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Comparative Effects of Herbal Extracts on Growth Performance and Nutritional Quality of Freshwater Prawn (*Macrobrachium rosenbergii*) in Biofloc System

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ABSTRACT

The freshwater prawn (*Macrobrachium rosenbergii*) constitutes an integral component of the aquaculture sector in Bangladesh, with biofloc technology (BFT) emerging as a sustainable and resource-efficient alternative to conventional farming methods. This study evaluated the comparative effects of three herbal extracts—ginger (GE), amla (AE), and garlic (GaE)—on the growth performance, survival rate, and nutritional composition of *M. rosenbergii* juveniles cultivated in a biofloc-based system over an eight-week period. Four experimental groups were established: a control (T1), GE (T2), AE (T3), and GaE (T4), with herbal extracts incorporated into commercial feed at a concentration of 200ml/ kg. Among the treatments, amla extract (T3) yielded the most favorable results, reflected in significantly higher mean weight gain (10.5 ± 0.5 g), percentage weight gain (275.5 ± 27.7%), and specific growth rate (2.6 ± 0.1%). The feed conversion ratio (FCR) was the lowest in T3 (0.8 ± 0.0), indicating superior feed efficiency. Proximate analysis of muscle tissue revealed that prawns in the AE group had the highest crude protein content (74.1%) along with optimal fat and fiber levels, highlighting its nutritional benefits. Additionally, the presence of biofloc improved water quality and performance metrics across all treatments compared to the control. These findings suggest that integrating amla extract with BFT can significantly enhance growth, feed utilization, and flesh quality in prawn aquaculture, offering an environmentally sustainable and economically viable strategy.

INTRODUCTION

The giant freshwater prawn (*Macrobrachium rosenbergii*), commonly referred to as 'Golda,' plays a crucial role in the economy of Bangladesh by generating foreign currency, creating employment opportunities, and enhancing protein production **(Barad *et al.*, 2024)**. This species is vital in aquaculture within tropical and subtropical regions, significantly contributing to the livelihoods of farmers in the southwestern coastal areas of Bangladesh **(Global Seafood Alliance, 2020; Bir *et al.*, 2024)**. *M. rosenbergii* thrives in the country's favorable agro-climatic conditions and mangrove ecosystems, benefiting from hatchery-produced seeds, skilled labor, and commercial feed **(Wahab *et al.*, 2012; Hassan *et al.*, 2013; Ghosh *et al.*, 2016; Islam *et al.*, 2021; Azad *et al.*, 2023; Bir *et al.*, 2024)**.

Prawn production increased from 46,189 metric tons in 2015 to 54,352 metric tons in 2022, contributing approximately USD 78.91 million to Bangladesh's economy **(New, 1995; DoF, 2023)**. Prawns grow rapidly and tolerate a broad range of temperatures (14–35°C) and salinities (0–25 ppt). Rising demand from Europe, the USA, Japan, Russia, and China is driving the expansion of GFP (Good Farming Practices) prawn farming in Bangladesh **(Wahab *et al.*, 2012; Hassan *et al.*, 2013; Ghosh *et al.*, 2016; Islam *et al.*, 2021; Azad *et al.*, 2023; Bir *et al.*, 2024)**.

Aquaculture plays a critical role in food security and economic development, with a projected 60% increase in production by 2050 to meet the needs of a growing population **(Shahabuddin *et al.*, 2024)**. In 2022, global aquaculture production reached 130.9 million tons, surpassing capture fisheries for the first time, and contributing to a per capita consumption rate of 20.7kg **(FAO, 2024)**. Since 2000, global production has grown by 45%, reaching 182 million tons in 2021 and involving the cultivation of over 622 species **(Ahmed & Turchini, 2021; FAO, 2023)**. The sector has expanded fivefold since the late 1980s, supporting livelihoods and advancing the United Nations Sustainable Development Goals **(Jiang *et al.*, 2022)**.

The increased use of natural feed additives, such as herbs, is driven by the environmental concerns linked to synthetic chemicals **(Ramesh *et al.*, 2022)**. Amla, rich in vitamin C, aids digestion, liver function, and protein synthesis **(Gul *et al.*, 2022; X. Li *et al.*, 2023)**. Garlic promotes growth and immune response in species like grey mullet **(Basuini *et al.*, 2024)**, while ginger shows effectiveness against fungal and parasitic infections due to its bioactive compounds **(Ayustaningwarno *et al.*, 2024)**. Despite its potential, the sector faces challenges such as climate change, which has raised temperatures and salinity levels in coastal areas, impacting future aquaculture efforts **(Bir *et al.*, 2024)**. This study explores the effects of herbal extracts on the growth and nutritional quality of juvenile *M. rosenbergii* cultured in a biofloc system.

Intensive aquaculture systems often struggle to maintain optimal conditions for high-density fish and shrimp production with minimal water exchange **(Ashraf *et al.*, 2024)**. Biofloc systems recycle nutrients into microbial biomass that serves as a natural food source and are increasingly adopted to address these challenges **(Ashraf *et al.*, 2024)**. These systems require only 50%–60% of the typical feed amount and result in a low feed conversion ratio (FCR) **(Heshmatfar *et al.*, 2023)**. Biofloc technology reduces the need for protein in artificial diets, thereby lowering feed costs compared to other intensive systems **(Jatobá *et al.*, 2014)**. It works by maintaining a high carbon-to-nitrogen ratio (C: N 10–20: 1), encouraging heterotrophic bacterial growth that transforms ammonia into bioflocs **(Hosain *et al.*, 2021; Ashraf *et al.*, 2024)**. These bioflocs, enriched with beneficial microorganisms, decompose organic waste and improve nutritional intake for shrimp **(De Jesús *et al.*, 2023)**. They are particularly valuable for detritivorous species like prawns **(Becerril-Cortés *et al.*, 2018; De Jesús *et al.*, 2023)**.

In Bangladesh, the freshwater prawn (*Macrobrachium rosenbergii*) sector is essential for rural livelihoods and contributes significantly to export revenues **(Nahid *et al.*, 2013)**. However, traditional farming methods face issues such as deteriorating water quality, disease outbreaks, and inefficient feed utilization. Biofloc technology has garnered attention for its potential to improve water quality, reduce feed costs, and enhance growth performance, though its application in prawn culture remains underexplored locally. At the same time, overuse of synthetic growth promoters and antibiotics poses environmental and public health concerns, spurring interest in natural alternatives. Herbal feed additives like ginger (*Zingiber officinale*), amla (*Phyllanthus emblica*), and garlic (*Allium sativum*) possess antimicrobial, immunostimulant, and growth-enhancing properties. However, their relative effectiveness in biofloc-based prawn systems has not been sufficiently evaluated.

This study aimed to evaluate the effects of three herbal extracts on the growth performance and nutritional quality of *M. rosenbergii* reared in a biofloc environment. The goal was to identify cost-effective, eco-friendly feed additives that can enhance sustainability and productivity in prawn aquaculture in Bangladesh.

MATERIALS AND METHODS

1. Experimental design and management practices

The study was carried out over a period of 8 weeks (56 days), at the Biofloc Laboratory of the Department of Aquaculture, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. Four distinct treatments were evaluated: Treatment-1 (Control) utilized solely commercial feed. Treatment-2 (GE) incorporated ginger extract into the feed diet. Treatment-3 (AE) incorporated amla extract. Treatment-4 (GaE) incorporated garlic extract. This investigation assessed the impact of these herbal supplements on the growth and nutritional profile of freshwater prawns. The tanks utilized for biofloc cultivation were made from PVC-coated tarpaulin, strengthened with iron frames, and each had a capacity of $2m^3$, consistently maintained at 80% throughout the study. Tanks were filled with freshwater and disinfected by using 3-5ppm chlorine. Oxygen supply was ensured by using three nano bubble tubes for each tank through a central air blower system. pH was adjusted using $CaCO_3$. For the start-up of the biofloc and maintaining C:N ratio of 10-15:1, 30g of molasses was added along with 10g of nursery powder feed.

The feed provided 0.5g of nitrogen, requiring 7.5g of carbon, which was supplied by 30g of molasses, as it contains 23.98% carbon.

The desired C:N ratio promoted heterotrophic bacterial growth in the tanks. Probiotics collected from Navio Plus (10–15g/ m^3) were used to enhance microbial activity, and the tanks were aerated continuously to develop the heterotrophic bacteria for seven days. Water quality parameters, including dissolved oxygen (>7mg/ L), pH (7.0–8.0), temperature (25–30°C), ammonia (<0.5mg/ L), TDS (800–1500 mg/L), and transparency (20–30 cm), were monitored regularly. Daily floc density was monitored using an Imhoff cone. One liter of water was collected from each tank and placed in the Imhoff cone to settle for 30 minutes. The floc density was recorded as ml/L. Post-larvae of prawns were bought from CP Hatchery, Comilla, Bangladesh, underwent disinfection, and subsequently placed in tanks at a density of approximately 88pcs/ m^3. The prawns were acclimatized and then released into the tanks after being transported in plastic bags containing a water-to-oxygen ratio of 3:1. Sampling of prawns was conducted at seven-day intervals.

2. Sample preparation

The ginger and garlic specimens were meticulously cleansed and peeled to eliminate the external covering, whereas the inner seeds of the amla specimens were extricated. The specimens were subsequently diced into diminutive fragments and processed into a paste. The pulverized specimens were immersed in a sanitized, amber-hued vessel containing 95% ethanol for a duration of two weeks, accompanied by intermittent agitation and stirring. The sealed vessel was maintained at a temperature of 25ºC throughout this duration. Upon completion of the cold extraction, the entire mixture was subjected to filtration through a cotton plug positioned in a sizable funnel to isolate the supernatant. The volume of the filtrate was then diminished to approximately using rotary evaporators (RE-52A, Wincom Company Ltd, China) at a temperature of 40ºC. This procedure was executed thrice, and the concentrated extract was amassed in accordance with the methodology delineated by **Afroz *et al.* (2015)**. The following equation was employed to ascertain the yield of the extract:

Total extract yield (%) = [Weight of extract (g)/Weight of sample (g)] × 100.

An isoenergetic commercial nursery shrimp feed collected from Quality Feeds Limited, Bangladesh, was implemented to guarantee an equivalent proportion of nutrients across all experimental treatments. Extracts of ginger (GE), garlic (GaE), and amla (AE) were applied at a rate of 200ml per kilogram of commercial feed. The preparation of the mixture occurred two hours before the feeding. Molasses was used as a binder for the extract. Prawns were fed twice daily, starting with 1-2% of their body weight and later increasing to 5%.

The proximate composition of the feed is given in Table (1).

Table 1. Proximate composition (% on DM basis) of feed and carbohydrate source (Molasses) used for freshwater prawn *Macrobrachium rosenbergii* cultured in biofloc system

Parameter	Feed	Molasses
Moisture	11.25±0.95	21.65±1.2
Crude protein	32.50±1.25	1.78±0.50
Fat	7.25±0.50	2.45±0.80
Carbohydrate	20.75±1.50	23.98±1.45
Fiber	3.50±0.75	0.05±0.01
Ash	10.10±0.70	4.86±0.35
Calcium	3.05±0.25	0.48±0.09
Phosphorus	2.02±0.60	0.13±0.05

3. Laboratory analyses

3.1 Water quality parameters

Prawns perform all their physiological functions in water; therefore, maintaining optimal water quality is essential for their survival and growth. Key water quality parameters—including temperature, pH, dissolved oxygen (DO), and ammonia concentration—were monitored daily throughout the study. A digital multimeter (HACH HQ40d) was used to measure temperature, pH, and total dissolved solids (TDS). Additionally, DO, ammonia, alkalinity, and water hardness were assessed using standard test kits. Biofloc volume (ml/L) was measured weekly using an Imhoff cone **(Avnimelech, 2009)**.

To maintain the carbon-to-nitrogen (C: N) ratio at 10: 1 during the experimental period, brown sugar was applied as a carbon source. Ethylenediaminetetraacetic acid (EDTA), a chelating agent, was used to soften the water by reducing metal ion concentrations and to facilitate prawn molting. EDTA was applied at a concentration of 10 mg/L on the days of the full moon and new moon. Furthermore, following sampling and molting, mineral supplements were administered at a concentration of 20g/ m^3 of water to support prawn tissue development, exoskeleton formation, and help regulate osmotic pressure.

3.2 Growth parameters

Prawn growth was monitored regularly. Sampling was conducted using a scoop net to measure both total body weight and length for growth analysis. Growth parameters were calculated using the following equations:

1) Weight gain = Mean final weight − Mean initial weight **(De Silva & Anderson, 1994)**

2) $\text{Percentage weight gain} = \frac{\text{Mean final prawn weight} - \text{Mean initial prawn weight}}{\text{Mean initial prawn weight}}$ **(De Silva & Anderson, 1994)**

3) $\text{Survival rate (\%)} = \frac{\text{No. of total live prawn}}{\text{No. of total prawn stocked}} \times 100$ **(De Silva & Anderson, 1994)**

4) $\text{Specific growth rate (SGR)(\% per day)} = \frac{\ln W_2 - \ln W_1}{T_2 - T_1} \times 100$ **(De Silva & Anderson, 1994)**

Where,

W_1= Initial weight, W_2= Final weight, T_1= Time of stock and T_2= Time of harvest

5) $\text{Feed conversion ratio (FCR)} = \frac{\text{Total feed consumed (g)}}{\text{Live weight gain (g)}}$ **(De Silva & Anderson, 1994)**

6) $\text{Feed conversion efficiency (FCE) \%} = \frac{\text{Weight gain of fish (g)}}{\text{Feed consumed (g)}} \times 100$ **(De Silva & Anderson, 1994)**

7) $\text{Reactive growth rate (RGR) \%} = \frac{\ln(w_2) - \ln(w_1)}{T} \times 100$ **(De Silva & Anderson, 1994)**

Where,

W_1= Initial weight, W_2= Final weight, T= Time period of the growth (days)

8) $\text{Net Production (kilogram/m}^3) = \frac{\text{Survival (\%)} \times \text{Stocking density} \times \text{Weight gain (g)}}{100 \times 1000}$ **(De Silva & Anderson, 1994)**

3.2 Proximate analysis

3.2.1 Proximate composition of biofloc

The proximate composition of the microbial floc was determined using standard procedures to analyze the nutrient content **(Van Soest *et al.*, 1991)**.

3.2.2 Proximate composition of cultured freshwater prawn

The body muscle composition of freshwater prawns was analyzed for various proximate components, including moisture content, crude protein, total ash, crude fiber, crude fat, and carbohydrate.

3.2.3 Moisture content

The moisture content of the prawn muscle samples was evaluated according to the methodology described by **AOAC (2005)**. Samples were dried at 105°C in a hot air oven until a constant weight was achieved. The moisture content was calculated using the following formula:

$$\text{Moisture (\%)} = \frac{\text{Initial weight of sample (g)} - \text{Final weight (g)}}{\text{Initial weight (g)}} \times 100$$

3.2.4 Crude protein analysis

The crude protein content was determined using the Micro-Kjeldahl method, based on procedures outlined by **AOAC (2000)**. The nitrogen content was measured, and the protein content was calculated by multiplying the nitrogen value by a factor of 6.25:

$$\text{Crude protein (\%)} = \frac{\text{Nitrogen content (\%)}}{\text{Sample weight (g)}} \times 6.25$$

3.2.5 Ash content analysis

The ash content was measured following **AOAC (2005)** procedures. The muscle samples were incinerated at 550°C in a muffle furnace until only ash remained. The ash content was calculated as:

$$\text{Ash (\%)} = \frac{\text{Weight of ash (g)}}{\text{Weight of sample (g)}} \times 100$$

3.2.6 Crude fiber analysis

Crude fiber was measured using the method described by **Van Soest *et al*. (1991)**, which involved sequential digestion with acid and alkali, followed by drying and incineration at 550°C. The crude fiber content was calculated as:

$$\text{Crude fiber (\%)} = \frac{\text{Weight of fiber residue (g)}}{\text{Weight of sample (g)}} \times 100$$

3.2.7 Lipid analysis

The lipid content of the prawn muscle was determined using Soxhlet extraction as described by **Folch *et al*. (1957)**. The following formula was used to calculate lipid content:

$$\text{Total lipid (\%)} = \frac{\text{Weight of ectractted lipid (g)}}{\text{Weight of sample (g)}} \times 100$$

3.2.8 Carbohydrate content

The carbohydrate content was calculated by subtracting the sum of the moisture, ash, crude protein, crude fiber, and lipid percentages from 100%:

$$\text{Carbohydrate} = 100\% - (\%\ \text{moisture} + \%\ \text{ash} + \%\ \text{crude protein} + \%\ \text{fat})$$

4. Statistical analysis

Data were recorded and the mean value was calculated from the average of 20 randomly captured individual data. It was accomplished by using software MS Excel and SPSS (Statistical Package for Social Sciences). All non-repeatedly measured variables (prawn growth parameters) were analyzed by one-way ANOVA Tukey HSD programme using SPSS software at 5% level of significance.

RESULTS

1. Water quality parameters

The water quality parameters in the freshwater prawn biofloc culture system remained stable across all treatments (Table 1). Temperature fluctuated minimally between 29.2 and 29.3°C, which is within the optimal range of 26–32°C for prawn culture. The pH was consistently recorded at 7.9 across all treatments, falling within the acceptable range of 6.0–9.0. Dissolved oxygen (DO) levels exceeded the minimum requirement, ranging from 6.5 to 6.6mg/ L. Ammonia (NH_3) concentrations were low at 0.3 mg/L across all treatments—well below the critical threshold of 1 mg/L.

Alkalinity ranged from 183.4 to 185.0mg/ L, and hardness varied between 112.3 and 115.5mg/ L, both of which align with recommended values for prawn culture. Total dissolved solids (TDS) were the highest in Treatment 2 at 1062.8mg/ L, slightly exceeding the suggested limit of 1000mg/ L, while other treatments ranged from 974.3 to 981.9mg/ L.

The control group exhibited no measurable floc volume, whereas the treatment groups displayed values ranging from 13.5 to 13.9mL/ L—within the ideal range of 10–15mL/ L. This indicates that the addition of bioactive extracts (ginger, amla, and garlic) effectively supported biofloc development while maintaining optimal water quality parameters conducive to prawn growth.

Table 2. Water quality parameters of freshwater prawn (*Macrobrachium rosenbergii*) culture in biofloc system during the experimental period

Parameter	Treatments				Optimum level
	Treatment-1 (Control)	**Treatment-2 (GE)**	**Treatment-3 (AE)**	**Treatment-4 (GaE)**	
Temperature (°C)	29.3±1.03	29.3±1.01	29.2±0.95	29.2±1	26-32
pH	7.9±0.24	7.9±0.2	7.9±1.73	7.9±0.19	6-9
DO (mg/l)	6.6±0.51	6.5±0.58	6.5±0.67	6.5±0.67	≥3
NH_3 (mg/l)	0.3±0.072	0.3±0.01	0.3±0.07	0.3±0.08	<1
Alkalinity (mg/l)	183.8±15.5	183.4±16.66	185.0±21.4	184.5±17.2	150-200
Hardness (mg/l)	115.5±7.46	112.3±8.77	112.9±7.63	113.9±7.19	100-120
TDS (mg/l)	974.3±121.1	1062.8±119.2	981.9±169.9	974.7± 178.7	<1000
Floc volume (ml/l)	0.0	13.5±1.43	13.8±2.15	13.9±1.92	10-15

*Data represent mean ± SE (n=12).

GE= Ginger Extract, AE= Amla Extract, GaE= Garlic Extract.

2. Growth and development of prawn in different treatments

2.1 Length of prawn

The initial average length of the prawn was recorded at 4.48 ± 0.61 cm, which was selected as the baseline for the experimental setup (Table 3). After 14 days, the highest average length (6.53 ± 0.10 cm) was observed in Treatment 1 (Control), as shown in Table (3). However, at 28 and 56 days, Treatment 3 (AE) exhibited superior growth performance, with average lengths of 7.30 ± 0.15 cm and 8.48 ± 0.13 cm, respectively—outperforming all other treatments.

Table 3. Mean length (cm) of freshwater prawn (*Macrobrachium rosenbergii*) in different treatments during the experimental period in the biofloc system

Treatment	**Mean length (cm) over time (Days)**				
	0	**14**	**28**	**42**	**56**
Treatment-1 (Control)	4.46±0.61	6.53±0.1	7.32±0.22	7.03±0.07	8.41±0.02
Treatment-2 (GE)	4.37±0.41	6.20±0.20	7.15±0.21	7.47±0.15	8.24±0.17
Treatment-3 (AE)	4.10±0.31	6.13±0.15	7.31±0.15	8.47±0.25	8.48±0.13
Treatment-4 (GaE)	4.27±0.11	5.30±0.10	5.68±0.07	7.60±0.17	9.00±0.20

*Data represent mean ± SE (n=12).

GE= Ginger Extract, AE= Amla Extract, GaE= Garlic Extract.

2.2 Weight of prawn

The initial mean weight of the prawn was 3.2g stocked for conducting the experiment (Table 4). After 14 days, the mean length was seen to be higher (7.88±0.13g) in Treatment-1 (Control) tanks. After 42 days, the highest mean weight (11.04±0.47) was found in Treatment-4 (GaE) tanks. Subsequently, after 56 days, Treatment-3 (AE) gave the best results for mean weight (13.76±0.45g) as compared to other treatments. Growth of prawn in the extract given treatments was far better than without the extract and floc abundant environment.

Table 4. Mean weight (g) of freshwater prawn (*Macrobrachium rosenbergii*) during the experimental period in the biofloc system

Treatments	**Mean weight (g) over time (Days)**				
	0	**14**	**28**	**42**	**56**
Treatment-1 (Control)	3.14±0.11	7.88±0.13	8.68±0.16	9.83±0.38	10.56±0.26
Treatment-2 (GE)	3.04±0.16	6.38±0.28	7.50±0.55	9.18±0.49	10.50±0.37
Treatment-3 (AE)	3.26±0.09	6.42±0.53	9.49±0.30	10.28±0.58	13.76±0.45
Treatment-4 (GaE)	3.36±0.06	7.06±0.76	10.4±0.46	11.04±0.47	12.76±0.38

* Data represent mean ± SE (n=12).

GE= Ginger Extract, AE= Amla Extract, GaE= Garlic Extract.

3. Growth parameters

In this study, the growth performance of *Macrobrachium rosenbergii* was evaluated under four treatments in a biofloc system (Table 5). Among all groups, Treatment-3 (Amla Extract) produced the most favorable outcomes, with significantly higher ($P < 0.05$) values in several key growth parameters compared to the control (Treatment-1) and ginger extract (Treatment-2). Prawns in Treatment-3 achieved the highest mean final weight (13.8 ± 0.5g), total weight gain (786.0 ± 47.5 g/m^3), feed conversion efficiency (124.2 ± 3.1%), and relative growth rate (423.4 ± 20.8%), all of which were statistically superior to Treatments 1 and 2.

Moreover, gross and net production were significantly higher ($P < 0.05$) in both Treatment-3 and Treatment-4 (Garlic Extract), each recording 1.1 ± 0 kg/m^3/crop and 0.8 ± 0.1 kg/m^3/crop, respectively. Treatment-3 also yielded the highest mean weight gain (10.5 ± 0.5g) (Fig. 1), percentage weight gain (275.5 ± 27.7%) (Fig. 2), and the most efficient feed conversion ratio (0.8 ± 0) (Fig. 3), all showing statistically significant improvements over the control and Treatment-2. The specific growth rate (2.6 ± 0.1%) in Treatment-3 was also the highest among all treatments and significantly better than in Treatment-1 and Treatment-2 (Fig. 4).

Although Treatment-4 (Garlic Extract) had the highest survival rate (95.2 ± 0.7%), Treatment-3 surpassed it in most other growth-related metrics. These results clearly demonstrate that Amla Extract (Treatment-3) significantly enhances growth performance and production efficiency of *M. rosenbergii* in biofloc systems, underscoring its potential as a highly effective dietary supplement.

Table 5. Growth parameters of freshwater prawn (*Macrobrachium rosenbergii*) applying herbal extract in different treatments

Parameter	Treatments			
	Treatment-1 (Control)	**Treatment-2 (GE)**	**Treatment-3 (AE)**	**Treatment-4 (GaE)**
Mean initial weight (g)	3.14±0.1	3.04±0.2	3.26±0.1	3.36±0
Mean final weight (g)	10.6±0.3^{a}	10.5±0.4^{a}	13.8±0.5^{b}	12.8±0.4^{b}
Total weight gain (g/m^3)	518.8±10.6^{a}	532.1±28.3^{a}	786.0±47.5^{b}	773.5±35.4^{b}
Survival (%)	85.6±1.3^{a}	86.6±0.7^{a}	88.5±1.0^{a}	95.2±0.7^{b}
FCR	1.2±0^{a}	1.0±0^{c}	0.8±0^{b}	0.9±0.1^{b}
FCE (%)	83.2±2.1^{a}	95.9±2.2^{a}	124.2±3.1^{b}	113.8±7.0^{b}
RGR (%)	336.3±2.8^{a}	347.7±22.9^{a}	423.4±20.8^{b}	380.3±11.7^{ab}
Protein intake	245.4±6.7^{ab}	217.9±11.0^{b}	248.2±11.5^{ab}	268.5±11.5^{a}
Lipid intake	40.6±1.1^{ab}	36.1±1.8^{b}	41.1±1.9^{ab}	44.4±1.9^{a}
Gross production (kg/m^3/crop)	0.8±0^{a}	0.8±0^{a}	1.1±0^{b}	1.1±0^{b}
Net production (kg/m^3/crop)	0.5±0^{a}	0.5±0^{a}	0.8±0.1^{b}	0.8±0^{b}
Weight gain (%)	187.9±6.9^{a}	201.0±22.7^{ab}	275.5±27.7^{c}	262.1±16.7^{bc}
Mean weight gain (g)	7.4±0.2^{a}	7.4±0.5^{a}	10.5±0.5^{b}	9.4±0.4^{b}
SGR (%)	2.2±0^{a}	2.2±0.1^{a}	2.6±0.1^{b}	2.4±0.1^{ab}

*Data represent mean ± SE (n=12). Values in the same row with different superscript letters indicate statistically significant differences (P<0.05).

GE= Ginger Extract, AE= Amla Extract, GaE= Garlic Extract.

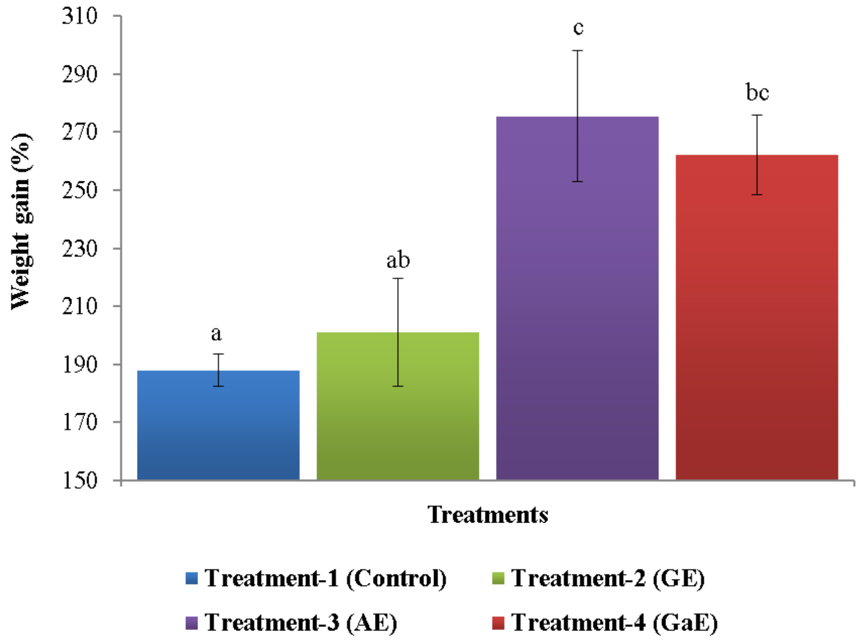

Fig. 1. Mean weight gain (g) across four treatments (Control, Ginger Extract (GE), Amla Extract (AE), and Garlic Extract (GaE)) of cultured *Macrobrachium rosenbergii* in biofloc technology

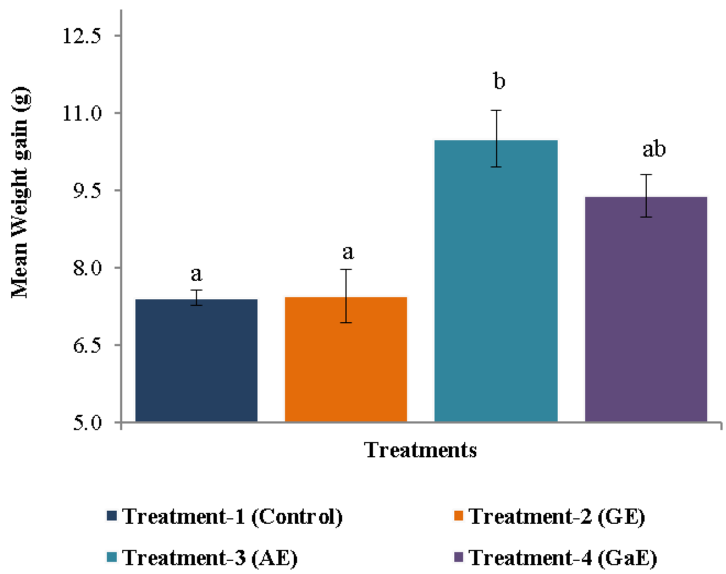

Fig. 2. Weight gain (%) across four treatments (Control, Ginger Extract (GE), Amla Extract (AE), and Garlic Extract (GaE)) of cultured *Macrobrachium rosenbergii* in biofloc technology

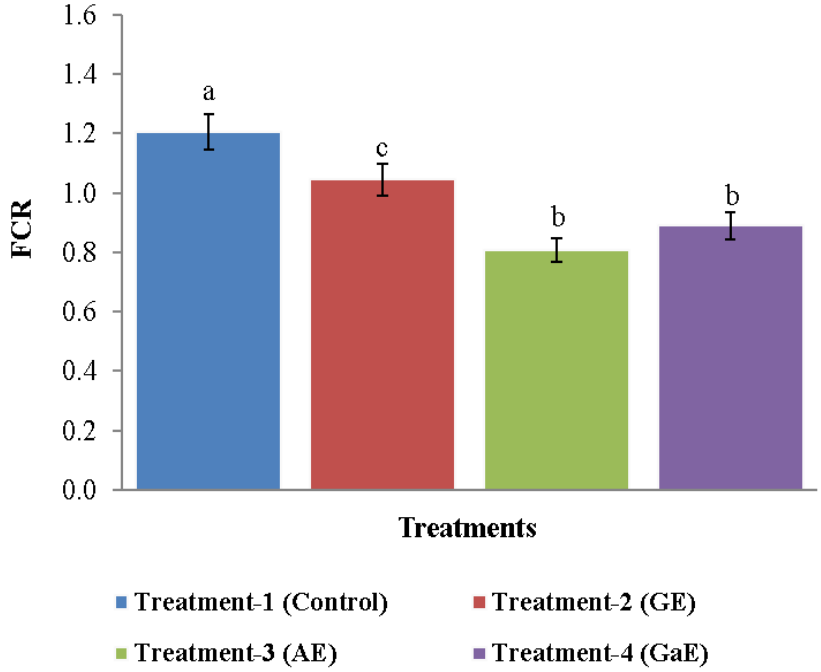

Fig. 3. Feed conversion ratio (FCR) across four treatments (Control, Ginger Extract (GE), Amla Extract (AE), and Garlic Extract (GaE)) of cultured *Macrobrachium rosenbergii* in biofloc technology (dry feed basis)

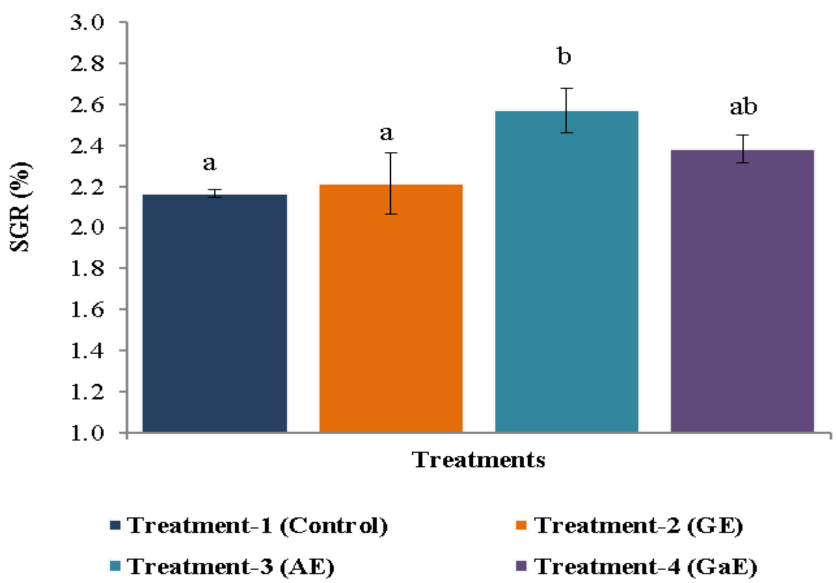

Fig. 4. Specific growth rate (%) across four treatments (Control, Ginger Extract (GE), Amla Extract (AE), and Garlic Extract (GaE)) of cultured *Macrobrachium rosenbergii* in biofloc technology

4. Proximate composition

4.1 Proximate composition of the floc

The analysis revealed that the floc comprised 21.7% protein, 69.13% carbohydrate, 1.7% fat, and no acidic substances were detected (Fig. 5).

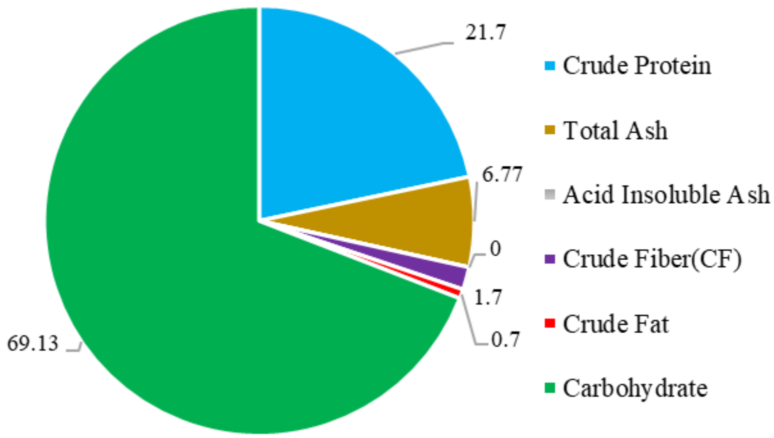

Fig. 5. Proximate composition of floc produced in the treatment's tanks

4.2 Proximate composition of cultured freshwater prawn

The proximate composition of *M. rosenbergii* cultured in biofloc systems exhibited notable variations among the treatments, with Treatment-3 (AE) yielding the most beneficial nutritional results (Table 6). This treatment exhibited the highest crude protein content at 74.1%, surpassing the other treatments: Treatment-1 (66.77%), Treatment-2 (56.73%), and Treatment-4 (64.1%). This highlights the efficacy of amla extract in facilitating protein synthesis, which is crucial for growth. Regarding the crude fat content, Treatment-3 exhibited a balanced lipid profile at 2.63%, which is higher than Treatment-2 at 1.72% and comparable to Treatment-4 at 3.05%. The carbohydrate levels in Treatment-3 (5.46%) were moderate, reflecting a balance between Treatment-2 (17.2%) and Treatment-4 (10.89%), suggesting improved nutritional harmony. Moreover, the ash content observed in Treatment-3 (17.37%) was found to be lower than that of the control (22.29%) and Treatment-4 (21.35%), indicating a more favorable mineral to nutrient ratio. In contrast, Treatment-2, despite exhibiting a lower ash content (23.75%), demonstrated deficiencies in both protein and fat content. The findings indicate that the amla extract utilized in Treatment-3 provides a diet of enhanced nutritional value for *M. rosenbergii*, exceeding the performance of the other treatments in critical growth and nutritional quality parameters.

Table 6. Proximate composition (% on DM basis) of freshwater prawn (*Macrobrachium rosenbergii*) applying herbal extracts in different treatment

Variable	Treatments			
	Treatment-1 (Control)	**Treatment-2 (GE)**	**Treatment-3 (AE)**	**Treatment-4 (GaE)**
Moisture	77.03 ±1.29	81.6±2.3	79.12±0.35	77.86±0.81
Dry matter	22.97±1.29	18.4±2.3	20.88±0.35	22.14±0.81
Crude protein	66.77±1.92	56.73±1.39	74.1 ±0.68	64.1 ±1.34
Total ash	22.29±0.92	23.75±0.6	17.37±1.19	21.35±1.05
Crude fiber	0.51±0.08	0.6±0.02	0.4±0.11	0.61±0.06
Crude fat	3.28±0.27	1.72±0.29	2.63±0.25	3.05±0.26
Carbohydrate	7.14±2.64	17.2±1.1	5.46±0.88	10.89±0.15

*Data represent mean ± SE (n=12).

DM= Dry Matter, GE= Ginger Extract, AE= Amla Extract, GaE= Garlic Extract.

DISCUSSION

Prawn farming significantly contributes to the economy of Bangladesh, particularly with the emergence of freshwater shrimp (*Macrobrachium rosenbergii*) cultivation in biofloc systems, which offer a sustainable and resource-efficient alternative to conventional farming methods. This study evaluated four distinct treatments: a control group (Treatment 1), ginger extract (Treatment 2, GE), amla extract (Treatment 3, AE), and garlic extract (Treatment 4, GaE), focusing on their effects on prawn growth performance and nutritional composition.

Among all treatments, amla extract (Treatment 3) demonstrated the most favorable outcomes, with a mean weight gain of 10.5 ± 0.5 g and a percentage weight gain of $275.5 \pm 27.7\%$. This performance surpasses the maximum weight gain of 133.71% reported by **Anand *et al.* (2013)** for *Penaeus monodon* under similar biofloc conditions. Furthermore, the specific growth rate (SGR) observed in Treatment 3 was $2.6 \pm 0.1\%$, exceeding values reported by **Ballester *et al.* (2018)**, who recorded SGRs between 1.21% and 2.19% across various treatments.

The nutritional analysis further supports the efficacy of amla extract (AE), with Treatment 3 prawns exhibiting the highest crude protein content at 74.1%, along with lower crude fat (2.63%) and fiber (0.41%) levels. These findings align with earlier studies by **Ferdose and Hossain (2011)** and **Asaikkutti *et al.* (2016)**, who reported crude protein levels in *M. rosenbergii* ranging from 54.39 to 74.85%. The high protein content and reduced fat levels in Treatment 3 indicate the beneficial influence of herbal additives on improving the nutritional quality of cultured prawns.

The impact of biofloc systems is also evident, as the control group (Treatment 1) consistently produced less favorable results compared to treatments with biofloc and herbal extracts. This observation supports the findings of **Emerenciano *et al.* (2017)**, who emphasized the positive influence of biofloc on prawn growth and system efficiency. Similarly, **Negrini *et al.* (2017)** reported increased weight gain and survival rates in biofloc systems compared to traditional methods, which corresponds with the higher survival rates recorded in this study.

Survival rates of $95.2 \pm 0.7\%$ in Treatment 4 (GaE) and $88.5 \pm 1.0\%$ in Treatment 3 (AE) are consistent with findings by **Paul and Rahman (2016)**, who observed survival rates of approximately 86% in *M. rosenbergii* under various treatments. These results further support the role of biofloc systems in enhancing prawn survivability, a critical factor for the success of aquaculture operations.

The feed conversion ratio (FCR), an essential metric for evaluating feed efficiency, was notably low in Treatment 3 at 0.8 ± 0.0, indicating superior feed utilization. In contrast, FCR values were 1.2 ± 0.0 in the control (Treatment 1) and 1.0 ± 0.0 in Treatment 2 (GE). These results demonstrate a clear improvement over the FCR of 2.25 reported by **Ballester *et al.* (2018)** in similar biofloc systems, highlighting the effectiveness of amla extract in optimizing feed efficiency.

The specific growth rates (SGRs) observed in Treatment 3 are also notably higher, consistent with earlier reports by **Paul and Rahman (2016)** and **Ballester *et al.* (2018)**, reinforcing the growth-promoting potential of herbal supplementation in biofloc systems.

A commercial feed containing 35% protein was used during the experiment to meet the dietary requirements of prawns, in line with recommendations of **Sarman *et al.* (2011)** and **Becerril-Cortés *et al.* (2018)**. Adequate floc volume was maintained throughout the study, with protein content in the biofloc recorded at 21.7%. This is comparable to values reported by **Anand *et al.* (2013)** and **Rajkumar *et al*. (2015)**, who noted floc protein content ranging from 24.3o to 25.29%, thereby affirming the nutritional contribution of biofloc to prawn diets.

In conclusion, this study underscores the potential of integrating herbal extracts—particularly amla (AE)—with biofloc technology to enhance the growth performance, feed efficiency, and nutritional quality of *M. rosenbergii*. These findings add to the growing body of evidence supporting the adoption of natural feed additives and sustainable aquaculture practices, offering a practical solution for improving productivity and environmental sustainability in prawn farming.

CONCLUSION

This study provides compelling evidence for the beneficial role of herbal extracts—particularly amla (*Phyllanthus emblica*)—in enhancing the growth performance, feed efficiency, and nutritional quality of freshwater prawn (*Macrobrachium rosenbergii*) reared under biofloc technology (BFT) conditions. Among the treatments evaluated, the inclusion of amla extract at 200ml/ kg of feed (Treatment 3) consistently outperformed the control and other herbal treatments, yielding significantly higher weight gain, specific growth rate, and protein deposition in muscle tissue. The superior feed conversion ratio (FCR) and optimal body composition observed in this group further reinforce its potential as an effective natural growth promoter.

The integration of herbal extracts with biofloc systems not only enhances prawn productivity but also presents a sustainable and eco-friendly alternative to synthetic additives and antibiotics, addressing key environmental and food safety challenges in aquaculture. Moreover, the stable water quality parameters and increased microbial biomass associated with BFT contributed to improved survival rates and overall prawn health across treatments.

Given these promising outcomes, this research highlights the potential of combining biofloc technology with herbal feed additives—particularly amla extract—as a viable strategy for intensifying prawn aquaculture in Bangladesh and other tropical regions. To further validate these findings, long-term studies are recommended to assess the immunological responses, disease resistance, and economic feasibility of large-scale implementation.

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