Colegio de Postgraduados

Evaluation of different salinities in polyculture of tilapia *Oreochromis* sp., and white shrimp *Litopenaeus vannamei* in a biofloc system

Silva-Reyna, Saul[1]; Castillo-Márquez, Edna F.[1]; Lango-Reynoso, Fabiola[1]; Castañeda-Chávez, María R.[1]; Martínez-Cárdenas, Leonardo[2]

[1] Tecnológico Nacional de Mexico/Instituto Tecnológico de Boca del Río. Carretera Veracruz-Córdoba Km 12, A. P. 68. Boca del Río, Veracruz, México. C.P. 94290.
[2] Secretaria de Investigación y Posgrado, Universidad Autónoma de Nayarit, Ciudad de la Cultura Amado Nervo s/n. Tepic, Nayarit. México. (C. P.). 63190.
***** Correspondence: fabiolalango@bdelrio.tecnm.mx; leonardo_martinez@uan.edu.mx

ABSTRACT

Objective: Polyculture in aquaculture is considered an effective strategy for improving production yields per unit area, and the use of biofloc systems represents a viable alternative for mitigating the negative environmental impacts associated with aquaculture discharges. This study evaluated the effect of different salinities on a polyculture of *Litopenaeus vannamei* post-larvae and *Oreochromis* sp. hatchling in a biofloc system.

Design/Methodology/approach: The experiment lasted 60 days, during which, four different salinities (T1=5 g/L, T2=10 g/L, T3=15 g/L, T4=20 g/L) were tested in triplicate, in addition to a control treatment (TC=2 g/L). The stocking density was 60 tilapia fry and 20 white shrimp post-larvae per treatment. The parameters evaluated included growth (weight and length) and survival of both organisms.

Results: Regarding growth, no significant differences were observed among treatments for any of the species ($p>0.05$). The average growth values for tilapia were 8.51±2.76 g and 5.92±0.85 cm, and for shrimp 1.73±2.55 g and 5.84±1.98 cm, with no differences among treatments. However, significant differences were found in survival. Treatments T1 (5 g/l) and T2 (10 g/l) showed higher survival for tilapia (96.43±1.19%) and shrimp (90.97±1.69%) compared to T3 (15 g/l) and T4 (20 g/l), which showed lower survival (tilapia: 73.10±5.11%, shrimp: 74.47±15.65%). The control treatment (CT) showed similar survival to treatments T1 and T2 for both species ($p<0.05$).

Limitations on study/implications: The scale of the study, conducted in experimental tanks, could limit the direct extrapolation of the results to larger-scale commercial conditions.

Findings/conclusions: The results highlight the effectiveness of biofloc systems in combination with polycultures, especially under low to moderate salinity conditions, as a sustainable, economical, and efficient strategy for aquaculture production.

Keywords: polyculture, biofloc, post-larva, survival.

Citation: Silva-Reyna, S., Castillo-Márquez, E. F., Lango-Reynoso, F., Castañeda-Chávez, M. R., & Martínez-Cárdenas, L. (2025). Evaluation of different salinities in polyculture of tilapia *Oreochromis* sp., and white shrimp *Litopenaeus vannamei* in a biofloc system. *Agro Productividad*. https://doi.org/10.32854/ksnv2s38

Academic Editor: Jorge Cadena Iñiguez
Associate Editor: Dra. Lucero del Mar Ruiz Posadas
Guest Editor: Juan Francisco Aguirre Medina

Received: June 10, 2025.
Accepted: November 14, 2025.
Published on-line: December XX, 2025.

Agro Productividad, 18(11). November. 2025. pp: 91-101.

INTRODUCTION

Global fisheries and aquaculture production reached 223.2 million tons in 2022, comprising 185.4 million tons of aquatic animals and 37.8 million tons of algae. Notably, for the first time, aquaculture production (94.4 million tons) surpassed that of extractive fisheries (92.3 million tons), accounting for 51% of the total. Approximately 89% of aquatic

animal output is directed toward direct human consumption, underscoring its critical role in global food security. In the same year, around 61.8 million individuals were employed in the fisheries and aquaculture sector, which remains vital to the livelihoods of millions worldwide. According to projections by the Food and Agriculture Organization (FAO, 2024), aquatic animal production is expected to increase by 10% by 2032, reaching 205 million tons, primarily driven by the expansion of aquaculture and the recovery of extractive fisheries. Nonetheless, a key challenge in aquaculture lies in managing water quality within production ponds, where issues are often addressed through routine water replacement. This approach, however, leads to increased operational costs, significant water wastage, and environmental degradation in receiving ecosystems. In light of rising global demand for aquaculture products, there is an urgent need to refine production practices to enhance sustainability, ensure social acceptability, and safeguard food security (CONAPESCA, 2022). Within this framework, polyculture emerges as a strategic approach that enhances the natural productivity of ponds and the water column. Effective implementation, however, necessitates a thorough evaluation of species based on their feeding habits, behavior, environmental adaptability, and pond productivity to identify the most profitable combinations (Luján Monja, 2010). The application of biofloc technology (BFT) has also gained prominence as a sustainable alternative, addressing environmental concerns linked to effluent discharge and the industry's reliance on fishmeal and fish oil (De Schryver *et al.*, 2008). Biofloc systems are composed of aggregates of microalgae, bacteria, protozoa, and other particulate organic matter as feces and uneaten feed which collectively enhance environmental control in production systems and help prevent disease outbreaks in intensive aquaculture (De Schryver *et al.*, 2008). These systems promote the bioconversion of organic matter, thereby improving water quality and fostering a healthier environment for aquatic organisms. In Ecuador, tilapia has demonstrated strong adaptability to brackish water aquaculture due to its robust physiological resilience, enabling trials in polyculture with the white shrimp *Litopenaeus vannamei*. This approach has emerged as a promising strategy to mitigate mortality caused by White Spot Virus (WSV). Tilapia has proven beneficial by enhancing the bioecological conditions of the culture environment and reducing horizontal disease transmission (Massaut & Rodríguez-Grimón, 2004). Prior studies indicate that tilapia, which thrives under euryhaline conditions, exhibits rapid growth and favorable performance in captivity qualities that make it an ideal candidate for shrimp polyculture. Moreover, its omnivorous diet, adaptability to formulated feeds, and growing international market demand further enhance its appeal. This study aims to evaluate the effects of varying salinity levels on the polyculture of tilapia (*Oreochromis* sp.) and white shrimp (*Litopenaeus vannamei*) within a biofloc system, with the objective of identifying optimal conditions to maximize production efficiency and sustainability in aquaculture.

MATERIALS AND METHODS

Study location

This study was conducted at the Boca del Río Technological Institute (IT-BOCA), located in the municipality of Boca del Río, Veracruz, Mexico. Specifically, the research

took place in the LIAA Aquaculture Laboratory, situated at 19° 05' 48.33" N and 96° 06' 30.20" W, at an elevation of 8.0 meters above sea level.

Experimental design and system construction

A biofloc system was employed to evaluate the polyculture of *Litopenaeus vannamei* post-larvae, with an average total length and weight of 3.2±0.3 cm and 0.277±0.008 g (mean ± SD), respectively, and *Oreochromis* sp. fry, with an average total length and weight of 1.5±0.7 cm and 0.113±0.004 g (mean ± SD), respectively. Four salinity treatments were tested in triplicate (T1=5 g/L, T2=10 g/L, T3=15 g/L, T4=20 g/L), along with a control treatment (TC=2 g/L), using plastic tanks with a working volume of 200 L. Each tank represented an independent experimental unit, enabling full treatment replication. Stocking density was maintained at 60 tilapia fingerlings and 20 shrimp post-larvae per tank. Continuous aeration was provided through a 1.27 cm diameter PVC pipe per tank, connected to a 1.9 cm diameter aeration line with flow control valves, all powered by a 2 HP Pioneer® blower linked to a 3.81 cm diameter PVC main line. Water was sourced from two 10,000 L reservoirs on-site: Reservoir 1 held water at 30 g/L salinity, and Reservoir 2 contained freshwater (0 g/L).

Animal acquisition

Tilapia fry (*Oreochromis* sp.) were obtained from the LIAA laboratory at IT-BOCA (60 individuals), while 20 *L. vannamei* post-larvae were acquired from a commercial shrimp hatchery located along Mexico Highway 150 and the Gulf Coast Highway, in Veracruz-Minatitlán. Specimens were randomly assigned to experimental units. Prior to introduction, animals were acclimated for 20 minutes per replicate, ensuring equal water temperatures between the source and destination environments to avoid thermal shock.

Feeding regime

Three feed particle sizes were utilized throughout the study: powdered feed, 1.0 mm pellets, and 2.0 mm pellets. During the first 30 days, powdered feed and 1.0 mm pellets were offered; in the subsequent 30 days, only 2.0 mm pellets were used. The commercial diets included Purina® powder feed (45% protein, 15% fat) and Bio Fingerling® pellets (35% protein, 15% fat), administered twice daily (09:00 and 17:00 h). A fixed feeding rate of 15% of the estimated biomass was established at the outset, in alignment with the metabolic requirements of the juvenile stages (El-Sayed, 2006). However, the feeding rate was not adjusted during the experiment, and no detailed monitoring of feed intake or waste was conducted.

Molasses supplementation

To maintain a carbon-to-nitrogen (C:N) ratio of 14:1 in the culture water, molasses was added biweekly to all tanks (including controls). The supplementation rate followed the recommendations of Asaduzzaman *et al.* (2008).

Water quality monitoring

Water quality parameters were assessed daily at 09:00 h using a YSI 560 multiparameter instrument (±0.1 °C precision) to measure temperature (°C), salinity (g/L), dissolved oxygen (mg/L), and pH. Concentrations of ammonia (NH_3), nitrite (NO_2^-), and nitrate (NO_3^-) were measured every three days via colorimetric testing. No water exchange was performed during the experiment; only evaporative losses were replenished every five days.

Growth assessment

Growth performance was evaluated biweekly. In each sampling round, 20 tilapia and 10 shrimp were randomly selected per treatment (TC, T1, T2, T3, T4). Specimens were gently dried on a cloth and measured using an ichthyometer (precision ±0.1 mm) and an Ohaus® analytical balance (precision ±0.0001 g). Total length measurements were taken from the rostrum to the telson for shrimp and from the mouth to the caudal fin for tilapia. Sampling was non-destructive, although individual tracking was not possible. Nevertheless, the sample size was statistically representative (Hendrickx, 1995).

Survival analysis

Survival rate (%) was calculated at the conclusion of the study using the formula:

$$Survival(\%) = \left[\left(Initial\ number - Final\ number\right) / Inital\ number\right] \times 100$$ (Utne, 1979).

Primary productivity assessment

To analyze biofloc composition, samples were collected biweekly. For phytoplankton analysis, 1 mL samples were observed under an Olympus ZSX50 microscope (100x objective) following Azim & Little (2008). For zooplankton (ciliates, rotifers, nematodes), 10 mL samples were preserved in 5% formalin and analyzed under a stereoscopic microscope. Taxonomic identification was performed to the genus level (Aladro Lubel, 2009). Organism density was estimated using a Neubauer chamber, counting 20 fields of view per sample, and results were expressed as cells/mL.

Determination of settleable solids

Biofloc volume was measured using Imhoff cones. A 1 L homogeneous water sample from each tank was transferred to the cones and allowed to settle for 20 minutes. The settled biofloc volume was then recorded (Avnimelech, 2009).

Health status evaluation

To monitor the health of cultured organisms, five tilapia and three shrimp per tank were collected every 30 days and euthanized via rapid freezing. External and internal examinations were conducted under a 10x stereoscopic microscope (Leica Zoom 2000, Switzerland) to detect melanized lesions or external parasites. Gills and muscle tissues were also examined under a 10x optical microscope (Leica MCE, Switzerland) for signs of necrosis or discoloration indicative of stress or disease (Bruce A, 2002).

Table 1. Summary table of the experimental design (species, treatments, density, replication).

Treatment	Species involved	Stocking density	Replication
T1	*L. vannamei* / *Oreochromis* sp.	60 tilapia+20 shrimp	Triplicate
T2	*L. vannamei* / *Oreochromis* sp.	60 tilapia+20 shrimp	Triplicate
T3	*L. vannamei* / *Oreochromis* sp.	60 tilapia+20 shrimp	Triplicate
T4	*L. vannamei* / *Oreochromis* sp.	60 tilapia+20 shrimp	Triplicate
TC (control)	*L. vannamei* / *Oreochromis* sp.	60 tilapia+20 shrimp	Triplicate

Table 2. Survival rates (%) of *Litopenaeus vannamei* in polyculture with *Oreochromis* sp. (mean ± standard deviation, n=3) under five salinity treatments: 2 g/L (control, TC), 5 g/L (T1), 10 g/L (T2), 15 g/L (T3), and 20 g/L (T4).

Species	TC	T1	T2	T3	T4
Oreochromis sp.	93.76±1.63^{a}	96.21±1.44^{a}	96.66±1.39^{a}	75.66±2.86^{b}	70.5±2.92^{b}

Means with different superscripts within a row are statistically different ($p<0.05$).

RESULTS

Survival

In *Litopenaeus vannamei*, treatments T1 (5 g/L) and T2 (10 g/L) exhibited the highest survival rates, reaching 90.97±1.69% and 88.45±2.33%, respectively. These values were statistically superior ($p<0.05$) to those observed in treatments T3 (15 g/L), T4 (20 g/L), and the control (TC, 2 g/L), which ranged between 70% and 75% (Figure 1). These results indicate that moderate salinities (5-10 g/L) enhance shrimp viability in polyculture systems operating under biofloc technology. A similar trend was observed in *Oreochromis* sp., where treatments T1 and T2 yielded significantly higher survival rates (96.43±1.19%

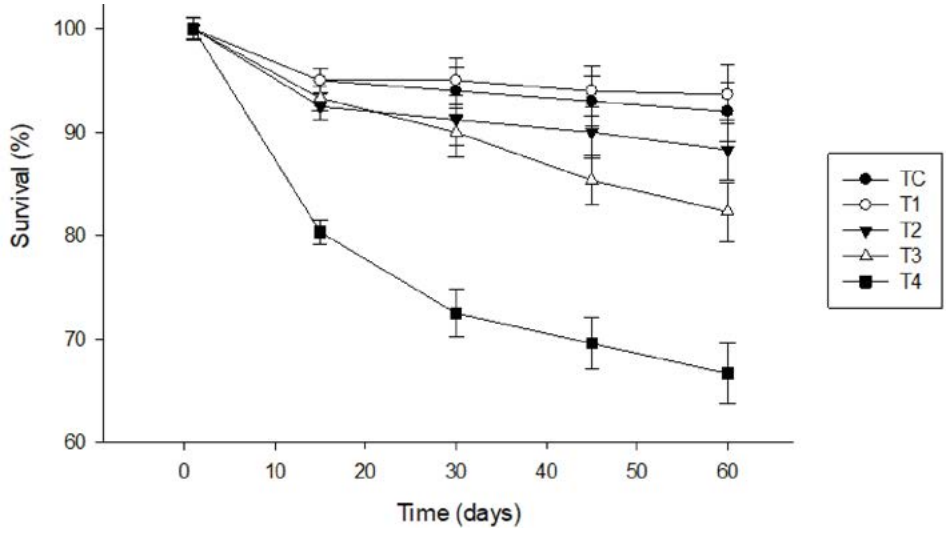

Figure 1. Survival rates (mean ± standard deviation, n=3) of *Litopenaeus vannamei* post-larvae cultured over 60 days in polyculture with *Oreochromis* sp. across five salinity levels: 2 g/L (control, TC), 5 g/L (T1), 10 g/L (T2), 15 g/L (T3), and 20 g/L (T4).

and 94.87±2.01%, respectively) compared to T3, T4, and the control group ($p<0.05$) (Figure 2). This finding suggests that although tilapia is a euryhaline species, salinity levels exceeding 15 g/L may induce osmotic stress, adversely affecting survival under biofloc culture conditions.

Growth

As shown in Tables 3 and 4, no statistically significant differences ($p>0.05$) were observed among treatments for either species. *Oreochromis* sp. attained an average final weight of 8.51±2.76 g and a length of 5.92 cm, while *Litopenaeus vannamei* reached an average weight of 1.73±2.55 g and a length of 5.84±1.98 cm. Although these differences

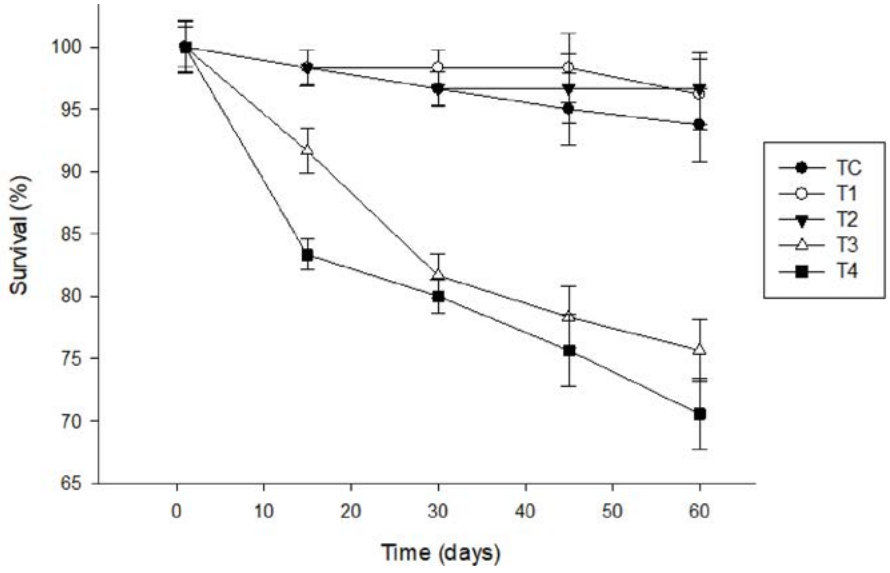

Figure 2. Survival rates (mean ± standard deviation, n=3) of *Oreochromis* sp. fry cultured for 60 days in polyculture with *Litopenaeus vannamei* under five salinity conditions: 2 g/L (control, TC), 5 g/L (T1), 10 g/L (T2), 15 g/L (T3), and 20 g/L (T4).

Table 3. Growth performance of *Oreochromis* sp. (mean ± standard deviation, n=3) cultured under five salinity treatments: 2 g/L (control, TC), 5 g/L (T1), 10 g/L (T2), 15 g/L (T3), and 20 g/L (T4).

	TC	T1	T2	T3	T4
Growth (weight) *Oreochromis* sp.	8.95±1.33[a]	9.91±1.45[a]	8.76±1.29[a]	7.86±1.94[a]	7.07±2.23[a]
Growth (length) *Oreochromis* sp.	6.00±1.54[a]	6.17±1.39[a]	5.98±1.68[a]	5.82±1.88[a]	5.65±2.36[a]

Means with different superscripts within a row are statistically different ($p<0.05$).

Table 4. Growth performance of *Litopenaeus vannamei* (mean ± standard deviation, n=3) cultured under five salinity treatments: 2 g/L (control, TC), 5 g/L (T1), 10 g/L (T2), 15 g/L (T3), and 20 g/L (T4).

	TC	T1	T2	T3	T4
Growth (weight) *L. vannamei*	2.00±1.27[a]	1.87±1.56[a]	1.76±1.43[a]	1.69±2.15[a]	1.35±2.12[a]
Growth (length) *L. vannamei*	6.26±1.83[a]	5.98±1.44[a]	5.92±1.35[a]	5.77±1.79[a]	5.31±1.99[a]

Means with different superscripts within a row are statistically different ($p<0.05$).

were not statistically significant, there was a slight tendency for improved growth in lower salinity treatments (TC, T1, and T2), potentially due to enhanced feed conversion efficiency and reduced osmotic stress. These findings partially support the hypothesis that salinity influences the performance of species cultured in polyculture under biofloc technology. While growth was not significantly affected, survival exhibited a clear salinity-dependent pattern, with optimal outcomes observed at moderate salinities (5-10 g/L). This supports the use of polyculture systems with moderate salinity levels as a sustainable strategy for maximizing productivity in biofloc-based aquaculture.

Water quality

Average water quality parameters recorded throughout the polyculture period are presented in Table 3. These values remained generally stable within each treatment. Primary productivity, particularly of diatoms, rotifers, and cladocerans, was notably higher in treatments T1, T2, and TC. The mean diatom density for these treatments was 77,895.00±6,321.14 cells/mL, and productivity remained consistent throughout the experimental period. The highest diatom density was observed in the control treatment (TC) during the first month, reaching 109,288.00±1,125.12 cells/mL. In contrast, significantly lower diatom densities were recorded in treatments T3 and T4, averaging 31,246.19±5,335.54 cells/mL and 25,575.99±3,791.11 cells/mL, respectively. These values were markedly lower than those in T1 and T2, which registered 74,523.49±3,142.24 cells/mL and 65,879.41±4,238.97 cells/mL, respectively. Throughout the experimental period, water transparency declined significantly across all treatments, as measured using a Secchi disk. Initial transparency levels ranged between 30 and 35 cm; however, by the end of the experiment, values had decreased to between 10 and 15 cm. This reduction in transparency corresponded with an increase in microbial biomass and a visible shift in water coloration from green to brown indicative of elevated suspended solids and active biofloc formation, characteristic of BFT systems.

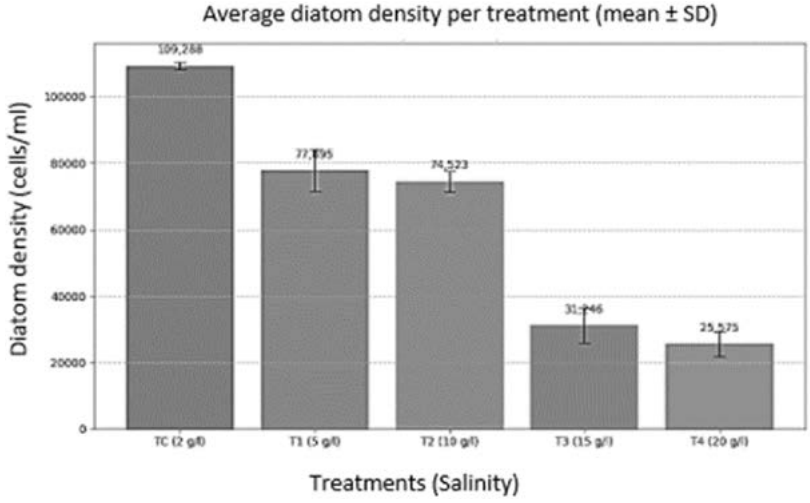

Figure 3. Average diatom density (cells/mL) per treatment during the polyculture of *Litopenaeus vannamei* and *Oreochromis* sp. in a biofloc system.

Table 5. Physicochemical variables (mean ± SD per treatment) evaluated during the study.

Treatment	Temperature (°C)	Salinity (gL^{-1})	O_2 ($mg\ L^{-1}$)	pH	Ammonium ($mg\ L^{-1}$)
TC	28.14±0.26[a]	2.98±1.46[b]	6.97±1.55[a]	8.54±0.34[a]	0.1±0.01[a]
T1	28.38±0.53[a]	5.57±0.27[b]	6.88±1.56[a]	8.49±0.37[a]	0.1±0.01[a]
T2	28.26±0.52[a]	9.90±1.36[b]	6.70±1.53[a]	8.62±0.32[a]	0.1±0.01[a]
T3	28.43±0.59[a]	14.52±3.16[b]	6.68±1.61[a]	8.55±0.36[a]	0.1±0.01[a]
T4	29.10±0.22[a]	18.81±4.85[b]	6.47±1.56[a]	8.49±0.24[a]	0.1±0.01[a]
Optimal	28-30 °C	6-9	5-9	6.5-9	<0.1

Means with different superscripts within a row are statistically different ($p < 0.05$).

Although ammonium concentrations remained stable across all treatments (0.10±0.01 $mg\ L^{-1}$), pH values ranged from 8.49 to 8.62. Under these conditions, it is important to consider that total ammonium (NH_4^+) can be converted to un-ionized ammonia (NH_3) in biofloc systems, especially at elevated pH levels. This is particularly relevant in treatments such as T2, where pH reached 8.62, potentially increasing the proportion of toxic NH_3. Despite the low total ammonium concentrations, the interaction between high pH and ammonium could pose a risk of ammonia toxicity. Although no negative effects on growth or survival were observed during this study, this interaction warrants close monitoring in longer-term or higher-density commercial applications.

Health status of the organisms

The results revealed a clear increase in health anomalies at higher salinities, particularly in treatments T3 and T4. Both fish and shrimp exhibited early signs of physiological stress, including gill necrosis and melanized lesions. In contrast, no visible pathologies were observed in treatments TC, T1, and T2, indicating that lower salinities (2-10 $g\ L^{-1}$) are more conducive to maintaining organismal health under biofloc conditions. The increased incidence of external parasites and tissue necrosis in the higher salinity treatments may be attributed to osmotic stress and a consequent reduction in immune response, as previously documented in saline or high-density polyculture systems. These findings underscore the importance of optimizing salinity levels to preserve the physiological integrity and welfare of aquatic species cultured in biofloc systems.

Table 6. BTC=Total harvested biomass; AT=Total feed; TCAA=Apparent feed conversion ratio.

Treatment	*Oreochromis* sp.			*L. vannamei*		
	BTC (kg)	AT (kg)	TCAA	BTC (kg)	AT (kg)	TCAA
TC	1.6±0.21[a]	1.5±0.00[a]	0.94±0.48[a]	0.06±0.27[a]	0.18±0.00[a]	2.72±0.41[a]
T1	1.8±0.25[a]	1.5±0.00[a]	0.83±0.37[a]	0.07±0.23[a]	0.18±0.00[a]	2.43±0.29[a]
T2	1.4±0.33[a]	1.5±0.00[a]	1.07±0.64[a]	0.06±0.33[a]	0.18±0.00[a]	2.90±0.38[a]
T3	0.81±0.38[a]	1.5±0.00[a]	1.85±0.55[a]	0.05±0.22[b]	0.18±0.00[a]	3.52±0.26[a]
T4	0.58±0.29[a]	1.5±0.00[a]	2.58±0.93[a]	0.02 ±0.31[b]	0.18±0.00[a]	7.5±0.79[b]

Means with different superscripts within a row are statistically different ($p < 0.05$).

This study confirms the viability of polyculture involving *Litopenaeus vannamei* and *Oreochromis* sp. in biofloc systems under low-salinity conditions, demonstrating its potential as a sustainable and efficient aquaculture strategy. The significantly higher survival rates observed at 5 g L^{-1} and 10 g/L (T1 and T2) indicate that these salinity levels provide optimal physiological conditions for both species (Li *et al.*, 2008; Verdegem *et al.*, 2008). Although no statistically significant differences in growth were detected across treatments, marked differences in survival and health were evident, particularly in T3 and T4 (15 and 20 g L^{-1}), where a higher incidence of lesions, tissue necrosis, and reduced phytoplankton density were observed. These findings suggest that elevated salinities may induce sublethal osmotic stress, compromising immune function, as previously reported (Van Wyk & Scarpa, 1999; Verdegem *et al.*, 2008). Additionally, a significant difference in primary productivity was recorded, with higher values in treatments T1, T2, and TC, indicating that moderate salinities promote phytoplankton particularly diatom growth. This enhanced productivity likely contributes to increased availability of natural food, potentially supporting better feed conversion and survival, although these relationships were not directly quantified (Azim & Little, 2008; Martínez-Córdova *et al.*, 2015). Despite consistently optimal levels of dissolved oxygen, temperature, and pH, ammonium concentrations remained low ($<$0.1 mg/L) across all treatments, demonstrating the efficacy of biofloc systems in nutrient remediation (Avnimelech, 2009; De Schryver *et al.*, 2008). This aligns with the findings of Avnimelech (2009), who highlighted the role of microbial communities in metabolizing nitrogenous waste, thereby improving water quality. However, the interaction between pH and ammonium warrants further investigation, particularly given that alkaline conditions ($>$8.4 pH) can favor the formation of toxic un-ionized ammonia (NH_3). The lack of observed toxicity may be attributed to the rapid assimilation of ammonium by heterotrophic bacteria within the biofloc, as previously reported (Crab *et al.*, 2012). The observed differences in health and survival may be linked to the physiological demands imposed by salinity stress. Tilapia expend greater energy to maintain osmotic homeostasis at salinities exceeding 10 g/L, potentially compromising growth and immune function (Li *et al.*, 2008; Suresh & Lin, 1992). Moreover, salinity-induced changes in the microbial composition of the biofloc may have affected the availability and nutritional quality of microbial feed, thus influencing metabolic efficiency (Ekasari *et al.*, 2015). One notable limitation of this study is its small experimental scale (200 L tanks), which, while allowing for controlled conditions, may limit extrapolation to commercial-scale operations, where variables such as water flow, organic loading, and climatic fluctuations can significantly influence biofloc dynamics and species interactions (Martínez-Porchas & Martínez-Córdova, 2012). Additionally, an economic assessment was not included, which would be crucial for evaluating the financial viability of this system under real-world production conditions.

The findings suggest that a salinity level of 5 g L^{-1} is optimal for operating tilapia-shrimp polycultures in biofloc systems. This salinity supports high survival and health in both species (Li *et al.*, 2008; Verdegem *et al.*, 2008), maintains elevated primary productivity (Azim & Little, 2008), and enables efficient biofloc operation without water exchange (Avnimelech, 2009; Ekasari *et al.*, 2015). From an operational standpoint, maintaining salinities around 5 g L^{-1} is feasible in regions with access to both freshwater and brackish

water, allowing for salinity adjustment without high salt concentrations thereby reducing both economic and environmental costs. Nonetheless, pilot-scale trials on commercial farms are recommended to validate these findings under production conditions (Crab *et al.*, 2012; De Schryver *et al.*, 2008).

The findings of this study confirm that the polyculture of *Litopenaeus vannamei* and *Oreochromis* sp. in biofloc systems under low to moderate salinity conditions (≤ 10 g L^{-1}) represents a viable and promising strategy for advancing more sustainable aquaculture practices. Elevated survival rates and enhanced primary productivity particularly diatom abundance were observed under these conditions, indicating that salinity directly influences both the physiological resilience of the cultured species and the availability of natural food resources within the system. Nevertheless, it is important to underscore that these results are derived from a pilot-scale experiment (200 L tanks) conducted under controlled laboratory conditions. As such, caution should be exercised in extrapolating the findings to commercial operations without further validation. Future studies should account for variables such as stocking density, environmental fluctuations, and economic feasibility.

For practical application, a salinity range of 5 to 10 g L^{-1} is recommended for polyculture of white shrimp (*L. vannamei*) and tilapia (*Oreochromis* sp.) in biofloc systems. This range appears to optimize survival and maintain water quality without imposing additional stress on the organisms. Routine monitoring of key parameters particularly phytoplankton composition, pH, and ammonium concentrations is essential for maintaining system balance and preventing biological disruptions. Salinities above 15 g L^{-1} are not advisable in systems involving tilapia, as they may compromise health and performance due to osmotic stress.

CONCLUSIONS

From a research and development standpoint, it is imperative to conduct commercial-scale trials that incorporate economic variables, including production costs, feed efficiency, and profitability, to assess the system's viability under real-world farming conditions. Furthermore, a more in-depth evaluation of interactions among key water quality parameters especially pH and ammonium are warranted to fine-tune biofloc management strategies.

Future investigations should also integrate physiological and stress biomarkers (*e.g.*, cortisol levels, gene expression profiles, or hepatic enzyme activity) to establish a direct link between salinity and the health status of cultured organisms. Additionally, exploring the role of biofloc-associated microbiota under varying salinity regimes could yield valuable insights into its influence on host immunity and nutrition, thereby informing strategies to enhance overall system performance and sustainability.

ACKNOWLEDGMENTS

The authors express their sincere gratitude to Prof. Jacob Parker and Dr. Cándido Silva for their valuable contributions in reviewing and improving earlier drafts of this manuscript. Special thanks are also extended to the National Council of Science and Technology (CONACYT) for providing scholarships to the students who participated in the development of this work.

REFERENCES

Aladro Lubel, M. A. (2009). Manual de prácticas de laboratorio de Protozoos. Facultad de Ciencias, Universidad Nacional Autónoma de México.

Asaduzzaman, M., Wahab, M. A., Verdegem, M. C. J., Huque, S., Salam, M. A., & Azim, M. E. (2008). El control de la relación C/N y la adición de sustrato para el desarrollo de perifitones mejoran conjuntamente la producción de camarón de agua dulce *Macrobrachium rosenbergii* en estanques. *Aquaculture, 280*(1), 117-123.https://doi.org/10.1016/j.aquaculture.2008.04.019

Avnimelech, Y. (2009). Biofloc technology: A practical guide book. https://www.cabidigitallibrary.org/doi/full/10.5555/20113266301

Azim, M. E., & Little, D. C. (2008). La tecnología de bioflóculos (BFT) en tanques interiores: Calidad del agua, composición de bioflóculos y crecimiento y bienestar de la tilapia del Nilo (*Oreochromis niloticus*). *Aquaculture, 283*(1),29-35 https://doi.org/10.1016/j.aquaculture.2008.06.036

Bruce A, B. (2002). Stress in Fishes: A Diversity of Responses with Particular Reference to Changes in Circulating Corticosteroids1 | Integrative and Comparative Biology | Oxford Academic. https://academic.oup.com/icb/article-abstract/42/3/517/723932

CONAPESCA. (2022). Anuario Estadístico de Acuacultura y Pesca. gob.mx. http://www.gob.mx/conapesca/documentos/anuario-estadistico-de-acuacultura-y-pesca

Crab, R., Defoirdt, T., Bossier, P., & Verstraete, W. (2012). Biofloc technology in aquaculture: Beneficial effects and future challenges. *Aquaculture*, 356-357,351-356. https://doi.org/10.1016/j.aquaculture.2012.04.046.

De Schryver, P., Cangrejo, R., Defoirdt,T., Boon, N., & Verstraete, W. (2008). The basics of bio-flocs technology: The added value for aquaculture. *Aquaculture, 277*(3-4),125-137. https://doi.org/10.1016/j.aquaculture.2008.02.019

Ekasari, J., Rheza Rivandi, D., Putri Firdausi, A., Harris Surawidjaja, E., Zairini Jr., M., Bossier, P., & De Schryver, P. (2015). La tecnología Biofloc afecta positivamente el rendimiento de las larvas de tilapia del Nilo (*Oreochromis niloticus*) ScienceDirect. https://www.sciencedirect.com/science/article/abs/pii/S0044848615000939?via%3Dihub

El-Sayed, A. F. M. (Ed.). (2006). Tilapia culture (1.a ed.). CABI Publishing. https://doi.org/10.1079/9780851990149.0000

FAO. (2024). The State of World Fisheries and Aquaculture 2024. FAO ; https://openknowledge.fao.org/handle/20.500.14283/cd0683en

Hendrickx, M. E. (1995). Camarones. Guía FAO para la identificación de especies para los fines de la pesca. Pacífico centro-oriental, 1, 417-537.

Li, E., Chen, L., Zeng, C., Yu, N., Xiong, Z., Chen, X., & G. Qin, J. (2008). Comparison of digestive and antioxidant enzymes activities, haemolymph oxyhemocyanin contents and hepatopancreas histology of white shrimp, *Litopenaeus vannamei*, at various salinities. *Aquaculture, 274*(1),80-86. https://doi.org/10.1016/j.aquaculture.2007.11.001

Luján Monja, M. B. (2010, septiembre 6). La tilapia: Especie ideal para los policultivos. https://aquahoy.com/la-tilapia-especie-ideal-para-los-policultivos/

Martínez-Córdova, L. R., Emerenciano, M., Miranda-Baeza, A., & Martínez-Porchas, M. (2015). Microbial-based systems for aquaculture of fish and shrimp: An updated review. *Reviews in Aquaculture, 7*(2), 131-148. https://doi.org/10.1111/raq.12058

Martinez-Porchas, M., & Martinez-Cordova, L. R. (2012). World Aquaculture: Environmental Impacts and Troubleshooting Alternatives. *The Scientific World Journal*, 2012, 1-9. https://doi.org/10.1100/2012/389623

Massaut, L., & Rodríguez-Grimón, R. (2004). (PDF) El efecto de la Tilapia sobre la producción de Camarón bajo condiciones de mancha blanca. ResearchGate. https://www.researchgate.net/publication/318135299_El_efecto_de_la_Tilapia_sobre_la_produccion_de_Camaron_bajo_condiciones_de_mancha_blanca

Suresh, A. V., & Lin, C. K. (1992). Tilapia culture in saline waters: A review. *Aquaculture, 106*(3), 201-226. https://doi.org/10.1016/0044-8486(92)90253-H

Utne, F. (1979). Utne, F. (1979). Standard methods and terminology...GoogleAcadémico.https://scholar.google.com/scholar?hl=es&as_sdt=0%2C5&q=Utne%2C+F.+%281979%29.+Standard+methods+and+terminology+in+finfish+nutrition.&btnG=

Van Wyk, P., & Scarpa, J. (1999). Water quality requirements and management. *Farming marine shrimp in recirculating freshwater systems*, 4520, 141-161.

Verdegem, M. C. J., Hilbrands, A. D., & Boon, J. H. (2008). Influencia de la salinidad y la composición dietética en los valores de los parámetros sanguíneos de la tilapia roja híbrida, *Oreochromis niloticus* (Linnaeus)×*O. mossambicus* (Peters) Verdegem 1997 Investigación en acuicultura Wiley Online Library. https://onlinelibrary.wiley.com/doi/abs/10.1046/j.13652109.1997.00880.