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Combined effects of powdered oyster shell (*Ostreidae*) and lemongrass (*Cymbopogon citratus*) as a feed additive for growth development of quail (*Coturnix coturnix japonica*)

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Abstract:

Calcium, obtained from various sources, is essential to fulfil the dietary requirements of birds. Oyster shells are excellent sources of calcium and are widely used in bird diets. Calcium is a critical factor in eggshell deterioration, affecting its absorption. Consequently, this study aimed to determine the combined effects of powdered oyster shell and lemongrass on the growth, development, and egg quality of birds, specifically using 5, 10, and 15 grams of oyster shell powder as a calcium source. A completely randomised design was used to assess the efficacy of varying amounts of powdered oyster shell. Results revealed that there was no significant change in growth development at different inclusion levels of oyster shell powder and lemongrass solution. However, egg quality exhibited a significant variance at different inclusion levels of oyster shell powder. Similarly, lemongrass solution as a supplement for laying quails demonstrated a significant difference. Therefore, supplementing the calcium source with a blend of 15 g of oyster shell powder and 300 ml lemongrass solution enhanced egg performance and eggshell quality of laying quail by 5%.

Keywords: ***Coturnix coturnix japonica*, *Cymbopogon citratus*, egg quality, feed additive, powdered oyster shell, water supplement.**

Classification number: **3.1**

1. Introduction

The quality of poultry egg has become integral to the successful marketing of animal products. As public understanding and awareness of nutrition and health have grown, local communities have begun to select eggs with specific nutritional characteristics, such as low cholesterol and fat content [1-2]. One of the most significant economic losses to the poultry industry is egg breakage, which is still a problem today. It is estimated that 13 to 20% of total production is damaged or lost before reaching its final destination [3]. To prevent eggs from breaking during hatching or handling, and to promote optimal growth and development, laying quails must receive sufficient calcium in their diet [4, 5].

Many farmers raise quail for both meat and eggs as an additional source of household income. Quail meat provides an abundance of vitamin C, iron, minerals, and amino acids [6]. However, as the population grows, so does the demand for egg products. The global population is projected to reach 9 billion by 2050, suggesting that food demand will continue to increase in the coming decades [7]. To meet the needs of Filipinos, some farmers raise quails, leading to an increased demand for ingredients for compound feed. In the Philippines, quail eggs are a primary ingredient in kwekwek, a popular street food.

Various sources of calcium are used to meet the dietary requirements of birds. Oyster shells, abundant sources of calcium, are widely incorporated into bird nutrition [8, 9]. According to M. Alagawany, et al. (2021) [10], lemongrass extract can be obtained from boiled lemongrass and is said to contain a very high amount of vitamin C and antioxidant activity. It also boasts antimicrobial capacity and can serve as a substitute antibiotic in the poultry industry [11].

Problems related to shell quality have been extensively studied in chickens, but minimal information is available on quail. A deficiency of calcium in quail feed leads to decreased egg production. The optimal dietary calcium level for high egg production and hatchability appears to be 5 to 15 g, with higher levels leading to reduced hatchability [5]. Today, some plant-based feed additives are used in poultry and animal nutrition to enhance growth and performance, referred to as phytogenic feed additives [12]. At present, small and medium-sized farmers are attempting to commercially increase the production of quail and poultry products by providing feed additives such as oyster shell powder. Although much work has been done to examine shell quality, there has been minimal research on overall egg quality and egg production of laying quail. Farmers need to produce high-quality shell eggs [13], requiring the selection of a high-quality and inexpensive source of calcium for

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their diet. Various sources of calcium are available to as a dietary supplement to improve shell quality, but there is often a debate over which is the most effective. Notably, research on calcium levels reveals a gap between the 5 and 15 g levels. Therefore, the present study aimed to evaluate the effects of powdered oyster shells on egg quality, and the impact of lemongrass solution on the growth development of *Coturnix coturnix*, using 5, 10 and 15 g, respectively.

The research examining the impact of calcium sources on the growth and development of Japanese quail holds considerable valuable for several reasons. Firstly, the study focuses on an essential aspect of poultry production: optimising egg production and eggshell quality to increase marketability, indicating stability among quail farmers. Egg performance and eggshell quality are key factors that determine the profitability of poultry farming. Secondly, the study explores alternative calcium sources, which could have practical implications for poultry farmers. Using powdered oyster shells and lemongrass as calcium sources is innovative and could offer a more sustainable and cost-effective alternative to traditional calcium sources. Thirdly, the study proves that combining 15 g of a powdered oyster shell with 300 ml of lemongrass solution can significantly increase egg performance and eggshell quality of laying quail by 5%. This finding is significant as it offers a practical solution for poultry farmers to improve egg production and quality without incurring substantial costs.

Overall, this study enriches the existing literature on poultry farming and highlights the potential benefits of using alternative calcium sources for improving egg performance and quality. The findings of this study could have practical implications for poultry farmers looking to optimise their production processes and enhance profit. Furthermore, providing an alternative and potentially cost-effective calcium source for the poultry industry could benefit small-scale farmers and reduce reliance on traditional calcium sources such as limestone. Using lemongrass as a supplement is unique and could be a viable alternative to conventional calcium sources, such as limestone, and may have additional benefits for egg performance and eggshell quality in laying quail. This study's findings could contributes to developing new and sustainable feed supplements for the poultry industry.

2. Materials and methods

2.1. Source of the test preparation ingredients

Fresh oyster shells were manually collected at Barangay Lilo-an Cebu, Philippines, primarily because the location is known for breeders of oysters. The shell and oyster were separated, thoroughly washed with clean water, boiled at 80^{o}C for 30 min, and dried under the sun's heat for 2-3 days. Dried shells were smashed into a fine powder using a hammer.

Cymbopogon citratus was obtained from a private farm in the municipality of Asturias. A sufficient quantity of the plant was taken, and, after removing the impurities and cleaning them well, they were air-dried at room temperature. The dried leaves of the lemongrass plant were heated with 1 litre of tap water and boiled at 100^{o}C for 10 min. The solution was cooled, filtered, and set aside in an empty container. The concentration of the solution included 10 g lemongrass for 100 ml concentrated extract of lemongrass per litre of drinking water, a concentration of 20 g for 200 ml concentrated extract of lemongrass per litre of drinking water, and a concentration of 30 g for 300 ml of concentrated extract of lemongrass per litre of drinking water.

2.2. Application of powdered oyster shell and lemongrass solution

Applying powdered oyster shells to the experimental birds included mixing with commercial feed according to the standard treatment recommendations of 540 grams/treatment/day. The solution was administered as a water supplement at 100, 200, and 300 ml/l with every treatment. By testing different levels of oyster shell and lemongrass extract supplementation, this study can determine the most effective combination of these two calcium sources for improving egg performance and eggshell quality in laying quail. This information can be useful for poultry farmers looking to optimise their production processes and improve the profitability of their operations. Overall, the choice of oyster shell and lemongrass extract levels in animal nutrition research is based on a combination of factors including previous research, practical experience, and safety considerations.

2.3. Preparation of experimental birds

A total of 72 female quail heads in a cage were used in the study. These were purchased in Catmon, Cebu and transferred to the breeding unit at Purok 2, Tubigagmanok, Asturias, Cebu, as the animal production experimental area.

2.4. Brooding management

Upon arrival, the quail chicks were placed in the hatchery and given copious amounts of electrolyte water to replenish lost electrolytes. The walls of the incubator were covered to avoid cold temperatures along with artificial light (50 watts). Pieces of cardboard/paper were laid out as flooring, which was changed regularly. When the quails were twenty days old, they were placed in their experimental cage with six birds each for treatment. After one week, the treatment was applied. Each treatment was properly labelled for easy identification. Four treatments over three replicates were performed for a total of seventy-two heads. All the birds received the same conditions, such as good ventilation, slatted floor, light bulbs, and feeding schedule, until the study was completed.

2.5. Experimental pen preparation and management

The quails were placed in a shed-type housing in an experimental pen of dimensions 1.8x1.2x0.40 m. The floor was divided into twelve compartments with six quail heads each for treatment. Each experimental cage was equipped with housing facilities such as feeders and water dispensers. The feeding troughs were placed in the cage and tied according to the height of the prospects to reach the feed, facilitate cleaning, and to avoid feed spillage. The shape and size of the trough were semi-circular and adjustable to allow for effortless adjustment and ease of cleaning.

2.6. Light management

Quails received the same daily light duration at all experimental sites, adjusted with increasing age. The laying quail received 15 hours of light for 20 to 38 days and 16 hours per day for 39 days from the laying stage until the end of the study.

2.7. Application of treatment

The same commercial quail layer mash feeds were given to all experimental quail. Through random selection, quails were treated using powdered oyster shells at three different inclusion levels and replicated three times. In each replication, female quails were fed with 90 g quail layer mash (QLM) feeds (without Ca supplements) in the morning and afternoon, 90 g QLM+5 g POS, 90 g QLM+10 g, and 90 g QLM+15 g powdered oyster shell, respectively. The concentrations encompassed 10 g for a dose of 100 ml concentrated extract of lemongrass/litre of drinking water, a concentration of 20 g for a dose of 200 ml concentrated extract of lemongrass/litre of drinking water, and a concentration of 30 g for a dose of 300 ml concentrated extract of lemongrass/litre of drinking water. This scheme was followed throughout the entire study.

2.8. Application of feeds and treatment for quail

In quail 30-36 days old, the feed intake was 180 g of booster/day without supplementation, at 37-43 days, the feed intake was 180 g of quail layer mash /day without supplementation, and at 44-72 days, the feed intake was 180 g of quail layer mash/day with different levels of powdered oyster shell.

T_0: control (100% commercial feeds) + water; T_1: 900 ml of tap water with 100 ml of lemongrass extract + 5 g oyster shell powder; T_2: 800 ml of tap water with 200 ml of lemongrass extract + 10 g oyster shell powder; T_3: 700 ml of tap water with 300 ml of lemongrass extract + 15 g oyster shell powder.

2.9. Feeding management

In this study, the experimental birds were fed twice daily at 7:30 a.m. and 5:00 p.m.

2.10. Statistical analysis

The study was statistically analysed through Sirichai Statistics Version Significant for complete randomised block design. Duncan's Multiple Range Test (DMRT) was used to determine the significant difference among treatments. This was laid out in a Complete Block Design (CBD) consisting of four treatments, six heads per treatment. Commercial growers/finishers with powdered oyster shells as a feed additive and lemongrass extracts for water supplement.

2.11. Experimental unit

The quails were placed in shed-type housing with 12 compartments, each containing six quails for each treatment, resulting in a total of 216 quails with compartment dimensions of 1.8x1.2x0.40 m. Each compartment was equipped with housing facilities such as feeders and water dispensers. The quails were given the same daily light duration, adjusted with increasing age, and were fed the same commercial quail layer mash feeds. The treatments consisted of powdered oyster shells at three different inclusion levels (5, 10, and 15 g) and lemongrass extract at three different concentrations (100, 200, and 300 ml/l). The experiment was replicated three times.

3. Results and discussion

Table 1 shows the effect of adding oyster shell powder to the feed and lemongrass solution to the drinking water on the mean week gain within six weeks of coverage. There was no significant difference between T_0 and T_1, and T_2 and T_3 shared similar differences compared to the body weight of laying female quail ranging from 120 to 160 g [14]. This study's results were contradictory to those of previous studies [15, 16] as adding oyster shell powder to the feed for six weeks led to significant improvement in weight and average weekly weight gain compared to the control. The reason for this may be due to the calcium and active compounds in calcium oyster shell and lemongrass such as flavonoids and linalool solution, which improves digestion and increases the secretion of digestive enzymes in birds. The process of benefiting from food intake improves and is reflected in laying quails' growth and weight gain. As presented herein, there is no significant difference between the oyster shell powder and lemongrass solution when used as a supplement to laying quail.

Table 1. The weekly gain of laying quail with varied levels of oyster shell powder and lemongrass.

Treatment	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
T_0	149.20^a	150.97^a	152.67^a	154.03^a	154.85^a	156.36^a
T_1	146.36^a	148.77^a	151.17^a	153.20^a	154.63^a	156.45^a
T_2	147.96^a	151.26^a	154.09^a	156.86^a	158.71^a	160.99^a
T_3	150.36^a	153.96^a	157.46^a	160.78^a	163.27^a	166.41^a

T_0: control (100% commercial feeds) + water; T_1: 900 ml of tap water with 100 ml of lemongrass extract + 5 g oyster shell powder; T_2: 800 ml of tap water with 200 ml of lemongrass extract + 10 g oyster shell powder; T_3: 700 ml of tap water with 300 ml of lemongrass extract + 15 g oyster shell powder. Different letters indicate statistically significant differences ($p \leq 0.05$).

Table 2 indicates the mean average feed consumption from the experiment across different inclusion levels. For the mean average consumption of the first and second week of the experiment, T_3 (15 g oyster shell powder) exhibited a significant difference compared to other treatments. During the third week of the experiment, T_1 (5 g oyster shell powder) demonstrated a significant effect compared to T_2 (10 g oyster shell powder) and T_3 (15 g oyster shell powder). In the fourth week of the experiment, T_0 (control) had significant differences compared to all the oyster shell powder treatments. In the fifth week, T_1 (5 g oyster shell powder) significantly differed from T_3 (15 g oyster shell powder). Finally, during the last week of the experiment, T_3 (15 g oyster shell powder) and T_0 (control) had significant differences in comparison to T_1 (5 g oyster shell powder) and T_2 (10 g oyster shell powder). The results of this study are consistent with M. Dian, et al. (2017) [17] in that calcium and active compounds in oyster shells as well as lemongrass flavonoids and linalool improve digestion, increase digestive enzyme secretion, and increase feed consumption in the experimental birds. This information can be helpful to poultry producers in optimising the nutrition of their laying hens for better performance and health [18].

Table 2. The result of mean feed consumption with different inclusion levels of lemongrass and oyster shell powder.

Treatment	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
T_0	162.05^{a}	162.61^{a}	170.11^{ab}	176.44^{a}	163.39^{ab}	175.33^{a}
T_1	161.17^{a}	160.50^{a}	176.50^{a}	167.17^{b}	169.61^{a}	164.22^{b}
T_2	159.05^{a}	162.31^{a}	154.16^{c}	160.89^{b}	162.167^{ab}	166.72^{b}
T_3	144.67^{b}	157.66^{b}	142.33^{c}	162.78^{b}	156.61^{b}	175.33^{a}

T_0: control (100% commercial feeds) + water; T_1: 900 ml of tap water with 100 ml of lemongrass extract + 5 g oyster shell powder; T_2: 800 ml of tap water with 200 ml of lemongrass extract + 10 g oyster shell powder; T_3: 700 ml of tap water with 300 ml of lemongrass extract + 15 g oyster shell powder. Different letters indicate statistically significant differences ($p \leq 0.05$).

In Table 3, quails fed with commercial layer feeds showed the highest value among treatments. Those given high calcium levels showed the lowest feed conversion ratio. As presented above, laying quails fed commercial feed + 15 g oyster shell powder had the most efficient results compared to the rest of the oyster shell powder treatments. It is evident that poor results were exhibited by laying quails fed with commercial layer feeds without Ca supplements. The result of this present study is in agreement with M. Dian, et al. (2017) [17] in that active compounds such as Ca in oyster shell improve digestion, increases the secretion of digestive enzymes, and increase feed consumption in the laying quail.

Table 3. The result of feed conversion ratio with different inclusion levels of lemongrass and oyster shell.

Treatment	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
T_0	2.58	2.49	2.60	2.68	2.45	2.63
T_1	2.57	2.53	2.72	2.57	2.55	2.45
T_2	2.47	2.47	2.29	2.38	2.39	2.39
T_3	2.21	2.47	2.17	2.37	2.29	2.50

T_0: control (100% commercial feeds) + water; T_1: 900 ml of tap water with 100 ml of lemongrass extract + 5 g oyster shell powder; T_2: 800 ml of tap water with 200 ml of lemongrass extract + 10 g oyster shell powder; T_3: 700 ml of tap water with 300 ml of lemongrass extract + 15 g oyster shell powder.

The study investigates the effect of various levels of lemongrass solution added to the drinking water on the total water consumption rate in quail birds over six weeks (Table 4). In the first week, T_3 (300 ml lemongrass solution) recorded the highest rate of water consumption and showed a significant difference among treatments. During the second week, T_1 (100 ml lemongrass solution) was significantly different from both T_0 (control) and T_3 (300 ml lemongrass solution). In the third and fourth weeks, T_3 (300 ml lemongrass solution) displayed a significant variance between T_0 (control) and T_1 (100 ml lemongrass extract). In agreement with X. Cheng and N. Zhonghua (2023) [4], the rise in water consumption can potentially increase feed intake. The lemongrass solution may enhance the flavour and taste of the drinking water, thus increasing palatability and subsequentially boosting water consumption, particularly in treatments involving the aforementioned drinking solution.

Table 4. Mean water consumption with different inclusion levels of lemongrass and powdered oyster.

Treatment	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
T_0	976.11^{b}	1021.83^{b}	869.96^{c}	805.78^{c}	864^{d}	994.83^{c}
T_1	1055.39^{b}	1263.72^{ab}	872^{c}	851.11^{c}	950.72^{c}	871.33^{d}
T_2	1074.33^{b}	1347.55^{a}	1163.94^{b}	1158.44^{b}	1357.53^{a}	1126.17^{b}
T_3	1187.89^{a}	1048.17^{b}	1382.28^{a}	1384.83^{a}	1184.89^{b}	1340.11^{a}

T_0: control (100% commercial feeds) + water; T_1: 900 ml of tap water with 100 ml of lemongrass extract + 5 g oyster shell powder; T_2: 800 ml of tap water with 200 ml of lemongrass extract + 10 g oyster shell powder; T_3: 700 ml of tap water with 300 ml of lemongrass extract + 15 g oyster shell powder. Different letters indicate statistically significant differences ($p \leq 0.05$).

The results in Table 5 demonstrate significant differences ($p<0.05$) in the water conversion factor at six weeks, particularly between T_3 (300 ml lemongrass solution) and T_0 (control). T_3 (300 ml lemongrass solution) recorded the most efficient water conversion factor, exhibiting a significant

improvement ($p \leq 0.05$) in comparison to T_0 (control). These results align with Y.A. Attia, et al. (2020) [18], which posited that the improvement in the efficiency of nutritional conversion may be attributable to the active compounds in lemongrass solution. These compounds may have a role in improving the flavour and taste of drinking water, thereby increasing its palatability and consequentially boosting water consumption, particularly for treatments involving lemongrass solution.

Table 5. Results of water conversion ratio with different inclusion levels of lemongrass and powdered oyster.

Treatment	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
T_0	6.5	6.75	5.65	5.25	5.59	6.39
T_1	7.27	8.60	5.77	5.56	6.16	5.57
T_2	7.79	8.90	7.56	7.39	8.56	7
T_3	7.92	6.82	8.91	8.62	7.27	8.06

T_0: control (100% commercial feeds) + water; T_1: 900 ml of tap water with 100 ml of lemongrass extract + 5 g oyster shell powder; T_2: 800 ml of tap water with 200 ml of lemongrass extract + 10 g oyster shell powder; T_3: 700 ml of tap water with 300 ml of lemongrass extract + 15 g oyster shell powder.

Laying quails with 15 g of oyster shell powder had the highest number of eggs laid, followed by 5 g and 10 g of oyster shell powder. However, laying quails given pure commercial feed and plain water had the lowest number of eggs among feed treatments across all inclusion levels. Table 6 shows that the number of eggs increased with the highest oyster shell powder treatment. This result is contrary to a study by A. Khalifaha, et al. (2021) [19], who found that the addition of Ca adversely affected feed intake and egg production due to excessive levels of Ca and other minerals such as magnesium, present in Ca sources. Additionally, they suggested that the extreme amounts of Ca added to their diet was not absorbed by the digestive tract, thus significantly affecting some egg yields.

Table 6. The total number of eggs laid with different inclusion levels of lemongrass and oyster powder.

Treatment	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Total
T_0	-	16	69	58	64	87	294
T_1	-	15	75	82	60	98	330
T_2	-	9	50	64	68	113	304
T_3	-	12	74	91	83	115	375
Total	-	52	268	295	275	413	1303

T_0: control (100% commercial feeds) + water; T_1: 900 ml of tap water with 100 ml of lemongrass extract + 5 g oyster shell powder; T_2: 800 ml of tap water with 200 ml of lemongrass extract + 10 g oyster shell powder; T_3: 700 ml of tap water with 300 ml of lemongrass extract + 15 g oyster shell powder.

Mean egg weight: As observed in Table 7, laying quails given 15 g of oyster shell powder obtained the highest weight, followed by 10 g and then 5 g of oyster shell powder. The result showed a relatively minor difference in egg weights when the calcium source was given at different inclusion levels. However, laying quails without oyster shell inclusion had the poorest performance. Table 7 highlights the effects of calcium source, the oyster shell powder, added in the diets of laying quails, indicating that T_1 and T_2 were marginally significant compared to T_0 and T_3. Laying quails supplemented with 15 g of oyster shell powder were not significantly different from those given 10 g of oyster shell powder, but they did significantly differ from those receiving 5 g and pure commercial feeds. Generally speaking, the normal egg weight of quail ranges from 6 to 8 g, with an average weight of 9 g [9, 12]. These results align with A. Mako, et al. (2017) [8], which proposed that increased calcium levels improve eggshell thickness and egg weight with three calcium levels (3.75, 4.15 and 4.55%) in laying phase diets. Thus, 5 g of oyster shell powder and the control group, which were given only pure commercial feed, offered a lower Ca amount to laying quails. Calcium is one of the critical nutrients required for optimum egg production and eggshell quality in laying quails [20], and appropriate levels should be identified and considered.

Table 7. The mean egg quality with different inclusion levels of lemongrass and oyster powder.

Treatment	Weight (g)	Length (mm)	Width (mm)	Eggshell percentage (%)	Shell thickness (mm)	Egg yolk colour
T_0	7.95^{c}	28.91^{a}	23.37^{a}	0.45^{c}	0.12^{b}	More yellow
T_1	8.32^{bc}	29.27^{a}	23.52^{a}	0.56^{b}	0.17^{b}	Light yellow
T_2	8.69^{ab}	29.87^{a}	24.07^{a}	0.65^{b}	018^{b}	Lighter yellow and less orange
T_3	9.01^{a}	29.40^{a}	3.97^{a}	0.93^{a}	0.21^{b}	Light orange

T_0: control (100% commercial feeds) + water; T_1: 900 ml of tap water with 100 ml of lemongrass extract + 5 g oyster shell powder; T_2: 800 ml of tap water with 200 ml of lemongrass extract + 10 g oyster shell powder; T_3: 700 ml of tap water with 300 ml of lemongrass extract + 15 g oyster shell powder. Different letters indicate statistically significant differences ($p \leq 0.05$).

Egg length and width: The mean egg quality in terms of length and width of laying quail eggs given oyster shell as a calcium source at different inclusion levels is discussed here. Egg height and width were classified based on the USDA's guidelines. According to A. Saki, et al. (2019) [21], the longest length is attributed to the oldest quail-laid eggs at 32.6 mm, and the maximum width at 25.8 mm. The analysis of variance demonstrates that the supplementation

of oyster shell powder was not significantly different when compared across different inclusion levels. Oyster shell powder at different inclusion levels did not significantly affect the laying quail egg's quality in terms of length and width across all treatment levels. This result implies that addition of oyster shell powder at various levels does not significantly improve egg length and width.

Egg shell percentage: Among the treatment levels, oyster shell powder given at 15 g had the highest shell percentage, sequentially followed by 10 and 5 g. Conversely, laying quails given only pure commercial feeds had the lowest percentage. Therefore, the supplementation of oyster shell powder significantly varied. Oyster shells given to laying quails at 15 g and 10 g yielded a significantly different result at a 5% level ($p<0.005$) compared to 5 g and birds fed purely on commercial feeds. Most research reported that increased dietary calcium levels showed a linear improvement in eggshell quality [22]. Also, a linear increase in eggshell quality was observed when feeding calcium above 6.5 g/day. An increase in calcium intake from 4.08 to 4.64 g/day improves eggshell thickness in aged Brown Layers [23], an outcome not consistent with the results of this study. In another study, results led to the definition of a linear effect on dietary Ca with eggshell quality, which reported that using 90- and 108-week laying hens showed no effects of dietary Ca on eggshell strength and thickness [24]. Still, the eggshell percentage and weight per surface area (ESWSA) increased by increasing the Ca concentration in the diet. Likewise, the present study showed a linear effect on eggshell percentage and thickness.

Egg shell thickness: Laying quail eggs supplemented with 15 g oyster shell had the thickest shell (0.21 mm), followed by a calcium level at 10 g (0.18 mm). However, laying quails receiving only commercial feeds had the thinnest eggshell (0.17 mm) amongst all treatment levels. The average shell thickness is reported to range between 0.08 and 0.17 mm [20]. As reflected in this study's results, supplementing calcium in suitable quantities greatly affects eggshell quality. However, the shell thickness of different inclusion levels of oyster shell treatment showed no significant difference. The results indicated that varying levels of calcium inclusion from oyster shells do not significantly impact eggshell thickness. These results align with those in study of M. Islam and M. Nishibori (2021) [9], who observed no significant difference in shell thickness when limestone was replaced with oyster shells.

Egg yolk colour: Visual scoring, conducted using a Roche Colour Fan, revealed that T_3, treated with 15 g of oyster shell powder, has the highest value of 14, boasting a more orange egg yolk colour amongst the different inclusion levels. According to a study published by the *Journal of Food Science*, egg yolks with darker colours (such as mustard yellow or light orange) typically contain more omega-3s and vitamins than lighter egg yolks.

4. Conclusions

Oyster shell powder and lemongrass solution, used as supplements for laying quails, exhibited significant differences. The growth development of the quails was not significantly impacted at various inclusion levels of oyster shell powder and lemongrass solution. On the other hand, egg quality significantly differed with different inclusion levels, the supplementation of these two ingredients had substantial effects. The administration of calcium sources at a 15 g level notably increased egg performance and eggshell quality of laying quail. Consequently, quail growers are advised to utilise this promising feed additive at a higher inclusion level, as this supplement offers a favourable return on investment.

CRediT author statement

Florieza Mangubat: Data analysis and Interpretation, Writing and Revising manuscript; Cerela Looc: Method, Data analysis and Writing; Fretzel Mad: Method, Data analysis and Writing.

COMPETING INTERESTS

The authors declare that there is no conflict of interest regarding the publication of this article.

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