Eggshell Powder as a Sustainable Calcium Supplement: Enhancing Turkey Egg Production, Shell Quality, and Hatchability in Bangladesh

Syed Sarwar Jahan [1], Md Zahirul Islam [1], Shuvrodeb Sarkar [1], Jafor Raihan [1], Md Sumon Ali [1], Md Shariful Islam [1*]

Abstract

Background: Turkey (Meleagris gallopavo) production is a burgeoning sector of poultry farming with significant potential for meat and egg production. Despite the high demand for poultry products in Bangladesh, turkey farming remains underexplored. Calcium (Ca) is a critical nutrient in turkey nutrition, playing vital roles in bone formation, eggshell quality, and overall egg production. Eggshells, a waste product, offer an eco-friendly, cost-effective alternative to traditional Ca sources like limestone. This study aimed to evaluate the impact of eggshell supplementation on the egg production performance, egg quality, and fertility of laying turkeys, while addressing environmental waste concerns. Methods: A total of 40 laying turkeys, aged 25 weeks, were randomly divided into four groups with two replicates each. The experimental groups were fed: a control diet (T0) without Ca supplementation, 4% dietary Ca from limestone (T1), 2% Ca from limestone and 2% Ca from eggshell (T2), and 4% Ca from eggshell (T3). Eggshells were processed into fine powder, sterilized, and incorporated into the diet. Egg production, egg weight, eggshell weight, albumen weight, yolk weight, eggshell thickness, fertility, and hatchability were recorded over 15 weeks. Data were statistically analyzed using ANOVA within a completely randomized design. Results: Egg production was significantly higher ($p<0.01$) in T2 (82.8%), followed by T3 (79.9%), T1 (72.7%), and T0 (71.0%). Average egg weight was highest in T3 (67.29 g) but showed no significant differences across groups. Eggshell weight and thickness were highest in T3 (9.5 g and 0.67 mm, respectively), though the differences were statistically insignificant. Albumen and yolk weights were significantly improved in T3, with yolk weight reaching 25.6 g. Fertility and hatchability percentages were highest in T3 (86.1% and 83.3%, respectively) and showed significant differences ($p<0.01$) among groups. Conclusion: Supplementing turkey diets with eggshell as an alternative Ca source improves egg production, egg quality, and reproductive performance, with the combined supplementation (T2) offering optimal results.

Keywords: Turkey production, Eggshell calcium, Sustainable poultry feed, Eggshell recycling, Hatchability

Significance | This study determined eggshell powder as a sustainable calcium supplement, improving egg production and hatchability while addressing environmental concerns.

*Correspondence. Md Shariful Islam, Department of Veterinary and Animal Sciences, Faculty of Veterinary and Animal Sciences University of Rajshahi, Rajshahi-6205, Bangladesh.
E-mail: msips06@ru.ac.bd

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Introduction

Turkey (*Meleagris gallopavo*) is a big gallinaceous bird of the family Meleagridae that is native to North America, domesticated in Europe, and is now a vital source of meat and eggs in many areas of the globe. Turkey flesh has been served as customary on Thanksgiving and Christmas Day since the Pilgrims hunted wild turkeys to adorn their tables (Moreki 2015). The demand for chicken products has quickly expanded in Bangladesh and is

Author Affiliation.
[1] Department of Veterinary and Animal Sciences, Faculty of Veterinary and Animal Sciences University of Rajshahi, Rajshahi-6205, Bangladesh.

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propelled by growing income levels, population, and urbanization (Asaduzzaman et al., 2017). Domestic turkey is a popular kind of fowl. Turkey has an important place next to chicken and duck. Turkey production is also a promising sector of poultry with big potentials like enormous body size quick development rate, high fecundity, and good meat quality which is determined to be of greater percentage protein than the carcass of a chicken. Turkey develops quicker than broiler chickens and becomes fit for slaughter within a relatively short period. Turkey production is a vital and very successful agricultural business with expanding worldwide demand for their product and they are adaptable to a broad variety of environmental circumstances (Yakubu et al., 2013). But turkey production has not been effectively explored in Bangladesh like in other developing nations despite its tremendous potential over other poultry species (Asaduzzaman et al., 2017).

Calcium (Ca) is one of the main nutrients in turkey nutrition. In addition to its critical activities as the major component of bone formation and involvement in acid-base balance and enzymatic system, calcium is also the key component of eggshell. It is believed that each egg contains 2.2g of calcium, contained mostly in the eggshell (Pelicia et al., 2009). Egg farmers typically employ two additional sources of dietary Ca, oyster shell, or limestone. Oyster shells and limestone both offer Ca in the form of Ca carbonate, and each contains around 38% Ca. In addition, eggshells might be an alternate supply of calcium for laying turkeys. The Ca content of the eggshell is equivalent to limestone and oyster shells (Sheideler, 1998).

The chicken eggshell is a waste item from domestic sources such as hatcheries, poultry farms, egg product manufacturers, residences, and restaurants. Numerous research has explored methods to repurpose eggshell waste, for example, by utilizing eggshell powder as a stabilizing element for enhancing soil qualities (Amu et al., 2005), and as a source of Ca in human nutrition (Schaafsma et al., 2000). In addition, extruded eggshells, including membranes, may be employed as a Ca source in layer diets without deleterious impacts on egg production (Froning and Bergquist, 1990). Eggshell (ES) is a key source of calcium carbonate and is an aviculture by-product that has been classified internationally as one of the biggest environmental concerns, particularly in those nations where the egg product sector is well. In the U.S. alone, roughly 150,000 tons of this material is disposed of in landfills (Patricio et al., 2004). ES includes roughly 95% calcium carbonate in the form of calcite and 5% of organic and inorganic elements. Calcium (Ca), magnesium (Mg), and sodium (Na) are significant inorganic elements of the ES. ES has a comparatively lower density and inexpensive cost compared to mineral and commercial calcium carbonate. ES powder is a natural source of calcium and other elements (e.g., strontium and fluorine) which may have a good impact on bone metabolism (Patricio et al., 2004). Further, in animal and human experiments, eggshell calcium demonstrates enhanced bone density, decreased arthritic pain, and even encourages cartilage formation (Rovensky et al., 2003). The management of agricultural waste is vital and a significant approach in global waste management. For sustainable development, wastes should be recycled, repurposed, and channeled toward the creation of value-added goods (Abdulrahman et al., 2014).

To the best of our knowledge, no research on this problem from Bangladesh has been done or is in process. So, the current research was targeted to prevent environmental pollution and health dangers of discarded eggshells by effective recycling and reuse in layer turkey diet as alternate sources of Ca supplement.

2. Materials and methods

2.1 Husbandry and experimental design

The experiment was conducted out for 18 weeks to examine the impact of chicken eggshells as an alternative to calcium supplements on the egg production performance of turkey. A total of 40 laying Turkey (25 weeks of age) were randomly allocated into four groups with two replications, comprising of five birds per replicate with a tom. Group 1 (T0, control) was fed with a hand-mixed layer ration without Ca supplementation, group 2 (T1) with 4% dietary Ca from limestone, group 3 (T2) with 2% Ca from limestone and 2% Ca from eggshell and group 4 (T3) with 4% Ca solely from the eggshell. The birds were allowed unrestricted access to food, water, natural mating, and other amenities. The methods and procedures involved in animal care and handling were authorized by the Animal Ethics Committee of the Department of Veterinary and Animal Sciences, Rajshahi University, Bangladesh. A ready-made break house with tin shade was selected for this experimental purpose. The shade was enclosed with metal iron wire and a unique net with a 20 mm mesh size. The floor was coated with concrete. The available floor area was 180 sq. ft (18ft×10ft). The floor area allocated for each bird was 3.5 sq. ft./bird in this experiment.

2.2 Processing of eggshell powder

Eggshells were gathered from hotels near the campus of our institution. After collecting shells were rinsed with tap water and sterilized in boiling water for 2 h, and then dried in an oven at 95°C for 24 h. The dried eggshells were crushed and mixed via an electric blender into powder. As produced macro-sized powder was again processed by a mortar pestle or ball mill into a fine powder and lastly put into a polyethylene plastic bag for subsequent tests and usage. The produced eggshell powder was tested for Salmonella spp. infection using various culture mediums for a varied duration. There was no Salmonella spp. found in processed eggshell powder (Figure 1). Therefore, as an excellent source of Ca and eco-friendly, the produced eggshell powder was employed as a substitute to commercial Ca supplement in turkey layer feed.

2.3 Experimental diet and feeding management

A hand-mixed experimental diet was formulated based on ground maize, soybean meal, broken rice, and rice polish to meet production requirements for laying hens (Table 1). Then the formulated diet was provided from 28 weeks to 43 weeks of age. After 3 weeks for acclimation, the birds were fed the experimental diets for 15 weeks. Feed and water were provided on *ad libitum* basis.

The nutrient composition of the supplied hand-mixed diet for the experimental birds was analyses and was found to be competent (Table 2).

A 4-inch deep litter was used with good insulating material and rice husk was used as litter material for this study. Enough waterers, feeders, and feed trays or pans were provided around the living area of experimental birds. The wet portion of the litter including dropping materials was removed and disposed of regularly. Then, the new litter was added to maintain the normal depth of litter. The litter was stirred normally 2 times a day. Although turkeys are very hardy birds and have excellent disease-resistance capability, vaccination was performed regularly with appropriate medication. After all vaccination birds were supplied with anti-stress electrolytes and supplements. Vaccination was done early in the morning with an empty stomach of the birds. Water was provided in a round-type drinker per replication. Drinkers were cleaned daily. Hens were provided with 14 hours of continuous light. When the hens were exposed to natural daylight and the day length was less than 14 hours, additional artificial light was provided according to the requirement with the minimum intensity of a 12-foot candle or 120 lux. The day length was unchanged during the laying period. Strict biosecurity measures were followed during the experimental period. Nests were prepared by using wood materials. Adequate space was confirmed in the nests. The dimension of the nests was 25cm x 75cm x 100cm (height x width x length). The nests were placed in a corner of each pen so that the breeders were not disturbed at laying time.

2.4 Record keeping and data calculation

Hen-housed egg production was tracked daily from 28 to 43 weeks of age. During this time, the eggs in each replication were collected daily, weighed, and cumulatively added. The complete gathered eggs were weighed at a time in a day for each replication and the mean weight was reported correspondingly. The weights of the eggshell, albumen, and yolk were determined as the proportion of total egg weight. After breaking the eggs, the eggshells were stored and allowed to dry for a time. Then the thickness of eggshells was tested by utilizing a screw gauze on a repeat basis. The fertility of the hatching eggs was measured as a percentage by applying the following equations (1) and (2).

$$\text{Egg fertility (\%)} = \frac{\text{Total number of fertile eggs}}{\text{Total number of eggs set}} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$\text{Hatchability on fetile eggs (\%)} = \frac{\text{Total number of Chick hatched}}{\text{Total number of fertile eggs}} \times 100 \ldots\ldots\ldots\ldots\ldots (2)$$

2.5 Statistical analysis

The data were statistically analyzed to compare the control and treated groups of birds using the analysis of variance (ANOVA) method within a completely randomized design (CRD). This analysis used Kaleida Graph Version 4.5 (Synergy Software, USA). The results are presented as means ± standard deviation (SD). The $p < 0.05$ and $p < 0.01$ probability level was deemed statistically significant.

3. Results and discussion

3.1 Egg production (hen-housed)

Table 3 displays the egg production performance of experimental turkeys subjected to various treatments. Egg production was significantly higher (p<0.01) with a combined supplementation of limestone and eggshell (T_2; 82.8%), followed by eggshell supplementation (T_3; 79.9%) and limestone supplementation (T_1; 72.7%). The minimum egg production recorded in this research occurred in T_0 (control; 71.0%). It was evident that turkeys produced the greatest quantity of eggs when provided with a dietary supplement of mixed limestone and eggshell. Research indicated that dietary calcium from diverse sources significantly influenced egg production (Florcscu et al., 1986). Conversely, Saunders-Blades et al. (2009) indicated that feed consumption, body weight, and egg production were comparable among chickens provided with various calcium sources. Moreover, it was shown that varying quantities of dietary calcium had no substantial impact on egg production, egg weight, and egg bulk (Keshavarz and Nakajima, 1993). A further study found no significant changes in egg production or egg weight among dietary calcium levels of 3.0%, 3.6%, or 4.2% in elderly laying hens (Yusuf 2014). A study indicated that egg production was 61.18%, 69.24%, and 68.28% with dietary supplements of 100% limestone, 50% eggshell, and 100% eggshell, respectively (Gongruttananun 2011). In this present investigation, the maximum egg production (82.78%) was seen with the addition of 50% limestone and 50% eggshell (T2) thought to be attributable to the freshness of the eggshell.

3.2 Egg weight

It was revealed that there were no significant (p>0.05 differences among the treatments**.** Average egg weight was recorded as 60.27 g,

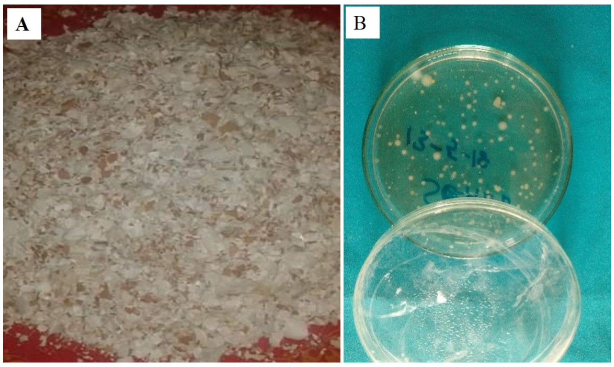

Figure 1. *Salmonella* spp. test of prepared eggshells (A) by nutrient broth culture (B).

Table 1. Ingredient combination of the supplied hand-mixed diet for the experimental turkey

Ingredient	**Amount** (Kg)
Maize crushed	59
Soybean meal	15
Broken Rice	12
Rice polish	7
Salt	0.5
Propack protein supplement	2.5
* Ca	4
Total	**100**

**Calcium was added to the diet according to the design of the experiment.*

Table 2. Nutrient composition of the supplied hand-mixed diet for the experimental turkey

Nutrient composition	**Unit**
ME (Kcal/kg)	2800
CP (%)	18.0
Fiber (%)	3.50
Calcium (%)	3.80
Av. Phosphorous (%)	0.42
Methionine (%)	0.46
Lysine (%)	0.90
Moisture (%)	12.0

Table 3. Effect of different Ca treatments on egg production and qualities

Variables	**Treatments (mean ± SD)**				
	T_0	**T_1**	**T_2**	**T_3**	***p***
Egg production (%)	71.0^b±1.88	72.7^b±3.03	82.8^a±1.58	79.9^a±1.22	0.00
Egg weight (g)	60.3±0.54	62.6±2.28	63.6±2.74	67.3±1.34	0.43
Albumen weight (g)	28.6±0.32	30.9±1.99	28.8±0.16	31.7±0.33	0.57
Yolk weight (g)	22.4^b±0.46	22.8^b±3.35	25.3^a±0.38	25.6^a±1.26	0.02
Shell weight (g)	9.3±0.20	8.3±0.57	9.5±0.54	9.5±0.93	0.78
Shell thickness (mm)	0.55±0.007	0.65±0.004	0.61±0.006	0.67±0.01	0.31
Fertility (%)	66.2^b±6.01	85.5^a±2.27	71.2^b±2.02	86.1^a±2.27	0.00
Hatchability (%)	50.0^d±2.00	66.5^b±4.35	60.0^c±3.00	83.1^a±2.01	< .0001

[abcd] Means in the same row without common letter are different at ***p***<0.05 and ***p***<0.01

62.64 g, 63.58 g, and 67.29 g for T_0, T_1, T_2, and T_3, respectively. Richter et al., (1999) used dietary calcium from various sources and found no significant difference in egg weight. Scheideler (1998) and Rabon et al., (1991) also observed that egg weight was not significantly different due to various Ca sources. However, in this study, the highest average egg weight was noticed under T_3 with the supplementation of 100% eggshell might be due to the ready bioavailability of Ca from the supplied eggshell.

3.3 Eggshells weight

It was recorded that the average eggshell weight under different treatments was 9.29g, 8.92g, 9.48g, and 9.48g for T_0, T_1, T_2, and T_3, respectively. The eggshell weight did not differ significantly (p>0.05) among the treatments due to different sources of calcium (Table 3). In a previous study, Richter et al., (1999) used dietary calcium from various sources and found no significant difference in eggshell weight. However, Anderson et al. (1982), Cheng and Coon (1990) also observed shell

quality when they used substitute limestone instead of eggshell and found a significant difference. Furthermore, Ahmed et al. (2013) and Mankpondji et al. (2012) found non-significant differences and eggshell weights of 5.21-5.45g and 6.05-6.58g, respectively when dietary Ca was given from outer sources to the laying hens. In this current study, eggshell weight was higher (9.5 g) than the previous studies. It is worth mentioning that although there were non-significant differences among the treatments, the highest eggshell weight was noticed under the supplementation of 100% eggshell.

3.4 Albumen weight

Insignificant (p>0.05) differences among albumen weights were observed under various treatments (Table 3). The highest average albumen weight was noticed with the supplementation of 100% eggshell (T_3, 31.7g) followed by T_1 (30.9g), T_2 (limestone & eggshell, 28.8 g), and T_0 (28.6g) (Table 3). In this study, average albumen weight was found to be ranging from 28.8 to 31.7g and an almost similar result was reported by Ahmed et al. (2013). The authors recorded albumen weight ranging from 28.7 to 31.1g after feeding dietary Ca from various sources to the laying hens. On the contrary, Ajakaiye et al. (2011) reported higher average albumen weight in their study.

3.5 Yolk weight

It is found that differences among yolk weight of various treatments were significant (p<0.05). The findings revealed that the yolk weight of T_0, T_1, T_2, and T_3 treatment was 22.4g, 22.8g, 25.3g, and 25.6g, respectively. The highest yolk weight was recorded for eggshell supplementation (T_3, 25.6g) and the lowest yolk weight was observed in control (T_0, 22.4g). Further, the average yolk weight of limestone and combined supplementation was recorded at 22.8g and 25.3g, respectively. On the other hand, Ahmed et al. (2013) found no significant difference with the average yolk weight of 16.46-16.46g when dietary Ca was added to laying hens. However, our finding was supported by Mróz et al. (2014) and the authors reported that yolk weight was significantly different due to various calcium sources.

3.6 Eggshells thickness

Eggshell thickness is an important parameter of eggs whether used for table or hatching purposes. The average eggshell thickness recorded for different treatments is presented in Table 3. It is revealed that the eggshell thickness was the highest in T3 and lowest in T0. The eggshell thickness of T_0, T_1, T_2, and T_3 treatment was 0.55 mm, 0.65 mm, 0.61 mm, and 0.67 mm, respectively. The findings revealed that eggshell thickness was not significantly (p>0.05) different among the treatments (Table 3). This result is contradictory to the finding of Cheng and Coon (1990). The authors observed significant differences in eggshell thickness when substituting limestone and eggshell. It is worth mentioning that the current study reported higher eggshell thickness than reported by Ahmed et al. (2013). The authors recorded eggshell thickness ranging from 0.27 to 0.28 mm after the addition of dietary Ca to the laying hens (Ahmed et al., 2013).

3Fertility and Hatchability percentage

The results revealed that the highest fertility (%) was noticed in T_3 (86.1%) followed by T_1 (85.5%), T_2 (71.2%), and T_0 (66.2%) (Table 3). It is indicated that the fertility percentage of the four treatment groups differed significantly (p>0.01). This result was supported by Robinson (1996). On the contrary, Gongruttananun (2011) found insignificant differences and reported fertility 96.4, 97.5, and 96.2%, respectively for 100% limestone, 50% eggshell, and 100% eggshell supplementation. Therefore, the current study is quite contradictory to the findings of Gongruttananun (2011).

The hatchability percentage of Turkey eggs obtained in the current study is presented in Table 3. It is revealed from the findings that hatchability was the highest in T_3 followed by T_1, T_2, and T_0. The hatchability percentage of T_0, T_1, T_2, and T_3 treatment was 50.0, 66.7, 60.0, and 83.3%, respectively. It is revealed from the present study that the variable of hatchability percentage was significantly ((p>0.01)) different among the groups (Table 3). The current study is supported by Anderson (1982) who reported different hatchability percentages by supplementation of different calcium sources to the hens. On the other hand, Gongruttananun (2011) recorded 70.3, 76.4, and 77.1% hatchability under the supplementation of 100% limestone, 50% eggshell and 100% eggshell, respectively with insignificant differences among the treatments. The current study is quite contradictory to the findings of Gongruttananun (2011).

4. Conclusion

This study determined the significant potential of chicken eggshell powder as a cost-effective and eco-friendly alternative calcium source in turkey layer diets. Eggshell supplementation demonstrated promising outcomes in terms of egg production, egg weight, yolk weight, eggshell thickness, fertility, and hatchability rates. Among the tested treatments, T3 (100% eggshell supplementation) consistently showed superior performance in several parameters, including the highest fertility (86.1%) and hatchability (83.3%), along with notable improvements in egg weight and yolk weight. These findings underscore the high bioavailability and nutritional value of calcium derived from eggshells. Furthermore, incorporating eggshell powder into turkey diets addresses the dual challenges of environmental sustainability and resource optimization by repurposing poultry waste. Despite the positive outcomes, some parameters, such as eggshell weight and albumen weight, showed no significant differences among treatments, warranting further research. Overall, this study supports the feasibility of eggshell recycling as a sustainable solution for enhancing poultry production efficiency.

Author contributions

M.S.I. and M.Z.I. conceptualized the study and defined its objectives. S.S.S. provided research supervision, while S.S. conducted the literature review and managed references. J.R. and M.S.A. drafted the manuscript, with M.S.I. performing the final revisions. All authors reviewed and approved the manuscript for submission.

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Competing financial interests

The authors have no conflict of interest.

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