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Effect of the aeration system on water quality parameters and productive performance of red tilapia (*Oreochromis* sp.) grown in a biofloc system

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ABSTRACT - The objective of this work was to assess the performance of two aeration types, splash and blower, used on a commercial biofloc technology (BFT) farm of red tilapia, *Oreochromis* sp., and their effect on growth performance and water quality parameters. For this, red tilapia juveniles were randomly distributed into twelve tanks. Each tank had an independent aeration system, and two experimental groups were characterized: six tanks used splash aerators (SPL group; one per tank, 1 hp), and the remaining tanks used a blower aerator (BLW group) with the same potency (1 hp). Water quality parameters were registered daily, and after 90 days of commercial culture, we obtained final growth parameters for each batch (tank). We observed no statistical differences on growth parameters, while water quality parameters showed that dissolved oxygen and oxygen saturation were significantly higher for the SPL group. Therefore, this field study corroborated indications from prior research at laboratory conditions that, at a commercial scale, splash aerators are more adequate for the production of red tilapia in BFT conditions.

Keywords: aerators, aquaculture, growth parameters, oxygen concentration

1. Introduction

Aquaculture is one of the fastest-growing food-producing sector worldwide, having achieved an annual growth rate of 4.6% during the period 2010-2020 and a total production of 122.6 million tons in live weight in 2020 (FAO, 2022). Concerns regarding water management in aquaculture facilities have led to the development of zero water exchange autotrophic heterotrophic systems such as biofloc technology (BFT) (Harun et al., 2019). This intensive system is based on the recycling of organic and inorganic waste through microorganisms present in the water (Avnimelech, 2015). Biofloc technology allows for waste retention and its conversion to floc, which are aggregates of algae, bacteria, protozoans, and other types of particulate organic matter. These bioflocs can also serve as a natural food source within the productive system (Hargreaves, 2013).

During implementation of a BFT system, it is crucial to monitor water quality parameters, such as dissolved oxygen (DO), pH, temperature, and alkalinity. This allows for the application of corrective measures when necessary and ensures the persistent maintenance of adequate conditions for the farmed species (Collazos-Lasso and Arias, 2007). Dissolved oxygen is the main physicochemical parameter that limits productivity, as it directly affects survival and fish growth (Sanchez-Estrada, et al., 2018). Different techniques, such as water renewal and aeration devices, are available to improve oxygen concentrations in the water (Collazos-Lasso and Arias, 2015). Aeration systems allow constant water movement and the suspension of fish waste (Azim and Little, 2008), indirectly influencing the formation of the biofloc (Harun et al., 2019).

Aeration systems are mandatory in BFT systems (Collazo Collazos-Lasso and Arias, 2015) and can be generally classified into three categories: gravity aerators, air diffusion systems, and mechanical aerators (Harun et al., 2019). Among the diffusion systems, blowers are the most commonly used in small-scale BFT production units (Malpartida Pasco et al., 2018). However, their efficiency is compromised in shallow tanks (Tucker, 2005). Splash or pump aerators, which are a type of mechanical aerators, have greater potential for aquaculture facilities due to their higher aeration efficiency. However, concerns arise regarding the excess of turbulence they create, which could affect the formation of bioflocs (Lara et al., 2017; Malpartida Pasco et al., 2018).

A few studies have addressed the influence of aeration type and productive indices on water quality parameters in BFT systems. Malpartida Pasco et al. (2018) reported that splash aerators are more adequate for *Oreochromis niloticus* production, while Lara et al. (2017) found that micro-perforated hoses supplied through blowers exhibited superior performance for *Litopenaeus vannamei.* Performance appears to vary considerably between studies, and information on this topic is still scarce.

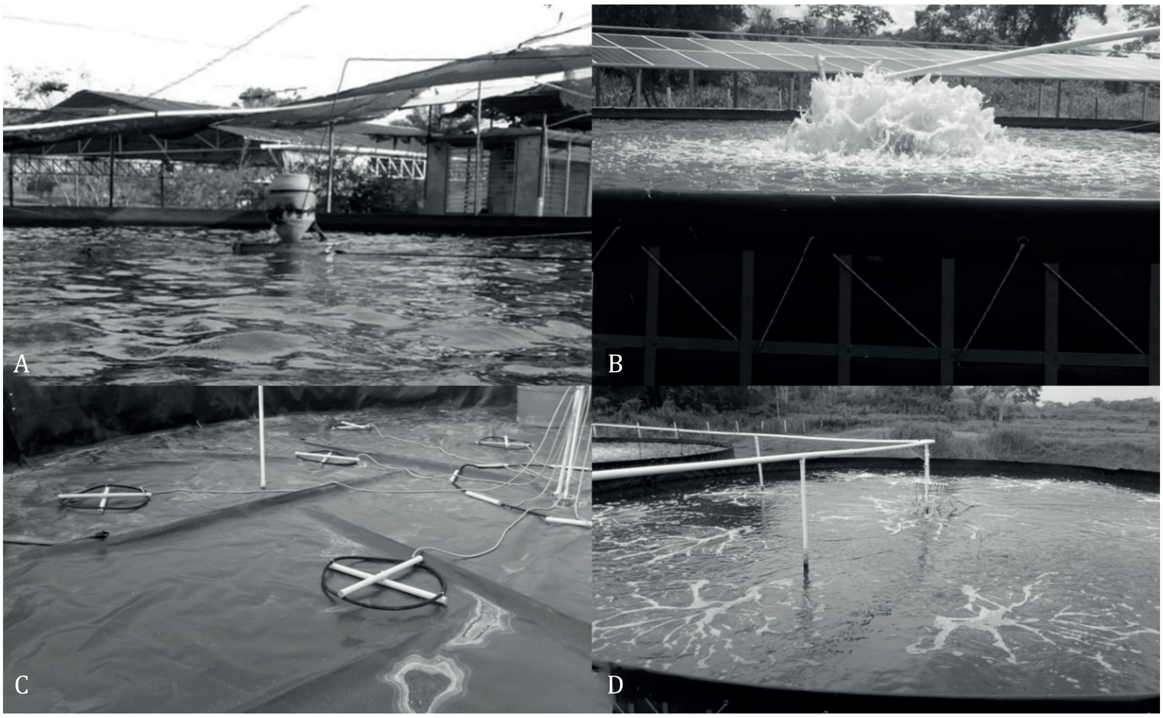
Thus, the objective of this work was to assess the effect of two types of aerators on the water quality parameters and the productive performance of red tilapia juveniles cultured under a commercial BFT system.

2. Material and Methods

This work was carried out in a productive station in Arauquita, Department of Arauca, Colombia. The station is composed of tanks covered with high-density polyethylene (HDPE) equipped with individual aeration systems. The present study was conducted using a production cycle already stablished on a commercial tilapia farm, and no additional management of the animals was performed. The Subcommittee on Bioethics in Research of the Cooperative University of Colombia, campus Bucaramanga, allowed the research to be developed according to their scientific, technical, and administrative standards for health research (process no. 008-2021).

2.1. Experimental design and conditions

Red tilapia (*Oreochromis* sp.) juveniles, with a mean weight 140±0.09 g, were randomly and equally distributed (3,500 fish per tank, 30 fish/m^3) into twelve HDPE lined tanks. The HDPE tanks had 1-mm thickness, with a capacity of 153 m^3, a diameter of 14 m, height of 1.10 m, though to avoid spillage, 5 cm of freeboard was introduced. Each tank was equipped with an independent aeration system, with six tanks utilizing splash aerators (SPL; one per tank, 1 hp), and the remaining tanks utilizing one blower aerator (BLW) with the same potency (1 hp). The SPL appliances were positioned in the middle of the tanks (Figure 1). The BLW utilized micro-perforated poly diffuser hoses Aerotubes®, with an air flow of 0.037 m^3 min^{-1} m^{-1}, which were distributed in grids at the bottom of the tanks. Both types of aerators worked 24 h a day during a 90-day culture period. Fish were fed a commercial feed comprising 2.3 to 1.5% of the total biomass, four times a day, the entire 90-day period. The balanced diet contained 30% crude protein (CP) at the beginning of the culture period, was reduced to 24% CP when fish achieved 370-395 g, and finally to 20% CP when fish achieved more than 470 g.



A and B depict the splash-type aerator (centrally positioned), while C and D represent the blower-type aerator with micro-perforated diffuser hoses at the bottom of the tank.

Figure 1 - Aerator types used in this research.

2.2. Biofloc management

To ensure optimal water quality conditions for red tilapia culture, we followed the recommendations of Avnimelech (2015). The nitrogen:carbon ratio was maintained at 20:1, achieved by using sugar cane molasses with a carbon content of 480 g of carbon per kg. Sugar cane molasses were used as an external source of carbon because of its availability in the region where the study was carried out, its efficiency in controlling the total ammonia nitrogen concentration, and the production of microbial flocs (Lima et al., 2018). Once the biofloc reached maturity, with decantable solids reaching a value of 25-50 mL L^{-1} at this point, the ratio was adjusted to 6:1. The amount of molasses required was calculated based on the ammonia level present in the production system. Additionally, to maintain alkalinity above 120 ppm, agricultural or carbonated lime was added at a ratio of 10% of the feed supply (Ebeling et al., 2006).

The decantable solids were managed through settlers, which had a capacity of 1% of the total tank volume. These settlers were installed as external tanks connected to pipes, allowing the transfer of water containing a significant number of solids through an airlift system. There was no water renewal conducted in any of the experimental tanks, and water consumption was minimized; it was determined by the initial filling and by the replacement lost through evaporation and settlers (1% of the total volume).

2.3. Growth performance

At the end of the feeding period, growth performance was assessed using the methodology described by Conrado et al. (2020). All animals from each tank were weighed using a digital scale (PCE-BSH 6000, PCE Instruments, Germany) and then returned to their cultivation tanks. The performance values were calculated as follows:

$$\text{Weight gain} = (\text{final weight} - \text{initial weight})\ (\text{g})$$

$$\text{Average daily weight gain} = (\text{final weight} - \text{initial weight})/\text{days}\ (\text{g day}^{-1})$$

$$\text{Biomass} = \text{final average weight} \times \text{number of animals}\ (\text{kg})$$

$$\text{Feed conversion ratio} = \text{feed consumption}/\text{biomass gain}\ (\text{kg of feed/kg of gain})$$

$$\text{Survival rate} = (\text{number of final fish}/\text{number of initial fish}) \times 100\ (\%)$$

2.4. Water quality parameters

The measurement of water parameters followed the methodology described by Cala Delgado et al. (2018). Temperature, DO, and oxygen saturation (OS) were evaluated twice (8:00 and 15:00 h), using a multiparameter water probe (YSI EcoSense® DO200A, Yellow Springs, USA). For pH, total suspended solids, and electric conductivity measurement, a different water probe was used (Hanna® 991300, Woonsocket, USA). Chemical parameters, including total ammonium nitrogen (TA-N), nitrite (NO_2-N), nitrate (NO_3-N), alkalinity, and orthophosphates were assessed once a week, using established colorimetric methodologies (APHA, 2005). Settleable solids were measured daily before the first feed, by collecting 1 L of water in Imhoff cones (APHA, 2005).

2.5. Statistical analysis

The statistical analysis included testing the data for normality using Shapiro-Wilk test and checking for homoscedasticity using the Levene test. Student's t test was used to identify statistical differences between groups ($P<0.05$). Results are reported as mean ± standard deviation (SD). The data analysis was performed using Prism 8.01 (GraphPad Software, La Jolla, USA).

3. Results

3.1. Growth performance

There were no significant differences ($P>0.05$) in the productive performance of red tilapia cultivated in tanks with SPL or BLW aeration systems (Table 1). The survival rate was slightly higher (2% higher) in the SPL tanks compared with the BLW tanks.

Table 1 - Growth parameters (mean ± standard deviation) of red tilapia juveniles raised in a biofloc technology system aerated with two different systems, splash (SPL) and blower (BLW), for 90 days

Index	SPL	BLW
Initial weight (g)	140±0.09	140±0.09
Final weight (g)	560±16	569±11
Weight gain (g)	420.0±16.0	429.0±11.0
Daily weight gain (g d^{-1})	3.1±0.2	3.2±0.1
Final biomass produced (kg)	1833.0±70.0	1833.0±48.0
Feed conversion ratio	1.02±0.03	1.02±0.01
Survival (%)	97.0	95.0

Student's t test was applied.

3.2. Water quality parameters

The statistical analysis of the water quality parameters showed that temperature, DO, and OS were significantly affected by the aeration system used in the tank ($P<0.05$) (Table 2). The remaining water quality parameters, pH, total suspended solids, electric conductivity, total ammonia, nitrate, nitrite, alkalinity, orthophosphates, and settleable solids were not affected by the aeration system ($P>0.05$) (Table 2).

Table 2 - Mean water quality parameters on a biofloc technology farm of red tilapia (*Oreochromis* sp.) juveniles cultivated in tanks with two different aeration systems, splash (SPL) and blower (BLW)

Parameter	SPL	BLW
Temperature (°C)	28.5±1.9a	29.3±1.6b
Dissolved oxygen (mg L^{-1})	4.4±0.8a	4.2±0.8b
Oxygen saturation (%)	58.1±9.3a	55.8±9.3b
pH	7.3±0.3	7.2±0.2
Total suspended solids (mg L^{-1})	993.0±82.0	985.0±63.0
Electric conductivity (µS cm^{-1})	832.0±62.0	835.0±71.0
Total ammonia (TA-N; mg L^{-1})	0.25±0.0	0.25±0.0
Nitrite (NO_2-N; mg L^{-1})	15.0±0.5	10.0±0.1
Nitrate (NO_3-N; mg L^{-1})	0.1±0.0	0.1±0.0
Alkalinity ($CaCO_3$; mg L^{-1})	150.0±10.0	140.0±15.0
Orthophosphates (mg L^{-1})	0.15±0	0.15±0.0
Settleable solids (mL L^{-1})	35.0±5.0	40.0±2.0

a-b - Different letters in a row indicate significant differences between aerator treatments determined by Student's t test ($P<0.05$).

4. Discussion

The water quality parameters maintained during the production course were within the ranges established for the species and were adequate for the biofloc operation. Mean concentrations of DO were > 4 mg L^{-1} in all treatments, which is required for bacteria in the nitrification process and the survival of red tilapia (Widanarni et al., 2012). The temperature was maintained between 28-30 °C in all treatments, which falls within the optimal ranges for the growth of red tilapia (Watanabe et al., 1993). Finally, alkalinity remained above 100 mg L^{-1} in both treatments and were adequate for the nitrification process and sequestration of ammonia by chemoautotrophic bacteria (Avnimelech, 2015), as evidenced by the low total ammonia values.

The present study confirms that the type of aeration in BFT systems affects water quality parameters, including DO, OS, and temperature. The use of SPL aerators resulted in higher concentrations of oxygen (DO and OS) in the water when compared with the BLW aerators. These findings align with the results reported by Malpartida Pasco et al. (2018) for super-intensive Nile tilapia farming in BFT systems, without water renewal, where SPL aerators exhibited significantly higher DO and OS values compared with BLW aerators. Splash aerators enhanced oxygen concentrations in the water, by increasing the gas solubility trough the generation of turbulence, which promotes higher transfer rates and atmospheric oxygen diffusion (Tucker, 2005).

Studies conducted with *L. vannamei* cultivated in BFT system have shown that aerators with higher airflow have greater efficiency in the nitrification process with the biofloc. This suggests that systems with higher aeration or oxygen availability could potentially enhance productive performance (Morais et al., 2020). However, in the present experiment, no statistical differences were found between aeration systems for any of the productive indices. This finding suggests that both aeration systems provided similar environmental quality for the fish.

The water temperature in the tanks equipped with the BLW was higher than that in the tanks with the SPL aerator. The temperature difference may be attributed to the mechanisms by which the aerators integrate oxygen into the water. The SPL model allows greater contact between the water and the air, leading to an increased thermal exchange and a decrease in the water temperature, compared with the BLW aerators, which utilize hoses and do not generate as much turbulence nor external contact (Bosworth et al., 2004). Despite the difference in water temperature between aeration treatments, it did not affect the productive performance of the animals. These findings corroborate previous research conducted on Nile tilapia cultivated in BFT (Malpartida Pasco et al., 2018).

The water pH remained stable throughout the 90-day period and did not exceed a value of 7.6. This may be explained due to the water alkalinity levels (greater than 120 ppm) that allow no major variations on this parameter. Lara et al. (2017), utilizing three different aerator types (blower, vertical pump and propeller), also described no significant differences in the water pH for *L. vannamei* biofloc cultures.

The constant control of organic matter performed by removing the excess through the decantation system and the application of molasses as a carbon source allowed the control of ammonia, nitrites, and nitrates in both treatments. Higher water alkalinity, lower nitrites and nitrates, as well as lower settleable solids and total suspended solids were reported in *L. vannamei* biofloc cultures aerated with vertical pump (splash) when compared with tanks aerated with blowers (Lara et al., 2017). However, data from the present study did not show any differences in these parameters for biofloc cultures of red tilapia juveniles.

5. Conclusions

The study revealed no differences in the growth performance of red tilapia farmed with different aeration types (blowers or splash) in a commercial BFT farm. However, fish tanks equipped with splash aerators demonstrated higher availability of dissolved compared with those with blower aerators for the production of red tilapia juveniles in a commercial BFT system. The present study indicates that at a commercial scale, splash aerators are more beneficial for the culture of red tilapia in BFT systems than blowers.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization: D.L. Cala-Delgado and N.C. Alvarez-Rubio. Data curation: D.L. Cala-Delgado, N.C. Alvarez-Rubio and V.A. Cueva-Quiroz. Formal analysis: D.L. Cala-Delgado and V.A. Cueva-Quiroz. Funding acquisition: D.L. Cala-Delgado. Investigation: D.L. Cala-Delgado, N.C. Alvarez-Rubio and V.A. Cueva-Quiroz. Methodology: D.L. Cala-Delgado, N.C. Alvarez-Rubio and V.A. Cueva-Quiroz. Project administration: D.L. Cala-Delgado. Supervision: D.L. Cala-Delgado. Writing – original draft: D.L. Cala-Delgado and N.C. Alvarez-Rubio. Writing – review & editing: D.L. Cala-Delgado and V.A. Cueva-Quiroz.

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