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Original Article

The effect of addition of calcium mineral in feed containing fishery wastes on egg production and hatching performance of Mojosari ducks

Efeito da adição de mineral cálcio em ração contendo resíduos de pesca na produção de ovos e desempenho de incubação de patos Mojosari

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Abstract

Calcium (Ca) is an essential mineral for eggshell formation and muscle contraction, and a lack of it can result in poor egg quality and decreased egg output in laying ducks. This study aims to see how feeding the mineral Ca in a ration containing Shrimp head meal and Bilis fish head affects the laying performance and quality of hatching eggs in Mojosari ducks. A total of 105 female and 15 male Mojosari ducks, aged 78 weeks, were raised for three months and randomly divided into 15 flocks (each flock containing seven females and one male duck). There were three kinds of treatment, namely P0 (control, without mineral), P1 (ratio of Shrimp head meal and Bilis fish head 2:1 + 1% mineral), and P2 ((ratio of Shrimp head meal and Bilis fish head 1:2 + 1% mineral). The findings revealed that adding mineral Ca to feed, including Shrimp head meal and Bilis fish head, had no significant influence (P>0.05) on laying Mojosari duck performance in terms of feed intake, egg production, egg weight, egg quality, ducklings produced, and income over feed cost (IOFC). Furthermore, Ca addition in the ration did not result in substantial increases (P>0.05) in fertility, hatchability, or egg size characteristics. Based on the findings of this study, feeding ducks with shrimp head meal and Bilis fish head can be used as an alternate calcium-free feed formulation.

Keywords: egg quality, fishery wastes, hatchery, Mojosari duck, performance.

Resumo

O cálcio (Ca) é um mineral essencial para a formação da casca do ovo e a contração muscular. Sua falta pode resultar em má qualidade do ovo e diminuição da produção de ovos em patas poedeiras. Este estudo tem como objetivo verificar como a adição do mineral Ca em uma ração contendo farinha de cabeça de camarão e cabeça de peixe Bilis afeta o desempenho de postura e a qualidade dos ovos para incubação em patos Mojosari. Um total de 105 patos Mojosari fêmeas e 15 machos, com idade de 78 semanas, foram criados durante três meses e divididos aleatoriamente em 15 bandos (cada bando contendo sete fêmeas e um pato macho). Foram realizados três tipos de tratamento: P0 (controle, sem mineral), P1 (proporção de farinha de cabeça de camarão e cabeça de peixe Bilis 2:1 + 1% mineral) e P2 (relação farinha de cabeça de camarão e cabeça de peixe Bilis 1:2 + 1% mineral). Os resultados revelaram que a adição do mineral Ca à ração, incluindo farinha de cabeça de camarão e cabeça de peixe Bilis, não teve influência significativa (p>0,05) sobre o desempenho de poedeiras em termos de consumo de ração, produção de ovos, peso dos ovos, qualidade dos ovos, patinhos produzidos e renda sobre o custo da ração (IOFC). Além disso, a adição de Ca na ração não resultou em aumentos substanciais (p>0,05) em fertilidade e eclodibilidade, ou características de tamanho dos ovos. Com base nos resultados deste estudo, a alimentação com farinha de cabeça de camarão e cabeça de peixe Bilis pode ser usada como uma formulação alternativa de ração livre de cálcio.

Palavras-chave: qualidade de ovos, resíduos de pesca, incubatório, pato Mojosari, desempenho.

1. Introduction

Calcium (Ca) is essential for egg production, eggshell formation, and bone quality in laying birds. Many studies have reported that Ca deficiency can affect performance, eggshell, and tibial quality/microarchitecture (Chen et al., 2015; Xia et al., 2019). Inadequate Ca intake can also result in thin or weak eggshells that easily break, leading to

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decreased hatchability and increased embryonic mortality (Chen et al., 2015). There's a lot to know about the different impacts of dietary Ca on the physiology and performance of chickens, but there's less information available for laying ducks and duck breeders.

Studies have shown that dietary Ca level, source, and particle size can affect hens' laying performance, eggshell quality, and tibial quality (An et al., 2016; Ganjigohari et al., 2018; Manangi et al., 2018). Their other report on Longyan laying ducks aged 20-33 weeks found that feeding 3.6% calcium (Ca) and 0.40% phosphorus (P) optimised egg production and size. Formulating diets combining 3.6% Ca and 0.40% available P was recommended to optimise egg production, egg mass, feed efficiency, and bone properties. Xia et al. (2019) claim that the Ca levels set for laying ducks' present demands are insufficient to suit the needs of female laying ducks, which differ genetically in terms of their egg production capacity, egg quality, egg size, fertility, and hatchability. The US National Research Council (NRC, 1994) advised a Ca level of 2.75% for white Pekin duck breeders. According to Xia et al. (2015), Huang et al. (2016), and Wang et al. (2020b), local Linwu ducks needed 2.79 to 2.98% Ca to support laying performance during the early laying phases and 3.50% Ca to improve the quality of eggs during the peak laying seasons. A study by An et al. (2016) reported that calcium levels could be increased up to 4.7% in laying hens, resulting in a linear reduction in cracked eggs and a slight increase in tibial breaking strength without negatively affecting their egg-laying capacity.

A necessary breed of waterfowl in Indonesia, Mojosari ducks (*Anas javanica*) are endemic to the country and are prized for their prolific egg production. However, sufficient Ca intake is essential to maintain their high egg production performance and the hatchability of their eggs. A previous study reported that the level of Ca in Mojosari laying ducks' diet was 3.25% when they were aged 40 weeks old (Edi et al. 2018), 1% when they were 20 weeks old (Purwandani et al., 2017), and 2-3% when they were 38 weeks old (Indarsih et al., 2015). These findings suggest that the optimal Ca level in Mojosari ducks' diet may vary based on age and the specific stage of their egg-laying cycle. Farmers need to monitor the Ca intake of their Mojosari ducks to ensure optimal egg production and hatchability of eggs.

Using alternative feed ingredients in duck diets has gained attention recently. Two examples of such items reported to provide critical elements such as protein and minerals are Shrimp head meal and Bilis fish head. Shrimp head meal can be produced by drying and grinding shrimp waste, which has been found to have high protein, chitin, and mineral content (Gunawan and Junianto 2021). According to Liu et al. (2021), based on the composition of dry matter, Shrimp heads contain 6.56-9.97% crude protein, 3.04-6.88% crude fat, 4.11-7.3% ash, and 2.38-3.99% crude fibre. Meanwhile, the Bilis fish head (*Encrasicholina* sp.) has been reported to be a good source of minerals like Ca and phosphorus (P) (Gencbay and Turhan, 2016). The by-product of Bilis fish has 44,43% protein, 13.68% carbs, and 6.62% ash (Ali et al., 2018). To ensure that the feed's overall nutrient composition satisfies the needs of the ducks, it is crucial to remember that the inclusion rate of these nutrients must be carefully evaluated.

In Tanjungpinang Municipality, duck farmers have traditionally use shrimp head meal and Bilis fish head for laying duck feed ingredients and various other feed ingredients. However, the amount of administration has yet to be calculated based on recommendations for the nutritional content of ducks and with a relatively low ration price. Meanwhile, feed costs can be cheaper with local raw materials readily available. Bilis fish is commonly available locally as by-catch by local fishermen; thus, it is always available, provided fresh to ducks, and does not require any processing before being given to ducks, implying that the price is reasonably affordable. Meanwhile, shrimp heads are sourced from a processing business some distance from the duck-rearing site and require additional costs to be converted into flour. So, the price of a Shrimp head meal is relatively higher than that of a Bilis fish head.

A well-balanced duck diet should consist of various grains and protein sources, with vitamins and minerals supplied as needed or in supplement form. The effect of Ca supplementation in the feed containing these meals on egg production and quality has yet to be studied. Therefore, this study attempted to complete this research gap by examining the influence of varied ratios of Shrimp head meal and Bilis fish head, adding 1% Ca supplement, on the egg hatching quality and laying performance of Mojosari ducks. So, the findings of this study are intended to provide information on the effects of delivering shrimp heads and Bilis fish heads with 1% Ca on the egg-hatching quality and laying performance of Mojosari ducks.

2. Materials and Methods

2.1. Diet preparation and experimental design

The ration consisted of cornmeal, Kentucky Fried Chicken (KFC) waste, rice bran, Shrimp head meal, Bilis fish head, commercial concentrate, Ca-Mineral, rejected oil, premix, and dicalcium phosphate DCP). Ingredients such as KFC waste are sourced from KFC restaurants, shrimp heads from processing facilities, Bilis fish heads from traditional markets, and other ingredients from local poultry stores. Shrimp heads, Bilis fish heads, and KFC waste were collected fresh, while the remaining ingredients were in flour or mashed form. Formulation and nutrient content are shown in Table 1.

This study was conducted with local farmer groups in Dompak Village, Tanjungpinang City, Indonesia, for three (3) months, from September to December 2022. The experiment used a completely randomised design (CRD). A total of 105 female and 15 male Mojosari ducks, aged 78 weeks, were raised for three months and randomly divided into 15 flocks (each flock containing seven females and one male duck). There were three kinds of treatment, namely P0 (control, without mineral), P1 (ratio of Shrimp head meal and Bilis fish head 2:1 + 1% mineral), and P2 ((ratio of Shrimp head meal and Bilis fish head 1:2 + 1% mineral). During the trial, the ducks were fed 150 g of each duck daily and had access to water ad-libitum.

Table 1. The composition and nutrient content of Mojosari duck rations.

Item	Treatments		
	P0	P1	P2
Feed ingredients (% DM)			
Cornmeal	23.90	16.00	15.00
Fried chicken/FC waste (flour)	18.92	28.50	26.50
Fried chicken/FC waste (oil)	1.00	1.00	1.00
Rice bran	19.92	17.10	20.10
Shrimp head meal	19.92	22.50	11.00
Bilis fish head	11.95	11.00	22.50
Commercial concentrate	3.99	2.00	2.00
Ca-Mineral	-	1.00	1.00
Premix	0.20	0.20	0.20
Turbo	0.20	0.20	0.20
Dicalcium Phosphate/DCP	-	0.50	0.50
Total	100.00	100.00	100.00
Nutrient contents (%)			
Energy metabolism (kcal/kg)	2,945.84	2,951.88	2,932.07
Crude protein (%)	21.21	19.02	19.06
Ether extract (%)	7.78	6.84	7.25
Crude fibre (%)	5.46	5.66	5.16
Ca (%)	1.37	5.51	5.19
P (%)	0.42	0.46	0.35

Note: P0 (control, without mineral), P1 (ratio of Shrimp head meal and Bilis head meal 2:1 + 1% mineral), and P2 (comparison of the meal from the Shrimp head and Bilis head meal 1:2 + 1% mineral). DM (Dry Matter); Ca (Calcium); P (Phosphor)

The average temperature outside the cage was 28.10 °C in the morning and 30.55 °C in the afternoon, while the average temperature inside the cage was 26.69 °C in the morning and 29.17 °C in the afternoon. The average temperature inside the incubator machine in the morning and afternoon is 38.95 °C and 38.40 °C, respectively. The average humidity inside the incubator machine in the morning and afternoon is 28.00% and 43.67%, respectively.

2.2. Chemical analyses and parameters

Dry matter (DM), crude fibre contents, ash, ether extract, and crude protein were evaluated in duplicate using AOAC procedures (AOAC, 2007). Similarly, the Ca and P levels were assessed in duplicate for each sample using the AOAC methods (AOAC, 2007). The parameters observed were egg production, egg weight, feed conversion ratio (FCR), consumption of crude protein, consumption of Ca, income over feed cost (IOFC), hatchability, fertility, egg index, egg weight loss, and the weight of the produced ducklings.

The method to calculate egg production is to divide the number of eggs by the number of hens by 100% (Bello et al., 2022). Egg weight was determined by weighing the eggs daily using a digital scale (Hasyim et al., 2021). The FCR value is the ratio between the amount of feed consumed by ducks and the body weight of the ducks (Ismoyowati et al., 2020). The hatchability rate is calculated using the formula: the number of successfully hatched eggs divided by the total number of eggs incubated in the machine x 100% (Abd El-Hack et al., 2022). Fertility is calculated by dividing the number of eggs that develop embryos by the number of eggs set, then x 100% (Abd El-Hack et al., 2019). IOFC was calculated using the following formula: Egg selling income - feed cost. The egg index is calculated from egg width/length x 100% (Wu et al., 2019). Egg weight loss is calculated from ((Egg weight before incubation - Transfer of egg weight to hatcher)/Egg weight before incubation) x 100%. The weight of the duckling was determined by weighing it using a digital scale. The eggs were weighed once a week; each repetition unit included up to ten eggs and eight weighings.

2.3. Hatching procedure

The primary tool used in the hatching process was a manual hatching machine with a maximum capacity of 500 eggs. This machine has a heater and a thermostat for temperature control. It was equipped with supporting tools, such as a digital hygrometer (HTC-2, China) to measure temperature and humidity, an infrared thermometer (UX-A-01, Germany) to measure eggshell temperature, and a digital scale (AJ 3000, Osaka, Japan) to weigh the eggs weekly. The hatching process for duck eggs in this study began with the initial stage of collecting duck eggs, which were collected for a maximum of 7 days (Alsoyabel et al., 2013).

The machine was fumigated using 40% formalin and KMnO4 in a ratio of 2:1. Other equipment was also disinfected to minimise bacterial contamination. During hatching, the machine temperature was set in the range of 37.0-38.0 °C, and the humidity was 80% during the setter period, reduced to 60% during the hatcher period (Lase et al., 2023). The hatching machine has ventilation to support air circulation, ensuring optimal embryo development (Ipek and Sozcu, 2017).

The total hatching time for duck eggs in one period was 30 days, divided into two parts: the setter period, from days 1 to 28, and the hatcher period, from days 28 to 30, or until the eggs hatch (Lase et al., 2023). During the hatcher period, the temperature and humidity are lowered to help the embryos hatch. Throughout the hatching process, the weight of the eggs was monitored weekly to determine egg weight loss. At the end of the hatching period, the hatchability of the eggs was then calculated. The hatches were 75 eggs each for three treatments, totalling 225 eggs.

2.4. Statistical analysis

Analysis of variance (ANOVA) was used to analyse the data using the General Linear Models process. Any significant differences (P<0.05) in the mean were further tested using Duncan's multiple-range test. SAS software version 9.1 was used for all statistical operations.

3. Results and Discussion

3.1. Egg-laying performance

In the present study, the crude protein consumption for the P1 and P2 feed was lower and considerably different statistically (P<0.05) from the control feed (P0); meanwhile, supplementation of Ca 1% significantly increased (P<0.05) the intake of calcium (Table 2). There were no significant differences in protein consumption across diets P1 and P2 due to variations in the Shrimp head meal to Bilis fish head ratio. This research suggests that the higher the crude protein content in the feed, the greater the crude protein consumption. The difference in protein levels was 2.19% in P1 and 2.15% in P2 compared to the control (P0). This study showed that the control feed produced a significantly higher protein consumption than other feed treatments. This aligns with the research reported by Zhang et al. (2021). The control feed had an energy and protein ratio of 138.88, while the P1 and P2 feeds were 155.19 and 153.83, respectively. According to Fouad et al. (2018), energy and protein are important nutrients that need to be considered when compiling feed, and the recommended ratio of energy and protein for laying ducks is 147. The energy and feed protein ratio is crucial to maximising ducks' protein consumption. Feeding with the right energy-protein ratio will support optimal duck growth and efficient protein use. Other factors such as feed quality, environmental temperature, and duck activity can also affect protein consumption in duck livestock (Widjastuti et al., 2015; Wang et al., 2020a).

Furthermore, it mentioned that feed consumption is influenced by feed quality, environment, palatability, livestock species, type, age of livestock, growth speed, harvest age, feed texture, crude fibre, and anti-nutrition. This also applies to calcium, as the content of calcium increased by 3.8-4.0 times compared to P0 in the groups supplemented with 1% Ca (P1, P2) and supplementation of Ca 1% significantly increased (P<0.05) the intake of calcium. However, increasing Ca consumption is not always accompanied by an increase in serum Ca concentration; serum Ca concentration was affected by dietary P and the interactions but not by dietary Ca (Zhu et al., 2018). According to Wang et al. (2020b), the need for Ca can vary depending on the feed source used. Furthermore, it was stated that applying the values from the 1994 NRC needs to be re-evaluated on modern duck breeds/varieties. The exact Ca needs of ducks can vary depending on their diets, which come with different sources of Ca.

The results showed no significant difference among treatments on egg production, egg weight, and feed conversion ratio (P>0.05), as displayed in Table 2. Egg production ranged from 48.93% to 51.07%, egg weight ranged from 58.14 to 69.82 g, and the feed conversion ratio varied between 2.18 and 2.79. However, this study indicates that supplementation with Ca minerals, Shrimp head meal, and Bilis fish heads slightly increased egg production by 2-5% and egg weight by 11-14%. Additionally,

Table 2. Egg production, egg weight, and feed conversion ratio of Mojosari ducks fed the different experimental diet.

Variables	Treatments			P value
	P0	P1	P2	
Crude protein intake (g DM)	31.82±0.01b	28.21±0.29a	28.59±0.01a	<0.001
Ca intake (g DM)	2.06±0.01a	8.27±0.01b	7.79±0.01b	<0.001
Egg production (%)	48.93±1.75	51.07±4.49	53.77±4.32	0.151
Egg weight (g)	58.14±28.59	69.82±1.47	72.38±2.58	0.636
Feed conversion ratio (FCR)	2.79±0.75	2.39±0.25	2.18±0.13	0.731
Income Over Feed Cost (IOFC) (IDR)	17,488±1,283	22,972±2,068	23,768±3,243	0.381

Note: Different letters between rows differ at P < 0.05. P0 (control, without mineral), P1 (ratio of s\Shrimp head meal and Bilis head meal 2:1+1% mineral), P2 (comparison of Shrimp head meal and Bilis head meal 1:2+1% mineral). DM (Dry Matter); IDR (Indonesian Rupiah).

the efficiency of the feed conversion ratio (FCR) slightly improved by 0.4-0.61 units. It follows research reported by Xia et al. (2019) that increasing Ca in feed will increase egg production and feed conversion. It suggests that the dosage of Ca in Mojosari duck's diet provided through Ca mineral, Shrimp head meal, and Bilis fish heads at a Ca level of 5% is not significant enough to increase egg-laying performance. It could be due to insufficient dosage and the low availability of Ca in the feed ingredients. These findings were supported by Xia et al. (2015), who found that feeding dietary Ca >3.6% from finely powdered limestone to laying Longyan shelducks aged 20 to 33 weeks enhanced egg production and egg mass while decreasing the FCR while not affecting egg weight. It has also been found that Ca availability influences duck eggshell characteristics. Similarly, another study by Xia et al. (2019) reported that increasing the dietary Ca levels from 2.8% to 4.4% increased egg production and egg mass and improved FCR in an early-laying period of egg-laying Longyan-duck breeder (50% < egg production < 80%, 23 to 40 weeks of age). However, contrary to our findings, Chen et al. (2015) found a substantial drop in relative shell weight in ducks fed 1.8% or 0.38% Ca. Shell development occurs when the uterine portion of the oviduct secretes Ca2+ and HCO3-, which are connected with shell matrix proteins. According to Xia et al. (2015), Ca accounts for around 35% of shell dry matter (approx. 8.3 g in Longyan ducks), with nearly 3 g required for each egg.

The present study also indicates that using Shrimp head meal did not negatively affect the parameters related to egg production. This is consistent with recent research by Yulianti and Muharlien (2020) and Ahmad et al. (2021), who reported that Shrimp waste meal had no significant effect on duck egg production or egg weight. However, Ahmad et al. (2021) noted that 20% Shrimp head feed resulted in huge egg weights and increased output. Shrimp waste is known to have high nutritional content, especially in terms of protein, which is comparable to fish meal but with a relatively lower cost, making it an attractive option for reducing feed costs (Abun et al. 2022a).

The use of Shrimp waste has limitations due to the presence of chitin in a quantity of about 15-20 per cent, which binds strongly to proteins, fats, and minerals with β-covalent bonds (Abun et al., 2017; Cheba et al., 2018; Doan et al., 2019; Hasbuna et al., 2021; Abun et al., 2022a). It hinders the digestion of poultry digestive enzymes (Brito et al., 2020). Another study by Abun et al. (2022b) discovered that employing Shrimp waste extract in chicken substantially affects dry matter, organic matter, and protein digestibility. The current study using Bilis fish head in poultry has not been available. Other research on fish has found that consuming Bilis fish heads can reduce the need for fish meal by 30% (Manullang et al., 2018) or 100% (Ali et al., 2018).

The value of income over feed costs (IOFC) is the difference between income and feed costs (Rostini et al., 2021). As shown in Table 2, the IOFC ranged from Rp 17,488 to Rp 23,768. A higher IOFC value indicates significant business income or profit generated. IOFC calculations were carried out in this study to ascertain the economic value of feed to the income of duck farmers. The IOFC in IDR in the present study revealed no significant difference between the Ca supplementation treatment (P1 and P2) and the group without (P0). The highest IOFC value was obtained from the P2 treated feed; this means that the P1 and P2 feed, which are improvements to the P0 from an economic point of view, are acceptable although not significantly different (P<0.05).

3.2. Hatching performance and egg quality

The results of the study indicated that adding calcium to diets that included bilis fish head and shrimp head meal (2:1) did not improve the quality of the eggs. It showed that the treatment did not have a significant effect (P>0.05) on fertility, hatchability, and egg index (Table 3). P1 produced the highest average hatchability; the treatment was Shrimp head meal and Bilis fish head (2:1), plus 1% Ca mineral, resulting in a hatchability of 89.17%. The P2 treatment had the lowest average hatchability at 73.17%, while the control treatment (P0) produced a hatchability of 76.73%.

Research reported by Widiyaningrum et al. (2016) obtained that the fertility of local duck eggs ranged from 81-84%, with hatchability ranging from 68.7-70.7%. The results of this study received a higher value of hatchability. Many factors contribute to ducks' low fertility and hatchability (Giri et al., 2022). It was found that freshly hatched eggs have high fertility and hatchability rates. The resulting

Table 3. Egg quality and DOD weight of Mojosari ducks fed different experimental diets.

Parameter	Treatment			P value
	P0	P1	P2	
Fertility (%)	71.52±17.22	56.97±17.85	67.73±10.71	0.343
Hatchability (%)	76.73±12.42	89.17±16.56	73.17±24.67	0.390
Egg length (mm)	57.31±0.83	57.43±0.66	56.62±0.46	0.159
Egg width (mm)	46.02±0.21	46.02±0.21	45.96±0.60	0.965
Egg index (%)	80.22±0.92	80.13±0.73	81.17±1.27	0.231
DOD weight (gram)	38.11±1.36	38.35±1.38	37.51±1.99	0.700

Note: Different letters between rows differ at P < 0.05. P0 (control, without mineral). P1 (ratio of Shrimp head meal and Bilis head meal 2:1+1% mineral), P2 (comparison of Shrimp head meal and Bilis head meal 1:2+1% mineral). DOD (Day-Old Duckling).

hatchability rate in this study was higher than that reported by Nandhra et al. (2015), which was only 33.33%.

Ducks with low calcium levels have thinner, weaker eggshells and less calcium deposited in their eggshells because there is less calcium in the plasma and shell gland and fewer genes expressed about calcium transportation and eggshell biomineralisation (Chen et al., 2015). This research aligns with Xia et al. (2019), who reported that sufficient Ca in duck feed can increase fertility and egg quality. Research on egg-type duck breeders discovered that optimising feed Ca levels could alter incubation, tibialis, plasma, ovarian indices, and matrix protein gene expression (Xia et al., 2019). Raising laying hens' dietary Ca levels by up to 4% during the late stage of chicken production may be a beneficial technique for improving laying performance, eggshell quality, Haugh unit, and physiological and immunological health (Attia et al., 2020).

The resulting egg index in this study ranged from 80.13% to 81.17%. These findings are consistent with the research of Sumiati et al. (2020), who reported that the duck egg index ranges from 77.98 to 82.89%. According to Ipek and Sozcu's (2017) research, egg weight influences fertility and hatchability, with large eggs having lower fertility and hatchability than light and medium eggs. According to the findings of Ipek and Sozcu (2017), this study applies to fertility since eggs produced from P0 have a lower average weight and produce higher average fertility than P1 and P2. Although statistically, there is no substantial difference. During incubation, embryo development occurs, accompanied by a decrease in egg weight and a temperature rise. According to Figure 1, the weight loss of hatching eggs in this study was 15.67% for the P1 treatment, which had the most significant weight loss, followed by P2 at 14.55%. The drop in egg weight during the second week was noticeable. The variation in egg weight loss between treatments in the second week is assumed to be caused by varying embryo development times and egg weights. The starting weight of eggs in this study influenced weight loss after hatching, with P0 eggs having lower weights than P1 and P2, perhaps impacting loss throughout this period. However, this study did not prove the actual reason for this occurrence and warrants additional inquiry. Harnsoongnoen and Jaroensuk's (2021) investigation found that at specific initial egg weights, the rate of weight loss during 30 days of storage at room temperature can vary. This is due to the physical features of the eggs, which cause water to evaporate more quickly. The key factors influencing embryo growth are incubation temperature and light. It has been shown that embryo metabolic development is temperature dependent, which impacts how egg nutrients are used and the embryo's overall growth (Abd El-Hack et al., 2019; Yalcin et al., 2022). Maintaining an incubation temperature of 37 to 38°C, usually between 37.5 and 37.8°C, improves hatchability.

Table 3 shows that feed treatment did not affect duckling production (P>0.05). Ducklings that hatch weigh between 37.28 and 38.60 grams. This number is less than that published by Sidadolog et al. (2017), who calculated a duck weight of 40.24 g. The weight discrepancy between the ducklings could be due to the difference in the initial weight of the eggs as they hatch. Ipek and Sozcu (2017) found that differences in egg weight affect egg quality, embryo growth, incubation results, and hatching time. The embryo's growth during incubation and hatching is critical for producing quality ducks and increasing earnings.

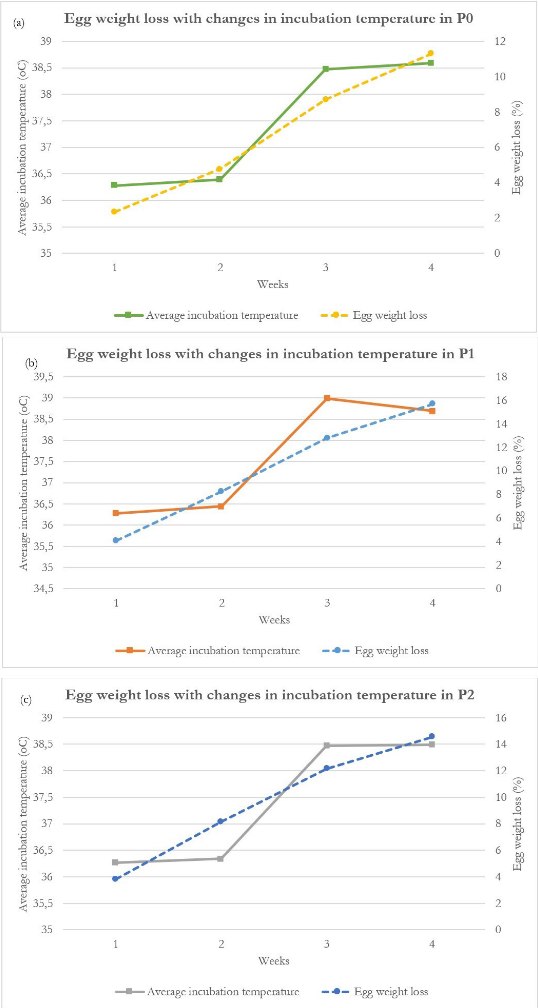

Figure 1. Egg weight loss (%) and incubator temperature (°C) during the 4-week incubation period in (a) P0, (b) P1, and (c) P2.

4. Conclusions

Adding mineral Ca to feed, including Shrimp head meal and Bilis fish head, had no significant influence (P>0.05) on laying Mojosari duck performance in terms of feed intake, egg production, egg weight, egg quality, ducklings produced, and income over feed cost (IOFC). Ca addition in the ration of Mojosari ducks did not result in substantial increases in fertility, hatchability, or egg size characteristics. Feeding ducks with shrimp head meal and Bilis fish head can be used as an alternative calcium-free feed formulation.

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