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ASSESSMENT OF DESIGN INDOOR CULTURE SYSTEMS FOR PRODUCTION OF GLADIATOR SWIMMING CRAB (CALLINECTES PALLIDUS, ROCHEBRUNE, 1883)

MORFOW NKEZE PAUL[1], , BENEDICTA OSHUWARE MBU OBEN[2], NOR AZMAN KASAN[1]*

[1)] Higher Institution Centre of Excellent (HICoE), Institute of Tropical Aquaculture and Fisheries, Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, Malaysia.
[2] Department of Animal Sciences, University of Buea, Republic of Cameroon

Corresponding author: norazman@umt.edu.my

Abstract

This study investigated the growth performance, survival, and water quality variations in Gladiator swimming crab (*Callinectes* sp.) aquaculture across three different systems: Recirculating Aquaculture System (RAS) with ultraviolet filter (System A), RAS without ultraviolet filter (System B), and a flow-through system (System C). Initial growth performance assessments showed a uniform average initial weight of 1.63 g across all systems. After six weeks, significant differences in final weight, carapace length, and width were observed among the systems (p<0.05). Crabs in System C exhibited the highest growth performance, achieving a final average weight of 16.45 ± 0.58 g, a Specific Growth Rate (SGR) of 35.50 ± 1.0%, and carapace measurements of 31.45 ± 1.34 mm in length and 52.40 ± 0.93 mm in width. Statistical analyses revealed strong correlations between water quality parameters and growth performance metrics, with ammonia nitrogen concentrations showing a significant relationship with specific growth rate and weight gain. These findings highlight the importance of optimized water quality management and appropriate feeding strategies in enhancing the growth and survival of Gladiator swimming crabs in aquaculture systems. The study concluded that flow-through systems offer the most favourable environment for *C. pallidus* growth, particularly when combined with trash fish feeding. These results can inform future aquaculture practices and contribute to the sustainable production of Gladiator swimming crab in tropical regions.

Keywords: Advanced technology; trash fish; Ultra violet filter; production systems; crab aquaculture.

1. INTRODUCTION

Globally, aquaculture is expanding due to the adoption of new farm technology and systems of production, which often require less water and culture area. These technologies have made it possible to culture aquatic organisms in any geographical locations, either on land or open water bodies.

Generally, these technologies allow for intensive production and are quite easy to manage with their wastewater released in a controllable manner into the environment. Furthermore, these systems such as the Recirculating Aquaculture System (RAS) and Flow Through System (Raceway) are very suitable for intensive production of most species both finfish and shellfish. In addition, their flexibility in mode of operation have greatly facilitated research, discoveries and diversification of several aquatic organisms at their different stages of culture.

Globally, shellfish aquaculture of shrimps and crabs has been on the increase on global scale. In terms of preference in demand of aquaculture production, crustacean aquaculture products are top on global market. Crustacean production is rapidly spreading worldwide, and the production has been expanding since the last decade (Bondad-Reantaso *et al*., 2012; Rocha *et al*., 2022). In 2012, freshwater finfish (57.9%) dominated the world aquaculture production, while total crustacean production stood at 6.4 million tons, representing just 9.7% of total aquaculture food fish production and 22.4% was the total monetary value (FAO, 2014). Top amongst the cultured crustaceans were penaeid shrimps, freshwater prawns and crabs that are highly appreciated and commercialized (Alfaro-Montoya *et al*., 2019).

Since 2022, global crab and crab meat production was reported at 3.6MT with a commercial value estimated at 33.1billion US dollars (FAO,2024). China still leading as a major producers followed by other Asia Pacific regions such as Indonesia and India while the United States remains a leading importer (FAO, 2024). According to FAO (2024) production trend has known some fluctuation observed in some countries. This is argued on insufficient technical knowledge in production technology and management. Thus, it is expedient for advance technology to be deployed for crab culture to curb environmental and production challenges and ensure sustainable production of crabs.

2. MATERIAL AND METHODS

The study was conducted in the coastal town of Limbe, located in the Fako Division of the Southwest Region of Cameroon. Limbe is Cameroon's third-largest port, following the nearby port of Douala. The study site was centred at the Divisional Delegation of Livestock, Fisheries, and Animal Industries (MINEPIA) in Limbe.

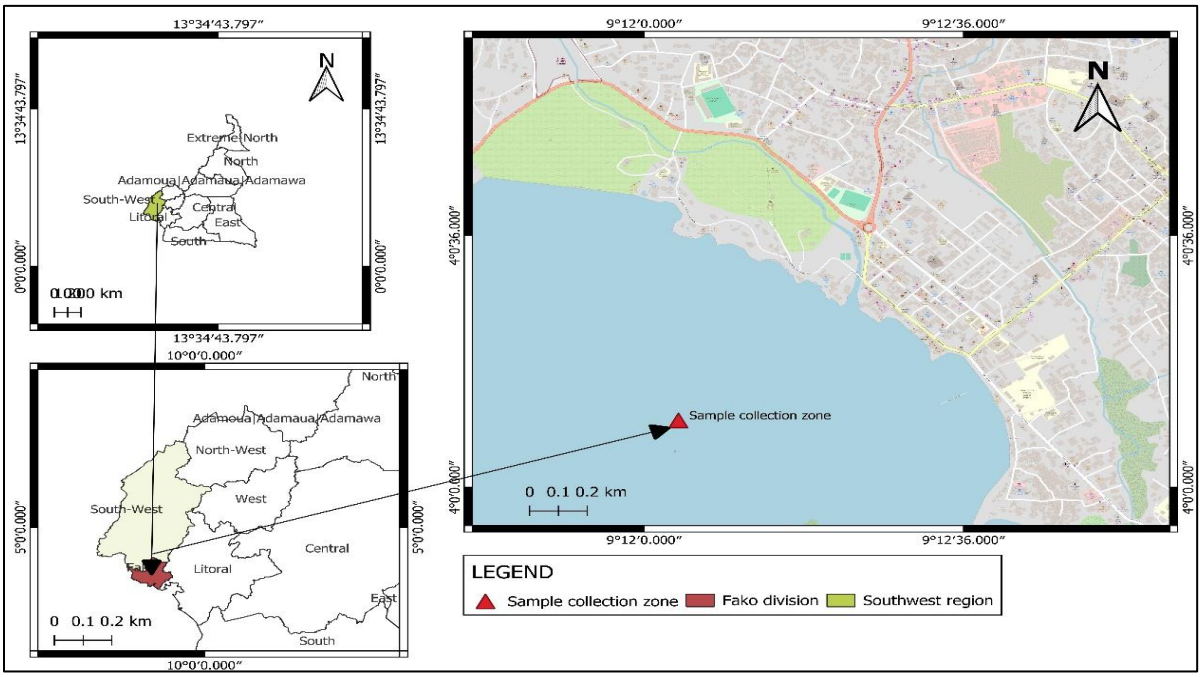


Figure 1: Map of research area in Limbe Cameroon.

Juvenile of *Callinectes* spp. were caught from the wild using seine nets deployed during low tide and at specific depths 50 to 200m. They were strategically trapped from target areas of high crab activity, ensuring minimal environmental disturbance. Specifically, from clean, clear ocean water in the early morning to ensure minimal stress during transport. The collected crabs were transported to the laboratory using transparent plastic containers equipped with portable aerators. Upon arrival, the crabs were quarantined for 24 hours to ensure their safety and acclimatization before the experiment commenced (Shelley & Lovatelli, 2011). Quarantining is critical in preventing pathogen introduction and reducing mortality rates before stocking.

2.1. Design systems

The RAS systems were constructed using locally available materials, including plastic containers and PVC pipes purchased from a nearby pet shop. Four rearing containers were plumbed to a sedimentation unit using normalized PVC pipes. The sedimentation unit contained locally sourced materials known as "kakabans," which trapped solid waste from the water. An electric pump was submerged in the sedimentation unit to lift water into the biofiltration unit (Timmons et al., 2002).

The biofilter was composed of imported filter blocks covered with a tarpaulin batch, which provided a suitable environment for the growth of nitrifying bacteria, including *Nitrosomonas* sp. and *Nitrobacter* sp. These bacteria facilitated the nitrification process, breaking down harmful ammonia into nitrites and subsequently into less harmful nitrates, thus maintaining water quality in the system (Chen et al., 2006). In System A, a 13-watt UV sterilizer was connected to the pipe transferring water from the biofilter back to the rearing containers, ensuring that pathogens were controlled before the water returned to the rearing tanks. In contrast, System B followed the same recirculation process but without passing water through a UV sterilizer, relying solely on the biofiltration unit for water treatment (Crab et al., 2007).

The three aquaculture system designs: Recirculating Aquaculture System (RAS) with UV filter (System A), RAS without UV filter (System B), and flow-through systems (System C) were constructed using similar materials and housed in an indoor environment to minimize environmental variability. Each system contained four plastic containers with a uniform volume of 24 liters of water per container and a total 120L per system. A total of 24 juvenile crabs with same average initial weight of 1.63g were randomly distributed across the three systems. Stocked at a rate of 2 crablets per 24-liter container. The crablets were maintained for 42 days, and all systems were monitored daily for water quality and crab growth parameters.

Detailed measurements of critical morphological parameters, including carapace width, length, and the distances between spines were recorded using digital calipers. Observed features were systematically documented in a standardized data sheet, which included measurements, coloration patterns, and spine arrangements. To confirm species-level identification, a dichotomous key was applied systematically (Saxena, 2005).

2.2. Experimental procedure

Crablets were fed a diet of trash fish of the species (*Sardinella maderensis*) and commercial catfish feed (Gouessant) crush into paste at a rate of 3 mg/L, constituting 5% of their body weight. Feeding occurred twice daily, at 08:00 AM and 05:00 PM. This feeding regime experiment was designs to access its influence on water quality, growth and survival rates of Crablets (Parker *et al.,* 2014). Trash fish was selected as a feed source due to its local availability and nutritional suitability for promoting growth in crabs (Lutz, 2003).

Water quality parameters such as temperature, salinity, pH, and dissolved oxygen were measured *in-situ* daily to monitor the environmental conditions in each system. More comprehensive parameters like hardness, alkalinity, ammonia, nitrates, and nitrites were measured at the beginning and end of the study (Boyd & Tucker, 1998). In System A (RAS with UV filter), water passed through a UV sterilizer before recirculating back into the rearing tanks, helping to control pathogen levels and maintain water quality. System B (RAS without UV filter), water followed the same recirculation pattern as in System A but without the use of UV filtration. System C (flow-through system), water was manually changed by replacing 20% of the total water volume every two days, ensuring that water was not recirculated but rather flowed through the system continuously. The experiment concluded after six weeks, and data on water quality were collected for further analysis.

2.3. Growth performance measurement

Growth was measured once a week by weighing a sample of crablets from each system. To ensure accuracy, one crablet per treatment container was randomly selected for weekly weighing. Each crablet was weighed using an analytical balance with a precision of 0.01 g, as outlined by Boyd & Tucker (1998). The mean wet body weight (BW) of the sampled crablets in each treatment was calculated and recorded. These mean BW values were used to track growth over time.

The Specific Growth Rate (SGR) was calculated at the end of the experiment using the following formula:

SGR (%) =

$$\frac{\text{InFinal body weight(g)} - \text{InInitial body weight (g)}}{\text{Culture period (day)}} \times 100$$ (Ikhwanuddin et al. 2012)

Where:

W_0 = InInitial body weight of the crablets (g)

W_t = InFinal body weight of the crablets (g)

t = Culture period (days)

The SGR was calculated for each system (System A, System B, and System C) to compare the growth performance across the different treatments. The initial body weight (W*o*) was measured at the start of the experiment, while the final body weight (W*t*) was measured at the end of the 42-day culture period.

Survival rates were monitored daily to assess the effect of trash fish feeding on crab health and viability. Any mortalities were immediately recorded, and the cause of death (if identifiable) was noted (Lutz, 2003). The total number of live crabs in each replicate was counted at the end of each week. The survival rate (%) for each system was calculated weekly using the following formula:

$$\text{Survival rate (\%)} = {}^{Number\ of\ live\ crabs}/_{initial\ number\ of\ crabs}\ X\ 100$$

Survival rates were compared between the systems to determine the impact of trash fish on crab survival under different rearing conditions.

The data collected from the experiment were analyzed using SPSS for Windows version 16.0. To assess whether there were statistically significant differences between treatments, ANOVA test was employed. This test was chosen to compare the means of different treatments and determine the impact of system design and trash fish feeding on the growth and survival of Atlantic blue swimming crabs (*Callinectes sp.*). Results were presented as means ± standard deviation (SD) to provide a clear understanding of the variability within each treatment group. Differences between treatments were considered statistically significant if the p-value was less than 0.05 ($p < 0.05$), following standard statistical conventions. This significance threshold allowed for the identification of meaningful differences between the growth performance and survival rates of crabs in the three culture systems. In addition, Principal Component Analysis and Canonical Correspondence analysis were also carried out using OriginPro2022.

3. RESULTS

3.1. Crab growth performance across the different systems

The growth performance of Gladiator swimming crabs (*Callinectes spp.*) was assessed across three aquaculture systems: RAS with UV filter (System A), RAS without UV filter (System B), and flow-through system (System C). The crabs had a uniform initial average weight of 1.63 g across all systems. After the 6-week experimental period, significant differences ($p < 0.05$) in final average weight were observed among the systems. Crabs in System C (flow-through system) exhibited the highest final average weight of 16.45 ± 0.58 g, followed by System A (RAS with UV filter) at 14.00 ± 0.63 g, and System B (RAS without UV filter) at 8.45 ± 0.46 g. The Specific Growth Rate (SGR) followed a similar trend, with System C demonstrating the highest SGR of 35.50 ± 1.0%, significantly surpassing System A at 29.67 ± 0.9% and System B at 16.24 ± 0.7% ($p < 0.05$). These results indicated that the flow-through system provided optimal conditions for weight gain and growth rate compared to the other systems.

Carapace length and width were also significantly influenced by the culture system ($p < 0.05$). The initial carapace length was uniform at 15.00 mm across all systems. After the experimental period, the final carapace lengths

were recorded as 31.45 ± 1.34 mm in System C, 29.45 ± 1.16 mm in System A, and 26.88 ± 0.97 mm in System B. Similarly, the initial carapace width was uniform at 31.00 mm across all systems, while the final carapace widths were 52.40 ± 0.93 mm in System C, 51.70 ± 0.95 mm in System A, and 47.50 ± 1.10 mm in System B. These findings highlight that System C consistently outperformed the other systems in facilitating carapace growth. Overall, the flow-through system (System C) demonstrated superior growth performance in terms of weight gain, SGR, and carapace measurements, followed by the RAS with UV filter (System A), while the RAS without UV filter (System B) exhibited the least favorable results.

Table 1: Overall crab growth performance in the different systems

Parameter	System A (Mean ± SD)	System B (Mean ± SD)	System C (Mean ± SD)
Initial Weight (g)	1.63 ± 0.0^{a}	1.63 ± 0.0^{a}	1.63 ± 0.0^{a}
Final Weight (g)	14.00 ± 0.63^{b}	8.45 ± 0.46^{c}	16.45 ± 0.58^{a}
Specific Growth Rate (SGR, %)	2.22 ± 0.9^{b}	1.70 ± 0.7^{c}	2.39 ± 1.0^{a}
Initial Carapace Length (mm)	15.00 ± 0.0^{a}	15.00 ± 0.0^{a}	15.00 ± 0.0^{a}
Final Carapace Length (mm)	29.45 ± 1.16^{b}	26.88 ± 0.97^{c}	31.45 ± 1.34^{a}
Initial Carapace Width (mm)	31.00 ± 0.0^{a}	31.00 ± 0.0^{a}	31.00 ± 0.0^{a}
Final Carapace Width (mm)	51.70 ± 0.95^{b}	47.50 ± 1.10^{c}	$52.40 \quad 0.93^{a}$

3.2. Survival rate of crabs in each system

Table 2 presents the Feed Conversion Ratio (FCR) and Survival Rate of blue crabs across the three experimental systems. The FCR values indicated that System A had a significantly better feed conversion efficiency (1.45) compared to System B (3.10), while System C (1.40) demonstrated comparable efficiency to System A. The survival rate (%) showed notable differences, with System C achieving the highest survival rate at 50%, followed by System A at 37.5%, and System B with the lowest survival rate at 12.5%.

Table 2: Feed Conversion Ratio (FCR) and Survival Rate of blue crabs across the three experimental systems

Parameter	System A	System B	System C
Feed Conversion Ratio (FCR)	1.45	3.1	1.4
Survival Rate (%)	37.5	12.5	50

3.3. Water quality variation across the three systems

The water quality levels across the three systems—System A (RAS with UV filter), System B (RAS without UV filter), and System C (flow-through system) were monitored weekly throughout the six-week experimental period, revealing distinct trends in water quality management.

3.3.1. pH variation across the three systems

Initially, System B exhibited the highest pH (7.30), followed closely by System A (7.21) and System C (7.16). As the experiment progressed, System B consistently maintained the highest pH, reaching 7.40 by week 1, while System A increased slightly to 7.24, and System C dropped to 7.11. By week 2, System A experienced a significant rise to 7.56, whereas System B remained stable at 7.34, and System C showed only a minor increase to 7.21. During weeks 3 and 4, both System A and System C displayed relative stability, with pH values around 7.43 and 7.27, respectively, while System B exhibited minor fluctuations, dropping to 7.23 in week 3 but rebounding to 7.42 in week 4. In the final weeks, System A peaked at 7.79 in week 5 before stabilizing at 7.62 by week 6, while System B reached its highest pH of 7.80. In contrast, System C maintained the lowest pH levels throughout the study, concluding at 7.33 (Figure 1).

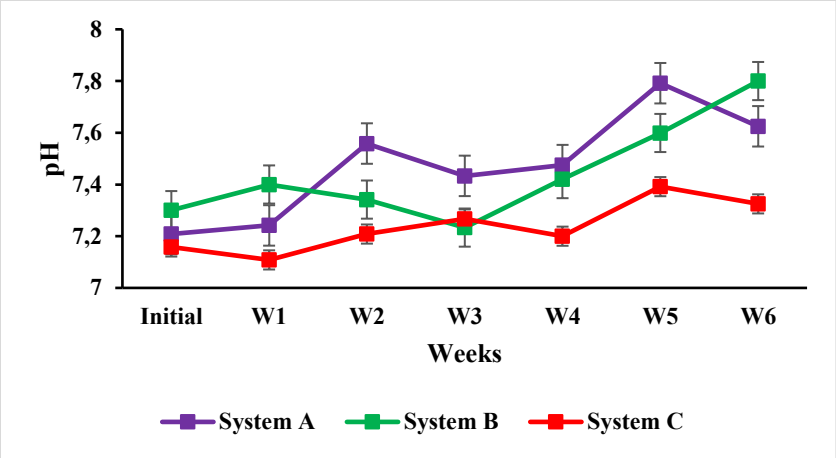


Figure 1: pH variation across the three systems

3.3.2. Temperature variation across the three systems

As illustrated in figure 2, initially, all systems had similar temperatures, with System C at 25.5°C, System B at 25.3°C, and System A at 25.1°C. During week 1, System A slightly increased to 25.5°C, while System C remained stable at 25.4°C, and System B held steady at 25.3°C. However, by week 3, System B experienced a significant spike to 29.5°C. In contrast, System A and System C maintained consistent temperatures at 26.4°C and 25.0°C, respectively. Throughout weeks 4 and 5, System A showed a stable range of 25.5°C to 26.1°C. System B stabilized after its spike, fluctuating between 25.2°C and 26.6°C, while System C exhibited minimal variation, staying between 24.9°C and 25.6°C. By week 6, temperatures were 25.7°C for System A, 26.6°C for System B, and 25.6°C for System C.

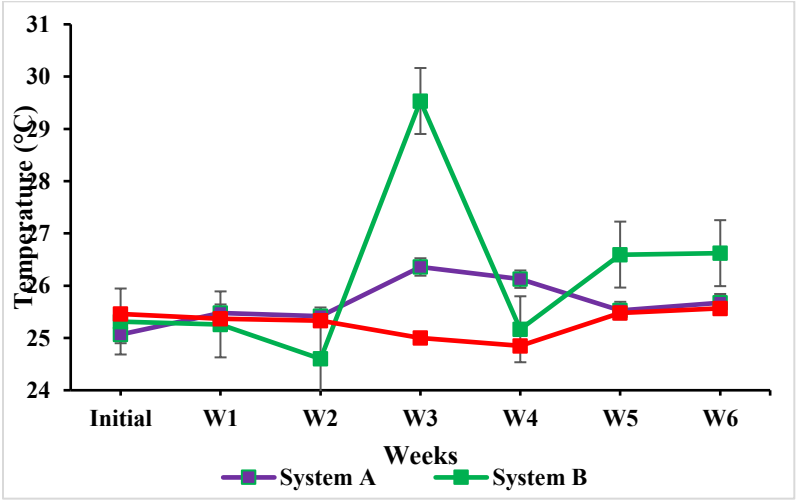


Figure 2: Temperature variation across the three systems

3.3.3. Alkalinity variation across the three systems

The alkalinity levels across the three systems—System A (RAS with UV filter), System B (RAS without UV filter), and System C (flow-through system) demonstrated significant variation throughout the six-week experimental period, highlighting the differences in water quality control (Figure 3). Initially, no variation were observed among the systems, as the baseline alkalinity values were similar: 67.8 mg/L for System A, 68.1 mg/L for System B, and 67.9 mg/L for System C, indicating uniform initial conditions. During week 1, alkalinity levels remained stable, with no variation among the systems. However, from week 2 onward, variations emerged, with Systems B (85 mg/L) and C (85.1 mg/L) showing notable increases compared to System A (67.9 mg/L), which experienced a more gradual rise.

In weeks 3 and 4, alkalinity levels converged across the systems, Nonetheless, by week 5, variations were observed, with System C exhibiting the highest alkalinity levels at 101.9 mg/L, compared to 84.9 mg/L in System A and 102.0 mg/L in System B. By week 6, System C maintained significantly higher alkalinity levels at 119.6 mg/L, while Systems A and B remained relatively stable at 101.9 mg/L and 102.0 mg/L, respectively.

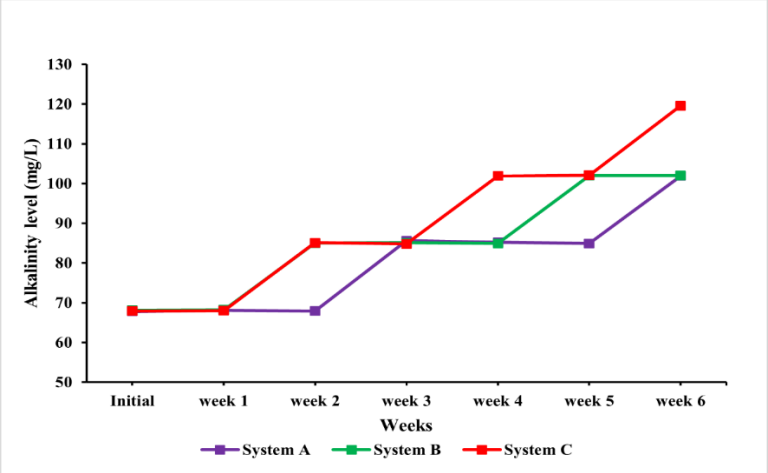


Figure 3: Alkalinity variation across the three systems

3.3.4. Salinity variation in the three systems

As shown in figure 4, the salinity levels of the three systems were monitored over six weeks to assess their stability and influence on crab production. At the initial stage, the salinity across all systems was relatively similar, with no significant variation observed. The initial salinity values were 32.8 ppt for System A, 32.6 ppt for System B, and 32.5 ppt for System C. Salinity levels remained stable within all three systems, with only minor fluctuations. In week 1, there were no significant variation across the systems, and this stability continued in weeks 2 and 3, with consistent salinity values of approximately 32.4 ppt for all systems. By week 4, System B showed a slight increase in salinity to 33.4 ppt. During week 6, a significant variation was observed, with System B showing the lowest salinity (32.1 ppt), different from System A (32.8 ppt) and System C (32.7 ppt).

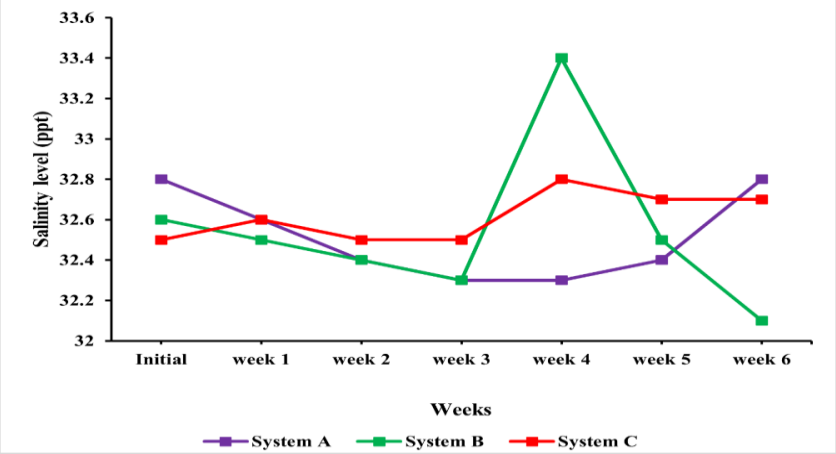


Figure 4: Salinity variation in the three systems

3.3.5. Dissolved Oxygen (DO) variation across the three systems

Figure 5 shows that at the initial stage, DO levels were relatively consistent, with System A and System B showing 7.4 mg/L and System C showing 7.2 mg/L. As the experiment progressed, a decline in DO was observed across all systems, though the pattern of reduction differed. By week 2, System B experienced a significant drop in DO (6.2 mg/L), which was notably lower than both System A and System C. However, in week 3 and week 4, the DO levels in all systems converged, with no significant variation among the systems. In week 5, System A and System C maintained similar DO levels at around 6.4–6.5 mg/L, but System B showed a relatively higher DO concentration of 6.8 mg/L. Then by week 6, System B exhibited the lowest DO level (5.8 mg/L), significantly lower than System A and System C, which recorded DO levels of 6.3 mg/L and 6.2 mg/L, respectively.

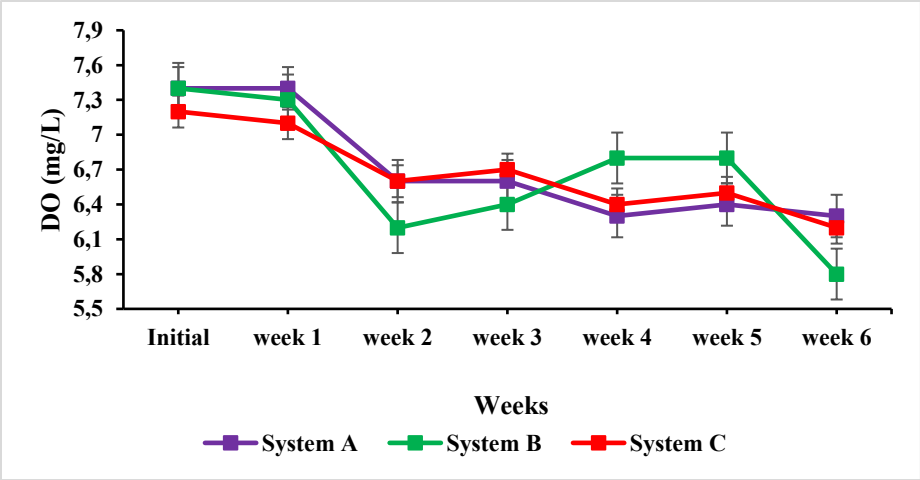


Figure 5: Dissolved Oxygen (DO) variation across the three systems

3.3.6. Ammonia nitrogen variation across the three systems

As shown in Figure 6, initially, NH_3-N levels were low and comparable across all systems, with System A and System C recording 0.03 ± 0.0 mg/L, while System B showed a slightly lower value of 0.02 ± 0.0 mg/L. There were no significant differences between the systems at this stage ($p > 0.05$). Throughout the study, NH_3-N levels increased, with noticeable fluctuations. By week 1, both System A and System C recorded an NH_3-N concentration of 0.3 ± 0.0 mg/L, while System B showed a slightly lower concentration of 0.2 ± 0.0 mg/L ($p > 0.05$). NH_3-N levels remained relatively stable in week 2 ($p > 0.05$). System A maintained an ammonia concentration of 0.14 ± 0.2 mg/L, while Systems B and C recorded 0.03 ± 0.0 mg/L and 0.04 ± 0.0 mg/L, respectively. By week 4, the ($p > 0.05$) concentration in System C increased slightly to 0.08 ± 0.0 mg/L than Systems A and B, both recording 0.06 ± 0.0 mg/L ($p < 0.05$). As from week 5, NH_3-N levels in System B increased sharply to 0.42 ± 0.5 mg/L, while Systems A and C maintained similar concentrations of 0.06 ± 0.0 mg/L and 0.08 ± 0.0 mg/L, respectively. Although the p-value for week 5 was not significant ($p > 0.05$), the rise in ammonia in System B could be attributed to its lack of UV filtration, leading to the accumulation of waste and inefficient breakdown of ammonia by nitrifying bacteria by the final week (week 6), all systems showed a marked increase in NH_3-N concentration, reaching 0.7 ± 0.0 mg/L across the board.

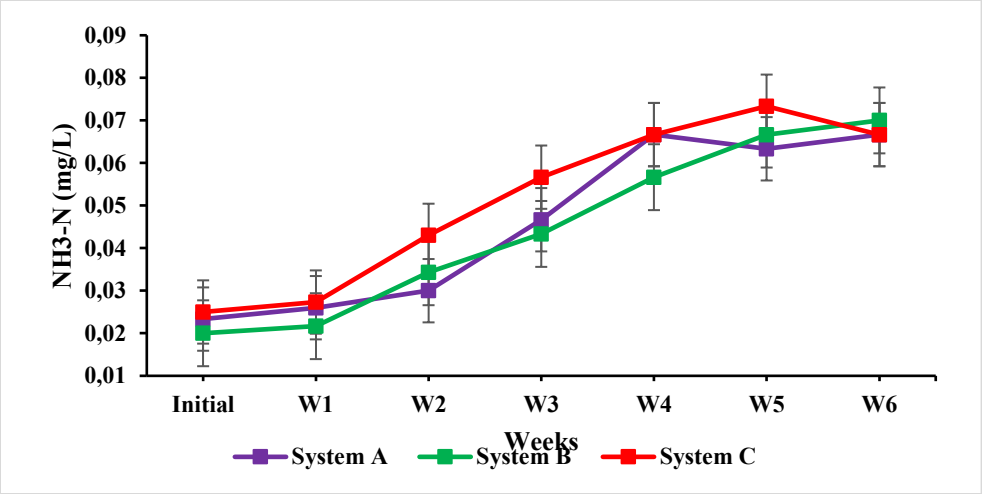


Figure 6: Ammonia nitrogen variation across the three systems

3.4. Water quality maintenance in each system

Water quality maintenance was aimed at improving and maintaining water quality at optimal level for crab culture.

3.4.1. pH maintenance in each system

The mean pH values for the three systems (System A, System B, and System C) were compared, revealing notable variations (Figure 7). System A had the highest mean pH (7.529 ± 0.160), followed closely by System B (7.425 ± 0.187), while System C recorded the lowest mean pH (7.121 ± 0.078). Pairwise statistical analyses showed no significant difference in pH values between System A and System B ($p > 0.05$). However, there was a highly significant difference between the pH of System A and System C ($p < 0.001$), with System A exhibiting a higher pH level. Similarly, the difference between System B and System C was statistically significant ($p < 0.01$), with System B had a higher pH than System C.

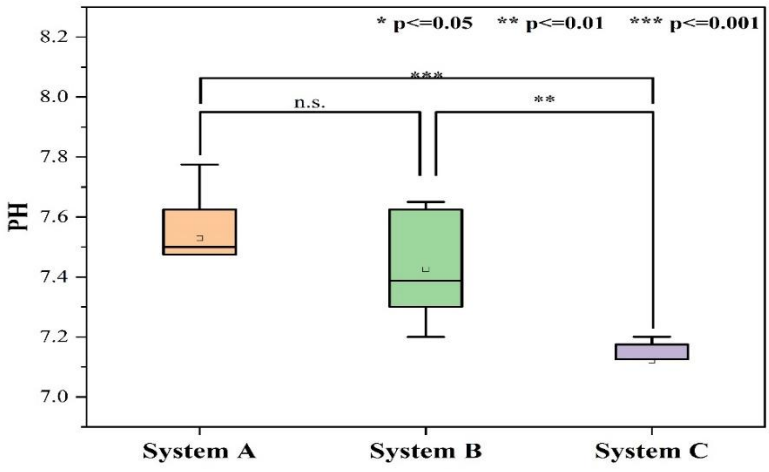


Figure 7: Mean level of pH in each system

3.4.2. Temperature maintenance in each system

In terms of temperature maintenance, System A (RAS with UV filter) provided the most stable conditions with a mean of 25.66 ± 0.48°C. System B (RAS without UV filter) exhibited the highest mean temperature at 26.16 ± 1.60°C, while System C (flow-through system) maintained the lowest average temperature at 25.29 ± 0.28°C with excellent stability. Pairwise statistical analyses showed no significant difference in temperature values between the systems (p> 0.05). Overall, System A demonstrated superior temperature consistency, while System B had the greatest variability as illustrated in figure 8.

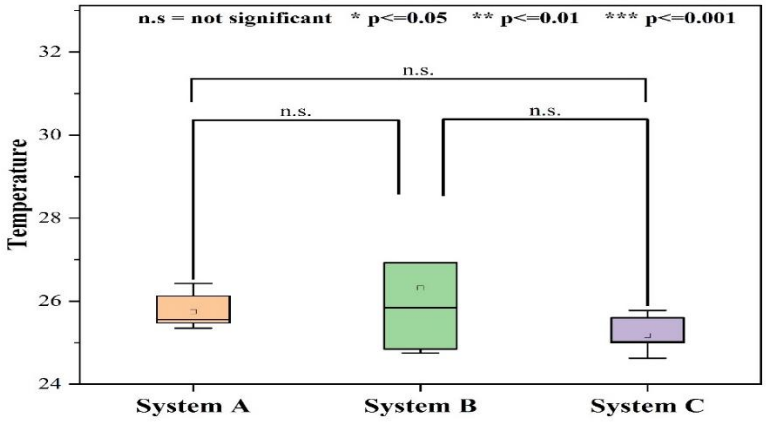


Figure 8: Mean level of temperature in each system.

3.4.3. Alkalinity maintenance in each system

The alkalinity levels were evaluated across the three systems, with System A recording a mean alkalinity of 82.17 ± 5.22 mg/L, while Systems B and C both recorded higher mean values of 93.50 ± 7.28 mg/L. Despite the observed differences in mean values, statistical analysis revealed no significant differences between the systems (p> 0.05). Pairwise comparisons confirmed that the alkalinity levels in System A were not significantly different from those in System B or System C, and similarly, no significant differences were observed between Systems B and System C (figure 9).

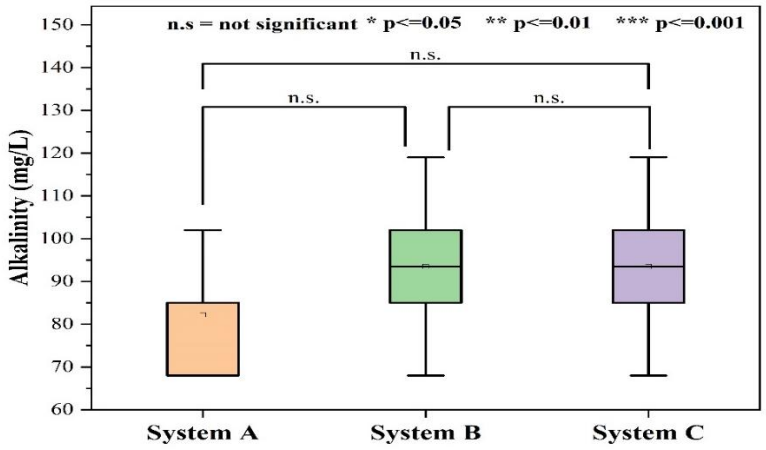


Figure 9: Mean level of alkalinity in each system

3.4.4. Salinity maintenance in each system

The salinity levels measured across the three systems (System A, System B, and System C) showed no statistically significant differences (p> 0.05), as indicated by the pairwise comparisons (Figure 10). The mean salinity

values for System A, System B, and System C were 32.49 ± 0.20 ppt, 32.52 ± 0.45 ppt, and 32.50 ± 0.09 ppt, respectively. These findings indicated that salinity was stable and uniform across the systems.

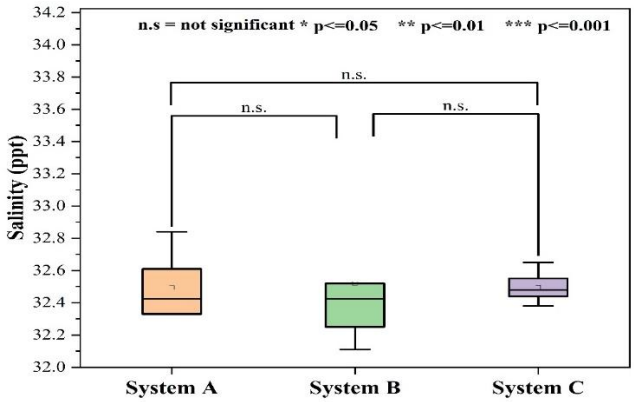


Figure 10: Mean level of salinity in each system

3.4.5. Dissolve oxygen maintenance in each system

According to figure 11, the dissolved oxygen levels were measured across the three systems, and no statistically significant differences were observed between the systems. The mean dissolved oxygen concentration for System A was 6.57 ± 0.16 mg/L, while System B recorded 6.51 ± 0.23 mg/L, and System C had 6.52 ± 0.11 mg/L. Pairwise comparisons revealed no significant differences between System A and System B, System A and System C, or System B and System C ($p > 0.05$). These results suggested that dissolved oxygen levels were consistent across the systems.

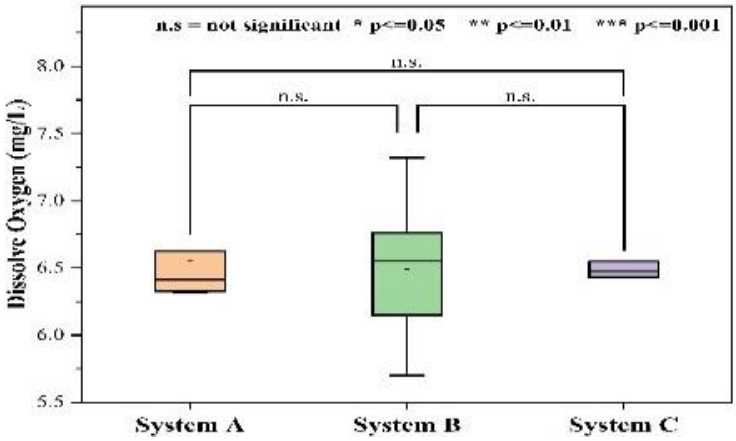


Figure 11: Mean level of dissolve oxygen in each system

3.4.6. Nitrogen ammonia maintenance in each system

The analysis of ammonia nitrogen levels across the three systems (A, B, and C) revealed slight variations in the mean values (figure 12). System A recorded a mean value of 0.0475 ± 0.0184 mg/L. System B exhibited a slightly higher mean of 0.0490 ± 0.0206 mg/L. System C showed the highest mean ammonia nitrogen level of 0.0553 ± 0.0196 mg/L. Pairwise comparisons between the systems indicated no statistically significant differences in ammonia nitrogen levels across the various systems ($p>0.05$). These findings suggest that the ammonia nitrogen levels are relatively consistent across the three systems.

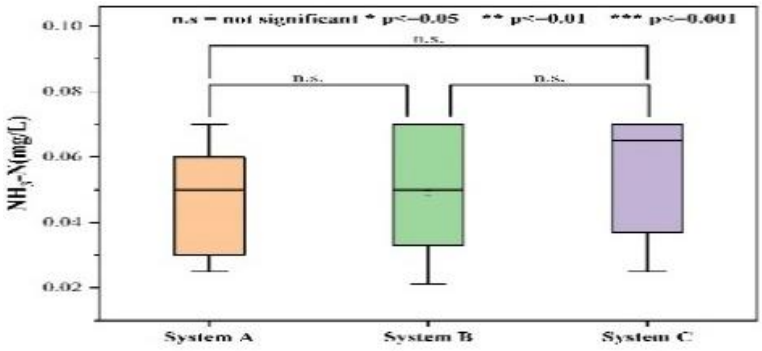


Figure 12: Mean level of nitrogen ammonia in each system

3.4.7. Correlation between water quality and growth performance

The correlation analysis between water quality parameters and growth performance metrics revealed several significant relationships (figure 13). pH showed a weak positive correlation with final weight (r=−0.39), weight gain (r=−0.39), and specific growth rate (r=−0.31), while demonstrating a moderate negative correlation with survival rate (r=−0.45). Temperature exhibited weak negative correlations with growth metrics such as final weight (r=−0.39) and weight gain (r=−0.39). Additionally, temperature showed a weak positive correlation with food conversion ratio (r=0.35).

Dissolved oxygen (DO) was weakly positively correlated with survival (r=0.04) and growth metrics. Ammonia nitrogen (NH_3^-) displayed strong correlations with growth metrics such as final weight (r=0.10) and weight gain (r=0.10). However, a negative correlation between ammonia and dissolved oxygen (r=−0.61) was observed. The growth metrics themselves, including final weight, weight gain, weight gain percentage, and specific growth rate, were highly positively correlated (r> 0.99), reflecting their interconnected nature as measures of production efficiency. Specific growth rate was strongly negatively correlated with food conversion ratio (r=−0.99). Survival rate demonstrated strong positive correlations with weight gain (r=0.99) and final carapace length (r=0.99).

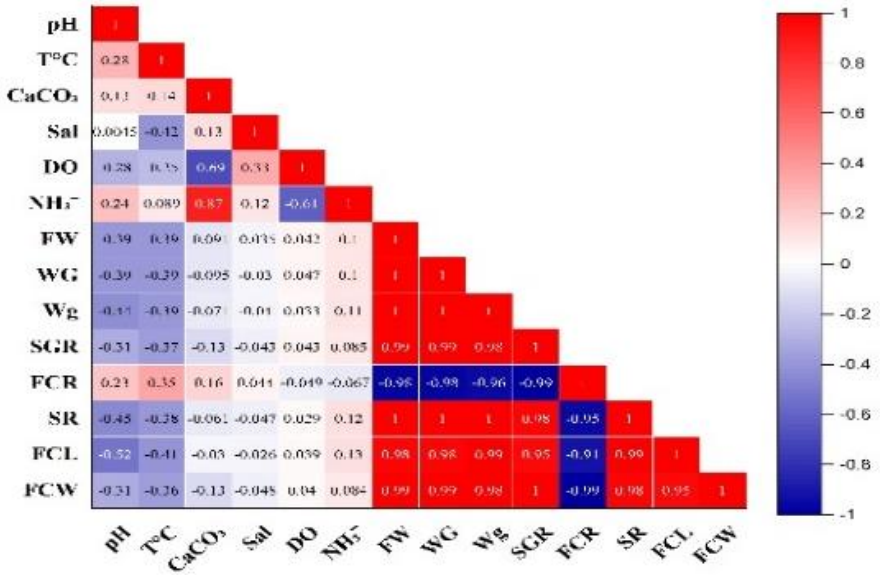
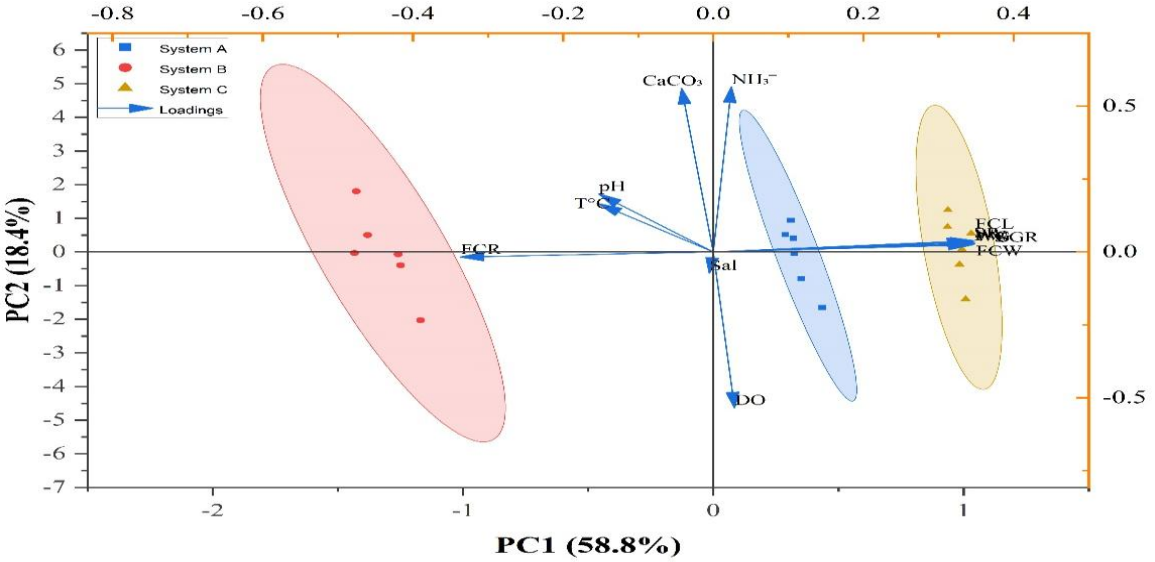


Figure 13: Correlation matrix between water quality parameters and growth parameters

3.4.8. Principal Component Analysis (PCA) of water quality and growth performance

Principal Component Analysis (PCA) was used to explore the relationships between water quality parameters and growth performance metrics across the three systems (Figure 14). The analysis revealed that the first principal component (PC1) explained 8.23% of the total variance, primarily driven by pH, which exhibited a strong negative loading (-0.15242). The second principal component (PC2) accounted for 2.57% of the variance, with temperature (T°C) emerging as a key contributor (-0.15255). Among the water quality parameters, DO had a strong negative loading in PC2 (-0.53481). NH_3^- exhibited a significant positive loading in PC2 (0.56578). Regarding growth metrics, weight gain (WG) and specific growth rate (SGR) showed positive loadings in PC2 (0.34766 and 0.34421, respectively), which showed strong correlations with ammonia nitrogen levels. Feed conversion ratio (FCR) displayed a negative loading in PC2 (-0.33703), signifying its inverse relationship with other growth performance indicators.
System clustering revealed distinct groupings based on water quality and growth performance. System A clustered separately, influenced by its association with pH and dissolved oxygen levels. System B was linked to temperature and moderate growth performance, clustering near intermediate values of ammonia nitrogen. System C, characterized by higher ammonia nitrogen levels, demonstrated superior growth performance metrics, including WG, SGR, and survival rate, clustering distinctly due to its optimized efficiency.

Figure 14: Principal Component Analysis of water quality and growth performance



3.5.

Influence of environmental conditions on growth performance

The relationship between environmental conditions and the growth performance of the cultured species was evaluated using canonical correlation analysis (figure 15). The analysis revealed strong correlations, particularly with the first canonical variate, which explained 64.43% of the total variation. The canonical correlation for this variate was 0.96619, suggesting a very strong association between environmental conditions (such as pH, temperature, ammonia nitrogen) and growth performance (including weight gain, specific growth rate, and feed conversion ratio).

The first canonical variate accounted for the largest portion of the variance in the data, with a Chi-squared value of 61.44 (p = 0.09197), approaching significance. The second canonical variate, with a correlation of 0.90181 and explaining 35.69% of the variation, showed a moderate association between water quality and growth performance metrics. However, the significance of this variate was lower (p = 0.43561), indicating a diminishing contribution to the explanation of variance in the data. Further canonical variates displayed progressively lower correlations and non-significant p-values. The key environmental factors that contributed most significantly to the first canonical variate included ammonia nitrogen (NH_3^-), with a coefficient of 33.65, and dissolved oxygen (DO), which had a coefficient of 0.57669. Temperature (T°C) and pH also had moderate contributions to this variate, with coefficients of 0.346 and -4.36104, respectively.

In terms of growth performance metrics, SGR was highly correlated with the first canonical variate, exhibiting a coefficient of 378.55, suggesting a strong positive relationship with water quality parameters, particularly

ammonia nitrogen and dissolved oxygen. FCR also showed a significant positive loading of 94.09. Weight gain (WG), with a coefficient of 17.47, similarly demonstrated a positive association with the first canonical variate.

The second canonical variate, which accounted for 19.75% of the variation, highlighted ammonia nitrogen (10.55) and temperature (0.6368) as important contributors. However, the effects on growth performance metrics were more mixed, with FCR (-57.48), weight gain (12.98), and specific growth rate (-185.24) showing varied contributions. Notably, some metrics like FCR exhibited negative coefficients.

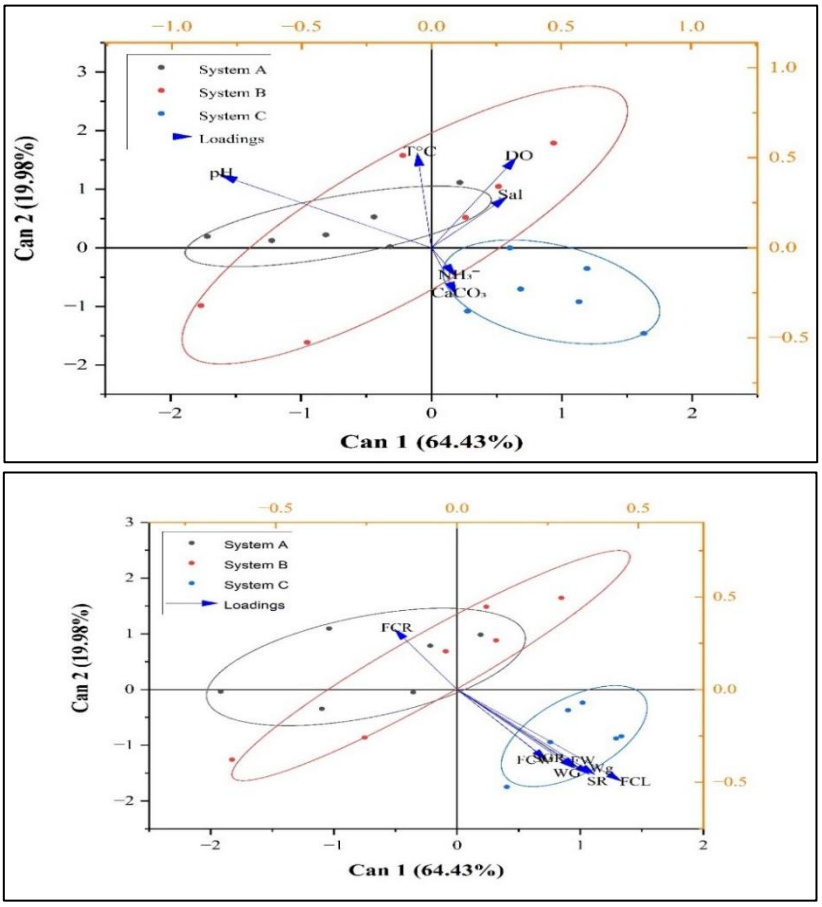


Figure 15: Cannonical Correspondence Analysis of environmental conditions and growth performance

4. CONCLUSION

The primary aim of this study was to design and construct three different indoor systems for the culture of Gladiator swimming crabs (*Callinectes* spp.) and to evaluate their overall performance in terms of production. The study aimed to raise awareness about sustainable crab culture in Cameroon, promote crab fattening for improved animal protein supply to enhance food security, and contribute to reducing the importation of frozen fish. Additionally, it sought to diversify and identify relevant potential crab species for marine aquaculture in the country.

The three experimental aquaculture systems; RAS with UV filter, RAS without UV filter, and flow-through system showed significant differences in crab growth performance. The flow-through system (System C) outperformed the other two systems, yielding the highest final weight, Specific Growth Rate (SGR), and carapace measurements. System C also had the highest survival rate at 50%, compared to 37.5% for System A (RAS with UV filter) and 12.5% for System B (RAS without UV filter).

Water quality parameters such as pH and ammonia nitrogen (NH_3-N) varied across the systems. System B (RAS without UV filter) showed fluctuations in pH and a higher increase in ammonia levels, potentially contributing to its lower crab survival rate. Principal Component Analysis (PCA) highlighted that water quality factors, such as pH and ammonia nitrogen, significantly influenced growth performance, with System C showing optimized efficiency in terms of both water quality and growth metrics. The study also investigated the effect of trash fish on crab growth. This suggests that trash fish could be an effective and sustainable feed source to improve growth performance in crab aquaculture.

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Author contributions

Morfow Nkeze Paul: wrote the original manuscript, Benedicta O. M: Critically commented on the first draft of the manuscript Friday E.O.: Formatted and critically revised and follow-up of the final manuscript before submission. Nor Azman Kasan: commented and approved the final revision of manuscript.

Conflict of interest

The authors declare no conflict of interest

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