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Laying performance and egg quality of Japanese quail fed *Pomacea canaliculata* meal as a feed supplement

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ABSTRACT: This study aims to evaluate the effects of golden apple snail meal (GASM) on Japanese quails' laying performance and egg quality. Sixty quails were divided into four groups: a control with 0% GASM and three groups with 1%, 2%, and 3% GASM supplementation. The main variables monitored over five weeks were feed intake, egg production, feed conversion ratio (FCR), and egg quality. The results showed that feed intake was higher in the control group and decreased with higher levels of GASM, with no significant differences observed at week 5. Egg production remained consistent across all groups, indicating that GASM supplementation did not impact overall egg production. FCR also showed no significant differences, suggesting that feed efficiency was not affected by GASM levels. However, egg quality improved with GASM supplementation: eggs from the 1% and 2% GASM groups had greater weight, shell thickness, and yolk weight than the control. The 2% GASM level also resulted in larger egg dimensions. Therefore, GASM supplementation reduced feed intake but did not negatively affect egg production or feed conversion efficiency; it also improved eggs' external and internal qualities, particularly at lower supplementation levels. Thus, GASM may be a beneficial alternative ingredient for improving egg quality in quail farming.
Keywords: *Coturnix japônica*; Golden Apple Snail; alternative feed resource; calcium source; feed efficiency; sustainable agriculture.

Desempenho de postura e qualidade dos ovos de codorna japonesa alimentada com farinha de *Pomacea canaliculata* como suplemento alimentar

RESUMO: Este estudo teve como objetivo avaliar os efeitos da farinha de caracol maçã dourada (GASM) no desempenho da postura e na qualidade dos ovos de codornas japonesas. Sessenta codornas foram divididas em quatro grupos: um controle com 0% de GASM e três grupos com suplementação de 1%, 2% e 3% de GASM. As principais variáveis monitoradas ao longo de cinco semanas foram o consumo de ração, a produção de ovos, a taxa de conversão alimentar (FCR) e a qualidade dos ovos. Os resultados mostraram que o consumo de ração foi maior no grupo controle e diminuiu com níveis mais altos de GASM, sem diferenças significativas observadas na semana 5. A produção de ovos permaneceu consistente em todos os grupos, indicando que a suplementação de GASM não impactou a produção geral de ovos. A FCR também não mostrou diferenças significativas, sugerindo que a eficiência alimentar não foi afetada pelos níveis de GASM. No entanto, a qualidade dos ovos melhorou com a suplementação de GASM: os ovos dos grupos com 1% e 2% de GASM apresentaram maior peso, espessura da casca e peso da gema do que o controle. O nível de 2% de GASM também resultou em dimensões maiores dos ovos. Por conseguinte, a suplementação com GASM reduziu o consumo de ração, mas não afetou negativamente a produção de ovos ou a eficiência da conversão alimentar; e ainda, melhorou diversas qualidades externas e internas dos ovos, particularmente em níveis mais baixos de suplementação. Dessa forma, o GASM pode ser um ingrediente alternativo benéfico para melhorar a qualidade dos ovos na codornicultura.
Palavras-chave: *Coturnix japônica*; caracol-maçã-dourado; fonte alimentar alternativa; fonte de cálcio; eficiência alimentar; agricultura sustentável.

1. INTRODUCTION

The growing popularity of street food in the Philippines reflects the country's rich culinary heritage and the increasing prominence of quail farming as a profitable and sustainable agricultural practice. A prime example is "kwek-kwek," a widely consumed street delicacy consisting of quail eggs coated in orange batter and deep-fried. The demand for quail eggs in such popular food items presents the potential significance of quail farming in the Filipino economy. Quail farming has been gaining popularity in the Philippines as a profitable and sustainable source of meat and eggs (LAMBIO et al., 2010). Quails, being small birds, are relatively easy to raise, requiring less space and feed compared to other poultry, and they have a high reproductive rate. They are particularly valued for their high laying performance and ability to produce good-quality eggs, making them an appealing choice for small-scale and commercial farmers. The most common breed raised in the Philippines, the

Japanese quail (*Coturnix japonica*), is well-known for its prolific egg production. With the rising demand for quail meat and eggs, government support and industry promotion, quail farming presents a significant opportunity for sustainable income and food production in the country.

In parallel with the rise of quail farming, the utilization of alternative feed sources has become increasingly important for sustainable agriculture. One such source is the golden apple snail (*Pomacea canaliculata*), a freshwater snail commonly found in Southeast Asia. Originally introduced to the Philippines in the early 1980s for cultivation as a food source, the snail quickly became a serious pest in rice fields due to its voracious feeding on live and fresh plant materials (JOSHI, 2007). However, under the Biosecurity Act of 2015, the golden apple snail was classified as prohibited, leading to the establishment of the Rice Biosecurity Zone for its management (DPI, 2017). As an alternative to chemical control methods, utilizing golden apple snails as animal feed, including for quails, offers an environmentally friendly solution. These snails are rich in calcium and other essential minerals, making them a valuable supplement in quail production. Calcium (Ca) is a critical mineral in layer nutrition, playing vital roles as a primary component of bone structure, maintaining acid-base balance, and supporting various enzymatic functions (GOFF, 2018; VANNUCCI et al., 2018). Calcium is also the main constituent of eggshells, with each egg containing approximately 2.2g of calcium, predominantly within the shell (TUNÇ; CUFADAR, 2015). Although commercial calcium supplements like limestone and oyster shell flour are commonly incorporated into quail diets, their cost and potential limitations in digestibility present challenges.

Recent studies exploring the use of Golden Apple Snail (GAS) as a dietary calcium source for quails have shown promising results, particularly when used in conjunction with fish meal substitution and the addition of phytobiotics (MALVAR; AGAPITO, 2020). However, the optimal supplementation levels of GAS and their specific impact on egg quality parameters, such as eggshell thickness, strength, yolk color, and albumen quality, remain unclear.

This study aims to investigate the effects of golden apple snail supplementation on quail laying performance and egg quality. By exploring this alternative calcium source, the study seeks to establish a cost-effective and sustainable option to replace commercial calcium supplements.

2. MATERIAL AND METHODS

2.1. Animal welfare

The methods employed in this study were designed to ensure the standards of animal welfare and ethical treatment. All procedures and protocols adhered strictly to the guidelines and regulations set forth by the Philippine Animal Welfare Act (RA 8485). This legislation mandates that all laboratory animals be treated humanely and respectfully throughout the research process.

2.2. Experimental Animals, treatments, and design

Sixty (60) ready-to-lay Japanese quails of uniform age and sex were used in this study, which followed a completely randomized design. The birds were randomly assigned to four treatments, each replicated three times with five quails per replicate. The study aimed to investigate the laying performance and egg quality of quails fed with golden apple snail meal (GASM) at different supplementation levels. The basal diet consisted of a commercial quail layer mash (Table 1). The experiment included four dietary treatments: Treatment 1 served as the control with 0% GASM, Treatments 2, 3, and 4 included 1, 2, and 3% GASM supplementation, respectively.

Table 1. Nutrient analysis of commercial quail layer mash.
Tabela 1. Análise de nutrientes da ração comercial para postura de codornas.

Nutrient Composition	Amount
Crude Protein (%)	19.5
Crude Fiber (%)	4
Crude Fat (%)	5
Moisture (%)	12.5
Phosphorus (g kg^{-1})	0.5
Calcium (%)	3.6

2.3. Experimental cages

The cages were constructed from lumber and plastic mesh and measured 120 cm in length, 135 cm in width, and 120 cm in height. Each cage was divided into three compartments using plastic mesh, each measuring 30 cm in length, 45 cm in width, and 30 cm in height. A waterer was installed at the back of the cage, and a feeder trough was placed at the front.

2.4. Preparation of golden apple snail (*P. canaliculata*) meal

Golden apple snails were collected from rice paddies in Patag, Naawan, Misamis Oriental. To purge toxins, the snails were stored in a container with water for two days, following the method described by Ulep and Santos (1995). Afterward, as recommended, the snails were boiled for 10 minutes at 100°C to eliminate pathogens and facilitate meat separation from the shell. The shells were removed, and the snail meat was sun-dried for two to three days (Usman et al., 2007). Finally, a grinder ground the dried snail meat into a fine powder. Various percentages of Golden Apple Snail Meal (GASM) were then incorporated into the quail's commercial feed ration, with preparations for each meal. The golden apple snail meal samples were sent to the DA Region X Feed Laboratory to analyze crude protein, calcium, and phosphorus content (Table 2).

Table 2. Proximate analysis of Golden Apple Snail (GAS) meal.
Tabela 2. Análise aproximada da farinha de Golden Apple Snail (GAS).

Nutrient Composition	Amount
Crude Protein (CP) (%[1])	63.00
Calcium (g kg^{-1})	42
Phosphorus (g kg^{-1})	2.16
Ash (%[1])	4.12

[1] Dry-matter (DM) basis; [1] Base de matéria seca (MS)

2.5. Feeding management

The study employed a twice-daily feeding schedule at 6:00-7:00 am and 3:00-4:00 pm. It was recommended to feed the quails at times coinciding with the highest egg-laying intensity, which ranged from 16 to 19 hours (Hassan et al., 2018). The birds were fed up to fifty (50) grams per day, based on the recommended amount. Dietary treatments were prepared for each meal based on the recommended feed consumption for quails, with varying percentages of Golden Apple Snail Meal (GASM) added. Water was provided ad libitum. The feed and water troughs were thoroughly cleaned to prevent contamination.

2.6. Egg collection

To minimize disruption, eggs were collected manually each morning before feeding the quail. Egg quality was assessed based on both external and internal factors. Laying performance was evaluated using hen-day egg production, allowing for a comparison of the quail's laying ability. Egg samples were collected and analyzed weekly. Collections occurred early each morning, before the quails were fed. To minimize the risk of cracks or breakage, eggs were carefully collected by hand. It was gently reached into each cage compartment and removed any eggs found on the nesting material. Following each collection, the eggs were placed on a tray. The quail cages were also cleaned regularly to maintain a clean and hygienic bird environment. Half of the eggs collected from each cage were chosen for weekly analysis. These selected eggs were then evaluated for both external and internal quality parameters.

2.7. Data gathered and computed

Feed intake: The amount of food ingested by an animal. To calculate the feed intake of an animal:

I = (Feed given – Feed efusal) (01)

Egg production (dozen): Weekly egg production per bird refers to the number of eggs each bird lays over a week. To express this production in dozens, each bird's total number of eggs each week is counted and then divided by 12. The following formula was used to make this conversion:

Weekly egg production per bird = (Total eggs collected in a week / 12) (02)

Weekly egg weight per bird (g): Was determined by collecting and weighing all the eggs produced by each bird each week. The total weight of the eggs laid by each bird was recorded, and the average weekly egg weight was calculated using the following formula:

Weekly egg weight per bird = (Total weight of eggs laid in a week / Number of birds) (03)

Hen-day egg production (HDEP): Is a measure used in poultry farming to determine the productivity of laying hens over a specific period. It represents the average number of eggs produced per hen per day. The formula for calculating hen-day egg production is used below;

HDEP = (No. of eggs / No. of hens alive) x 100 (04)

Weekly feed conversion ratio (FCR) (kg of feed per dozen eggs): Was determined by recording the total feed intake and the total number of eggs produced by each bird each week. The number of eggs was converted to dozens, and the FCR was calculated using the following formula:

Weekly FCR = [Total feed consumed (kg) / total eggs produced (dozens)] (05)

Weekly feed conversion ratio (FCR) (kg of feed per kg of egg weight): Was determined by recording the total feed intake of each bird and weighing all the eggs produced by each bird during the same week. The FCR was then calculated using the following formula:

Weekly FCR = [Total feed consumed (kg) / total weight of eggs produced (kg)] (06)

External qualities of egg: Egg weight was recorded using an electronic scale with 0.001g accuracy, while egg length and width were measured with a digital vernier caliper. Eggshell weight was determined by breaking the eggs, drying the shells, and weighing them with a carat scale. Shell thickness was measured using a micrometer vernier caliper after the eggshells were air-dried for 24 hours (EDEH et al., 2023).

Shape index: This measurement describes how elongated an egg is; it is calculated to assess its uniformity and suitability for various purposes. The following formula calculates it:

SI = [Egg width (mm) / Egg length (mm)] x 100 (07)

Percent Shell (%): A measure used to determine the proportion of an egg's weight made up of the eggshell. It is calculated using the following formula:

PS = [Weight of eggshell / Total egg weight] x 100 (08)

Internal qualities of egg: Yolk weight was determined by subtracting the empty beaker's weight from the beaker's weight with the egg yolk, using an electronic scale with 0.001g accuracy. Yolk width and albumen width were measured with a digital vernier caliper. Albumen weight was also measured using the carat scale. Additionally, the percentage of yolk was assessed.

Percent yolk (%): A measure used in poultry science to determine the proportion of an egg's weight made up of the yolk. It is calculated using the following formula:

PY = [Weight of yolk / Total egg weight] x 100 (09)

2.8. Statistical analysis

A completely randomized design (CRD) was used in the statistical analysis to examine the differences between the treatment groups. The data was analyzed using analysis of variance (ANOVA) to check for significant differences in the means of the treatment groups. Tukey HSD was used to compare any significant differences among treatment means.

3. RESULTS

3.1. Feed Intake

The results presented in Table 3 provide an overview of the weekly and total feed intake of Japanese quail (*Coturnix japonica*) when fed varying levels of golden apple snail meal (GASM) as a feed supplement. In Week 2, the control group showed the highest feed intake at 248.67 g/bird, which was significantly higher than the intakes observed in the 1%, 2%, and 3% GASM groups, whose intakes were 235.40, 226.40, and 216.87 g per bird, respectively. These differences were statistically significant ($p < 0.001$). In Week 3, the control group again had the highest feed intake at 265.73 g $bird^{-1}$. The feed intake decreased with increasing GASM levels, with the 1%, 2%, and 3% GASM groups consuming 258.93, 253.93, and 249.27 g per bird, respectively. This trend was statistically significant ($p = 0.006$). By Week 4, the control group's feed intake remained the highest at 272.00 g bird-1. The intake for the 1%, 2%, and 3% GASM groups decreased to 261.80 g, 261.13 g, and 261.53 g per bird, respectively. These differences were significant (p = 0.011). However, in Week 5, there were no significant differences in feed intake across the groups, with intakes ranging from 279.87 to 281.00 g per bird (p = 0.872). The total feed intake over the entire 35-day trial showed a similar pattern, with the control group having the highest total intake of 1.27 kg per bird. The intake decreased with increasing GASM levels, with the 1%, 2%, and 3% GASM groups consuming 1.24, 1.22, and 1.20 kg per bird, respectively. This overall effect was highly significant (p < 0.001). The addition of golden apple snail meal as a feed supplement reduced feed intake in Japanese quail, with significant differences observed in weekly and total feed intake across most of the treatment levels.

Table 3. Mean values ± SD of the feed intake of Japanese quail (*Coturnix japonica*) fed with varying levels of golden apple snail meal (GASM) as feed supplement.
Tabela 3. Valores médios ± DP do consumo de ração de codornas japonesas (*Coturnix japonica*) alimentadas com níveis variados de farinha de caracol-maçã-dourada (GASM) como suplemento alimentar.

Parameters	Control	1% GASM	2% GASM	3% GASM	p-value***
Weekly Feed Intake (g/b) *					
Week 2 (42-49)	248.67 ± 6.03a	235.40 ± 2.82ab	226.40 ± 7.37bc	216.87 ± 3.25c	<0.001
Week 3 (50-56)	265.73 ± 3.75a	258.93 ± 3.50ab	253.93 ± 2.04b	249.27 ± 5.97b	0.006
Week 4 (57-63)	272.00 ± 1.40a	261.80 ± 2.95b	261.13 ± 0.94b	261.53 ± 5.95b	0.011
Week 5 (63-70)	279.87 ± 0.23	280.53 ± 0.76	280.67 ± 1.85	281.00 ± 2.77	0.872
Total Feed Intake (kg bird-1) **					
TFI (kg)	1.27 ± 0.11a	1.24 ± 0.00b	1.22 ± 0.01bc	1.20 ± 0.01c	<0.001

T1 (control)-0%; T2- 1%GASM; T3-2%GASM; T4-3% GASM; *Weekly data over 7 days (numbers in parentheses refer to the age in terms of days for the Japanese quail) **Total data of the 35-day feeding trial (5 weeks) ***ANOVA=one way analysis of variance; <0.05=significant, >0.05=not significant; <0.001=highly significant.
T1 (controle) - 0%; T2 - 1%GASM; T3 - 2%GASM; T4 - 3%GASM; *Dados semanais ao longo de 7 dias (os números entre parênteses referem-se à idade em dias para a codorna japonesa) **Dados totais do ensaio de alimentação de 35 dias (5 semanas) ***ANOVA = análise de variância unidirecional; <0,05 = significativo, >0,05 = não significativo; <0,001 = altamente significativo.

3.2. Egg Production

Table 4 presents the effect of golden apple snail meal (GASM) as a feed supplement on Japanese quail egg production. During Week 2, the weekly egg production per bird was comparable across all groups, with the control group producing 1.80 eggs ± 0.53, the 1% GASM group producing 1.13 eggs ± 0.58, the 2% GASM group producing 1.93 eggs ± 0.42, and the 3% GASM group producing 1.80 eggs ± 0.40. The differences observed among these groups were not statistically significant (p = 0.253). In Week 3, there was a slight decrease in egg production for the 2% GASM group (4.07 eggs ± 0.92) compared to other groups, but again, these differences were not significant (p = 0.699).

Similarly, in Week 4, egg production ranged from 5.93 eggs ± 0.57 in the 2% GASM group to 6.53 eggs ± 0.81 in the control group, with no significant differences observed (p = 0.889). By Week 5, the control group and the 3% GASM group had the highest egg production (6.73 eggs ± 0.31 and 7.00 eggs ± 0.00, respectively), while the 2% GASM group had the lowest (5.87 eggs ± 0.61). However, these variations were not statistically significant (p = 0.133). The total egg production per bird over the entire 35-day trial was similar across all groups, with the control and 3% GASM groups producing 20.20 eggs ± 1.83 and 20.00 eggs ± 4.3, respectively, while the 1% and 2% GASM groups both produced 18.07 eggs ± 2.83 and 18.07 eggs ± 2.61, respectively. The differences in total egg production were not statistically significant (p = 0.583).

When examining weekly egg production in dozens, the results followed a similar pattern, with no significant differences across the GASM levels. The total egg production in dozens was consistent among the groups, with the control and 3% GASM groups yielding 1.68 dozen ± 0.15 and 1.67 dozen ± 0.20, respectively, compared to 1.50 dozen ± 0.24 and 1.50 dozen ± 0.22 for the 1% and 2% GASM groups, respectively (p = 0.583). Weekly egg weight per bird did not show significant differences across the GASM levels, except for Week 5, where the 3% GASM group had the highest weight (37.40 g ± 0.90), though this was approaching significance (p = 0.059). The total egg weight per bird was similar among all groups, ranging from 91.57 g ± 14.89 for the 2% GASM group to 100.83 g ± 10.81 for the 3% GASM group, with no significant differences (p = 0.790).

Finally, hen-day egg production percentages were also similar across all groups, with the control group at 57.71% ± 5.24, the 1% GASM group at 51.62% ± 8.09, the 2% GASM group at 51.62% ± 7.46, and the 3% GASM group at 57.14% ± 6.92 (p = 0.583).
The addition of GASM to the diet of Japanese quail did not significantly affect their egg production, egg weight, or hen-day egg production percentages.

3.3. Feed conversion ratio

The data presented in Table 6 shows the mean values and standard deviations of the feed conversion ratio (FCR) for Japanese quail (Coturnix japonica) supplemented with varying levels of golden apple snail meal (GASM) over a 35-day feeding trial. In Week 2 (days 42-49), the FCR (kg of feed per dozen eggs) for quail fed with 1% GASM was significantly higher at 2.88 ± 1.15 compared to the control group (1.77 ± 0.59) and the 2% (1.45 ± 0.33) and 3% (1.49 ± 0.32) GASM groups. However, the differences were not statistically significant (p = 0.105). During Week 3 (days 50-56), the FCR for all groups was relatively consistent, with values ranging from 0.65 ± 0.05 for the control to 0.78 ± 0.20 for the 2% GASM group, with no significant differences between groups (p = 0.715). In Week 4 (days 57-63), the FCR values for all groups were close, with the control group showing 0.50 ± 0.06 and the 1% GASM group showing 0.56 ± 0.19. The p-value of 0.916 indicates no significant differences across the groups. By Week 5 (days 63-70), the FCR values were relatively stable, with the 3% GASM group having the lowest FCR at 0.48 ± 0.00 and the 2% GASM group having the highest at 0.58 ± 0.07. However, the differences were not statistically significant (p = 0.174). For the overall FCR (kg of feed per dozen eggs), the control group had the lowest value at 0.76 ± 0.06, while the 2% GASM group had the highest at 1.82 ± 0.12 (Table 5). However, these differences were not statistically significant (p = 0.610). Regarding the weekly FCR based on egg weight, Week 2 showed a notable variation, with the 1% GASM group having the highest FCR at 53.86 ± 24.39, compared to the control group at 32.91 ± 8.58. However, the differences were not significant (p = 0.100). In Weeks 3 and 4, FCR values were consistent across all groups with no significant differences. In Week 5, the control group had the lowest FCR at 7.51 ± 0.12, whereas the 2% GASM group had the highest at 9.58 ± 1.11, which was insignificant (p = 0.073).

The overall FCR based on egg weight was similar across all groups, with the control group at 13.12 ± 1.33 and the 3% GASM group at 12.02 ± 1.37, showing no significant differences (p = 0.709). Including golden apple snail meal in the feed did not result in statistically significant changes in the feed conversion ratio for Japanese quail, suggesting that the levels of GASM tested may not affect feed efficiency.

Table 4. Mean values ± SD of the egg production of Japanese quail (*Coturnix japonica*) fed with varying levels of golden apple snail meal (GASM) as feed supplement.
Tabela 4. Valores médios ± DP da produção de ovos de codorna japonesa (*Coturnix japonica*) alimentada com níveis variados de farinha de caracol maçã dourada (GASM) como suplemento alimentar.

Parameters	Control	1% GASM	2% GASM	3% GASM	p-value***
Weekly Egg Production (per bird) *					
Week 2 (42-49)	1.80 ± 0.53	1.13 ± 0.58	1.93 ± 0.42	1.80 ± 0.40	0.253
Week 3 (50-56)	4.93 ± 0.42	4.40 ± 0.60	4.07 ± 0.92	4.73 ± 1.47	0.699
Week 4 (57-63)	6.53 ± 0.81	6.00 ± 1.73	5.93 ± 0.57	6.40 ± 1.04	0.889
Week 5 (63-70)	6.73 ± 0.31	6.53 ± 0.81	5.87 ± 0.61	7.00 ± 0.00	0.133
Total Egg Production (per bird) **					
TEP	20.20 ± 1.83	18.07 ± 2.83	18.07 ± 2.61	20.00 ± 43	0.583
Weekly Egg Production per bird (in dozens) *					
Week 2 (42-49)	0.15 ± 0.04	0.09 ± 0.05	0.16 ± 0.03	0.15 ± 0.03	0.253
Week 3 (50-56)	0.41 ± 0.03	0.37 ± 0.05	0.34 ± 0.08	0.39 ± 0.12	0.699
Week 4 (57-63)	0.54 ± 0.07	0.50 ± 0.14	0.49 ± 0.05	0.53 ± 0.09	0.889
Week 5 (63-70)	0.56 ± 0.02	0.54 ± 0.07	0.49 ± 0.05	0.58 ± 0.00	0.133
Total Egg Production per bird (in dozens) **					
TEP (dozen)	1.68 ± 0.15	1.50 ± 0.24	1.50 ± 0.22	1.67 ± 0.20	0.583
Weekly Egg Weight per bird (g)*					
Week 2 (42-49)	7.94 ± 2.25	5.33 ± 3.19	9.35 ± 2.54	8.76 ± 1.40	0.266
Week 3 (50-56)	22.04 ± 1.80	22.13 ± 2.31	21.32 ± 4.39	22.55 ± 6.28	0.966
Week 4 (57-63)	33.59 ± 5.61	30.82 ± 7.67	29.87 ± 4.17	31.91 ± 5.94	0.884
Week 5 (63-70)	33.33 ± 2.03	34.77 ± 4.10	29.57 ± 3.51	37.40 ± 0.90	0.059
Total Egg Weight per bird (g)**					
TEW (g)	97.91 ± 10.32	93.05 ± 13.58	91.57 ± 14.89	100.83 ± 10.81	0.790
Hen-day Egg Production (%) *					
HDEP, %	57.71 ± 5.24	51.62 ± 8.09	51.62 ± 7.46	57.14 ± 6.92	0.583

T1 (control)-0%; T2- 1%GASM; T3-2%GASM; T4-3% GASM; *Weekly data over 7 days (numbers in parentheses refer to the age in terms of days for the Japanese quail) **Total data of the 35-day feeding trial (5 weeks) ***ANOVA=one way analysis of variance; <0.05=significant, >0.05=not significant; <0.001=highly significant.
T1 (controle)-0%; T2- 1%GASM; T3-2%GASM; T4-3%GASM; *Dados semanais ao longo de 7 dias (os números entre parênteses referem-se à idade em dias para a codorna japonesa) **Dados totais do teste de alimentação de 35 dias (5 semanas) ***ANOVA=análise de variância unidirecional; <0,05=significativo, >0,05=não significativo; <0,001=altamente significativo.

3.4. Egg External Qualities

Table 6 showed significant differences in several parameters among the egg external qualities. The egg weight was highest in the 1% GASM group (10.04 ± 0.80 g), significantly greater than the control (9.47 ± 1.00 g) and other GASM levels. The 2% GASM group also had a higher egg weight (9.95 ± 0.75 g) than the control and 3% GASM group, though the difference was less pronounced. Similarly, GASM inclusion significantly affected egg length and width. The 2% GASM group exhibited the longest eggs (30.66 ± 1.50 mm), and the 1% GASM group had the widest eggs (24.44 ± 0.66 mm). These measurements were significantly higher than those of the control and 3% GASM groups.

Shell weight and shell thickness were also influenced by GASM supplementation. The 1% GASM group had the highest shell weight (1.02 ± 0.06 g) and shell thickness (0.20 ± 0.01 mm), significantly greater than those in the control group. The other GASM levels did not show significant differences in these parameters from the 1% GASM group. Regarding the percentage of egg shell, the 3% GASM group had a significantly higher percentage (10.45 ± 1.34%) than the control (10.12 ± 0.88%) and other GASM levels. The egg shape index did not show significant variation across the different GASM treatments, indicating that the shape of the eggs remained consistent regardless of the GASM level.

3.5. Egg Internal Qualities

The results in Table 7 revealed significant differences in yolk weight and width across the different GASM levels. Specifically, quail fed with 1% and 2% GASM exhibited significantly higher yolk weights (3.15 g and 3.19 g, respectively) compared to the control group (2.84 g), with the difference being highly significant (p < 0.001). Yolk width also increased with higher GASM supplementation, with quail receiving 2% GASM showing the widest yolks (26.00 mm), compared to the control (24.11 mm) and other GASM levels, which was again highly significant (p < 0.001). No significant differences between albumen weight and width existed among the treatment groups. The albumen weight ranged from 4.65 g to 4.83 g, and the albumen width varied from 41.15 mm to 43.36 mm, with p-values of 0.081 and 0.069, respectively, indicating that these parameters were not significantly influenced by GASM supplementation. Significant differences were observed in the percentage of yolk. Quail fed with 1%, 2%, and 3% GASM had a higher percentage of yolk (31.42%, 32.13%, and 32.12%, respectively) compared to the control (30.21%), with the differences being highly significant (p < 0.001). The inclusion of GASM in the diet positively influenced yolk weight, yolk width, and yolk percentage, demonstrating that GASM can be an effective feed supplement for enhancing certain internal egg qualities in Japanese quail.

Table 5. Mean values ± SD of the feed conversion ratio of Japanese quail (*Coturnix japonica*) fed with varying levels of golden apple snail meal (GASM) as feed supplement.
Tabela 5. Valores médios ± DP da taxa de conversão alimentar de codornas japonesas (*Coturnix japonica*) alimentadas com níveis variados de farinha de caracol-maçã-dourada (GASM) como suplemento alimentar.

Parameters	Control	1%GASM	2%GASM	3%GASM	p-value***
		Weekly FCR (kg of feed/per dozen eggs) *			
Week 2 (42-49)	1.77 ± 0.59	2.88 ± 1.15	1.45 ± 0.33	1.49 ± 0.32	0.105
Week 3 (50-56)	0.65 ± 0.05	0.71 ± 0.08	0.78 ± 0.20	0.67 ± 0.18	0.715
Week 4 (57-63)	0.50 ± 0.06	0.56 ± 0.19	0.53 ± 0.05	0.50 ± 0.10	0.916
Week 5 (63-70)	0.50 ± 0.02	0.52 ± 0.07	0.58 ± 0.07	0.48 ± 0.00	0.174
		Overall FCR (kg of feed/per dozen eggs) **			
FCR	0.76 ± 0.06	0.84 ± 0.14	1.82 ± 0.12	0.73 ± 0.09	0.610
		Weekly FCR (kg of feed/egg weight) *			
Week 2 (42-49)	32.91 ± 8.58	53.86 ± 24.39	25.62 ± 7.90	25.14 ± 3.62	0.100
Week 3 (50-56)	12.11 ± 0.95	11.78 ± 1.05	12.31 ± 2.87	11.60 ± 2.94	0.977
Week 4 (57-63)	8.27 ± 1.46	8.91 ± 2.48	8.86 ± 1.23	8.44 ± 1.95	0.965
Week 5 (63-70)	8.42 ± 0.53	8.15 ± 1.04	9.58 ± 1.11	7.51 ± 0.12	0.073
		Overall FCR (kg of feed/egg weight) **			
FCR	13.12 ± 1.33	13.51 ± 2.12	13.55 ± 2.15	12.02 ± 1.37	0.709

T1 (control)-0%; T2- 1%GASM; T3-2%GASM; T4-3% GASM; *Weekly data over 7 days (numbers in parentheses refer to the age in terms of days for the Japanese quail) **Total data of the 35-day feeding trial (5 weeks) ***ANOVA=one way analysis of variance; <0.05=significant, >0.05=not significant; <0.001=highly significant.
T1 (controle)-0%; T2- 1%GASM; T3-2%GASM; T4-3%GASM; *Dados semanais ao longo de 7 dias (os números entre parênteses referem-se à idade em dias para a codorna japonesa) **Dados totais do teste de alimentação de 35 dias (5 semanas) ***ANOVA=análise de variância unidirecional; <0,05=significativo, >0,05=não significativo; <0,001=altamente significativo.

Table 6. Mean values ± SD of the external egg qualities of Japanese quail (*Coturnix japonica*) fed with varying levels of golden apple snail meal (GASM) as feed supplement.
Tabela 6. Valores médios ± DP das qualidades externas dos ovos de codorna japonesa (*Coturnix japonica*) alimentadas com níveis variados de farinha de caracol-maçã-dourada (GASM) como suplemento alimentar.

Parameters*	Control	1% GASM	2% GASM	3% GASM	p-value**
Egg weight (g)	9.47 ± 1.00^{c}	10.04 ± 0.80^{a}	9.95 ± 0.75^{ab}	9.78 ± 0.86^{b}	<0.001
Egg length (mm)	29.86 ± 1.50^{c}	30.56 ± 1.08^{ab}	30.66 ± 1.50^{a}	30.26 ± 0.99^{b}	<0.001
Egg width (mm)	23.99 ± 0.99^{b}	24.44 ± 0.66^{a}	24.42 ± 0.66^{a}	24.38 ± 1.10^{a}	<0.001
Shell weight (g)	0.95 ± 0.92^{b}	1.02 ± 0.06^{a}	1.00 ± 0.06^{a}	1.01 ± 0.93^{a}	<0.001
Shell thickness (mm)	0.18 ± 0.08^{b}	0.20 ± 0.01^{a}	0.20 ± 0.01^{a}	0.21 ± 0.01^{a}	<0.001
Percent egg shell (%)	10.12 ± 0.88^{b}	10.23 ± 0.90^{ab}	10.13 ± 0.79^{b}	10.45 ± 1.34^{a}	0.012
Egg shape index (%)	80.43 ± 3.04	80.04 ± 2.49	79.83 ± 3.89	80.64 ± 4.24	0.182

T1 (control)-0%; T2- 1% GASM; T3-2 % GASM; T4-3% GASM *Total data of the 35-day feeding trial (5 weeks) **ANOVA=one way analysis of variance; <0.05=significant, >0.05=not significant; <0.001=highly significant.
T1 (controle) - 0%; T2 - 1% GASM; T3 - 2% GASM; T4 - 3% GASM *Dados totais do teste de alimentação de 35 dias (5 semanas) **ANOVA = análise de variância unidirecional; <0,05 = significativo, >0,05 = não significativo; <0,001 = altamente significativo.

4. DISCUSSION

4.1. Feed Intake

The observed reduction in feed intake of Japanese quail with higher inclusion levels of Golden Apple Snail Meal (GASM) can be due to several potential causes, including anti-nutritional factors in GASM. One primary factor could be the high levels of dietary fiber, particularly from the snail shells, which can cause a feeling of fullness or gastrointestinal discomfort, thereby decreasing feed consumption (NIEPES et al., 2023). This increased bulk can stretch the gastrointestinal tract, leading to a sensation of fullness that reduces the desire to consume additional feed. High fiber content can also slow **the** feed passage rate through the digestive system, potentially causing gastrointestinal discomfort or reducing the efficiency of nutrient absorption, which might further decrease feed intake (JHA; MISHRA, 2021; LATTIMER; HAUB, 2023).

Additionally, GASM may contain chitin, a complex exoskeleton found in the exoskeletons of snails, which can be difficult for quail to digest and may negatively impact feed intake by causing digestive inefficiencies (Nusantoro et al., 2024). Chitin, composed of long chains of N-acetylglucosamine, is structurally resistant to enzymatic breakdown because many animals, including Japanese quail, lack chitinase, the enzyme required to hydrolyze it (CHEN et al., 2011). Chitin passes through the gastrointestinal tract largely undigested, contributing to an increased bulk of indigestible material in the feed. This can disrupt normal digestive processes, decrease nutrient absorption, and potentially cause gastrointestinal discomfort or irritation, reducing feed intake and overall feed efficiency (YEGANI; KORVER, 2008). If not properly balanced with other dietary components, the presence of minerals such as calcium and phosphorus in the shells could also affect nutrient absorption and overall feed palatability (RYGALO-GALEWSKA et al., 2023). These anti-nutritional factors might alter the sensory characteristics of the feed, making it less appealing to the quail and reducing consumption.

Table 7. Mean values ± SD of the internal egg qualities of Japanese quail (*Coturnix japonica*) fed with varying levels of golden apple snail meal (GASM) as feed supplement.
Tabela 7. Valores médios ± DP das qualidades internas dos ovos de codorna japonesa (*Coturnix japonica*) alimentada com níveis variados de farinha de caracol maçã dourada (GASM) como suplemento alimentar.

Parameters*	Control	1% GASM	2% GASM	3% GASM	p-value**
Yolk weight (g)	2.84 ± 0.25[b]	3.15 ± 0.29[a]	3.19 ± 0.33[a]	3.13 ± 0.35[a]	<0.001
Yolk width (mm)	24.11 ± 1.94[c]	25.04 ± 2.13[b]	26.00 ± 3.14[a]	25.97 ± 3.02[a]	<0.001
Albumen weight	4.65 ± 0.70	4.77 ± 0.52	4.83 ± 0.50	4.73 ± 0.67	0.081
Albumen width (mm)	41.15 ± 7.73	43.18 ± 7.82	43.36 ± 8.97	43.02 ± 8.20	0.069
Percent yolk (%)	30.21 ± 3.46[b]	31.42 ± 1.81[a]	32.13 ± 2.86[a]	32.12 ± 3.27[a]	<0.001

T1 (control)-0%; T2- 1% GASM; T3- 2% GASM; T4- 3% GASM; *Total data of the 35-day feeding trial (7 weeks); **ANOVA=one way analysis of variance; <0.05=significant, >0.05=not significant; <0.001=highly significant.
T1 (controle)-0%; T2- 1% GASM; T3- 2% GASM; T4- 3% GASM; *Dados totais do ensaio de alimentação de 35 dias (7 semanas); **ANOVA=análise de variância unidirecional; <0,05=significativo, >0,05=não significativo; <0,001=altamente significativo.

4.2. Egg Production

The study's results indicate that these differences did not reach statistical significance. At the same time, there are observable trends in egg production and weight in response to varying levels of golden apple snail meal (GASM). This suggests that GASM supplementation may not substantially affect egg production metrics for Japanese quail within the ranges tested. Specifically, there was a trend toward increased egg production with higher GASM levels in certain weeks, particularly towards the end of the study. This could imply a potential benefit of higher GASM levels. However, this trend is inconclusive and may require further research with larger sample sizes and extended testing durations to validate these findings. Regarding egg weight, the impact of GASM was inconsistent, with some weeks showing potential improvements at higher GASM levels. Despite these observations, the lack of consistent significant differences suggests that GASM may not be a major determinant of egg weight.

Several factors can significantly impact quail egg production, each influencing various aspects of reproductive performance. One of the primary factors is nutrition; a well-balanced diet that provides adequate levels of protein, vitamins, and minerals is important for optimal egg production (SHIM et al., 2013). Nutritional deficiencies can lead to poor egg quality and lower production rates. Additionally, environmental conditions such as temperature, humidity, and lighting play a vital role (NAWAB et al., 2018).

Quail require stable and appropriate temperature and humidity levels to maintain comfort and reproductive efficiency, while proper lighting conditions help regulate their laying cycles. Genetics also contributes to egg production, as different quail breeds and strains have varying reproductive capabilities (IBRAHIM et al., 2021). Management practices, including housing density and sanitation, affect quail's health and stress levels, further influencing their egg production.

Golden apple snail meal (GASM) can improve poultry egg production through several mechanisms. Rich in protein, essential amino acids, and minerals, GASM can enhance the overall nutritional profile of poultry feed, which is crucial for optimal reproductive performance (PERTIWI; SAPUTRI, 2020). The high protein content in GASM supports the development and maintenance of healthy reproductive tissues and improves the quality of egg production. Additionally, the minerals present in GASM, such as calcium and phosphorus from the snail shells, contribute to stronger eggshells and better overall egg quality (BOAKYE et al., 2023). By integrating GASM into poultry diets, it is possible to provide a more balanced and nutrient-dense feed, potentially leading to improved egg production.

4.3. Feed Conversion Ratio

The supplementation of Japanese quail feed with golden apple snail meal did not result in statistically significant changes in feed conversion ratios compared to the control group. The variations observed in FCR across different weeks and treatment levels suggest that while some trends indicate potential improvements in feed efficiency with higher GASM levels, these differences were not consistent enough to achieve statistical significance.

The Feed Conversion Ratio (FCR) is a parameter of feed efficiency in poultry production, indicating how effectively feed is converted into desired outputs such as egg weight or quantity (ANENE et al., 2021). Regarding egg weight, FCR represents the amount of feed required to produce a specific weight of eggs, with a lower ratio indicating better efficiency. When expressed in terms of eggs per dozen, it measures the feed needed to produce a dozen eggs, again with a lower ratio being more favorable. The type of feed used plays a significant role in improving FCR. High-quality nutritionally balanced feeds, containing the right mix of proteins, vitamins, and minerals, can enhance feed utilization (PESTI; CHOCT, 2023). Supplements such as golden apple snail meal (GASM) can boost feed efficiency by providing additional essential nutrients and improving digestibility. This means birds can produce more or heavier eggs with the same or less feed. Well-formulated feeds support better overall health and productivity in poultry, reducing the feed required to achieve targeted production levels and thus leading to a more favorable FCR.

Golden apple snail meal (GASM) may improve the feed conversion ratio (FCR) in poultry by enhancing the nutritional quality and digestibility of the feed. GASM is rich in essential proteins, amino acids, and minerals, vital for optimal bird growth and egg production (NIEPES et al., 2023). Incorporating GASM into poultry feed enriches the overall nutrient profile, potentially addressing deficiencies in the standard feed and improving the birds' ability to utilize the feed more effectively. The high protein content and digestibility of GASM can support better muscle development and egg formation, which can translate to a more efficient conversion of feed into eggs.

4.4. Egg External Qualities

The golden apple snail meal (GASM) improves the external egg qualities of Japanese quail through its rich nutrient profile, which includes high levels of calcium, protein, and essential amino acids. Calcium is a critical component of eggshell formation, and its supplementation directly influences shell weight and thickness. The GASM may provide a bioavailable source of calcium that enhances the mineral content of the egg shell, resulting in stronger and thicker shells.

Additionally, the protein and amino acids in GASM contribute to overall egg quality by supporting the development of the egg's structural components. Protein is essential for synthesizing proteins like ovalbumin and ovomucin, which are key to maintaining egg integrity and improving egg weight (OBIANWUNA et al., 2022). At a 1% supplementation level, GASM effectively boosts shell weight and thickness by supplying sufficient calcium and protein to the quail's diet, optimizing these parameters. The 2% level further enhances egg dimensions, likely due to increased calcium and protein availability, leading to larger and well-formed eggs. However, at 3% supplementation, the benefits may plateau or even decline because of potential imbalances or the saturation of available nutrients, which might affect the overall efficiency of nutrient utilization and could lead to diminishing returns in egg quality (ROBERTS, 2004; CHANG et al., 2019). Thus, while GASM positively influences egg quality, excessive levels might not yield additional improvements and could negatively impact certain egg characteristics.

4.5. Egg Internal Qualities

Supplementing Golden Apple Snail Meal (GASM) to the diet of Japanese quail has been shown to improve certain internal egg qualities, particularly those related to the yolk. GASM is rich in essential nutrients like proteins, amino acids, and minerals such as calcium and phosphorus, which support better yolk development. These proteins contribute to the nutritional quality of the yolk, affecting its weight and size. Proteins and their constituent amino acids are vital for synthesizing yolk proteins, such as lipovitellin and phosvitin (KAWAMURA et al., 2023).

These proteins are key contributors to the nutritional value and structure of the yolk, influencing its weight, size, and overall quality. Additionally, proteins support the formation of albumen, or egg white, which contributes to the egg's consistency and protective functions (ROBERT, 2004). By ensuring an adequate dietary protein supply, birds can produce eggs with improved yolk and albumen characteristics, resulting in nutritionally richer eggs and better internal quality. This improvement in internal egg quality reflects a direct benefit of protein in the diet, as it supports the optimal development of critical egg components.

Calcium supports the formation of yolk membrane proteins, enhancing the firmness and stability of the yolk, while phosphorus aids in energy metabolism and cellular processes crucial for yolk development (Hamid, 2022). This leads to increases in yolk weight, width, and proportion. While GASM enhances these aspects of egg quality, it does not significantly impact albumen weight or width. This suggests that GASM effectively improves certain internal egg qualities without affecting all components equally.

5. CONCLUSIONS

The results of this study indicate that the inclusion of golden apple snail meal (GASM) as a feed supplement for Japanese quail (*Coturnix japonica*) affects feed intake, egg production, and egg quality. Over the 35-day trial period, feed intake decreased with higher GASM levels, with the control group consistently showing the highest intake across all weeks. The total feed intake followed a similar pattern, significantly reducing intake as GASM levels increased. Significant improvements regarding egg quality were observed in several external parameters with GASM supplementation. Specifically, eggs from the 1% GASM group were significantly heavier, longer, and wider than those from the control group.

The shell weight and thickness also improved with GASM inclusion, particularly in the 1% GASM group. However, the percentage of eggshell was notably higher in the 3% GASM group. Internal egg qualities, such as yolk weight and width, were significantly enhanced in quail fed with 1% and 2% GASM, suggesting a beneficial effect of GASM on yolk development.

GASM supplementation improved egg quality parameters, such as egg weight, shell thickness, and yolk weight. These positive results suggest that GASM can be a valuable feed additive for enhancing egg quality in Japanese quail. Although its impact on feed efficiency and production rates was limited, the benefits to egg quality show its potential value in quail nutrition.

6. REFERENCES

ANENE, D. O.; AKTER, Y.; THOMSON, P. C.; GROVES, P.; LIU, S.; O'SHEA, C. J. Hens that exhibit poorer feed efficiency produce eggs with lower albumen quality and are prone to being overweight. **Animals**, v. 11, n.10, e2986, 2021. https://doi.org/10.3390/ani11102986

BOAKYE, A. K.; ASANTE, B. O.; AKUTINGA, S.; AGYEMAN, D.; PRAH, S.; IDAN, F.; ANTWI, C.; ASANTE, I. S. Farmers' perceptions and willingness to adopt egg and snail shells as alternative calcium sources for poultry production in the Western region of Ghana. **Journal of Agriculture and Food Research**, v. 14, e100818, 2023. https://doi.org/10.1016/j.jafr.2023.100818

CHANG, L.; ZHANG, R.; FU, S.; MU, C.; TANG, Q.; BU, Z. Effects of different dietary calcium levels on the performance, egg quality, and albumen transparency of laying pigeons. **Animals**, v. 9, n. 3, e110, 2019. https://doi.org/10.3390/ani9030110

CHEN, J. K.; SHEN, C. R.; YEH, C. H.; FANG, B. S.; HUANG, T. L.; LIU, C. L. N-acetyl glucosamine obtained from chitin by chitin degrading factors in Chitinbacter tainanesis. **International Journal of Molecular Sciences**, v. 12, n. 2, p. 1187-1195, 2011. https://doi.org/10.3390/ijms12021187

DPI_Department of Primary Industries. **Golden apple snail**. New South Wales Department of Primary Industries website. 2017. Available on: from https://www.dpi.nsw.gov.au/biosecurity/plant/insect-pests-and-plant-diseases/golden-apple-snail. Accessed at: May 30, 2024, GOFF, J. P. Invited review: Mineral absorption mechanisms, mineral interactions that affect acid–base and antioxidant status, and diet considerations to improve mineral status. **Journal of Dairy Science**, v. 101, n. 4, p. 2763-2813, 2018. https://doi.org/10.1016/j.jafr.2023.100818

HAMID, M. S. **Effect of sea-shell based calcium carbonate supplement (cockle) on the egg quality of Japanese quail (*Coturnix coturnix* japonica)**. 90f. Doctoral Dissertation - Chittagong Veterinary and Animal Sciences University, Chittagong, 2022.

IBRAHIM, N. S.; EL-SAYED, M. A.; ASSI, H. A. M.; ENAB, A.; ABDEL-MONEIM, A. E. Genetic and physiological variation in two strains of Japanese quail. **Journal of Genetic Engineering & Biotechnology**, v. 19, n. 1, e15, 2021. https://doi.org/10.1186/s43141-020-00100-3

JHA, R.; MISHRA, P. Dietary fiber in poultry nutrition and their effects on nutrient utilization, performance, gut health, and on the environment: A review. **Journal of Animal Science and Biotechnology**, v. 12, n. 1, e51, 2021. https://doi.org/10.1186/s40104-021-00576-0

JOSHI, R. C. Problems with the management of the golden apple snail Pomacea canaliculata: An important exotic pest of rice in Asia. In: **AREA-WIDE control of insect pests: From research to field implementation**. Dordrecht: Springer Netherlands, 2007. p.257-264.

KAWAMURA, N.; YOKOYAMA, R.; TAKAYA, M.; ONO, R.; GOTO, T. Combined effect of feed and housing system affects free amino acid content of egg yolk and albumen in brown layer chickens. **The Journal of Poultry Science**, v. 60, n. 1, e2023007, 2023. https://doi.org/10.2141/jpsa.2023007

LAMBIO, A.; CAPITAN, S.; DAGAS, C. Production of native chickens and other poultry species. In: LAMBIO, A. (Org.) **Poultry Production in the Tropics**. Quezon City: The University of the Philippines Press, 2010. 160p.

LATTIMER, J. M.; HAUB, M. D. Effects of dietary fiber and its components on metabolic health. **Nutrients**, v. 2, n. 12, p. 1266-1289, 2010. https://doi.org/10.3390/nu2121266

MALVAR, L. A. A.; AGAPITO, E. R. Laying and egg quality of quail fed diets containing kuhol meal (*Pomacea canaliculata*) fortified with different phytobiotics. **Journal of Critical Reviews**, v. 7, n. 11, p. 781-788, 2020. https://doi.org/10.1590/1806-9061-2018-0732

NAWAB, A.; IBTISHAM, F.; LI, G.; KIESER, B.; WU, J.; LIU, W.; AN, L. Heat stress in poultry production: Mitigation strategies to overcome the future challenges facing the global poultry industry. **Journal of Thermal Biology**, v. 78, p. 131-139, 2018. https://doi.org/10.1016/j.jtherbio.2018.08.010

NIEPES, R. A.; MAÑA, M. A. T.; CAGARA, E. C. Effect of varying levels of golden apple snail (*Pomacea canaliculata* Lamarck) meal on the growth performance of mallard ducks (*Anas platyrhynchos* L.). **Livestock Research for Rural Development**, v. 35, e64, 2023. Available on: http://www.lrrd.org/lrrd35/7/3564rich.html.

NUSANTORO, S.; NATSIR, M. H.; SJOFJAN, O. Nutritive value of golden apple snail (*Pomacea canaliculata*) as animal and aquaculture feed. **Reviews in Agricultural Science**, v. 12, p. 147-164, 2024. https://doi.org/10.7831/ras.12.0_147

OBIANWUNA, U. E.; OLEFORUH-OKOLEH, V. U.; WANG, J.; ZHANG, H. J.; QI, G. H.; QIU, K.; WU, S. G. Natural products of plants and animal origin improve albumen quality of chicken eggs. **Frontiers in Nutrition**, v. 9, e875270, 2022. https://doi.org/10.3389/fnut.2022.875270

PERTIWI, M. P.; SAPUTRI, D. D. Golden apple snail (*Pomacea canaliculata*) as an alternative protein source in Pasupati catfish (*Pangasius* sp.) fish feed. **Nusantara Bioscience**, v. 12, n. 2, p. 162-167, 2020. https://doi.org/10.13057/nusbiosci/n120212

PESTI, G. M.; CHOCT, M. The future of feed formulation for poultry: Toward more sustainable production of meat and eggs. **Animal Nutrition**, v. 15, p. 71-87, 2023. https://doi.org/10.1016/j.aninu.2023.02.013.

ROBERTS, J. R. Factors affecting egg internal quality and egg shell quality in laying hens. **The Journal of Poultry Science**, v. 41, n. 3, p. 161-177, 2004.

RYGAŁO-GALEWSKA, A.; ZGLIŃSKA, K.; ROGUSKI, M.; ROMAN, K.; BENDOWSKI, W.; BIEŃ, D.; NIEMIEC, T. Effect of different levels of calcium and addition of magnesium in the diet on garden snails' (*Cornu aspersum*) condition, production, and nutritional parameters. **Agriculture**, v. 13, n. 11, e2055, 2023. https://doi.org/10.3390/agriculture13112055

SHIM, M. Y.; SONG, E.; BILLARD, L.; AGGREY, S. E.; PESTI, G. M.; SODSEE, P. Effects of balanced dietary protein levels on egg production and egg quality parameters of individual commercial layers. **Poultry Science**, v. 92, n. 10, p. 2687-2696, 2013. https://doi.org/10.3382/ps.2012-02569

TUNÇ, A. E.; CUFADAR, Y. Effect of calcium sources and particle size on performance and eggshell quality in laying hens. **Turkish Journal of Agriculture-Food Science and Technology**, v. 3, n. 4, p. 205-209, 2015. https://doi.org/10.24925/turjaf.v3i4.205-209.262

VANNUCCI, L.; FOSSI, C.; QUATTRINI, S.; GUASTI, L.; PAMPALONI, B.; GRONCHI, G.; GIUSTI, F.; ROMAGNOLI, C.; CIANFEROTTI, L.; MARCUCCI, G.; BRANDI, M. L. Calcium intake in bone health: A focus on calcium-rich mineral waters. **Nutrients**, v. 10, n. 12, e1930, 2018. https://doi.org/10.3390/nu10121930

YEGANI, M.; KORVER, D. R. Factors affecting intestinal health in poultry. **Poultry Science**, v. 87, n. 10, p. 2052-2063, 2008. https://doi.org/10.3382/ps.2008-00091

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