International Journal of Environmental & Agriculture Research (IJOEAR)
ISSN: [2454-1850]
[Vol-12, Issue-4, April- 2026]
Website: www.ijoear.com
Journal DOI: 10.25125/agriculture-journal

Effects of Piperine-Containing Diet on Production, Physical Quality, and Sensory Attributes of the Japanese Quail Eggs

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Received:- 09 April 2026/ Revised:- 18 April 2026/ Accepted:- 27 April 2026/ Published: 05-05-2026

***Abstract*— *Poultry farming serves an important role in modern society. As time goes on, there is a need to find other sources of poultry products to suffice the need and demand of poultry products. Japanese quails (Coturnix coturnix japonica) are avian species that can be a source of poultry products. However, few poultry farmers engage in quail farming as this species remains understudied. This study aimed to determine the effects of the application of piperine to the performance of Japanese quails and egg quality traits and sensory attributes of the produced eggs. The study was carried out in Randomized Complete Block Design (RCBD) to study the effects of piperine on the production, feed consumption, and egg quality traits of the Japanese quails while Complete Randomized Design (CRD) was used for sensory evaluation. The results indicated that the highest egg production was observed at 1.00% piperine inclusion with 24 eggs produced per week. Moreover, at 1.50% level, the quails gained the lowest feed conversion ratio (FCR) with an FCR of 1.91. The results revealed that at 1.50% to 2.00% piperine inclusion, egg quality traits were negatively affected with shell thickness of the egg tip observed to be 0.2917 mm, shell thickness of the butt to be 0.2425 mm, and egg shape index of 78.88%. The sensory evaluation indicated that piperine inclusion can affect egg white acceptability of the produced eggs, with 1.5% piperine inclusion having an egg white (color) acceptability of 'like moderately.'*

***Keywords*— Coturnix coturnix japonica, Piperine, Quail Performance, Egg Quality Traits, Sensory Evaluation.**

I. INTRODUCTION

Poultry farming is an important source of revenue generation for both small and large-scale farmers. Chickens are one of the most remarkable and recognized sources of poultry meat and eggs. However, as time goes on, the demand for poultry products also increases. Thus, it is essential to find other sources of poultry products and generate new knowledge with regards to their productivity and egg quality. The Japanese quail (*Coturnix coturnix japonica*) is another example of a poultry species that can produce poultry eggs. Japanese quails thrive in small cages and are inexpensive to keep. Factors affecting egg productivity of birds include improper nutrition, management mistakes, feed consumption, water intake, climate, parasite infestation, and diseases.

Black pepper (*Piper nigrum*) is one of the most commonly used spices globally (Meixner, 2019) and belongs to the Piperaceae family and has been used as flavoring for foods. Piperine is a major component of black pepper and is attributed for the pungency of *P. nigrum* (Park, 2012). Piperine has been recognized as a natural antioxidant and antimicrobial agent (Zarai et al., 2013). Recently, piperine has attracted much attention due to its pharmacological effects, which include antimicrobial, cardioprotective, immunomodulatory, antidiabetic, and antioxidant effects (Haq et al., 2021). These previous studies and observations support the hypothesis that piperine may positively affect laying performance of Japanese quails as well as the quality and sensory attributes of the Japanese quail egg. However, there is only limited knowledge that is known towards the effects of piperine-containing diet on the quality and sensory attributes of the Japanese quail egg and performance of Japanese quail (*C. coturnix japonica*). Hence, this present study was designed to determine and evaluate the effects of piperine-containing diet on performance of the Japanese quail and the quality and sensory attributes of the Japanese quail eggs in alleviating the current problem towards the supply of quail eggs.

II. MATERIALS AND METHODS

The study was conducted at Barangay Patag, Baybay City, Leyte from October 16 to December 4, 2024. A total of 100 eight-month-old Japanese quails were used in the study. The Japanese quails were subjected to one week of acclimatization and another week for feeding trials. In evaluating the quail performance and egg quality traits of the Japanese quail eggs, the study was carried out in Randomized Complete Block Design (RCBD) with cages serving as blocks. The experimental treatments were:

- T0 – 0.00% piperine inclusion
- T1 – 0.50% piperine inclusion
- T2 – 1.00% piperine inclusion
- T3 – 1.50% piperine inclusion
- T4 – 2.00% piperine inclusion

Meanwhile, the sensory evaluation was carried out in Complete Randomized Design (CRD) with a set plan of t = 5, k = 3, r = 4, b = 10, x = 1, E = 0.62 (Type V), where t = treatments, k = panelist groups, r = replications, b = blocks, x = sample size, and E = error.

2.1 Quail Performance:

The eggs laid by the Japanese quails were collected daily in the afternoon and were then weighed using a digital weighing scale. The amount of feed refused by the Japanese quails was also weighed daily in the afternoon. The weekly voluntary feed intake (WVFI) of the birds shows the amount of feed consumed by the Japanese quails on a weekly basis. The WVFI is computed using the formula below:

$$WVFI = \text{Feeds Given} - \text{Feeds Refused} \quad (1)$$

The feed conversion ratio (FCR), which shows the amount of feed needed to produce an egg, is computed using the following formula:

$$FCR = \frac{Feed\ Consumption_{in\ terms\ of\ grams}}{Number\ of\ Eggs\ Produced} \quad (2)$$

2.2 Egg Quality Traits

Five eggs per block were randomly selected in evaluating the egg quality traits of the produced Japanese quail eggs. The egg yolk color was determined using a yolk color fan; the eggshell thickness was determined using a micrometer from the VSU Department of Physics; the egg widths and lengths were determined using a vernier caliper. The width and length of the eggs allowed the researchers to compute the egg shape index in terms of percentage. The egg shape index (%) can be computed using the formula below:

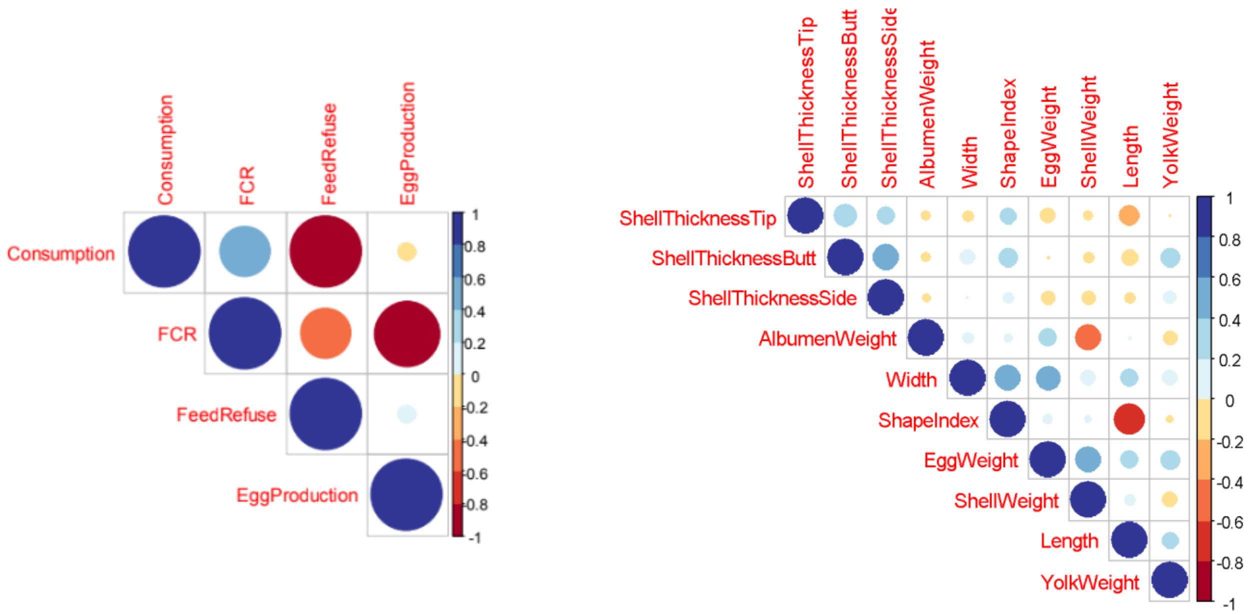
$$Egg\ Shape\ Index\ (\%) = \frac{Egg\ Width_{in\ terms\ of\ cm}}{Egg\ Length_{in\ terms\ of\ cm}} \times 100\% \quad (3)$$

III. SENSORY ATTRIBUTES

The sensory attributes of the Japanese quail eggs were evaluated by conducting a sensory evaluation with 120 selected respondents. The selected respondents were semi-trained and trained panelists from the VSU Department of Food Science and Technology. The 9-point hedonic scale was used as the system of evaluation during the sensory evaluation. The respondents were first informed as to what the study was about using the vernacular dialect of the area. Incentives were also provided to the respondents. The data that were gathered from the sensory evaluation of the produced Japanese quail eggs include the egg yolk color, egg albumen color, aroma, taste, texture, and general acceptability.

IV. RESULTS AND DISCUSSION

The results indicated that the parameters in quail performance and egg quality traits have a correlation among other parameters. The correlation plot shows the relationship among the different parameters of the study. The darker the color in the correlation plot, the stronger the relationship between parameters. Figure 1 shows the correlation plot for quail performance and the correlation plot for the egg quality traits.



(a) Correlation Plot for Quail Performance **(b) Correlation Plot for Egg Quality Traits**

FIGURE 1: Correlation Plots for the Quail Performance and Egg Quality Traits of the Produced Japanese Quail Eggs. (a) shows the correlation plot for the quail performance whereas (b) shows the correlation plot for the egg quality traits

The results for the analysis in quail performance and egg quality traits show that there are significant differences among the quails fed with varying levels of piperine inclusion. The highest egg production was observed at T2 while the lowest feed to egg conversion (lowest FCR) was observed at T3. Table 1 shows the performance of the quails and the egg quality traits of the Japanese quail eggs.

4.1 Quail Performance

The analysis indicated that there is a significant difference among the treatments in the different parameters for quail performance. One of the important parameters for quail performance are egg production and FCR. The egg production was observed to be at its highest at T2 wherein piperine inclusion was at 1.00%. Meanwhile, FCR was observed to be at its optimal level (lowest) at T3 with 1.50% piperine inclusion; a lower FCR suggests that a quail is performing well in terms of egg production as it needs lower feed consumption to produce as many eggs as others. Table 1 shows the result of the analysis for quail performance.

TABLE 1
QUAIL PERFORMANCE AS INFLUENCED BY THE PIPERINE-CONTAINING DIET

Parameter	T0 (0%)	T1 (0.5%)	T2 (1.0%)	T3 (1.5%)	T4 (2.0%)
Feed Refuse (g)	1.083333^{a}	8.633333^{b}	2.607143^{a}	8.720238^{b}	7.619048^{b}
Voluntary Feed Intake (g)	48.91667^{a}	41.36667^{b}	47.39286^{a}	41.27976^{b}	42.38095^{b}
Egg Production (eggs/week)	21.25000^{ab}	18.91667^{b}	24.29167^{a}	22.75000^{a}	22.91667^{a}
Feed Conversion Ratio (FCR)	2.489325^{a}	2.417120^{ab}	2.021809^{bc}	1.912829^{c}	1.981518^{bc}

Note: Values with different superscripts within the same row differ significantly (P<0.05)

The weekly voluntary feed intake of the Japanese quails has been affected due to the pungency of black pepper caused by the alkaloid piperine. Brenes et al. (2010) reported that spices have been observed to affect performance of avian species. Similar studies have also shown that piperine inclusion can affect feed consumption (Amad et al., 2011).

The weekly egg production was observed to be at its highest at T2 (1.00% piperine inclusion). Improper nutrition and diet among avian species can affect their egg production (Jacob et al., 2018). Since T2 has one of the highest feed consumptions, the quails were able to maximize the feeds given to them compared to other treatments. Thus, a higher feed consumption was observed at T2.

The treatment with the highest efficiency in feed to egg conversion (lowest FCR) was T3 (1.50% piperine inclusion). The feed consumption and egg production play a vital role in the FCR of the Japanese quails. The consumption of the quails in T3 is significantly different compared to other treatments and it also has one of the highest egg productions. Hence, the lowest FCR was observed at T3.

4.2 Egg Quality Traits

The analysis indicated that only egg weight, egg shape index, egg width, shell thickness tip, shell thickness butt, and yolk weight were affected by the piperine-containing diet. Table 2 shows the egg quality traits of the produced Japanese quail eggs upon analysis.

TABLE 2
EGG QUALITY TRAITS OF THE JAPANESE QUAIL EGGS WITH THE SUPPLEMENTATION OF THE PIPERINE-CONTAINING DIET IN THEIR FEEDS

Parameter	T0 (0%)	T1 (0.5%)	T2 (1.0%)	T3 (1.5%)	T4 (2.0%)
Egg Weight (g)	9.833^{b}	10.875^{a}	10.583^{a}	10.458^{ab}	10.333^{ab}
Egg Shape Index (%)	81.918^{a}	85.123^{a}	83.415^{a}	81.886^{ab}	78.883^{b}
Egg Width (cm)	2.423^{b}	2.526^{a}	2.499^{a}	2.487^{ab}	2.439^{ab}
Egg Length (cm)	2.961	2.983	3.009	3.039	3.111
Shell Thickness Side (mm)	0.254	0.26	0.285	0.296	0.259
Shell Thickness Tip (mm)	0.298^{ab}	0.303^{ab}	0.338^{a}	0.283^{b}	0.292^{b}
Shell Thickness Butt (mm)	0.276^{a}	0.264^{ab}	0.290^{a}	0.262^{ab}	0.243^{b}
Shell Weight (g)	2.167	2.583	1.958	1.792	1.792
Yolk Weight (g)	3.042^{bc}	3.000^{c}	3.417^{ab}	3.458^{a}	3.458^{a}
Albumen Weight (g)	4.625	5.292	5.208	5.208	5.083
Yolk Color	12.167	11.417	11.375	11.708	11.417

Note: Values with different superscripts within the same row differ significantly (P<0.05)

Egg weight is influenced by protein consumption and age of the quail (Wati et al., 2020; Hilmi et al., 2015). Studies have also shown that piperine can aid organisms in nutrient and protein absorption and that it acts as a nutritional bioenhancer (Dudhatra et al., 2012). The application of piperine in the quail's diet aided in nutrient and protein absorption, thus allowing the quail to maximize the protein content of the commercialized feed and affecting the weight of quail eggs. However, as piperine inclusion increased, the egg weight decreased. The enzyme Ca^{2+} ATPase affects absorption of calcium and is inhibited by piperine (Yoon et al., 2014). The decrease of egg weight is due to the result of calcium deficiency or excess of calcium in the diet, which is also in line with the findings of the study of Chang et al. (2019).

The egg shape index is affected by the observations made in egg width and egg length. The egg width and egg weight also have a correlational relationship which can affect the egg shape index of the quail eggs. Notably, the egg shape index is affected by the egg width and egg length and the relationship it shares with other egg traits.

The main factor affecting the eggshell thickness is calcium content (Ahmed et al., 2022). Gary and Richard (2019) found that the eggshell is composed of calcium carbonate. The amount of calcium present in the diet of the quails has affected the eggshell thickness. The addition of *P. nigrum* to the diet of the quails has affected the eggshell thickness since it has been observed to contain calcium (Al-Jassass and Jasser, 2012; Ashokkumar et al., 2021). An interaction between the eggshell thickness tip and duration of the study has also been observed. This is due to the quail getting older as the study progresses and to the constant addition of black pepper to their diet, which has been observed to decrease over time. Figure 2 shows the interaction between the shell thickness tip and weeks.

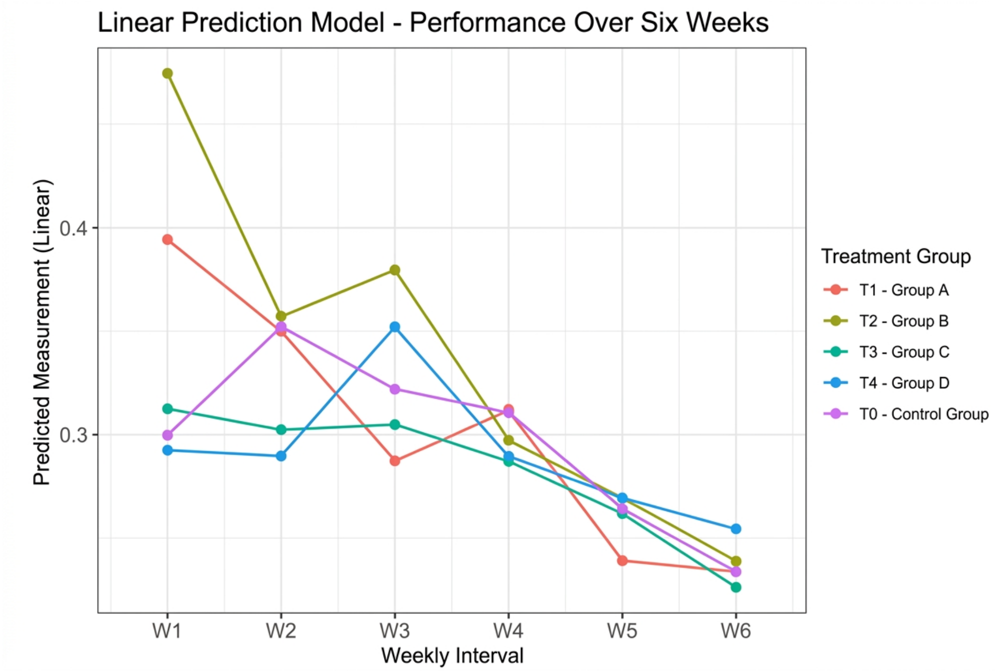


FIGURE 2: Egg Shell Thickness of the Produced Japanese Quail Eggs as Influenced by Piperine-containing Diet within Six Weeks

The calcium content in the diet of the quails is one of the major factors that affects the eggshell weight. However, the results of the study are not in line with the observations made in the eggshell thickness. Moreover, the shell weight does not share a correlational relationship with eggshell thickness. Narinc et al. (2015) found that the relative density or the specific gravity of the egg can affect the eggshell weight. The shell weight may have been affected due to the differences in their relative density.

The main factor that affects yolk weight is the protein content of the diet of the quails and the quails' absorption of proteins. Among avian species, the oviduct has a higher fractional rate of protein synthesis. Organisms voluntarily perform bodily processes and these processes cause the body to produce reactive oxygen and nitrogen species (RONS). The production of RONS can cause oxidative stress to proteins and lipids (Mishra and Jha, 2019). The production of oxidative stress can be prevented by inducing an antioxidant. The yolk weight increased as piperine inclusion increased since piperine has been observed to have antioxidative properties which prevented the oxidative stress of the quails (Losada-Barreiro et al., 2022).

The factors affecting the albumen weight are the age of the birds, egg weight, and temperature (Hegab and Hanafy, 2019; Willems et al., 2014). The reduction of albumen weight is due to the water consumption of the quails (Yolanda et al., 2020; Orakpoghenor et al., 2021). A decreased feed consumption indicates higher water consumption which is due to the quail reacting to the piperine-containing diet.

The primary factor that affects the yolk color of eggs is diet. Diets with higher concentration of carotenoids indicate a higher yolk color quality. The compound xanthophyll is a part of the carotenoid group division and is responsible for the pigmentation of the yolk color. Since black pepper and the quail's basal diet lack sufficient carotenoids content, not much differences were observed in the yolk color of the quail eggs among varying levels of piperine inclusion.

4.3 Sensory Attributes

The results of the sensory evaluation showed that only egg white color had a significant difference across the different treatments. Table 3 shows the results of the analysis for the sensory attributes of the produced Japanese quail eggs.

TABLE 3
SENSORY ATTRIBUTES OF THE JAPANESE QUAIL EGGS AS INFLUENCED BY THE PIPERINE-CONTAINING DIET

Treatments	Acceptability	Description	
		Acceptability	Sensory Parameter
Egg Yolk			
T0R1	6.750	Like Slightly	Yellow
T1R1	7.000	Like Moderately	Light Yellow
T2R1	6.750	Like Slightly	Light Yellow
T3R1	8.000	Like Very Much	Light Yellow - Yellow
T4R1	7.125	Like Moderately	Light Yellow
T0R2	6.400	Like Slightly	Yellow
T1R2	7.000	Like Moderately	Light Yellow
T2R2	6.750	Like Slightly	Light Yellow
T3R2	7.625	Like Moderately	Light Yellow
T4R2	7.333	Like Moderately	Light Yellow
T0 R3	6.500	Like Slightly	Light Yellow
T1R3	7.000	Like Moderately	Yellow
T2R3	7.125	Like Moderately	Light Yellow
T3R3	7.625	Like Moderately	Light Yellow
T4R3	6.625	Like Slightly	Light Yellow
Egg White			
T0R1	6.000^{abc}	Like Slightly	Grayish White
T1R1	6.375^{abcd}	Like Slightly	White – Off White
T2R1	6.500^{abcde}	Like Slightly	Off White
T3R1	6.875^{bcde}	Like Slightly	Off White
T4R1	6.750^{abcde}	Like Slightly	Off White
T0R2	5.700^{ab}	Neither Like nor Dislike	Grayish White
T1R2	7.250^{cde}	Like Moderately	White – Off White
T2R2	6.625^{abcde}	Like Slightly	Off White
T3R2	7.375^{de}	Like Moderately	Off White
T4R2	6.667^{abcde}	Like Slightly	Off White
T0 R3	5.500^{a}	Neither Like nor Dislike	Off White
T1R3	6.875^{bcde}	Like Slightly	White
T2R3	6.375^{abcd}	Like Slightly	Off White
T3R3	7.750^{e}	Like Moderately	Off White
T4R3	6.750^{abcde}	Like Slightly	Off White
Egg Aroma			
T0R1	6.000	Like Slightly	Slightly Perceptible – Perceptible Egg Aroma
T1R1	6.625	Like Slightly	Moderately Perceptible Egg Aroma
T2R1	6.125	Like Slightly	Perceptible – Moderately Perceptible Egg Aroma
T3R1	6.000	Like Slightly	Very Perceptible Egg Aroma
T4R1	6.625	Like Slightly	Perceptible Egg Aroma
T0R2	6.500	Like Slightly	Moderately Perceptible Egg Aroma
T1R2	6.250	Like Slightly	Moderately Perceptible Egg Aroma
T2R2	5.750	Neither Like nor Dislike	Perceptible Egg Aroma
T3R2	5.750	Neither Like nor Dislike	Perceptible Egg Aroma
T4R2	6.000	Like Slightly	No Perceptible Egg Aroma
T0 R3	5.875	Neither Like nor Dislike	Slightly Perceptible Egg Aroma
T1R3	6.875	Like Slightly	Moderately Perceptible Egg Aroma
T2R3	5.875	Neither Like nor Dislike	Slightly Perceptible Egg Aroma
T3R3	5.625	Neither Like nor Dislike	Perceptible – Moderately Perceptible Egg Aroma
T4R3	6.375	Like Slightly	Slightly Perceptible Egg Aroma
Egg Taste			
T0R1	5.750	Neither Like nor Dislike	Slightly Bland
T1R1	6.250	Like Slightly	Mild
T2R1	6.250	Like Slightly	Slightly Bland – Moderately Mild

T3R1	6.500	Like Slightly	Moderately Mild
T4R1	5.625	Neither Like nor Dislike	Slightly Bland
T0R2	6.100	Like Slightly	Slightly Bland - Mild
T1R2	6.750	Like Slightly	Mild
T2R2	6.250	Like Slightly	Slightly Bland - Mild
T3R2	5.500	Neither Like nor Dislike	Mild
T4R2	6.167	Like Slightly	Mild – Moderately Mild
T0 R3	6.125	Like Slightly	Slightly Bland
T1R3	6.500	Like Slightly	Mild
T2R3	6.250	Like Slightly	Mild
T3R3	6.625	Like Slightly	Mild
T4R3	6.125	Like Slightly	Mild
Egg Flavor			
T0R1	5.250	Neither Like nor Dislike	Slightly Perceptible Egg Flavor
T1R1	6.375	Like Slightly	Slightly Perceptible Egg Flavor
T2R1	6.375	Like Slightly	Slightly – Perceptible Egg Flavor
T3R1	6.375	Like Slightly	Perceptible Egg Flavor
T4R1	5.250	Neither Like nor Dislike	Slightly Perceptible Egg Flavor
T0R2	6.100	Like Slightly	Slightly Perceptible Egg Flavor
T1R2	6.750	Like Slightly	Perceptible – Moderately Perceptible Egg Flavor
T2R2	6.750	Like Slightly	Perceptible Egg Flavor
T3R2	5.750	Neither Like nor Dislike	Perceptible Egg Flavor
T4R2	6.333	Like Slightly	Perceptible Egg Flavor
T0 R3	6.375	Like Slightly	Slightly Perceptible Egg Flavor
T1R3	6.750	Like Slightly	Very Perceptible Egg Flavor
T2R3	6.500	Like Slightly	Perceptible Egg Flavor
T3R3	6.625	Like Slightly	Perceptible Egg Flavor
T4R3	6.375	Like Slightly	Perceptible Egg Flavor
Egg Texture			
T0R1	6.000	Like Slightly	Slightly Firm
T1R1	6.625	Like Slightly	Soft – Slightly Firm
T2R1	7.000	Like Moderately	Soft
T3R1	7.125	Like Moderately	Slightly Firm
T4R1	6.375	Like Slightly	Slightly Firm
T0R2	7.000	Like Moderately	Soft
T1R2	6.625	Like Slightly	Slightly Firm
T2R2	6.875	Like Slightly	Soft
T3R2	6.500	Like Slightly	Slightly Firm
T4R2	6.333	Like Slightly	Slightly Firm
T0 R3	6.750	Like Slightly	Soft
T1R3	6.875	Like Slightly	Slightly Firm
T2R3	7.250	Like Moderately	Slightly Firm
T3R3	6.500	Like Slightly	Slightly Firm
T4R3	6.375	Like Slightly	Soft

Note: R1, R2, R3 represent different panelist groups in the sensory evaluation

Coorey et al. (2015) found that diet can affect the acceptability of egg yolk color. The diet of the Japanese quails lacked carotenoids or food contents that can significantly affect egg yolk color. Hence, the eggs were observed to be lighter. The egg white has many functional properties, one of which is the antioxidative property (Li et al., 2021). Piperine has been observed to have antioxidative properties and its inclusion to the diet of the quails aided protein consumption. The inclusion of piperine to the diet of the quail affected egg white due to the properties piperine possessed.

The aroma of foods is mainly affected due to the aromatic compounds induced and present in the product (Elmore, 2015; Pereira et al., 2019). Moreover, when boiling eggs, sulfurous gases are released. These sulfurous gases are responsible for the odor and aroma of eggs. Additionally, egg proteins and reactions within the egg can affect the aroma of eggs. The sulfur-containing amino acid of the egg protein is methionine (Brosnan and Brosnan, 2006). However, not much methionine was observed in eggs and black pepper. Thus, piperine inclusion did not have significant effects on the aroma of the eggs.

The results indicated there is minimal difference in the taste of the quail eggs. The sensory parameters taste and aroma are linked. The taste can be affected by the aroma of the egg. Since taste and aroma are linked, their results do not have a significant difference among them.

The texture of the eggs is affected by reaction and temperature (Luo et al., 2020). The albumen and yolk determine the texture of the eggs. Even though there are differences in the albumen and yolk weight of the quail eggs, it did not affect its texture since denaturation of the eggs plays a vital role in the texture of quail eggs. Furthermore, the general acceptability of the produced Japanese quail eggs had no significant differences. Table 4 shows the general acceptability of the Japanese quail eggs.

TABLE 4

GENERAL ACCEPTABILITY OF THE PRODUCED EGGS AS INFLUENCED BY THE PIPERINE-CONTAINING DIET

Treatment	Panelist Group	General Acceptability Score	General Acceptability Description
T0	R1	6.25	Like Slightly
T0	R2	6.8	Like Slightly
T0	R3	6.5	Like Slightly
T1	R1	7	Like Moderately
T1	R2	6.875	Like Slightly
T1	R3	6.75	Like Slightly
T2	R1	6.75	Like Slightly
T2	R2	6.625	Like Slightly
T2	R3	6.875	Like Slightly
T3	R1	7	Like Moderately
T3	R2	6.125	Like Slightly
T3	R3	7	Like Moderately
T4	R1	6.5	Like Slightly
T4	R2	7	Like Moderately
T4	R3	6.5	Like Slightly

The general acceptability of the egg determines the overall acceptability of the overall product and is affected by the observations in the sensory parameters. Since only the egg white color was significantly affected among the sensory parameters, minimal differences were observed in the general acceptability of the produced eggs.

V. CONCLUSION

The addition of black pepper to the diet of the Japanese quails must be added at certain amounts since excess of black pepper can negatively affect the performance of the Japanese quails and the egg quality traits of the produced eggs. The highest performance was observed at 1.00% piperine inclusion (T2) since it produced the most eggs and its FCR is not as high compared to other treatments. Moreover, at 1.00% piperine inclusion, minimal negative effects were observed on the quail performance and egg quality traits. Furthermore, it must be noted that at varying levels, black pepper has minimal effects on the sensory parameters of the quail eggs. Black pepper and piperine do not have enough food content to affect the sensory parameters of quail eggs.

ACKNOWLEDGEMENT

The authors would like to thank the Visayas State University (VSU) Department of Physics, VSU Department of Statistics, VSU Integrated High School nursery, and the VSU Department of Food Science and Technology for providing assistance to the authors.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare. All co-authors have seen and agree with the contents of the manuscript and there is no financial interest to report. We certify that the submission is original work and is not under review at any other publication.

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