Karaalp, 2009; Ampode, 2019). Moreover, quail farming is one of the most promising livelihoods due to the high demand for cheap eggs and meat with good protein sources that do not compromise health (BAR, 2010). It is economically viable and technically feasible because quails are quite resistant to various diseases, reach sexual maturity at six weeks of age, and quickly adapt to multiple rearing conditions (Ampode and Espina, 2019; Randall and Bolla, 2008). In addition, the rapid multiplication ability of these birds makes their meat and eggs readily available for human consumption.

Furthermore, eggs are considered a "miracle food" because they contain approximately 40 proteins, including bactericidal and antihypertensive proteins (Dilawar *et al.*, 2021). In addition, the nutrient content of an egg has 18 different amino acids, including stable amino acid composition, nine essential amino acids, optimal proportion of saturated and unsaturated fatty acids, and no carbohydrates or trans fats (Dilawar *et al.*, 2021).

In the Philippines, quail eggs, known as *itlog ng pugo*, have become popular "street food" sold boiled or as orange-colored *kwek-kweks* (BAR, 2001; Ampode and Espina 2019). Quail eggs and meat are novelty items and were considered another addition to the Philippines expanding food production industry. The meat of quails is lean, lesser fat and fewer calories, rich in vitamins and essential amino acids, rich in choline (a chemical essential for brain function), and low cholesterol value as compared to chicken eggs forming an ideal food for health-conscious consumers (Tarhyel *et al.*, 2012). In addition, many quail raisers reported a return on investment (ROI) of ₱41 to ₱66 for every ₱100 invested in the business, with a six-month payback timeframe (Capitan, 2003).

One of the most significant issues in quail farming is the high cost of feed, which accounts for 70-80% of total operating expenses, making the development of poultry diets challenging (Seahan *et al.*, 2021). Because most quail raisers work on a small-scale basis, the costs of feeds, medications, biologics, and vitamin-mineral supplements cannot be mitigated (Capitan, 2003). Although quails have a more robust immune system and are less susceptible to bacterial infections than chickens, their immune systems still need to be boosted. It has been stated that the supplementation of antibiotics in a regular diet reduces morbidity and mortality (Mahesh *et al.*, 2018). However, using these commercially available antibiotics may show its adverse effect on public health by developing antibiotic-resistant microflora (Gouda and Bhandary, 2018; Islam *et al.*, 2014). Thus, many developed countries have made it legal not to use in-feed antibiotics (Gouda and Bhandary, 2018). The development of alternative synthetic antibiotics is a constant challenge for animal nutritionists, and the quest for alternative feed supplements has intensified. Hence, medicinal herbs have received a lot of interest as possible antibiotic alternatives (Ibrahim *et al.*, 2005). One of the phytochemicals that can be used as phytogenic feed supplements is curcumin, and it is found in the dried rhizome of the plant turmeric (Benediktsdottir *et al.*, 2015).

Turmeric (*Curcuma longa* Linn.) is one of the many medicinal herbs promising agricultural products as natural feed additives in poultry diets (Lagua and Ampode, 2021). It is widely used as a spice, food preservative, and coloring agent with biological activities and medicinal applications (Chattopadhyay *et al.*, 2004). The active ingredient found in turmeric is curcumin, dimethoxycurcumin, bisdemethoxycurcumin and tetrahydrocurcuminoids (Kafi *et al.*, 2017). Traditionally, it is used to treat various diseases such as jaundice, ulcers, inflammation, diabetes, stomach disorders, antifungal, antibacterial, and viral infections, including chickenpox (Mahesh and Prabhakar, 2018).

Moreover, evidence proves turmeric powder's effect in the stimulation of egg production in hens and increased the yolk weight and egg yolk index (Radwan *et al.*, 2018). It has been reported that turmeric was used as medicinal plants as a natural antibiotic to feed poultry farms. However, different results on turmerics' effect on poultry production are contradictory. Hence, this study was conducted to ascertain the potential of turmeric rhizome powder (TRP) as dietary supplements on the laying performance, egg quality traits, and return on investment of laying Japanese quails.

MATERIALS AND METHODS

Experimental quails and cages

All procedures used in the study follow the Good Animal Husbandry practices guidelines in rearing poultry and livestock animals in the Philippines (PNS/BAFPS, 2008). One hundred fifty (150) female Japanese quails at 110 days old were used in the experiment in 42 days feeding trial. These were purchased from a reliable poultry farm and housed at the Poultry Experimental Station of the College of Agriculture, Sultan Kudarat State University, Barangay Blingkong, Lutayan, Sultan Kudarat.

The Japanese quails were housed in layer cages with the recommended standard floor space requirement of 16 inches per bird. Steel layer cages with slightly sloping flooring were constructed so that eggs would roll to the front of the house, making egg collection more accessible. The feeders and waterers 121.92cm (4ft) long, 10.16 cm (4 inches) wide, and 5.08 cm (2 inches) cages 1.5m in height were used using water pipe. Proper ventilation and prevention against extreme weather conditions were provided.

Rearing management

A recommended 16 hours of light per 24-hour day period was provided by using two 7-watt LED bulbs during night time (from 6 PM to 10 PM) and a 12-hour daylight period, and the standard feeding program of layer quails was followed. The experimental ration was given at 6:00 in the morning and 3:00 in the afternoon following the recommended daily feed allowance of 23g of quail laying mash per head (Ampode and Espina, 2019; Capitan, 2003). The experimental birds were provided with individual feeding troughs, and the feed given, and the feed refused was measured using the digital weighing scale. Clean drinking water was given thrice a day to ensure freshness for the whole duration of the study. Proper sanitation and cleanliness were observed, and daily removal of dung was followed to rid of flies and foul odor.

Preparation of turmeric rhizome powder

The turmeric rhizome was collected from Barangay Sisiman, Lutayan, Sultan Kudarat. The turmeric rhizome was washed, sliced into 2mm pieces, and sundried for 96 hours (Figure 1). The dried turmeric rhizomes were ground in a mechanical grinder and sieved using a 1mm mesh to obtain turmeric rhizome powder (Dumaup and Ampode, 2020). The turmeric rhizome powder was stored in dry large plastic containers with tight-fitting lids and stored at room temperature to prevent contamination and mold infestation (Kennedy *et al.*, 2020).

The proximate analysis of turmeric rhizome powder was analyzed at the Office of the Regional Animal Feed Analysis Laboratory of the Department of Agriculture in Region 12, Cotabato City, following the methods described by the AOAC (2016). The crude protein was determined using the Kjeldahl method, crude fiber (filter bag method), ash (combustion method), and oven drying method to determine the moisture content.

Figure 1: (A) Fresh and clean turmeric rhizome; (B) Chopped turmeric rhizome; (C) Sun-drying of chopped turmeric rhizome; (D) Mechanical grinding of dried turmeric rhizome; (E) Turmeric rhizome powder; (F) Newly harvested and processed turmeric rhizome powder.

Figure 2: Evaluation of egg yolk color using the Roche Yolk color fan.

Preparation of homemade quail laying mash

The experimental homemade quail laying mash was formulated based on the Philippine Recommends for Livestock Feed Formulation (Table 1), and the maximum inclusion rate of feedstuff was considered (PCAARRD, 2000). The varying levels of turmeric rhizome powder of 1, 3, and 5% were supplemented into the diet and mixed homogenously. The proximate analysis of turmeric rhizome meal is presented in Table 2.

Determination of egg quality parameters

Eggs were collected daily for the entire period of 42 days. Egg samples were individually weighed using a digital weighing scale, measurement of the width (mm) and length (mm) using Vernier caliper, and egg yolk color evaluation using the ROCHE Yolk color fan (Figure 2). The evaluation of yolk color was done on fresh egg samples while the eggshells were air-dried for 24 hours then weighed, including the shell membrane, using the digital weighing scale.

Experimental treatments and design

One hundred fifty (150) female Japanese quails at 110 days old were used as experimental animals and randomly assigned to five (5) treatments replicated three (3) times with ten (10) birds every replication.

This study used the experimental treatments described as follows:

T_1- Commercial Quail Laying Mash; T_2- Homemade Quail Laying Mash + 0% Turmeric Rhizome Powder; T_3- Homemade Quail Laying Mash + 1% Turmeric Rhizome Powder; T_4- Homemade Quail Laying Mash + 3% Turmeric Rhizome Powder; T_5- Homemade Quail Laying Mash + 5% Turmeric Rhizome Powder.

Table 1: Dietary composition and chemical analysis of the basal diet of laying Japanese quails.

Feed ingredients	Parts by weight
Ground Yellow Corn	51.00
Rice Bran D_1*	5.00
Soybean Meal	23.00
Fish Meal	7.30
Copra Meal	5.00
Dicalcium Phosphate	2.00
Limestone	5.00
Lysine	0.50
D-L Methionine	0.40
L- Threonine	0.20
Vitamin Mineral Premix[1]	0.20
Salt (NaCl)	0.20
Vegetable Oil	0.20
Total	100.00
Chemical Analysis (%)[2]	
Crude Protein	19.81
Crude Fiber	3.91
Ash	10.89
Moisture	11.34
Calculated Analysis	
Metabolizable Energy (kcal/kg)	2739.36
Calcium	2.76
Phosphorus	0.66
Methionine	0.80
Lysine	1.66
L-threonine	1.02
L-Tryptophan	0.17

*D_1 is a category of rice bran which has fine quality/texture. [1]Vitamin Mineral Premix: Vitamin A 5,000,000 i.u. Vitamin D3 2,000,000 i.u. Vitamin E 2,000 i.u. Riboflavin 4,350 mg, Thiamine 1,800 mg, Pyridoxine 50 mg, Niacin 40,150 mg, Calcium Pantothenate 5,500 mg, Biotin 0.1 mg, Folic Acid 90 mg, Para Amino Acid Benzoic Acid 4,000 mg, Inositol 0.74 mg, Manganese Sulfate 98,000 mg, Ferrous Sulfate 40,000 mg, Potassium Iodine 1,500 mg, Cobalt Carbonate 800 mg, Copper Sulfate 3,000 mg, Zinc Oxide 40,000 mg, DL- Methionine 23,000 mg, L-Lysine 22,000 mg, Lecithin 20,000 mg, Cod Liver Oil 160,000 mg, Carrier q.s ad. [2]Analyzed following the AOAC (2016).

Table 2: Proximate Analysis of Turmeric Rhizome Meal.[1]

Parameter	Composition (%)
Dry Matter	83.81
Crude Protein	9.78
Crude Fiber	7.53
Moisture	16.19
Ash	9.17

[1]The analysis was performed in triplicate samples following the methods described by the AOAC (2016).

Data gathered

The following experimental parameters were collected to assess the growth and laying performance of Japanese quails:

1. *Initial Weight (g)* – obtained by weighing the birds individually on day 1
2. *Body Weight (g)*– the weight of the birds at the end of the duration of the study
3. *Bi-weekly Weight Gain (g)* – the total gain in weight of the quails computed using the formula:

$$\text{Weight Gain (g)} = \text{Body weight (g)} - \text{Initial weight (g)}$$

4. *Average Daily Gain (g)* - measures the daily gain in weight and computed using this formula:

$$\text{ADG (g)} = \frac{\text{Body weight} - \text{Initial weight}}{\text{Number of feeding days}}$$

5. *Bi-weekly Voluntary Feed Intake (g)* – measures the total weekly feed consumption of the birds and computed using this formula:

$$\text{VFI (g)} = \text{Total Feed Given} - \text{Feed Refused}$$

6. *Weekly Egg Production (%)* – the number of eggs produced per week.
7. *Feed Conversion Ratio* - measures the efficiency of quails in converting feed into the egg and computed using the formula:

$$\text{FCR} = \frac{\text{Total Feed Intake}}{\text{No. of egg produced x egg weight}}$$

Egg quality traits

- *Egg Weight (g)* – individually weighed using the digital weighing scale
- *Shell weight (g)* - eggshell with shell membrane was weighed using the digital weighing scale
- *Yolk color* – under the white background, yolk color was evaluated using the ROCHE Yolk color Fan
- *Egg Shape Index (%)* - length and width of the egg measured using a Vernier caliper, and then egg shape index was determined using the formula:

$$\text{Egg Shape Index} = \frac{\text{Width of egg (mm)}}{\text{Length of egg (mm}} \times 100$$

Return on investment (%)

Return on investment was calculated using the following formula:

$$\text{ROI (\%)} = \frac{\text{Net Income}}{\text{Total Production Cost}} \times 100$$

Statistical analysis

The data gathered was subjected to a One-way Analysis of Variance (ANOVA), and a comparison of treatment means was done using Tukey's Honest Significant Difference (HSD) Test using Statistical Package of Social Science software version 21. A p-value of <0.05 was considered significant.

RESULTS AND DISCUSSION

Bi-weekly weight gain

Turmeric powder had a chemical composition percentage of 83.81% dry matter (DM), 9.78% crude protein (CP), 7.53% crude fiber (CF), 16.19% moisture, and 9.17% ash. The body weight and bi-weekly weight gain of broiler chickens were not significantly affected (p>0.05) by the supplementation of turmeric rhizome powder (Tables 3 and 4). Numerically, quails fed with commercial quail laying mash got the highest cumulative body weight, while quails fed with 5% turmeric rhizome powder got the lowest. Data shows that quails fed with commercial quail laying mash (T_1) got 145.97g, followed by T_3, T_4, T_2, and T_5 with 145.01g, 141.09g, 140.49g, and 139.36g, respectively.

Table 3: The average body weight of the Japanese quail supplemented with graded levels of turmeric rhizome powder.

Treatment[1]	Initial Weight	Week 2	Week 4	Week 6	Total	Mean[ns]
$T_{1=}$ CQLM	132.93	140.43	145.87	151.63	437.93	145.97
$T_{2=}$ 0% TRP	127.27	134.97	140.40	146.10	421.47	140.49
$T_{3=}$ 1% TRP	130.97	139.10	144.97	150.97	435.04	145.01
$T_{4=}$ 3% TRP	127.20	135.27	141.07	146.93	423.27	141.09
$T_{5=}$ 5% TRP	125.87	133.77	139.23	145.07	418.07	139.36
p-value	0.193[ns]	0.172[ns]	0.149[ns]	0.116[ns]		0.560
CV	2.92	2.59	2.43	2.22		4.01

[1]CQLM: Commercial Quail Laying Mash; TRP: Turmeric Rhizome Powder; CV: Coefficient of Variance; [ns] = not significant (p>0.05).

Table 4: Bi-weekly weight gain of the Japanese quail fed with graded levels of turmeric rhizome powder.

Treatment[1]	Week 2	Week 4	Week 6	Total	Mean[ns]
$T_{1=}$ CQLM	7.50	5.43	5.77	18.7	6.23
$T_{2=}$ 0% TRP	7.70	5.43	5.70	18.83	6.28
$T_{3=}$ 1% TRP	8.13	5.87	6.00	20.00	6.67
$T_{4=}$ 3% TRP	8.07	5.80	5.87	19.74	6.58
$T_{5=}$ 5% TRP	7.90	5.47	5.83	19.2	6.40
p-value	0.703[ns]	0.259[ns]	0.956[ns]		0.990
CV	7.77	5.33	8.51		19.36

[1]CQLM: Commercial Quail Laying Mash; TRP: Turmeric Rhizome Powder; CV: Coefficient of Variance; [ns] = not significant (p>0.05).

Moreover, results revealed no significant difference (p>0.05) in the bi-weekly weight gain of Japanese quails at weeks 2, 4, and 6 (Table 4). Although not significant, it was observed that quails supplemented with 1% turmeric rhizome powder got the highest weight gain while quails fed with the commercial quail laying mash got the lowest gain in weight. The data shows that Treatment 3 gained 6.67g, followed by T_4 (6.58g), T_5 (6.40g), T_2 (6.27g), and T_1 (6.23g) in descending order. Although dietary supplementation of turmeric rhizome powder significantly reduced the feed intake, it did not affect quails' body weight gain. These findings are similar to the investigation of Al-Kassie *et al.* (2011), who reported that supplementation of turmeric at 5.0g/kg of feed could increase the body weight of broiler chickens. This could be attributed to the active ingredients present in turmeric, which increased the excretion of digestive enzymes, pancreatic lipase, and intestine villi size, thus improving feed utilization and nutrient absorption in birds (Platel and Srinivasan, 2000; Rajput *et al.*, 2013).

Voluntary feed intake

The weekly voluntary feed intake of the Japanese quail was significantly reduced (p<0.05) by the supplementation of turmeric rhizome powder (Table 5). The data shows that quails fed with commercial quail laying mash (T_1) got the highest voluntary feed intake with 153.98g, followed by T_2, T_3, T_4, and T_5 with 150.82g, 149.05g, 145.58g, and 141.85g, respectively.

It was observed that the higher levels of turmeric rhizome powder supplemented in the diet resulted in reduced feed intake. The present result contrasts with what is reported by Abou-Elkhair (2014), who found that turmeric rhizome powder had no significant effect on the feed intake of broiler chickens. Further, Wang *et al.* (2016) reported that daily feed intake of broilers increased by adding 100 and 200 mg/kg turmeric rhizome extract, but daily feed intake decreased by 300 mg/kg. These differences are consistent with the results of Moeini *et al.* (2011) and Malekizadeh *et al.* (2012), who added 3% turmeric rhizome powder to the laying hen diet.

However, the result of the present experiment confirms with the earlier investigation of Kilany and Mahmoud (2014) and Kennedy *et al.* (2020) that feed intake of laying Japanese quails was significantly reduced when turmeric powder was supplemented into the diet. The significant decreased in feed intake could be attributed to the active ingredients present in the turmeric, resulting in the change of aroma, palatability, and taste of feeds (Suwarta and Suryani, 2019).

Egg production

The cumulative egg production from week 1 to 6 of the

Japanese quails was significantly influenced ($p<0.05$) by the dietary supplementation of turmeric rhizome powder (Table 5). Data shows that quails fed with commercial quail laying mash (T_1) had the same egg production percentage as quails supplemented with 3% TRP (T_3) with 82.70%. Statistically, the cumulative egg production percentage of quails from week 1 to week 6 revealed a comparable result to the birds fed with commercial quail laying mash (T_1) and quails supplemented with 1%, 3%, and 5% TRP in the diet. However, quails fed with homemade quail laying mash without TRP supplementation (T_2) got the lowest egg production percentage compared to other treatments. Thus, the result of the study indicated that supplementation of TRP in the diet seems potential to improve the egg production performance of laying Japanese quails.

The egg production percentage of the current study is higher than the report of Mirzah and Djulardi (2019) that quails supplemented with turmeric extract have 79.99% hen-day egg production. Numerically, the decrease in egg production in laying quails supplemented with turmeric rhizome powder is most likely due to reduced feed consumption. It should be noted that high feed intake of laying quail increases nutrient consumption, particularly protein intake (Mirzah and Djulardi, 2019). Thus, reduced feed consumption will also reduce the available nutrients for egg production (Liu *et al.*, 2019). However, the result of the study is similar to the investigation of Liu *et al.* (2019) that supplementation of turmeric at higher levels decreased the egg production of the layer chicken.

Feed conversion ratio

Results revealed that supplementation of turmeric rhizome powder in the Japanese quails' diet from week 1 to 6 significantly affects ($p<0.05$) the feed conversion ratio (Table 5). The worst feed conversion ratio was observed in birds fed with homemade quail laying mash without TRP supplementation (T_2) with 2.66g, followed by T_1, T_3, T_4 with 2.64g, 2.63g, 2.49g, and the lowest (better) FCR was obtained in quails fed with HQLM supplemented with 5% TRP (T_5) with 2.39g. Consequently, it could be seen that quails supplemented with 5% TRP (T_5)

Table 5: The effects of turmeric rhizome powder on the laying performance of Japanese quails.

	WEEK						Total	Mean
	1	2	3	4	5	6		
Voluntary Feed Intake (g)								
$T_{1=}$ CQLM	157.20[a]	152.50[a]	152.60	154.40	153.30	153.90[a]	923.90	153.98[a]
$T_{2=}$ 0% TRP	150.10[ab]	149.90[ab]	151.70	151.60	152.30	149.30[ab]	904.90	150.82[b]
$T_{3=}$ 1% TRP	147.40[ab]	147.80[ab]	150.30	150.70	149.80	148.30[ab]	894.30	149.05[b]
$T_{4=}$ 3% TRP	145.30[ab]	145.60[bc]	145.90	145.80	145.00	145.90[ab]	873.50	145.58[c]
$T_{5=}$ 5% TRP	136.70[b]	139.60[c]	144.40	144.80	143.80	141.80[b]	851.10	141.85[d]
p-value	0.017*	0.001**	0.067[ns]	0.246[ns]	0.216[ns]	0.054[ns]		0.000**
CV	3.89	1.62	2.40	3.69	3.75	2.84		1.23
Egg Production (%)								
$T_{1=}$ CQLM	82.38	82.38	81.43	81.90	83.81	84.29	496.19	82.70[a]
$T_{2=}$ 0% TRP	80.95	80.48	80.95	80.00	80.48	81.43	484.29	80.72[b]
$T_{3=}$ 1% TRP	82.86	83.33	82.86	82.86	84.76	85.24	501.91	83.65[a]
$T_{4=}$ 3% TRP	81.90	82.38	82.38	82.38	83.81	83.33	496.18	82.70[a]
$T_{5=}$ 5% TRP	82.38	82.86	81.43	81.90	82.86	82.86	494.29	82.38[a]
p-value	0.846[ns]	0.376[ns]	0.916[ns]	0.147[ns]	0.281[ns]	0.585[ns]		0.000**
CV	2.62	2.10	3.46	1.56	2.81	3.48		1.01
Feed Conversion Ratio								
$T_{1=}$ CQLM	2.84	2.57	2.67	2.64	2.60	2.52	15.84	2.64[b]
$T_{2=}$ 0% TRP	2.79	2.61	2.65	2.66	2.69	2.54	15.93	2.66[b]
$T_{3=}$ 1% TRP	2.68	2.88	2.60	2.59	2.53	2.49	15.77	2.63[b]
$T_{4=}$ 3% TRP	2.66	2.46	2.47	2.51	2.39	2.45	14.95	2.49[ab]
$T_{5=}$ 5% TRP	2.48	2.35	2.45	2.40	2.37	2.30	14.35	2.39[a]
p-value	0.150[ns]	0.406[ns]	0.372[ns]	0.262[ns]	0.035*	0.242[ns]		0.000**
CV	5.99	12.67	6.39	5.92	4.70	5.30		3.90

CQLM: Commercial Quail Laying Mash; TRP: Turmeric Rhizome Powder; CV: Coefficient of Variance; ns = not significant ($p>0.05$). * = Means with different superscripts in the same column differ significantly ($P<0.05$); ** ($P<0.01$).

consumed less but produced a comparable number of eggs with other treatments except for quails without TRP (T_2) supplementation. In addition, numerical data shows that quails supplemented with 5% TRP (T_5) in the diet produced bigger or heavier eggs. These results may be due to differences in feed consumption and egg mass caused by differences in nutrient content in the diet, particularly the essential fatty acid, linoleic acid, choline, methionine, or TRP supplementation could improve feed utilization efficiency and digestibility (Suwarta and Suryani, 2019). Further, the relationship between feed consumption and egg mass is determined by feed conversion, and low feed conversion values indicate better feed use efficiency.

The recent findings confirm the studies conducted by Ali *et al*. (2007), who reported that 2% turmeric powder in the diet led to a better FCR. Further, Radwan *et al*. (2008) and Durrani *et al*. (2006) also reported that 2g per kg and 5g/kg of turmeric powder in the diet had a beneficial effect on egg mass production and body weight and it improved the feed conversion ratio.

Egg weight

The average egg weight of the Japanese quails supplemented with graded levels of turmeric rhizome powder from weeks 1 to 6 did not significantly influence ($p>0.05$) the egg weight. However, the numerical data shows that egg weight increases when higher TRP levels were supplemented in the diet (Table 6).

Numerically, the data shows that T_5 with 5% TRP in the diet got the highest egg weight compared to other treatments. On the other hand, laying quails supplemented with 1% TRP got the lowest egg weight (9.77g). The average egg weight observed in T_3 (1% TRP) was similar to those observed by Tuleum *et al*. (2013) that the average egg weight of laying quails fed with a diet consisting of 20% crude protein was 9.75g/egg. This result is also similar to the result 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. In addition, the increasing egg weight of hens supplemented with 5% TRP might be attributed to increased dietary fatty acids compared with those fed diets without TRP and those quails supplemented with lower levels of turmeric rhizome powder.

Egg shape index

The average egg shape index of the Japanese quails supplemented with graded levels of turmeric rhizome powder is presented in Table 6. The results revealed that dietary supplementation of turmeric rhizome powder did not significantly influence the egg shape index in laying Japanese quails. Numerical data shows that the highest egg shape index was observed in T_2 (0% TRP) followed by T_1, T_5, T_4 and T_3 with 80.34, 80.34, 79.98, 79.25, and 78.76, respectively.

The results obtained in the current study concur with Liu *et al*. (2019), who reported that turmeric supplementation in the diet did not affect the egg shape index in layer chicken. Moreover, the current experiment results were consistent with the studies conducted by Zita *et al*. (2013), which demonstrated that the egg shape index at 13 weeks of age is about 77.64 ± 0.19g. This finding indicated that the egg's shape index might be affected by the age of layers of the Japanese quails.

Shell weight

The results revealed that Japanese quails supplemented with graded levels of turmeric rhizome powder from week 1 to 6 did not significantly influence ($p>0.05$) the eggshell weight (Table 6). Numerical data shows that T_5 (5% TRP) got the highest eggshell weight with 0.92g, followed by T_1, T_4, T_3, and T_2 with 0.90g, 0.89g, 0.87g, and 0.86g, respectively.

The results obtained in the present study were consistent with the investigation of Saraswati *et al*. (2013), who reported that supplementation of turmeric powder in the diet did not significantly influence the eggshell weight and thickness of the Japanese quail eggs. 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.

Egg yolk color

The average egg yolk color of the Japanese quails supplemented with graded turmeric rhizome powder levels is presented in Table 6. Results revealed that supplementation of the TRP in the diet significantly improved Japanese quails' yolk color. It was observed that from week 1 to week 6, egg yolk of the Japanese quail supplemented with turmeric rhizome powder showed better results. The mean value of the egg yolk color showed that T_5 (5% TRP) got the highest value with 7.41, followed by T_4, T_3, T_2, and T_1 fed with commercial quail laying mash got the lowest yolk color of 7.26, 7.07, 6.94, and 4.78, respectively.

This implies that with the higher level of turmeric rhizome powder supplemented in the diet, the turmeric (curcumin) bioactive components were deposited in the yolk. Jacqueline *et al*. (1998) reported that the yolk color's intensity depends largely on a diet. It should be noted that egg yolk color is a vital egg quality trait for consumers (Hassan, 2016). Further, egg yolk is the primary source of protein, minerals, and lipids for the embryo's development (Duce *et al*., 2011).

Return on investment

The cost and return analysis of Japanese quail fed with homemade ration supplemented with graded levels of turmeric rhizome powder is presented in Table 7. The highest net profit of the Japanese quails per bird was observed in T_5 supplemented with 5% TRP having ₱37.01, followed by T_4, T_3, and T_2 with a net income of ₱36.75, ₱36.74, ₱34.11. The lowest net income was obtained in birds fed with commercial quail laying mash with a net profit of ₱30.86.

Likewise, birds fed with 5% TRP gained the highest ROI of 73.30%, and the lowest ROI of 54.48% was obtained in T_1 fed with commercial quail laying mash. The ROI was affected by the net income and the total production cost. Higher egg production and lower production costs will give a higher ROI.

Table 6: The effects of turmeric rhizome powder on the egg quality traits of Japanese quails.

	WEEK						Total	Mean
	1	2	3	4	5	6		
Egg Weight (g)								
$T_{1=}$ CQLM	9.63	10.31	10.05	10.21	10.06	10.35	60.60	10.10
$T_{2=}$ 0% TRP	9.52	10.20	10.14	10.20	10.09	10.33	60.50	10.08
$T_{3=}$ 1% TRP	9.52	9.12	9.97	10.03	10.00	9.99	58.62	9.77
$T_{4=}$ 3% TRP	9.53	10.26	10.25	10.07	10.31	10.20	60.63	10.10
$T_{5=}$ 5% TRP	9.56	10.24	10.37	10.57	10.48	10.66	61.87	10.31
p-value	0.997^{ns}	0.488^{ns}	0.763^{ns}	0.639^{ns}	0.537^{ns}	0.113^{ns}		0.109^{ns}
CV	4.71	9.11	3.99	4.46	3.76	2.62		3.25
Egg Shape Index (%)								
$T_{1=}$ CQLM	79.74	79.20	79.47	81.41	79.55	80.76	480.12	80.02
$T_{2=}$ 0% TRP	82.12	81.04	80.09	80.92	79.44	78.45	482.06	80.34
$T_{3=}$ 1% TRP	81.30	71.69	80.48	79.66	80.12	79.33	472.58	78.76
$T_{4=}$ 3% TRP	80.11	81.27	79.09	77.62	78.98	78.41	475.48	79.25
$T_{5=}$ 5% TRP	81.28	80.59	79.38	77.26	78.85	82.49	479.85	79.98
p-value	0.555^{ns}	0.553^{ns}	0.898^{ns}	0.008^{ns}	0.757^{ns}	0.768^{ns}		0.649^{ns}
CV	2.34	9.92	2.43	1.61	1.60	5.59		2.51
Shell Weight (g)								
$T_{1=}$ CQLM	0.89	0.83	0.91	0.88	0.93	0.93	5.37	0.90
$T_{2=}$ 0% TRP	0.77	0.85	0.87	0.86	0.91	0.88	5.14	0.86
$T_{3=}$ 1% TRP	0.80	0.86	0.89	0.87	0.89	0.89	5.20	0.87
$T_{4=}$ 3% TRP	0.81	0.90	0.90	0.88	0.93	0.90	5.32	0.89
$T_{5=}$ 5% TRP	0.83	0.91	0.92	0.94	0.95	0.97	5.52	0.92
p-value	0.189^{ns}	0.421^{ns}	0.263^{ns}	0.243^{ns}	0.417^{ns}	0.260^{ns}		0.115^{ns}
CV	6.68	6.30	3.51	5.02	4.86	6.02		5.02
Egg Yolk Color								
$T_{1=}$ CQLM	4.78^{b}	5.00^{b}	4.56^{b}	4.78^{b}	4.78^{b}	4.78^{a}	28.67	4.78^{b}
$T_{2=}$ 0% TRP	5.89^{a}	6.44^{ab}	6.78^{a}	7.22^{a}	7.67^{a}	7.67^{b}	41.67	6.94^{a}
$T_{3=}$ 1% TRP	6.00^{a}	6.89^{a}	7.22^{a}	7.33^{a}	7.33^{a}	7.67^{b}	42.44	7.07^{a}
$T_{4=}$ 3% TRP	6.33^{a}	7.00^{a}	7.33^{a}	7.44^{a}	7.67^{a}	7.78^{b}	43.56	7.26^{a}
$T_{5=}$ 5% TRP	6.22^{a}	6.89^{a}	7.56^{a}	7.78^{a}	8.00^{a}	8.00^{b}	44.44	7.41^{a}
p-value	.001**	.015*	.000**	.000**	.000**	.000**		.000**
CV	5.70	9.82	5.61	5.84	4.37	2.68		8.60

CQLM: Commercial Quail Laying Mash; TRP: Turmeric Rhizome Powder; CV: Coefficient of Variance; ^{ns} = not significant (p>0.05); * = Means with different superscripts in the same column differ significantly (P<0.05); ** (P<0.01).

Table 7: Cost and Return Analysis of the Japanese quail supplemented with graded levels of turmeric rhizome powder.#

Treatment[1]	Total no. of eggs	Price per egg (PhP)	Ready to lay quails (Price/head)	Expenses (Feed and supplement costs)	Total production costs	Gross Income	Net Income	BCR[2]	ROI[3] (%)
$T_{1=}$ CQLM	35	2.50	28.00	28.64	56.64	87.50	30.86	1.54	54.48
$T_{2=}$ 0% TRP	34	2.50	28.00	22.89	50.89	85.00	34.11	1.67	67.03
$T_{3=}$ 1% TRP	35	2.50	28.00	22.76	50.76	87.50	36.74	1.72	72.38
$T_{4=}$ 3% TRP	35	2.50	28.00	22.75	50.75	87.50	36.75	1.72	72.41
$T_{5=}$ 5% TRP	35	2.50	28.00	22.49	50.49	87.50	37.01	1.73	73.30

All costs were presented in Philippine peso (PhP); 1 USD = 48.55 PhP. [1]CQLM: Commercial Quail Laying Mash; TRP: Turmeric Rhizome Powder; [2]BCR: Benefit-cost ratio was calculated using this formula: Gross Income / Total Production Cost; [3]ROI: Return on investment.

CONCLUSIONS AND RECOMMENDATIONS

The supplementation of 5% turmeric rhizome powder (TRP) in the diet of Japanese quails significantly reduced the voluntary feed intake. Although the voluntary feed intake of laying quails decreases, the body weight gain and egg production percentage were not affected. Moreover, supplementation of 5% TRP improved the body weight gain, egg production percentage, feed conversion ratio, egg yolk color and gave a higher return on investment. Therefore, the supplementation of turmeric rhizome powder in the diet of quails is recommended to improve the egg yolk color, increase egg production, and obtain higher net income.

ACKNOWLEDGMENTS

The authors extend their sincere appreciation to Engr. Nathaniel D. Naanep and the University Veterinarian Dr. Ne B. Velasco for their suggestions and comments. Also, heartfelt gratitude is extended to the Office of the Regional Animal Feed Analysis Laboratory of the Department of Agriculture Region XII, Cotabato City, for the technical assistance and proximate laboratory services.

NOVELTY STATEMENT

The novelty of this study was the utilization of turmeric rhizome powder as phytogenic dietary supplements for Japanese quails, which significantly reduced the feed intake but did not affect the body weight gain and egg production of laying Japanese quails.

AUTHOR'S CONTRIBUTION

The authors contributed equally to this work.

Conflict of interest

The authors have declared no conflict of interest.

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