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Research Article

COMPARATIVE EVALUATION OF EGGSHELL POWDERS AS ALTERNATIVES TO LIME FOR IMPROVING WATER QUALITY PARAMETERS IN AQUACULTURE

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Abstract

Congenial water quality is a key issue for increasing the growth, health, and physiological performance of aquatic animals. In Bangladesh, lime is generally used in aquacultural ponds for improving water quality. Both agricultural lime and eggshell are consisting of calcium carbonate. Therefore, eggshell powder (ESP) can be used as alternative of lime. The objective of this study to examined efficacy of different poultry ESP as an alternative to lime for purifying water quality of aquaculture system. An in vitro trial was conducted to determine the effect of contact time on water quality using different eggshell powders. Five treatments were employed: hen eggshell powder (T_1), quail eggshell powder (T_2), duck eggshell powder (T_3), lime (T_4) and a control treatment without eggshell powder (T_5). Each treatment consisted of three replicates. One liter of clean tap water was placed in each experimental cylinder, after which clay particles were added at a concentration of 1 g/L. Eggshell powders and lime were incorporated at a rate of 30 mg/L. Water quality parameters were monitored at 6-hour intervals for 72 hours. Results demonstrated that majority of the physicochemical parameters altered rapidly during the initial phase and stabilized after 48 h. The T_4 group showed the significantly highest values of TDS (45 mg/L), EC (102.33 μ S/cm), pH (6.8) and hardness (75.66 mg/L), while T_3 exhibited the greatest water transparency (11.33 cm) compared to other treatments. No notable variances ($p > 0.05$) were found in the water temperature and dissolve oxygen, while ammonia, nitrate and nitrite remained negligible throughout the study. Overall, ESP revealed comparable effects to lime in bolstering major water quality indices, particularly by enlarging mineral contents, buffering capacity and transparency. These findings suggest that ESP can serve as a cost-effective, eco-friendly and sustainable alternative to conventional liming agent in aquaculture systems.

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Introduction

Aquaculture is recognized as one of the fastest-growing food production sectors globally (Bostock et al., 2010; Cai and Zhou, 2019). In Bangladesh, the aquaculture industry has experienced remarkable expansion over the last three decades, becoming a major contributor to the country's agro-food sector. Particularly, inland aquaculture has shown sustained growth, with total production increasing from 1.006 million MT in 2007–08 to 2.852 million MT in 2022–23, reflecting its increasing importance in ensuring food security, employment generation, and economic development (DoF, 2023; Haque and Mahmud, 2025). Aquaculture has played a pivotal role in this achievement, contributing 58.03% of the country's total fish production (DoF, 2023).

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The continuous expansion of inland aquaculture production has been a major driving force behind Bangladesh's progress in the fisheries sector. However, maintaining suitable water quality remains a critical challenge in aquaculture systems, as water quality directly affect the growth, survival, health, and overall productivity of fish and other aquatic organisms. The majority of aquaculture ponds of Bangladesh are earthen and unlined, making them highly susceptible to surface runoff and soil erosion, particularly during periods of heavy rainfall. Consequently, large amounts of suspended particles enter the water body, leading to increased turbidity. Excessive turbidity adversely influences pond productivity by reducing light penetration and limiting photosynthetic activity, which in turn lowers dissolved oxygen (DO) concentrations. Moreover, suspended particles can irritate and clog fish gills, impair feeding efficiency, and increase susceptibility to diseases. Therefore, effective turbidity management is essential for maintaining a healthy aquaculture environment. Among the various management practices, the application of lime (calcium carbonate) is widely recognized as a simple and effective method for reducing turbidity and improving water quality in aquaculture ponds. The application of lime plays an important role in aquaculture pond management by neutralizing soil and water acidity, resulting in an increase in pH. Liming releases calcium (Ca^{2+}) and carbonate (CO_3^{2-}) ions into the aquatic system, thereby increasing the concentration of dissolved minerals. Consequently, total dissolved solids (TDS) and electrical conductivity (EC) rise, creating favorable water quality conditions for aquatic organisms and enhancing pond productivity. Eggshell are predominantly composed of calcium carbonate and therefore exhibit chemical properties comparable to those of agricultural lime. In addition to these, due to their high mineral content, eggshell have found extensive applications in pharmaceutical formulations, medical and dental products, food supplementation, agricultural fertilization, and bone grafting materials (Murakami et al., 2007). These characteristics reflect the possibility of eggshell powder as a sustainable alternative liming material for turbidity control and water quality management in aquaculture.

Despite their valuable mineral composition, eggshell waste generated from poultry hatchery industries stays largely underutilized and is often improperly discarded in the environment. Therefore, the effective management of eggshell waste generated by the poultry hatchery industry is indispensable and constitutes a significant challenge for waste management systems in Bangladesh and worldwide. Heavy accumulation of such wastes poses significant threats to human health, animals, and aquatic ecosystems (Kari et al., 2023). The characteristics, quantity, and composition of agricultural waste vary substantially across countries due to differences in production systems and waste management practices (Waheed et al., 2020). Sustainable development goals emphasize the importance of recycling and reusing poultry eggshell waste for the production of value-added materials, thereby reducing environmental pollution and promoting a circular, zero-waste economy (Kabir et al., 2023). Although poultry eggshell are commonly considered agricultural by-products, they possess considerable potential as an inexpensive and sustainable mineral resource for aquaculture applications. Eggshell consists primarily of calcium carbonate (94–97%), which makes them a rich source of bioavailable calcium. In addition, they contain small amounts of essential trace elements; including magnesium, boron, manganese, phosphorus, sulfur, cobalt, iron, and zinc, further enhancing their value as a nutrient-rich material.

Globally, wild fish production exceeded the consumption of farmed fish in 2014 (FAO, 2016), however, continued depletion of wild fish stocks has greatly increased the dependency on aquaculture to meet growing fish demand (Allen et al., 2017). Despite its rapid expansion, aquaculture production is expected to decline in the future, particularly due to the limited availability and accessibility of high-quality water resources (OECD/FAO, 2018). Consequently, sustainable, cost-effective, and eco-friendly approaches for water

quality improvement are increasingly required. In recent years, natural bio-sorbents, particularly eggshell wastes, have gained substantial attention for their effectiveness in minimizing waste water contamination (Siti et al., 2013; Candido et al., 2019; Martins et al., 2019). Eggshell wastes offer a wide range of benefits, including low--cost, eco-friendliness, abundance, and large-scale availability (Sankaran et al., 2020). Moreover, previous studies have demonstrated the strong adsorption capacity of eggshell waste for removing both organic and inorganic contaminants from water (Mittal et al., 2016; Dayanidhi et al., 2020). But there is insufficient research to justify using eggshell powder as alternative to lime in aquacultural pond. Different eggshell may behave differently to improve water quality because of differences in their physical and chemical properties. The novelty of this study is to demonstrate that discarded eggshell waste can be recycled as sustainable pond amendment, reducing environmental waste and promoting a circular economy. Therefore, the present research aims to observe the effects of different eggshell powder on water quality parameters in an in-vitro system, with a notable focus on their potential as sustainable alternatives to conventional liming material.

Material and methods

2.1. Collection, pre-treatment and processing of eggshell

Raw poultry eggshell (Figure 1) which is discarded as by-product was collected from several local hatcheries in the Sylhet region as this study aim to convert the waste to a valuable product. Hen eggshell was collected from Kazi Farm, Shrimangal, Moulvibazar; Quail eggshell was collected from a local hatchery of Moulvibazar and Duck eggshell was collected from a government duck hatchery situated in Habiganj. A total of 5 kg of eggshell from each poultry species were gathered and transported to the laboratory for processing. The experiment was conducted from July-October, 2025 at the Wet Laboratory of Aquaculture, Sylhet Agricultural University, Sylhet, Bangladesh.

Upon collection, the eggshell was carefully inspected and manually sorted to remove unhatched eggshells, residual egg contents and other impurities. The selected eggshell was then thoroughly washed under running tap water to eliminate adhering dirt and contaminants. Then, the shells were immersed in hot water for approximately 15 minutes for further cleaning and microbial reduction, followed by oven drying at 70 °C for 15 minutes in accordance with the standard protocol described by Rajoriya et al. (2021), confirming that the moisture had been fully driven off. After drying, the eggshells were allowed to cool to room temperature and prepared for grinding. Approximately 3 kg of the processed eggshell from each poultry species were milled to obtain a fine powder and passed through a 100 µm mesh screen to get a homogenous powder (Figure 1). The resulting eggshell powder was stored in airtight container protected from light and moisture and kept until further analyses and experimental use.

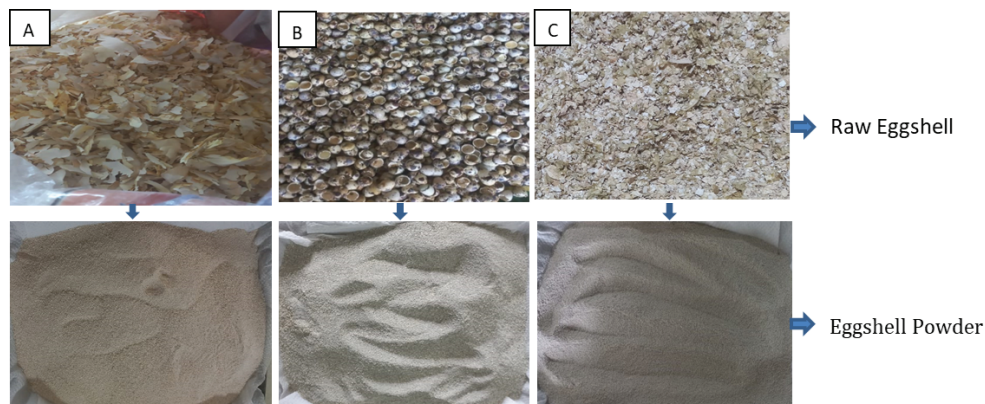


Figure 1. (A) Hen Eggshell; (B) Quail Eggshell; (C) Duck Eggshell

2.2. Quantification of calcium carbonate and calcium content in eggshells powder

The calcium carbonate (CaCO_3) content of the eggshell powder was quantified using the acid–base titration method following standard analytical procedures. Briefly, 0.4 g of eggshell powder from each poultry species was accurately weighed into separate Erlenmeyer flasks. Subsequently, 1 mL of ethanol was added as a wetting agent to ensure proper dispersion of the powder. An excess volume of 10 mL of 1 M hydrochloric acid (HCl) was then introduced to react with the calcium carbonate present in the samples. The reaction proceeded vigorously with the evolution of carbon dioxide gas; therefore, the flasks were placed on a Daihan SHR-2D orbital shaker and agitated at 110 rpm for 30 minutes to ensure complete dissolution and reaction of the eggshell material. Following the reaction period, the unreacted excess HCl was back-titrated with 0.1 M sodium hydroxide (NaOH) solution using phenolphthalein as the endpoint indicator. The endpoint was identified by the appearance of a persistent pale pink coloration. Each sample was analyzed in triplicate, and the mean value was used for subsequent calculations of CaCO_3 content.

The calcium (Ca) concentration in the eggshell powder samples was determined in triplicate following the procedures outlined by AOAC (1990). Briefly, approximately 5 g of powdered eggshell from each poultry species was accurately weighed into porcelain crucibles and dried in a hot-air oven at 105°C for 24 h to remove moisture. The dried samples were subsequently incinerated in a muffle furnace at 550°C overnight to obtain crude ash. Then, the samples were allowed to cool and digested with 5 mL of 65% nitric acid (HNO_3) for approximately 2 min. The digested solutions were then cooled to room temperature and filtered through Whatman No. 41 filter paper to remove any insoluble residues. The filtrates were quantitatively transferred and diluted to a final volume of 25 mL using 65% nitric acid.

Thereafter, 10 mL of the prepared solution from each sample was transferred into polypropylene test tubes for elemental analysis. Calcium concentration was quantified using an inductively coupled plasma–optical emission spectrometer (ICP–OES) (Perkin Elmer, USA). A reagent blank containing 65% nitric acid was analyzed concurrently with each batch of samples to account for background contamination and instrument drift. Quantification of calcium was performed by comparison with certified multi-element standard solutions (Perkin Elmer, AVIO 200, Waltham, USA). All measurements were conducted in triplicate and the mean values were used for subsequent statistical analyses.

2.3. Experimental design: Influence of exposure time on physicochemical parameters of water

To evaluate the effects of exposure time on water quality parameters in an in vitro system, an experiment was conducted using different eggshell powders as water treatment agents. Five treatments were established: hen eggshell powder (T_1), quail eggshell powder (T_2), duck eggshell powder (T_3), agricultural lime (T_4), and a control without eggshell powder or lime (T_5). Each treatment was arranged in triplicate following a completely randomized design. Application dose of ESP and lime was 30 mg/L because in aquatic pond this is often an effective maintenance dose for improving water quality without causing a dangerous increase in pH.

For the experiment, cylindrical plastic containers were filled with 1 L of clean tap water. To simulate turbid water conditions, clay particles were added at a concentration of 1 g L^{-1} . Eggshell powder or lime was then applied at a rate of 30 mg/L according to the designated treatment. The mixtures were homogenized using a magnetic stirrer for 5 min to ensure uniform dispersion of the particles throughout the water column.

Water quality parameters were monitored at 6-h intervals over a total observation period of 72 h. The physical parameters evaluated included water temperature, electrical conductivity (EC), total dissolved solids (TDS) and transparency, while the chemical parameters included pH, dissolved oxygen (DO), ammonia

(NH₃), nitrate (NO₃⁻) and nitrite (NO₂⁻) concentrations. Water temperature was recorded using a digital thermometer, whereas TDS and EC were measured using a portable TDS/EC meter. Dissolved oxygen was determined using a DO test kit (Nice Chemicals Pvt. Ltd.). The concentrations of ammonia, nitrate and nitrite, pH and hardness, were measured using the API Freshwater Master Test Kit (MARS Fishcare, USA) according to the manufacturer's instructions. Water transparency was assessed using a Secchi disc following standard procedures. All measurements were conducted for each replicate at every sampling interval, and the recorded data were subsequently used to assess the temporal effects of the different eggshell powders on water quality.

2.4. Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics software (Version 26.0) for Windows. One-way analysis of variance (ANOVA) was applied to compare the mean differences among quantitative variables across treatment groups. When significant differences were detected ($P < 0.05$), Duncan's Multiple Range Test (DMRT) was used as a post hoc test to identify pairwise differences among means. All results are expressed as mean $\pm$ standard deviation (SD). In addition, correlation analyses between independent and dependent variables were conducted using Microsoft Excel to assess the strength and direction of relationships among parameters.

Results

3.1. Calcium carbonate (CaCO₃) and calcium (Ca) contents of test ingredients

CaCO₃ and Ca concentrations in different ESP are presented in Table 1. Duck eggshell powder (DEP) exhibited the significantly highest ($p < 0.05$) concentrations of CaCO₃ and Ca when those compared to the hen eggshell powder (HEP) and quail eggshell powder (QEP). In addition, HEP exhibited intermediate values, whereas the lower contents of both CaCO₃ and Ca were noted in QEP.

Table 1. Calcium carbonate and calcium contents in various poultry eggshell (n=3)

Variables	HEP	QEP	DEP	Reference
CaCO ₃ (%)	94.88 $\pm$ 0.22 ^b	90.20 $\pm$ 0.15 ^c	95.55 $\pm$ 0.23 ^a	--
Ca (%)	38.99 $\pm$ 0.11 ^b	34.65 $\pm$ 0.10 ^c	39.66 $\pm$ 0.11 ^a	--
CaCO ₃ (%)	93.28 - 96.92	89.82 - 91.97	93.48 - 94.87	Kristl <i>et al</i> , (2019)
Ca (%)	35.37 - 38.02	34.26 - 35.71	36.24 - 37.42	Kristl <i>et al</i> (2019)

Values are expressed as mean $\pm$ standard deviation (SD). Different alphabets as superscripts in each row present significant difference. Abbreviation: HEP: Hen Eggshell Powder; QEP: Quail Eggshell Powder; DEP: Duck Eggshell Powder

3.2. Influence of exposure time on hydrological parameters

Table 2 represents the impacts of contact time (0 to 72 h) on various water quality parameters in vitro system treated with different kinds of poultry eggshell powder. Throughout the observation time, water temperature and dissolved oxygen (DO) contents remained unaffected and did not vary considerably ($P > 0.05$) across the various treatments. Correspondingly, the concentrations of ammonia, nitrite and nitrate were remained at zero in all test groups at all investigation periods. At the start of the experiment (0 h), electrical conductivity (EC) was remained insignificant ($P > 0.05$) among the different treatments. However, from 6 h onward, EC values varied significantly ($P < 0.05$) among treatments and continued to differ throughout the entire observation period up to 72 h. Significantly higher ($P < 0.05$) EC values were consistently found in the T₄ group at all examination times from 6 to 72 h. EC in T₄ treatment increased from 80.00 μ S/cm at 6 h to a pick of 102.33 μ S/cm at 48 h and remained at comparably elevated levels until the end of the trial.

Table 2. Hydrological characteristics of water recorded at various observation intervals after the application of different eggshell powder and lime supplements (n=3)

Time of Observation (h)	Parameters	Treatment				
		T1	T2	T3	T4	T5
0h	Temperature (°C)	30.00 ± 0.01	30.00 ± 0.01	30.00 ± 0.01	30.01 ± 0.02	30.00 ± 0.01
	EC (µS/cm)	66.00 ± 0.00	66.00 ± 0.00	66.00 ± 0.00	66.00 ± 0.00	66.00 ± 0.00
	DO (mg/L)	5.02 ± 0.01	5.01 ± 0.00	5.02 ± 0.01	5.02 ± 0.00	5.02 ± 0.00
	Ammonia(mg/L)	0	0	0	0	0
	Nitrate (mg/L)	0	0	0	0	0
	Nitrite (mg/L)	0	0	0	0	0
6h	Temperature (°C)	29.35 ± .01	29.30 ± 0.01	29.30 ± 0.01	29.35 ± 0.01	29.30 ± 0.01
	EC (µS/cm)	67.66 ± 0.57 ^b	67.00 ± 0.00 ^b	67.33 ± 0.57 ^b	80.00 ± 0.10 ^a	66.00 ± 0.00 ^c
	DO (mg/L)	5.00 ± 0.01	5.00 ± 0.01	5.01 ± 0.00	5.01 ± 0.00	5.00 ± 0.00
	Ammonia(mg/L)	0	0	0	0	0
	Nitrate (mg/L)	0	0	0	0	0
	Nitrite (mg/L)	0	0	0	0	0
12h	Temperature (°C)	29.00 ± 0.01	29.00 ± 0.01	29.00 ± 0.01	29.00 ± 0.01	29.00 ± 0.01
	EC (µS/cm)	68.66 ± 0.57 ^b	68.33 ± 0.00 ^b	68.33 ± 0.57 ^b	89.00 ± 0.57 ^a	66.00 ± 0.00 ^c
	DO (mg/L)	5.00 ± 0.01	5.00 ± 0.01	5.01 ± 0.00	5.01 ± 0.00	5.00 ± 0.00
	Ammonia(mg/L)	0	0	0	0	0
	Nitrate (mg/L)	0	0	0	0	0
	Nitrite (mg/L)	0	0	0	0	0
18h	Temperature (°C)	28.50 ± 0.01	28.51 ± 0.01	28.51 ± 0.01	28.50 ± 0.01	28.50 ± 0.01
	EC (µS/cm)	70.33 ± 0.57 ^c	72.66 ± 0.57 ^c	73.33 ± 0.57 ^b	93.33 ± 0.57 ^a	66.33 ± 0.57 ^d
	DO (mg/L)	5.00 ± 0.01	5.00 ± 0.01	5.01 ± 0.00	5.01 ± 0.00	5.00 ± 0.00
	Ammonia(mg/L)	0	0	0	0	0
	Nitrate (mg/L)	0	0	0	0	0
	Nitrite (mg/L)	0	0	0	0	0
24h	Temperature (°C)	29.50 ± 0.01	29.50 ± 0.01	29.51 ± 0.01	29.51 ± 0.01	29.50 ± 0.01
	EC (µS/cm)	72.33 ± 0.57 ^c	72.66 ± 0.57 ^c	77.66 ± 0.57 ^b	96.33 ± 0.57 ^a	66.33 ± 0.57 ^d
	DO (mg/L)	5.02 ± 0.01	5.01 ± 0.00	5.02 ± 0.01	5.02 ± 0.00	5.02 ± 0.00
	Ammonia(mg/L)	0	0	0	0	0
	Nitrate (mg/L)	0	0	0	0	0
	Nitrite (mg/L)	0	0	0	0	0
30h	Temperature (°C)	29.35 ± 0.01	29.30 ± 0.01	29.30 ± 0.01	29.35 ± 0.01	29.30 ± 0.01
	EC (µS/cm)	76.33 ± 0.57 ^c	76.66 ± 0.57 ^c	80.33 ± 0.57 ^b	99.00 ± 0.57 ^a	66.33 ± 0.57 ^d
	DO (mg/L)	5.00 ± 0.01	5.00 ± 0.01	5.01 ± 0.00	5.01 ± 0.00	5.00 ± 0.00
	Ammonia(mg/L)	0	0	0	0	0
	Nitrate (mg/L)	0	0	0	0	0
	Nitrite (mg/L)	0	0	0	0	0
36h	Temperature (°C)	29.00 ± .01	29.00 ± 0.01	29.00 ± 0.01	29.00 ± 0.01	29.00 ± 0.01
	EC (µS/cm)	80.33 ± 0.57 ^c	80.33 ± 0.57 ^c	81.66 ± 0.57 ^b	99.66 ± 0.57 ^a	66.33 ± 0.57 ^d
	DO (mg/L)	5.00 ± 0.01	5.00 ± 0.01	5.01 ± 0.00	5.01 ± 0.00	5.00 ± 0.00
	Ammonia(mg/L)	0	0	0	0	0
	Nitrate (mg/L)	0	0	0	0	0
	Nitrite (mg/L)	0	0	0	0	0
42h	Temperature (°C)	28.50 ± 0.01	28.51 ± 0.01	28.51 ± 0.01	28.50 ± 0.01	28.50 ± 0.01
	EC (µS/cm)	80.33 ± 0.57 ^c	80.66 ± 0.57 ^c	82.33 ± 0.57 ^b	101.33 ± 0.57 ^a	66.66 ± 0.57 ^d
	DO (mg/L)	5.02 ± 0.01	5.01 ± 0.00	5.02 ± 0.01	5.02 ± 0.00	5.02 ± 0.00
	Ammonia(mg/L)	0	0	0	0	0
	Nitrate (mg/L)	0	0	0	0	0
	Nitrite (mg/L)	0	0	0	0	0
48h	Temperature (°C)	29.50 ± 0.01	29.51 ± 0.01	29.51 ± 0.01	29.50 ± 0.01	29.50 ± 0.01
	EC (µS/cm)	73.33 ± 0.57 ^c	80.66 ± 0.57 ^c	82.33 ± 0.57 ^b	102.33 ± 0.57 ^a	66.66 ± 0.57 ^d
	DO (mg/L)	5.02 ± 0.01	5.01 ± 0.00	5.02 ± 0.01	5.02 ± 0.00	5.02 ± 0.00
	Ammonia(mg/L)	0	0	0	0	0
	Nitrate (mg/L)	0	0	0	0	0

54h	Temperature (°C)	29.35 ± 0.01	29.30 ± 0.01	29.30 ± 0.01	29.35 ± 0.01	29.30 ± 0.01
	EC (µS/cm)	73.33 ± 0.57 ^c	80.66 ± 0.57 ^c	82.33 ± 0.57 ^b	102.33 ± 0.57 ^a	66.66 ± 0.57 ^d
	DO (mg/L)	5.02±0.01	5.01 ± 0.00	5.02 ± 0.01	5.02 ± 0.00	5.02 ± 0.00
	Ammonia(mg/L)	0	0	0	0	0
	Nitrate (mg/L)	0	0	0	0	0
	Nitrite (mg/L)	0	0	0	0	0
60h	Temperature (°C)	29.02±.01	29.01 ± 0.01	29.01 ± 0.01	29.02 ± 0.01	29.01 ± 0.01
	EC (µS/cm)	73.33 ± 0.57 ^c	80.66 ± 0.57 ^c	82.33 ± 0.57 ^b	102.33 ± 0.57 ^a	66.66 ± 0.57 ^d
	DO (mg/L)	5.02 ± 0.01	5.01 ± 0.00	5.02 ± 0.01	5.02 ± 0.00	5.02 ± 0.00
	Ammonia(mg/L)	0	0	0	0	0
	Nitrate (mg/L)	0	0	0	0	0
	Nitrite (mg/L)	0	0	0	0	0
66	Temperature (°C)	28.50 ± 0.01	28.51 ± 0.01	28.51 ± 0.01	28.50 ± 0.01	28.50 ± 0.01
	EC (µS/cm)	73.33 ± 0.57 ^c	80.66 ± 0.57 ^c	82.33 ± 0.57 ^b	102.33 ± 0.57 ^a	66.66 ± 0.57 ^d
	DO (mg/L)	5.02 ± 0.01	5.01 ± 0.00	5.02 ± 0.01	5.02 ± 0.00	5.02 ± 0.00
	Ammonia(mg/L)	0	0	0	0	0
	Nitrate (mg/L)	0	0	0	0	0
	Nitrite (mg/L)	0	0	0	0	0
72h	Temperature (°C)	29.51 ± 0.01	29.50 ± 0.01	29.51 ± 0.01	29.50 ± 0.01	29.50 ± 0.01
	EC (µS/cm)	73.33 ± 0.57 ^c	80.66 ± 0.57 ^c	82.33 ± 0.57 ^b	102.33 ± 0.57 ^a	66.66 ± 0.57 ^d
	DO (mg/L)	5.02 ± 0.01	5.01 ± 0.00	5.02 ± 0.01	5.02 ± 0.00	5.02 ± 0.00
	Ammonia(mg/L)	0	0	0	0	0
	Nitrate (mg/L)	0	0	0	0	0
	Nitrite (mg/L)	0	0	0	0	0

Values are expressed as mean ± SD. Different alphabets as superscripts in each row present significant difference.

Variations in TDS among the different treatments are shown in Figure 2. At the start of the experiment (0 h), TDS did not differ significantly ($P > 0.05$) among the treatment groups. Following the addition of eggshell powder, TDS increased significantly ($P < 0.05$) as contact time increased up to 48 h. Beyond 48 h, the concentrations remained relatively constant, with no significant changes observed between 48 and 72 h. TDS value was significantly higher found in the T_4 treatment throughout the study time, reaching a maximum of 45 mg/L at 24 h. However, the significantly lowest ($P < 0.05$) TDS concentration (32.66 mg/L) was shown in the control group.

Furthermore, variations in water hardness across the different treatments are illustrated in Figure 3. Water hardness showed a progressive increasing trend during the experimental period, with significantly higher values ($P < 0.05$) observed in the T_4 treatment compared to the other treatment groups. The maximum hardness value (75.66 mg/L) was recorded in the T_4 group at 48 h of the experiment. Meanwhile, the lowest hardness value (60.33 mg/L) was observed in the T_5 treatment, which was significantly lower ($P < 0.05$) than those recorded in the other treatments.

Figure 4 illustrates the variation in water pH among the different treatments throughout the experimental period. The pH values exhibited a gradual increasing trend over time, reaching significantly higher levels ($P < 0.05$) in the T_4 treatment compared to the other treatment groups. The highest pH value (6.80) was recorded in the T_4 group at 42 h of treatment. In contrast, the T_5 treatment exhibited the lowest pH value (6.06), which was significantly lower ($P < 0.05$) than those recorded in the other treatments.

Figure 5 demonstrates the differences in water transparency, which exhibited considerable variations ($P < 0.05$) across the various treatments throughout the experimental period in this study. Water transparency followed an increasing trend over time and reached significantly higher values ($P < 0.05$) at 48 h (11.33 cm) in the T_3 treatment when those compared to the other treatment groups. Conversely, a significantly lower ($P < 0.05$) transparency value (8.50 cm) was observed in the control group (T_5).

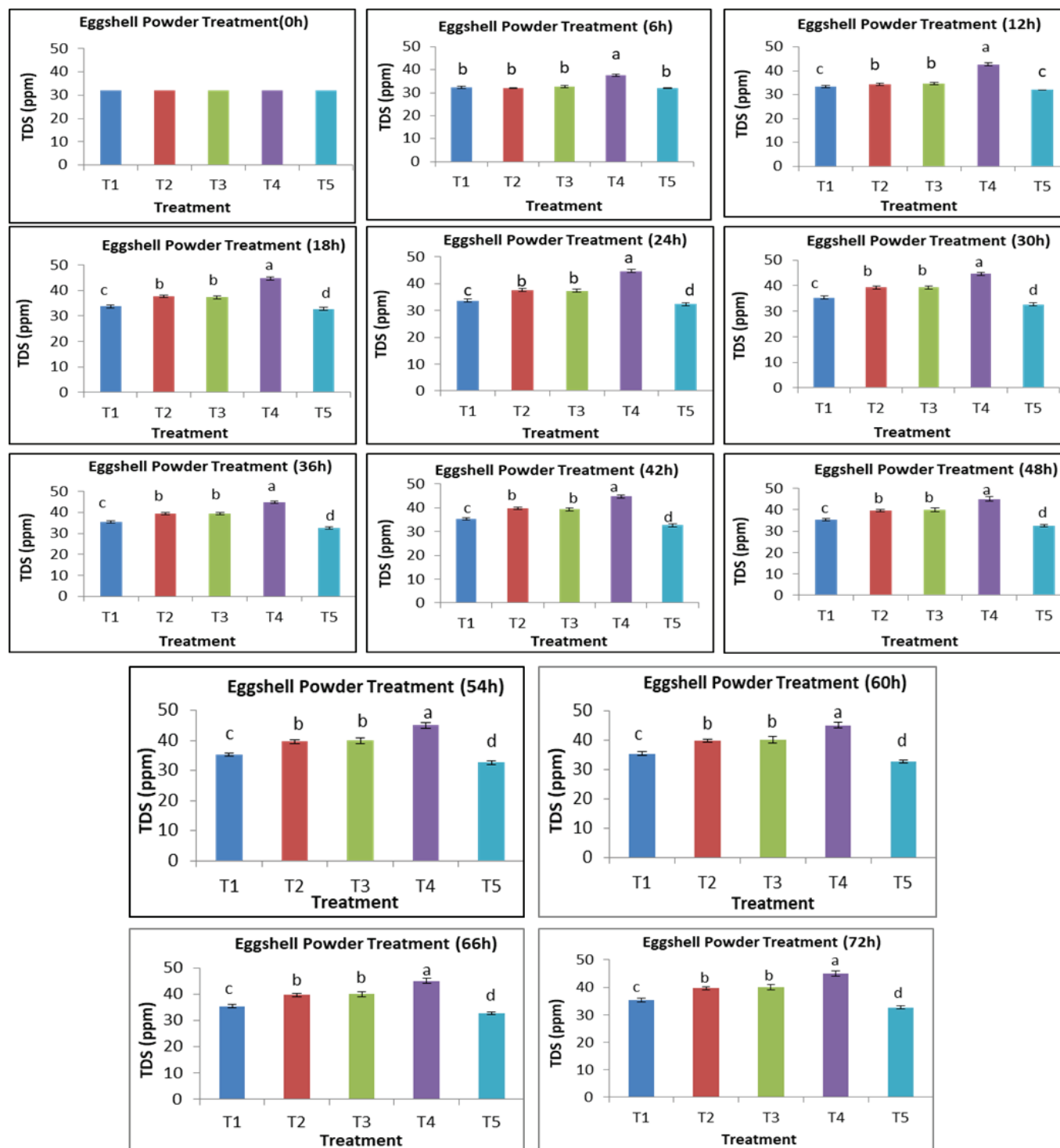


Figure 2. Changes in total dissolved solids (TDS) of water following supplementation with eggshell powder and lime treatments. Data are expressed as mean $\pm$ SD. Different superscript letters above bars indicate significant differences among treatments ($P < 0.05$).

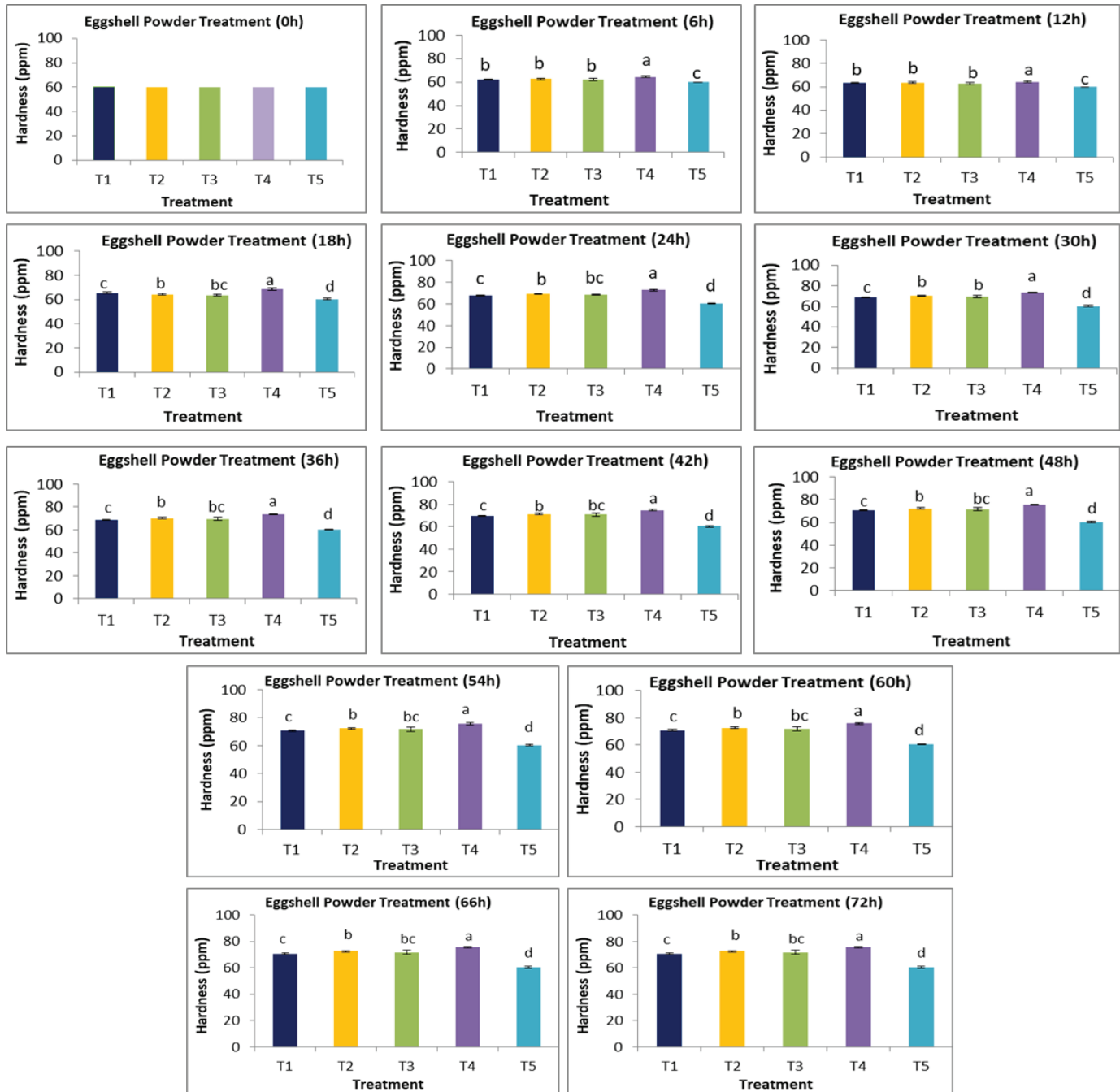


Figure 3. Changes in water hardness following supplementation with different eggshell powder treatments. Data are expressed as mean $\pm$ SD. Different superscript letters above bars denote statistically significant differences ($P < 0.05$).

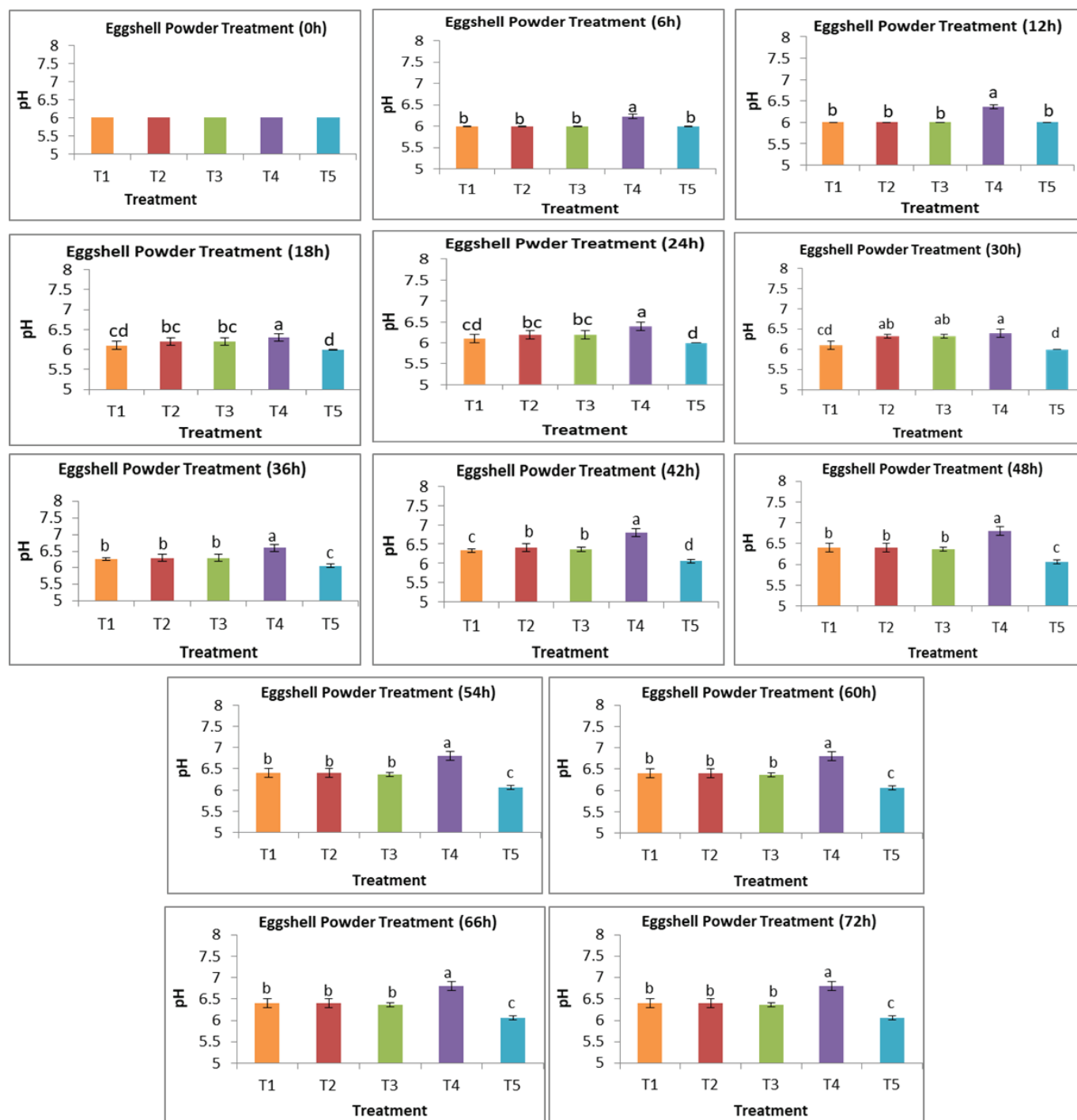


Figure 4. Changes in water pH following supplementation with different eggshell powder treatments. Data are expressed as mean $\pm$ SD. Different superscript letters above bars denote statistically significant differences ($P < 0.05$).

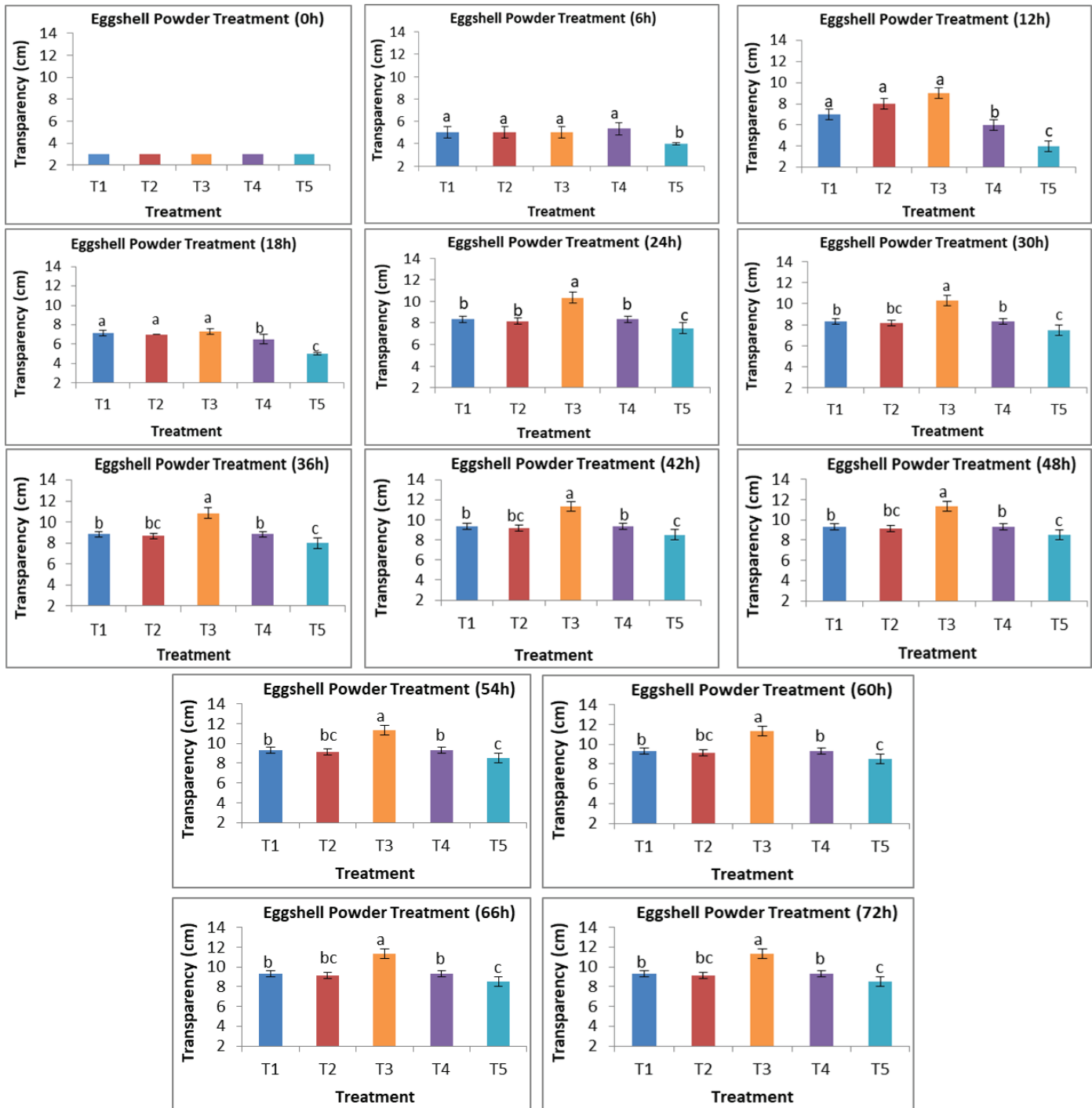


Figure 5. Changes in water transparency following supplementation with different eggshell powder treatments. Data are expressed as mean $\pm$ SD. Different superscript letters above bars denote statistically significant differences ($P < 0.05$).

3.3. Relationship between various water quality parameters

As illustrated in Table 3, the highest correlation coefficient (R^2) value for TDS and EC were observed in the T_1 ($R^2 = 0.95$), followed by T_3 ($R^2 = 0.94$), T_4 ($R^2 = 0.93$), T_2 ($R^2 = 0.75$), and T_5 ($R^2 = 0.62$). The highest R^2 value between pH and transparency was noted in the T_4 treatment ($R^2 = 0.88$) when compared to other groups. The T_1 , T_3 , and T_5 treatments showed greater relationship between TDS and hardness ($R^2 = 0.91$) in comparison with T_2 ($R^2 = 0.85$) and T_4 ($R^2 = 0.71$). The relationship between hardness and EC was higher in T_3 ($R^2 = 0.96$) and lower ($R^2 = 0.63$) in T_5 treatments.

Table 3. Correlation coefficient values of examined water quality parameters at various observation time points after being treated with eggshell powder and lime

Independent Variables	Dependent Variables	R^2 value				
		T_1	T_2	T_3	T_4	T_5
TDS	EC	0.95	0.75	0.94	0.93	0.62
pH	Transparency	0.78	0.81	0.84	0.88	0.63
TDS	Hardness	0.91	0.85	0.91	0.71	0.91
Hardness	EC	0.92	0.88	0.96	0.89	0.63

Discussion

A review of the existing literature indicates that this study is the first to experimentally examine how different poultry eggshell powder supplementations affect water quality parameters under in vitro conditions.. Eggshell, mainly composed of calcium carbonate, is a very fine adsorbent material with great possibility for water treatment. One of the remarkable industrial applications of eggshells is their routine use in water purification. Earlier studies have noted that eggshells can be used to purify water and other solvents (Mittal et al, 2016; Sun et al, 2018). It can lessen both organic and inorganic hazardous chemicals from water because of their inherent adsorbing characteristics (Naveen Kumar et al, 2022; Park et al, 2022). However, it is essential to determine an appropriate eggshell powder for optimizing its efficacy in water quality improvement. Thus, the aim of this investigation is to assess the efficiency of ESP in promoting water quality and lowering turbidity, which are critical concerns in aquaculture ponds.

The success of aquaculture productivity is largely dependent on the physicochemical features of water. Optimal physicochemical parameters are essential for improving fish health and production while reducing the risk of disease in the rearing environment (Suma et al., 2023). The results of this study demonstrated that different ESP treatments significantly influenced several water quality parameters, namely total dissolved solids (TDS), electrical conductivity, transparency, hardness, and pH. Most parameters exhibited a rapid increase during the early stages of the experiment, followed by stabilization after 48 hours, with values remaining relatively unchanged thereafter.

The TDS levels showed a highly significant difference among the ESP and lime-treated groups over the experimental period, with values increasing progressively over time up to 48 hours. The highest TDS value was observed in the T_4 treatment, where lime was applied at 24 hours of contact time due to its quick release and dissolution of Ca^{2+} and OH^- ions, resulting in sharp rise of ionic concentration. Conversely, in case of ESP, the highest TDS was observed at 48 hours of experimental period because of ESP is primarily contained $CaCO_3$, slowly releases Ca^{2+} and HCO_3^- ions, resulting in a moderate increase in TDS.

Similarly, water EC was significantly increased in all treated group in this study. Like TDS, EC values also increased with the increasing of time up to 48 hours. Highest EC was observed in lime treated (T_4) water

where lowest EC was observed in control group (T_5). The highest R^2 (0.95) values for TDS and EC was observed in T_1 which indicate that strong positive correlation among TDS and EC in T_1 . This finding support previous reports by Abowei (2010) and Ekubo and Abowei (2011), showing positive correlation between TDS and EC, indicating that conductivity rises with increasing dissolved solids.

The highest water hardness was recorded in the T_4 treatment where lime was used compared to the other groups in this study. The maximum hardness was observed in T_4 at 48 hours. The increase in hardness in lime-treated water is primarily due to the dissolution of calcium compounds, which contribute calcium ions (Ca^{2+}) to the water and thus increase total hardness (Boyd, 1995; APHA, 2017).

Water pH is a critical factor in fish farming, as it directly affects fish growth, survival, reproduction, and overall health (Nandi et al. 2025). The findings of the present study indicated that both ESP and lime treatments significantly influenced water pH, with a consistent increase observed over time up to 42 hours. The maximum pH value was recorded in the T_4 treatment, whereas the minimum pH was found in the control group (T_5). This increase of pH value is primarily occurred due to the alkaline nature of both materials, which either release hydroxide ions (OH^-) or neutralize hydrogen ions (H^+) in water (Boyd, 1995; Stumm and Morgan, 1996).

Water transparency reached its highest value in the T_3 treatment containing duck eggshell powder (ESP) after 48 h of exposure, whereas the lowest transparency was observed in the T_5 (control) group, with the difference being statistically significant ($p < 0.05$). Duck eggshell reduce water turbidity more effectively than hen and quail, this may happen due to duck eggshell may have more calcium and other minerals, duck eggshell is generally thicker than quail and hen. The enhanced transparency in the ESP-treated groups may be associated with the highly porous nature of eggshell particles. The interconnected pores and irregular surface morphology of ESP increase its surface area and adsorption potential, facilitating the removal of suspended impurities and improving water clarity (Pavlenko et al., 2022). The effectiveness of eggshell powder in water treatment can be attributed to its ability to adsorb pollutant molecules onto its surface. Following adsorption, contaminants are deposited as irregular coatings or clustered formations on the eggshell particles. The adsorbed pollutants may subsequently serve as bridges between neighboring particles, inducing aggregation and agglomeration. This process results in the formation of larger particle assemblies that promote the settling and removal of contaminants from the aquatic environment (Qianli et al., 2023).

In the present observation, however, other physicochemical parameters such as temperature, ammonia, nitrate, and nitrite revealed no noteworthy variations among the treated groups. This suggests that different eggshell powder application had no potential impact on these particular parameters. Temperature is independent of mineral supplement. ESP and lime do not generate heat or absorb heat in meaningful amounts. Therefore, no temperature change is expected. Moreover, the mineral supplements do not directly participate in nitrogen transformation reactions. Ammonia, nitrite, and nitrate levels in aquatic and soil systems are governed by biological processes, namely microbial nitrification and denitrification, and are influenced by organic loading, microbial community structure, oxygen availability, and environmental conditions. Calcium-based supplements do not directly participate in these nitrogen transformations (Akari Mitsuta et al, 2025). The results of the present study demonstrated that eggshell powder (ESP) effectively increased total dissolved solids (TDS), electrical conductivity (EC), pH, water transparency, and hardness, while significantly reducing turbidity, showing effects comparable to those of lime. These findings suggest that ESP has considerable potential as a water treatment agent for improving water quality in aquaculture systems. Moreover, the utilization of ESP offers a cost-effective and environmentally friendly alternative to conventional liming materials, contributing to sustainable aquaculture practices.

Conclusion

The results of this study demonstrate that eggshell powder can effectively improve water quality by stabilizing water pH, improving alkalinity and hardness, enhancing nutrient availability and providing a calcium source for aquatic organism. Therefore, the incorporation of poultry eggshell waste into aquaculture systems provides an economical and environmentally friendly strategy for water quality enhancement. This practice not only improves the physicochemical conditions necessary for fish growth and health but also contributes to waste recycling and the development of more sustainable aquaculture production systems. The future use of eggshell powder in aquaculture appears promising in regions with abundant egg-processing waste.

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Author contributions

S.K: Writing original draft, formal analysis, methodology; M.K., M.S.H., M.M.I: writing-review and editing; M.A.K: conceptualization, resources, project administration, study design, supervision.

References:

- Abowei JFN. 2010. Salinity, dissolved oxygen, pH and surface water temperature conditions in Nkoro river, Niger Delta, Nigeria. *Advance Journal of Food Science and Technology*. 2 (1): 16-21.
- Akari M, Késia SL, Jingjing C, Mart R, René S and Yoshitaka UEEK. 2025. Liming enhances the abundance and stability of nitrogen-cycling microbes: the buffering effect of long-term lime application. *Biology and Fertility of Soils*. 61:761–772
- Allen K, Rachmi AF and Cai J. 2017. Nigeria: faster aquaculture growth needed to bridge fish demand-supply Gap. *FAO Aquaculture Newsletter*. 57: 36-37.
- AOAC M. 1990. Association of Official Analytical Chemists. Official methods of analysis. AOAC. 1: 69–90.
- APHA (American Public Health Association). 2017. Standard methods for the examination of water and wastewater (23rd ed.). APHA, AWWA, WEF, Washington, DC.
- Bostock J, McAndrew B, Richards R, Jauncey K, Telfer T, Lorenzen K, Little D, Ross L, Handisyde N, Gatward I and Corner R. 2010. Aquaculture: global status and trends. *Philosophical transactions of the royal*. 365 (1554) :2897-2912.
- Boyd CE. 1995. Bottom soils, sediment and pond aquaculture. Chapman & Hall, New York.
- Cai J and Zhou X. 2019. Contribution of aquaculture to total fishery production: The 50-percent mark. *FAO Aquaculture Newsletter*. 60:43–45.
- Candido ICM, Soares JMD, Barbosa JDAB and Oliveira HP. 2019. Adsorption and identification of traces of dyes in aqueous solutions using chemically modified eggshell membranes. *Bioresource Technology Reports*. 7: 100267.
- Dayanidhi K, Vadivel P, Jothi S and Eusuff NS. 2020. Facile synthesis of silver eggshell nanocomposite: a heterogeneous catalyst for the removal of heavy metal ions, toxic dyes and microbial contaminants from water. *Journal of Environmental Management*. 271: 110962.

- DoF. 2023. Fisheries Resources Survey System (FRSS) Vol. 40. Department of Fisheries, Ministry of Fisheries and Livestock, Yearbook of Fisheries Statistics of Bangladesh, 2022-2023.
- Ekubo AA and Abowei JFN. 2011. Review of some water quality management principles in culture fisheries. *Research Journal of Applied Sciences, Engineering and Technology*. 3 (12):1342-1357.
- FAO, 2016. The state of world fisheries and aquaculture. Contributing to food security and nutrition for all. FAO, Rome, Italy.
- Haque MM and Mahmud MN. 2025. Potential role of aquaculture in advancing sustainable development goals (SDGs) in Bangladesh. *Aquaculture Research*. 2025(1): 6035730.
- Hem JD. 1985. Study and interpretation of the chemical characteristics of natural water (3rd ed.). U.S. Geological Survey Water-Supply Paper 2254.
- Kabir MA, Nandi SK, Suma AY and Ariff NSNA. 2023. Aquatic weeds as functional ingredients for aquaculture feed industry: recent advances, challenges, opportunities, new product development (NPD) and sustainability. *Agriculture Reports*. 2(2): 1-16.
- Kari ZA, Sukri SAM, Rusli ND, Mat K, Mahmud MB, Zakaria NNA, Wee W, Hamid NKA, Kabir, MA, Ariff NSNA and Abidin SZ. 2023. Recent advances, challenges, opportunities, product development and sustainability of main agricultural wastes for the aquaculture feed industry—a review. *Annals of Animal Science*, 23(1): 25-38.
- Kristl M, Jurak S, Brus M, Sem V and Kristl J. 2019. Evaluation of calcium carbonate in eggshells using thermal analysis. *Journal of Thermal Analysis and Calorimetry*. 138(4): 2751-2758
- Martins DD, Serra JCV, Zukowski JC and Pedroza MM. 2019. Efficiency of biochars in the removal of heavy metals, *Acta Bras*. 3: 131–138.
- Mittal A, Teotia M, Soni R and Mittal J. 2016. Applications of egg shell and egg shell membrane as adsorbents: a review. *Journal of Molecular Liquids*. 223: 376-387.
- Mohamed MH, Mohsen SH, Ahmed M. Al-Zayat, Mohamed M, El-Nawsany, Saad M. Alsaiaid and Mohamed BA. 2025. Using shells, limestone, and plastics for removing heavy metals, ammonia and improving water quality in fish farms. *Egyptian Journal of Aquatic Biology & Fisheries*, 29(4): 2513 – 2529
- Murakami FS, Rodrigues PO, Campos CMTD and Silva MAS. 2007. Physicochemical study of CaCO₃ from egg shells. *Food Science and Technology*. 27: 658–662.
- Nandi SK, Suma AY, Rashid A, Kabir MA, Goh KW, Kari ZA, Doan HV, Zakaria NNA, Khoo MI and Seong LW. 2023. The potential of fermented water spinach meal as a fish meal replacement and the impacts on growth performance, reproduction, blood biochemistry and gut morphology of female stinging catfish (*Heteropneustes fossilis*). *Life* 13 (1):176.
- Nandi SK, Hossain A, Nasren S, Kabir MA and Mamun MAA. 2025. Effects of immediate oxygen supplementation (Sodium Carbonate and Hydrogen Peroxide) on water quality Parameters, behavioural responses and survival of *Puntius sophore* fingerlings. *Veterinary Medicine and Science*. 11(6): e70624.
- Naveen K, Ajaya B and Pradeep K. 2022. Applications of waste egg shell and egg shell membrane: a review. *Materials Physics and Mechanics*. 50(3): 485-494.
- OECD/FAO. 2018. OECD-FAO agricultural outlook (Edition 2018), OECD agriculture statistics (database)

- Park B, Kim J, Ghoreishian SM, Rethinasabapathy M, Huh YS and Kang SM. 2022. Generation of multi-functional core-shell adsorbents: simultaneous adsorption of cesium, strontium and rhodamine B in aqueous solution. *Journal of Industrial and Engineering Chemistry*. 112: 201-209.
- Pavlenko V, Khosravi HS, Żółtowska S, Haruna AB, Zahid M, Mansurov Z, Supiyeva Z, Galal A, Ozoemena KI, Abbas Q and Jesionowski T. 2022. A comprehensive review of template-assisted porous carbons: Modern preparation methods and advanced applications. *Materials Science and Engineering: R: Reports*. 149: 17-32.
- Qianli M, Kristaps R, Ólafur ES, Torben H, Therese S, Signe, Z, Janis L, Dagnija L and Håvard J H. 2023. Eggshell-derived amorphous calcium phosphate: synthesis, characterization and bio-functions as bone graft materials in novel 3D osteoblastic spheroids model. *Smart Materials in Medicine*. 4: 522-537.
- Rajoriya S, Saharan VK, Pundir AS, Nigam M and Roy K. 2021. Adsorption of methyl red dye from aqueous solution onto eggshell waste material: Kinetics, isotherms and thermodynamic studies. *Current Research in Green and Sustainable Chemistry*. 4:100180.
- Sankaran R, Show PL, Ooi CW, Ling TC, Shu-Jen C, Chen SY and Chang YK. 2020. Feasibility assessment of removal of heavy metals and soluble microbial products from aqueous solutions using eggshell wastes. *Clean Technologies and Environmental Policy*. 22(4): 773-786.
- Siti NAA, Mohd HIS, Md LK and Shamsul I. 2013. Adsorption process of heavy metals by low-cost adsorbent: a review, *Res J. Chem. Environ.*, 18, 91–102.
- Stumm W and Morgan JJ. 1996. *Aquatic Chemistry: Chemical Equilibria and Rates in Natural Waters* (3rd ed.). Wiley-Interscience, New York
- Suma AY, Nandi SK, Abdul ZK, Goh KW, Wei LS, Tahiluddin AB, Seguin P, Herault M, Mamun AA, Téllez-Isaías G and Kabir MA. 2023. Beneficial effects of graded levels of fish protein hydrolysate (FPH) on the growth performance, blood biochemistry, liver and intestinal health, economics efficiency and disease resistance to *Aeromonas hydrophila* of Pabda (*Ompok pabda*) fingerling. *Fishes* 147
- Sun Y, Yang G and Zhang L. 2018. Hybrid adsorbent prepared from renewable lignin and waste egg shell for SO₂ removal: Characterization and process optimization. *Ecological Engineering*. 115: 139-148.
- Waheed M, Yousaf M, Shehzad A, Inam-Ur-Raheem M, Khan, MKI, Khan MR, Ahmad N, Abdullah and Aadil RM. 2020. Channelling eggshell waste to valuable and utilizable products: A comprehensive review. *Trends in Food Science & Technology*. 106: 78-90.