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Original Research

The Potential of Using *Sesuvium portulacastrum* L. to Treat Wastewater from Whiteleg Shrimp Farming Combined with Tilapia Fish, Aiming to Reduce Emissions and Circulate Nutrients

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Abstract

The Recirculating Aquaculture System (RAS) effectively integrates agriculture and aquaculture but faces challenges in selecting suitable plant species for treating wastewater in brackish environments. This study evaluates *Sesuvium portulacastrum* L. for its potential to improve water quality and nutrient cycling in a batch and aquaponic system (four-tank system), which includes tanks for whiteleg shrimp, tilapia fish, and wastewater recovery. Results showed that 1 g of *S. portulacastrum* processed 0.397 mg NH_4^+, 0.030 mg NO_2^-, 5.276 mg NO_3^-, and 2.477 mg total phosphorus. Shrimp weight increased from 4.6 g to 16.5 g, while tilapia weight increased from 30 g to 67 g. Key water parameters remained stable in the *S. portulacastrum* model compared to the control. This improved RAS model demonstrates an energy-efficient and effective solution for water and nutrient cycling, applicable in both small-scale urban and large-scale aquaculture systems.

Keywords: water cycle, whiteleg shrimp, *Sesuvium portulacastrum* L., aquatic aquaponic model

Introduction

Sesuvium portulacastrum L. (*S. portulacastrum*) is a rapidly growing succulent plant that thrives in various coastal and saline environments, including mangrove forests, sandy areas, salt marshes, and salt fields. It is well-adapted to regions with annual rainfall between 50 and 150 cm and can withstand prolonged dry periods and saline conditions, making it suitable for a wide range of habitats across Asia, Africa, Australia, South America, and North America [1, 2]. *S. portulacastrum* is particularly valued for its high tolerance to both salt and drought, enabling it to thrive in salt flats and other challenging environments.

Traditionally, *S. portulacastrum* has been recognized for its nutritional content and therapeutic properties, including antifungal, anti-inflammatory, and antioxidant effects. It is used as an herbal remedy to treat various conditions, such as epilepsy, conjunctivitis, dermatitis, and toothaches, and can also be used as animal fodder [1]. The plant contains a range of chemical substances, including alkaloids, carbohydrates, glycosides,

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flavonoids, phenols, saponins, sterols, terpenoids, quinones, diterpenes, and resins, with polyphenols playing a significant role in protecting the plant from environmental stress by combating oxidative damage [3, 4]. Additionally, secondary metabolites from *S. portulacastrum* have potential applications in the food industry, perfumery, cosmetics, and pharmaceuticals [5].

S. portulacastrum also has unique industrial applications. In the Chinese silk industry, it is utilized to manage the final developmental stage of caterpillars due to its high levels of ecdysteroids. It is also applied in preserving goatskin, demonstrating efficacy comparable to conventional salt methods [6, 7]. Moreover, its ability to absorb heavy metals such as uranium, strontium, cesium, and europium from water highlights its potential for biological remediation, with maximum absorption occurring in the roots, followed by the stem and leaves [8]. Adapted to severe saline conditions, *S. portulacastrum* shows elevated levels of antioxidant enzymes under high salinity, performing optimally at NaCl concentrations between 100 and 400 mM, and can survive up to 1000 mM NaCl without significant leaf toxicity [1]. Salinity affects root development and photosynthesis, with optimal growth occurring at 200-600 mM NaCl. At these concentrations, the plant accumulates proline, polyphenols, carotenoids, and anthocyanins, which protect the photosynthetic system and support growth. Research on salt-stressed *S. portulacastrum* plants has identified soluble sugars and proline as key protective substances against salt permeability, with glutathione metabolism playing a crucial role in managing oxidative stress, making *S. portulacastrum* a valuable species for phytoremediation of saline soils [9].

Despite extensive research on the plant's salinity tolerance and various applications, a notable gap remains in understanding its systematic utilization in integrated aquaponic systems, particularly for treating wastewater in shrimp farming. *S. portulacastrum* shows promise in cleaning shrimp farming wastewater, which contains high levels of dissolved nitrogen and phosphorus, but its effectiveness in real-world aquaponic systems has not been thoroughly explored [10].

Previous phytoremediation studies have primarily focused on plant species less tolerant to salinity, such as *Phragmites australis*, *Typha* spp., and *Scirpus* (*Schoenoplectus*) spp., which are typically applied to urban wastewater or livestock effluents and cannot tolerate salinity levels above 5‰ [11]. This limitation underscores the need for highly salt-tolerant plants like *S. portulacastrum* in wetland systems designed for wastewater treatment [12, 13]. Constructed wetland (CW) models, which vary widely in scale, have shown nitrogen removal capacities ranging from 30% to 50%, depending on the CW type and inflow load [14, 15]. However, comparing the effectiveness of plant species across different CW models is challenging due to varying scales and conditions.

Therefore, this study investigates the effectiveness of *S. portulacastrum* in treating wastewater from shrimp farming within integrated aquaponic systems. It aims to evaluate the plant's potential to enhance water quality, reduce waste, and support sustainable shrimp farming practices. By exploring how *S. portulacastrum* can be integrated into these systems, this research seeks to address existing knowledge gaps and optimize its application for improved wastewater management and resource efficiency.

Methodology

Material

The *Sesuvium portulacastrum* plants were collected from high-salinity areas near salt fields in Ly Nhon commune, Can Gio district, Ho Chi Minh City, where soil salinity is 65‰. Each plant cutting, averaging 10 cm in length, was planted in foam planting beds (25 x 40 cm) with 3 cm diameter holes, stabilized using water-absorbing foam sheets. The plants were cultivated in seawater supplemented with Masterblend hydroponic solution (Masterblend 5-12-25 and Calcium nitrate 15.5-0-0). At the start of the experiment, the plants were 20 days old, averaging 9.20 ± 1.45 cm in height and 2g in weight, with 84 plants per tray.

Whiteleg shrimp and tilapia used in the study were raised at the Institute for Environmental and Resources experimental site. The tilapia were included to consume excess shrimp feed, thereby improving food utilization efficiency in the aquaculture system.

The water for shrimp farming was sourced from salt fields in Ly Nhon commune, with a salinity level of 10%, diluted to achieve a 10‰ salinity level and a pH of 7.6 for the experiment.

Experimental Procedure

Batch System: To evaluate the growth of *Sesuvium portulacastrum* and the removal of contaminants from shrimp farming wastewater over 7 days in a batch reactor without circulation.

1. Preparation of planting environment

Germinate *Sesuvium portulacastrum* plants in planting beds within a seawater environment. To enhance growth, add 5 grams of mineral salt to 5 liters of seawater. The mineral salt composition is as follows:

- Total Nitrogen (N): 15% (4.6% Nitrate Nitrogen, 0.4% Ammoniacal Nitrogen)
- Available Phosphate (P_2O_5): 12%
- Soluble Potash (K_2O): 25%
- Magnesium (Mg): 4.1% (Water Soluble)
- Sulfur (S): 5.4% (Combined Sulfur)
- Boron (B): 0.10%
- Copper (Cu): 0.05% (Chelated Copper)
- Iron (Fe): 0.30% (Chelated Iron)
- Manganese (Mn): 0.10% (Chelated Manganese)

- Molybdenum (Mo): 0.01%
- Zinc (Zn): 0.05% (Chelated Zinc)
- Calcium (Ca): 19%

2. Tank Setup:

- Distribute the prepared seawater with mineral salt into five separate tanks with dimensions of 65×42×16 cm. Each tank will contain 84 *S. portulacastrum* plants as described in Fig. 1.
- Add 10 liters of shrimp farming water from the shrimp seed tank to each tank. Note that the water will not be recirculated during this phase.

3. Initial Sampling and Analysis:

- On day 0, measure the initial concentrations of the following parameters in each tank: $N\text{-}NH_4^+$, $N\text{-}NO_2^-$, $N\text{-}NO_3^-$, and total phosphorus.
- After 7 days, collect samples from each tank, combine them into a single composite sample, and analyze the concentrations of the same parameters.

4. Control Experiment:

- Set up a control by pouring 10 liters of shrimp farming water from the shrimp seed tank into a separate plastic tank without planting *S. portulacastrum.*
- Leave the control tank undisturbed for 7 days. After this period, collect and analyze the samples.

5. Calculation of Processing Capacity:

The processing capacity of the hydroponic system could be calculated using the following formula:

$$\text{Processing capacity (\%)} = \frac{(C_{start} - C_{end}) * 100}{C_{start}} \quad (1)$$

Where:

- C_{start} (mg/L) is the initial concentration of $N\text{-}NH_4^+$, $N\text{-}NO_2^-$, $N\text{-}NO_3^-$ and total phosphorus;
- C_{end} (mg/L) is the concentration of these parameters after 7 days.
- While the treatment coefficient per gram of biomass can be calculated using the formula:

$$\text{Treatment coefficient (mg/g biomass)} = \frac{(C_{start} - C_{end}) \times 5 \times 10}{\sum \text{biomass}} \quad (2)$$

Aquaponic system: To evaluate the treatment capacity of the plant in a continuous system over 70 days.

Aquaponic System Design

The experimental setup for *Sesuvium portulacastrum* cultivation included three identical models as seen in Fig. 2, each consisting of four tanks:

- Tank 1 (a): A 1.5 m³ tank stocked with whiteleg shrimp.
- Tank 2 (b): A 0.5 m³ tank stocked with tilapia.
- Tank 3 (c): Five small tanks, each equipped with a floating raft planted with *S. portulacastrum*, with dimensions of 65×42×16 cm.
- Tank 4 (d): A 0.2 m³ tank used for sludge settling and excess water discharge.

The system also included a 35W air pump for Tank 1, with a capacity of 2.4 m³/hour, and a 28W water pump for Tank 2, with a capacity of 1350 liters/hour.

Control System Design

The control setup also comprised three identical models described in Fig. 3, which are similar to the experimental system but without S. portulacastrum plants, as follows:

- Tank 1 (a): A 1.5 m³ tank stocked with whiteleg shrimp.
- Tank 2 (b): A 0.5 m³ tank stocked with tilapia.
- Tank 3 (c): A 0.2 m³ tank.
- Tank 4 (d): A 0.3 m³ tank, each containing 4 kg of HDPE plastic substrate with specific dimensions (L×H = 11×7 mm) and a specific surface area of ≥ 850–1000 m²/m³.

Fig. 1. Schematic of the batch system model during 7 days.

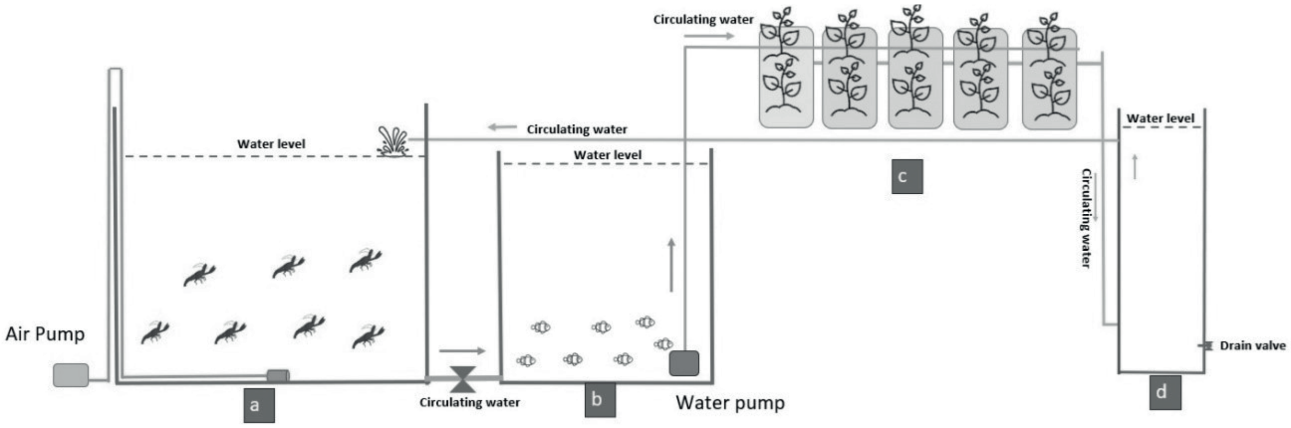

Fig. 2. Schematic of the aquaponic system.

The control system included a similar air blower and water pump addition with A 34 mm circulating water pipe.

Initial Conditions

The initial water supply for the experiment had a salinity of 10‰ and a pH of 7.6. The concentrations of N-NH_4^+, N-NO_2^-, N-NO_3^-, and total phosphorus were 3.91, 0.35, 53.6, and 33.2 mg/L, respectively.

- Whiteleg shrimp: Stocked at a density of 300 shrimp/m³, with an initial average weight of 4.20 ± 1.48 g.
- Tilapia: Stocked at a density of 30 fish/0.5 m³, with an initial average weight of 30.1 ± 2.98 g.

Feeding Regime

Whiteleg shrimp were fed a diet containing 39% crude protein four times daily (7:30 am, 12 pm, 5 pm, and 9 pm). The experiment lasted 70 days and was divided into 10 weeks, with feeding amounts increased weekly as follows: Week 1: 10 g/feeding; Week 2: 12 g/feeding; Week 3: 16 g/feeding; Week 4: 20 g/feeding; Week 5: 20 g/feeding; Week 6: 25 g/feeding; Week 7: 25 g/feeding; Week 8: 30 g/feeding; Week 9: 30 g/feeding; Week 10: 35 g/feeding. The same feeding regime was applied to both experimental tanks.

Procedure

A 28W submersible pump was installed in the fish tank (Tank 2) to circulate water from the bottom of the fish tank to the planted tank (Tank 3). Tanks 1 and 2 were connected via PVC pipes (diameter: 42 mm), allowing water to flow from the shrimp tank to the fish tank, where tilapia consumed the leftover shrimp feed. The water then flowed to Tank 3, where *S. portulacastrum* plants absorbed inorganic substances (N-NH_4^+, N-NO_2^-, N-NO_3^-) and other nutrients (replaced by circulation in the control experiment). Due to the tank design, the water flowed from Tank 3 to the sedimentation tank (Tank 4) and then back to the shrimp tank (Tank 1), completing the water cycle. The total area of floating vegetation on the two tanks was about 1.5 m². The experimental tanks were placed in a greenhouse with a glass roof, utilizing natural light ranging from 10.09 to 39.0 klx (with direct sunlight from 9 am to 2 pm). The average temperature was 28–29°C, with a maximum of 33°C and a minimum of 27°C.

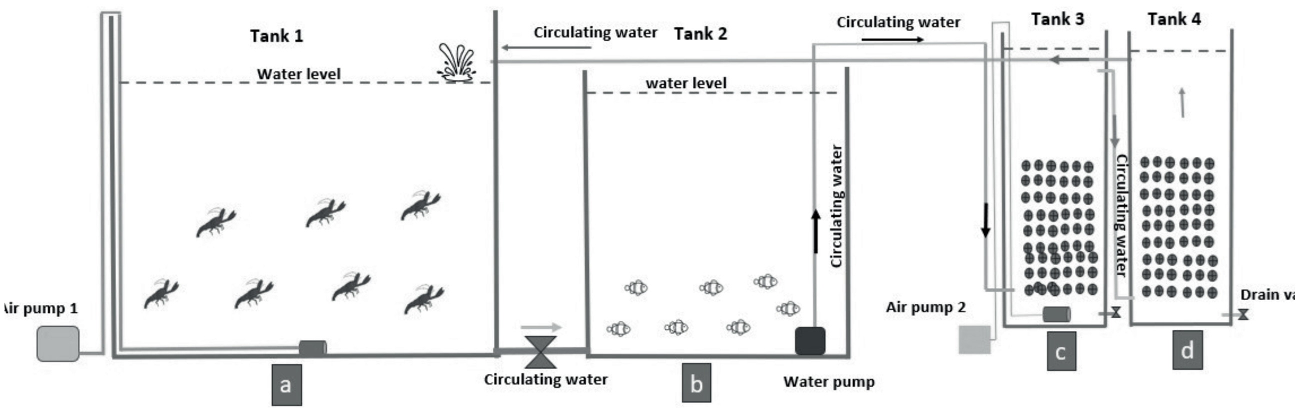

Fig. 3. Layout of the control culture setup.

Monitoring and Data Collection

Daily monitoring included dissolved oxygen (DO), pH, and salinity. Parameters such as $N\text{-}NH_4^+$, $N\text{-}NO_2^-$, $N\text{-}NO_3^-$, and total phosphate levels were analyzed at the beginning (day 0) and every 7 days. The shrimp growth was also monitored based on the weight and body length at the beginning and end of the experiment (70 days) with some monitoring indices:

$$\text{Average biomass at the end of the period (g)} = \frac{\text{biomass at the end (g)}}{\text{quantity of shrimp}} \tag{3}$$

$$\text{Weekly biomass gain (g/week)} = \frac{\text{average final biomass (g)} - \text{average starting biomass (g)}}{3} \tag{4}$$

$$\text{Average length (cm)} = \frac{\sum \text{length of 30 shrimp}}{30} \tag{5}$$

$$\text{Growth in length by week (cm/week)} = \frac{\text{Final length} - \text{initial length}}{3} \tag{6}$$

$$\text{Survival rate (\%)} = \frac{\text{Number of individuals at harvest}}{\text{Number of initial individuals}} \times 100 \tag{7}$$

$$\text{Weight gain (g)} = \text{end-of-period biomass (g)} - \text{initial biomass (g)} \tag{8}$$

$$\text{Feed Conversion Ration (FCR)} = \frac{\text{Total feed consumption}}{\text{weight gain}} \tag{9}$$

The growth of *S. portulacastrum* was also determined at the end of the experiment, including indicators such as average stem height and average fresh weight.

Data Analysis

Water samples were collected and processed systematically throughout the day to ensure thorough data acquisition. Specifically, two liters of water were extracted from the shrimp tank and transported to the laboratory. In the laboratory, the samples were filtered using a 0.45 µm pore size filter paper to remove sediment, algae, and other particulate matter. Following filtration, the samples underwent decontamination according to standardized procedures.

The analysis involved measuring various parameters: Ammonium ($N\text{-}NH_4^+$) levels were determined using SMEWW 4500-NH3 B&F:2017, phosphate ($P\text{-}PO_4^{3-}$) levels were analyzed as per SMEWW 4500-P.D:2017, nitrate ($N\text{-}NO_3^-$) was assessed with SMEWW 4500-NO_3^- .E:2017, and nitrites ($N\text{-}NO_2^-$) were evaluated according to SMEWW 4500-NO_2 B:2017. Daily measurement indicators included salinity, measured with an EC170 Extech (USA), pH, determined with an AZ 86021 (Taiwan), and dissolved oxygen (DO), assessed using a Milwaukee Mi605 (USA). Tree length was measured with a ruler, and fresh weight was recorded using a Nhon Hoa Scale with an accuracy of ±1 g.

Phytoplankton samples were collected using a Juday phytoplankton net with a mesh size of 20 µm, following SMEWW 10200B:2012 guidelines. These samples were fixed in situ with a saturated formalin solution, achieving a final concentration of approximately 4%. Marine phytoplankton identification was performed as previous study [16]. Quantitative analysis was carried out with a Sedgewick Rafter counting chamber, as outlined in SMEWW 10200:2017.

Data processing was executed using Microsoft Excel. The analysis involved calculating mean and standard deviation, with statistical significance tested using a p-value threshold of < 0.05. Results were visualized with descriptive statistics and charts to clearly communicate the findings.

Results and Discussion

Batch System

The efficacy of *Sesuvium portulacastrum* (*S. portulacastrum*) in treating nutrient-rich water from shrimp farming was assessed. The results, as depicted in Fig. 4a, indicate that *S. portulacastrum* significantly reduced nutrient concentrations compared to the control tank. Specifically, the concentration of ammonia ($N\text{-}NH_4^+$) decreased from 3.91 ± 0.01 mg/L to 0.05 ± 0.002 mg/L, achieving a reduction of 98.7%. Nitrate ($N\text{-}NO_3^-$) levels fell from 53.48 ± 0.006 mg/L to 2.24 ± 0.046 mg/L, representing a 95.8% reduction. Similarly, nitrite ($N\text{-}NO_2^-$) levels dropped from 0.31 ± 0.015 mg/L to 0.02 ± 0.002 mg/L, a decrease of 92.7%. Total phosphorus concentrations decreased from 33.60 ± 0.015 mg/L to 9.55 ± 0.026 mg/L, which is a reduction of 71.6%.

While in the control tank (which did not utilize *S. portulacastrum*) demonstrated lower nutrient removal efficiencies: 30.69% for $N\text{-}NH_4^+$, 34.04% for $N\text{-}NO_2^-$, 14.82% for $N\text{-}NO_3^-$ and 23.22% for total phosphorus. These results suggest that *S. portulacastrum* is substantially more effective at nutrient removal compared to traditional methods. The higher efficiencies observed in the *S. portulacastrum* treatment tank—68.02% for $N\text{-}NH_4^+$, 58.72% for $N\text{-}NO_2^-$, 80.99% for $N\text{-}NO_3^-$and 48.36% for total phosphorus—underline its superior performance in nutrient reduction.

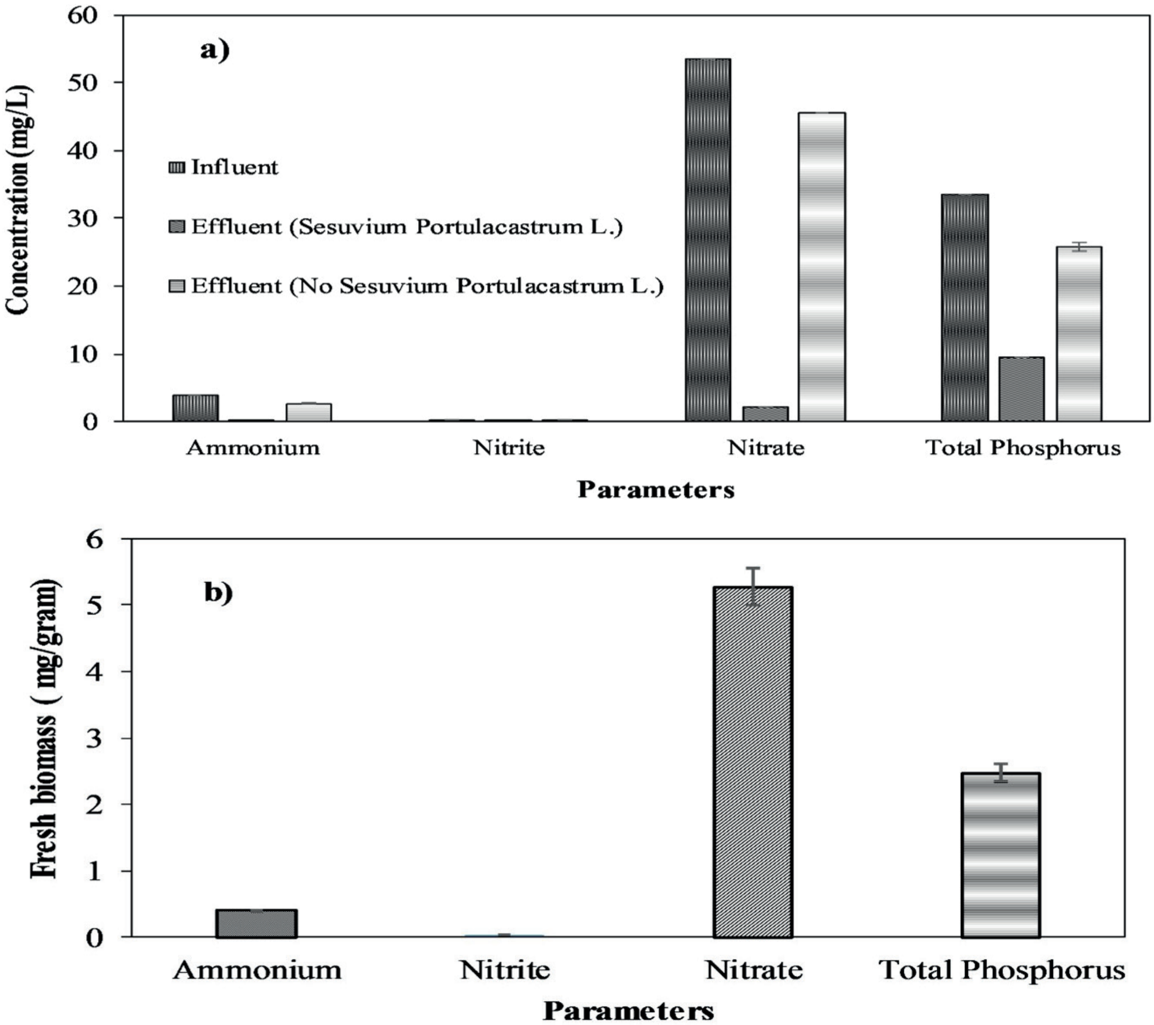

Fig. 4. Variation a) and accumulation b) of nutrients in the batch reactor.

Fig. 4b illustrates the nutrient removal capacity per gram of *S. portulacastrum*. Each gram of the plant can process 0.397 mg of N-NH_4^+, 0.030 mg of N-NO_2^-, 5.276 mg of N-NO_3^-, and 2.477 mg of total phosphorus. These findings align with Buhmann et al. (2015) [17] and Hu et al. (2015) [18], who reported the effectiveness of plants in reducing excess nutrients in aquaponic systems.

Aquaponic System

Fig. 5 shows the variations in nutrient concentrations in both the aquaponic system with *S. portulacastrum* and the control system over 70 days. High ammonia (NH_3) levels can adversely affect shrimp health, impairing organs such as gills and hepatopancreas, and increasing susceptibility to disease. The nitrification process, facilitated by *S. portulacastrum*, efficiently converts NH_3 to less harmful nitrate (NO_3^-) and nitrite (NO_2^-), enhancing water quality and shrimp health [19]. The increased dissolved oxygen levels in the *S. portulacastrum* tank further support the nitrification process.

In the control tank, nutrient concentrations increased over time due to waste accumulation, leading to elevated levels of NH_4^+, NO_3^-, NO_2^-, and PO_4^{3-}, particularly after day 14. This finding is consistent with previous studies indicating reduced efficiency in nutrient removal without plant intervention [20].

During the treatment, temperature and salinity were maintained at 28–29°C and 10 ppt, respectively. Fig. 6 illustrates that pH levels in the *S. portulacastrum* cultivation tank fluctuated between 7.49 and 7.96 but exhibited a decreasing trend over 70 days. Dissolved oxygen (DO) levels remained stable within the range of 6.10 to 6.86 mg/L. In the control tank, pH decreased from 7.95 to 6.97, and DO decreased from 6.70 mg/L to 5.07 mg/L. Both tanks maintained pH and DO levels within the permissible limits set by the Vietnamese national technical regulation on aquaculture water quality (DO ≥ 3.5 mg/L; pH: 7.0 – 9.0).

These results suggest that *S. portulacastrum* not only improves nutrient removal but also helps in maintaining better water quality parameters, consistent with He et al. (2022) [21].

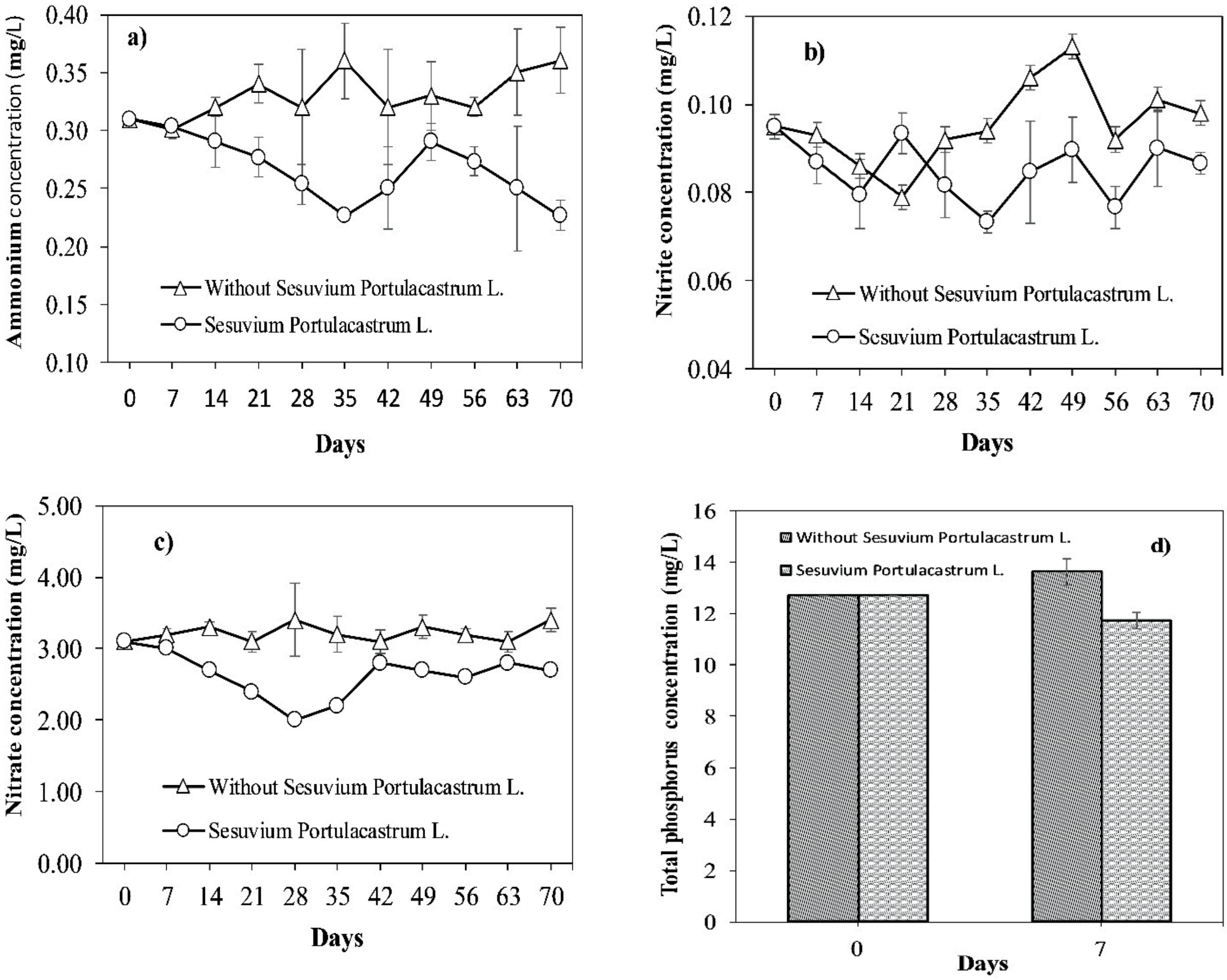

Fig. 5. Nutrient content variables in aquaponic and control system.

The good quality of water was evidenced by the analysis of phytoplankton composition and density in both tanks. Table 1 summarizes the findings. A total of 21 phytoplankton species were identified, with *Bacillariophyceae* (38.1%), *Cyanobacteria* (33%), and *Chlorophyceae* (28%). Although the species composition was similar between the tanks, the density of phytoplankton was notably different. The lower density of parasitic plants in the *S. portulacastrum* tank (2,842,400 individuals/L) compared to the control tank (9,442,310 individuals/L) indicates effective management of algal populations [22].

Shrimp growth and survival were significantly better in the *S. portulacastrum* tank. Table 2 summarizes shrimp growth and feed conversion metrics. The shrimp in the *S. portulacastrum* tank showed an average biomass increase from 4.20 ± 1.46 g to 19.01 ± 1.81 g, with a survival rate of 92.67% and a feed conversion ratio (FCR) of 1.62. In the control system, the average biomass increased to 16.30 ± 1.16 g, with a survival rate of 68% and an FCR of 3.13. These results reflect the positive impact of *S. portulacastrum* on shrimp health and productivity [23].

The growth of *S. portulacastrum* over the 70-day trial was substantial. The average plant height increased from 9.20 ± 1.45 cm to 39.28 ± 8.306 cm. The total fresh biomass of the *S. portulacastrum* reached 9,627.33 grams, with a fresh yield of 6.42 kg/m^2. These findings confirm that *S. portulacastrum* is well-suited for use in aquaponic systems, supporting water recirculation and reducing pollution discharge [17].

Comparison with Previous Studies

Numerous studies worldwide have explored the use of plants for treating water, soil, and air pollution. These studies have utilized a range of plant species, including woody, herbaceous, terrestrial, and aquatic plants. However, research specifically targeting the use of salt-tolerant plants for treating high-salinity wastewater (salt ≥ 10‰) has been relatively limited. The following Table 3 summarizes recent studies on salt-tolerant plant species used for brackish wastewater treatment:

The effectiveness of different plant species in wastewater treatment is complex. The treatment efficacy is influenced by several factors, including the plant

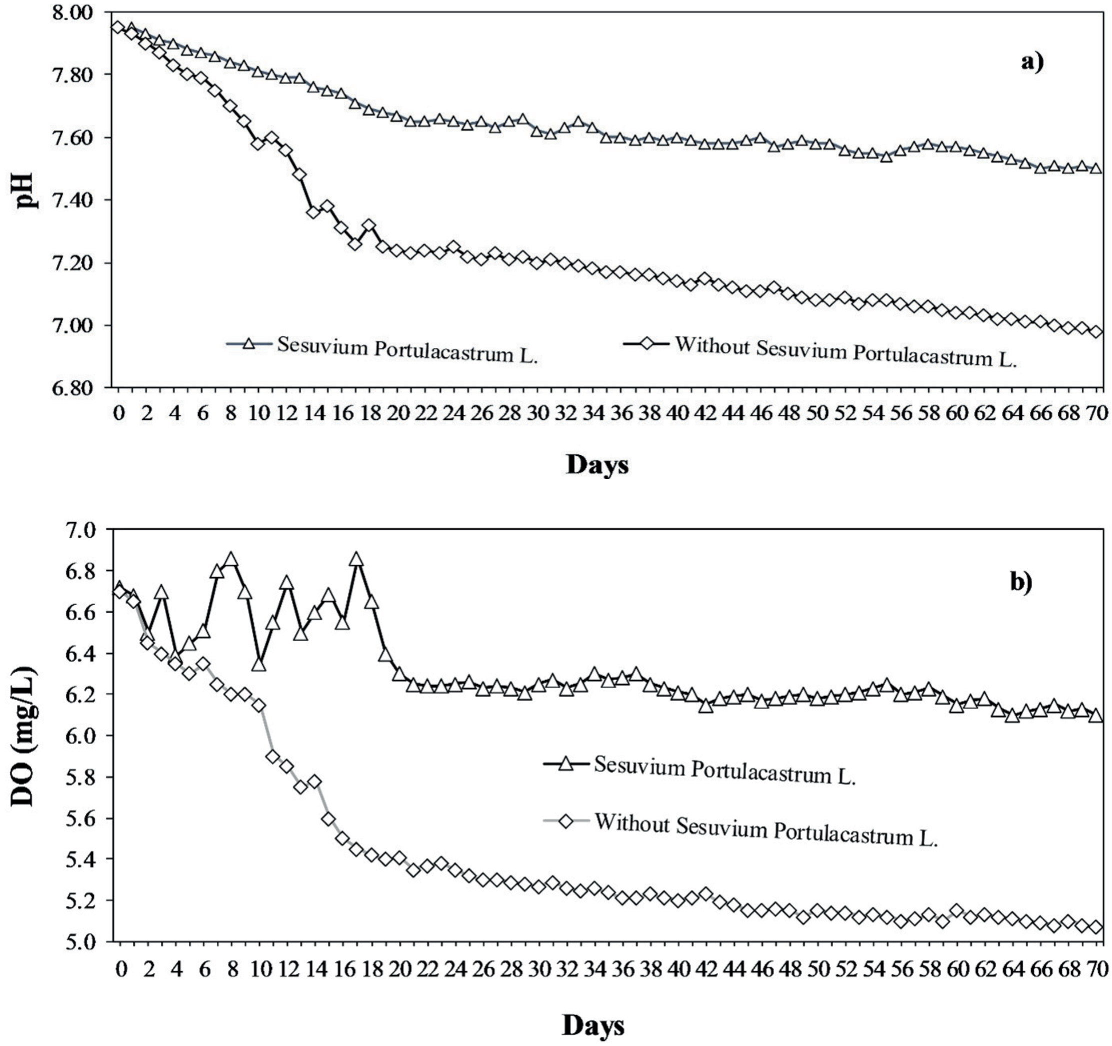

Fig. 6. Variation of pH and DO parameters in aquaponic and control system.

Table 1. Phytoplankton composition and density.

Phylum/Group	Day 0 Density (individuals/L)	Day 70 Density (individuals/L)
Cyanobacteria	72,000	142,000
Bacillariophyceae	34,300	51,100
Chlorophyceae	764,300	2,649,300
Total	870,600	2,842,400

species, the type of cultivation system (e.g., floating beds, sand, gravel), and the design of the treatment system. Additionally, the involvement of microorganisms, which are crucial for treatment, depends on environmental factors such as nutrient availability, pH, and salinity.

For instance, the study by Zhang et al. [11] using *S. portulacastrum* involved treating 3 liters of aquaculture wastewater with four plants at an experimental temperature of 24°C. However, the pH and salinity parameters were not provided. These factors are significant as they can affect both plant and microbial activity. While Quoc et al. [13] confirmed the qualitative effectiveness of *Sonneratia Caseolaris* in treating wastewater with nitrogen and phosphorus components, a detailed quantitative analysis was not included.

Fernando García-Ávila [15] reported a nitrogen removal rate of 20 mg N/m²/day for *Phragmites australis*. This is compared to the primary production requirements for nutrient uptake by *Rhizophora apiculata*, which are approximately 109.43 to 173.549 kg N/ha/year and 5.467 to 8.12 kg P/ha/year, respectively [24]. The findings showed that the treatment efficiency reached 383 mg N/m²/day, demonstrating the superior performance of *S. portulacastrum.* This high nitrogen removal efficiency is likely due to the species' rapid growth rate and its ability to accumulate nutrients as plant proteins.

Table 2. Shrimp and Tilapia growth metrics.

Metrics	-	*Sesuvium Portulacastrum*	Control
	Day 0	Day 70	Day 70
Shrimp	-	-	-
Average biomass (g)	4.20±1.46	19.01±1.81	16.30±1.16
Average length (cm)	7.86	13.34±0.43	12.66±0.27
Biomass total (g)	1,260	5,285	3,342
Total number of shrimp	300	278	205
Survival rate (%)	-	92.67	68.33
Feed conversion factor	-	1.62	3.13
Tilapia	-	-	-
Average biomass (g)	30.1	53.2	52.5
Total number of tilapia	30	30	30

Table 3. Salt-tolerant plant species utilized for brackish wastewater treatment.

Plant species	Target	Wastewater sources	Models	Reference
Sesuvium Portulacastrum	BOD, COD, N, P,	Aquaculture	Hydroponics	[11]
Sonneratia caseolaris.	Total N, P	Aquaculture	Constructed Wetland	[13]
Phragmites Australis	COD, BOD, P, N, *coliform*	Urban wastewater	Constructed Wetland	[15]
Rhizophora apiculata.	Zn, Cr, TN, TP and antibiotic	Aquaculture	Constructed Wetland	[24]
Sesuvium Portulacastrum	BOD, COD, N, P,	Aquaculture	Batch System Aquaponic system	This study

Conclusions

The research shows the potential application of the RAS model for combined shrimp-fish-*S. portulacastrum* cultivation in brackish water regions. In this model, the *S. portulacastrum* plant can eliminate nitrogen and phosphate compounds, helping to treat and control the water quality in the farming ponds while maintaining shrimp farming efficiency alongside the plant's good growth. Additionally, the green biomass from the *S. portulacastrum* plant can be utilized as feed in livestock farming, creating two food sources from one aquaculture system, thereby improving productivity and income in aquaculture. Further research issues to be investigated after this report include assessing the microbial community in the experimental model, analyzing the mineral content input and output of the model, and experimenting with using biomass from the *S. portulacastrum* plant for aquaculture feeding.

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Conflict of Interest

The authors declare no conflict of interest.

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