Influence of pond aeration on ponderal development of Tambaqui (*Colossoma macropomum*) in a semi-intensive commercial production system

Influencia de la aireación de estanques en el desarrollo ponderal del tambaquí (Colossoma macropomum) en un sistema de producción comercial semi-intensivo

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ABSTRACT. The present study aimed to evaluate the influence of artificial aeration (AA) on Tambaqui (*Colossoma macropomum*) productive performance (PP) in continuous water flow production systems. For this, eight semi-dug nurseries of 0.32 ha each were used, as well as 5,000 *C. macropomum* juveniles per pond, or experimental unit (EU). The animals had an initial average weight of 11.8±3.02g and 8.0±3.1cm of standard length, and were separated into two treatments: treatment 1 (T1) with a 1.0 CV surface spray aerator operating at night; and treatment 2 (T2) without artificial aeration, during 120 days. Animal biometrics were measured at intervals of 30 days. Fish productive performance was evaluated trough weight (W) (gr), standard length (SL) (cm), biomass (B) (kg), feed conversion (FC) , and animal condition factor (K). Water quality parameters as total ammonia (NH3 and NH4+), NO2- concentration (mg/L), hydrogen potential (pH), electrical conductivity (µS * cm-1), dissolved oxygen (mg/L), temperature (°C), and turbidity (cm) were registered twice a week. PP traits including W, SL and B improved from the beginning to the end of the experiment ($p<0.05$) with better values in T1 when compared to T2, by the end of the production cycle. Regarding water quality variables, only Electrical Conductivity (µS/cm) was affected by AA ($p<0.05$). These results indicate that applying artificial aeration in aquaculture continuous water flow production systems, improve Tambaqui productive performance, increasing production system efficiency of this species.

Keywords: aquaculture, biotechnology, ponderal development, oxygen.

RESUMEN. El presente estudio tuvo como objetivo evaluar la influencia de la aireación artificial (AA) en el rendimiento productivo (PP) del tambaquí (*Colossoma macropomum*) en sistemas de producción con flujo continuo de agua. Para ello, se utilizaron ocho viveros semi excavados de 0,32 ha cada uno, así como 5.000 juveniles de *C. macropomum* por estanque o unidad experimental (UE). Los animales presentaron un peso promedio inicial de 11,8 ± 3,02 g y una longitud estándar de 8,0 ± 3,1 cm, y se dividieron en dos tratamientos: tratamiento 1 (T1) con un aireador de aspersión superficial de 1,0 CV operando de noche; y tratamiento 2 (T2) sin aireación artificial, durante 120 días. Se midieron los datos biométricos de los animales a intervalos de 30 días. El rendimiento productivo de los peces se evaluó mediante peso en comedero (P) (g), longitud estándar (LE) (cm), biomasa (B) (kg), conversión alimenticia (CA) y factor de condición animal (K). Los parámetros de calidad del agua, como amoníaco total (NH_3 y Nh_3+), concentración de NO_2 (mg/L), potencial de hidrógeno (pH), conductividad eléctrica ($\mu S * cm^{-1}$), oxígeno disuelto (mg/L), temperatura (°C) y turbidez (cm), se registraron dos veces por semana. Los rasgos de PP, incluyendo P, LE y B, mejoraron desde el inicio hasta el final del experimento ($p<0,05$), con mejores valores en T1 en comparación con T2, al final del ciclo de producción. En cuanto a las variables de calidad del agua, solo la conductividad eléctrica (µS/cm) se vio afectada por el AA (<0,05). Estos resultados indican que la aplicación de aireación artificial en sistemas de producción acuícola de flujo continuo de agua mejora el rendimiento productivo del tambaquí, incrementando la eficiencia del sistema de producción de esta especie.

Palabras clave: acuicultura, biotecnología, desarrollo ponderal, oxígeno.

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INTRODUCTION

Facing the growing demand for animal protein by millions of people worldwide, animal husbandry strategies must be developed maximizing productivity and profitability, while reducing production costs (1). This is how aquaculture presents itself as one of the fastest growing food production sectors, as it is currently responsible for more than half of the global seafood production (2) and with dominant productivity rates in fresh water (3).

Among aquaculture species with commercial importance, Tambaqui (*Colossoma macropomum*) is one of main native species grown in Brazil. In 2018, its production was estimated at 102,554,429 tons, corresponding to 16.98% of the total volume produced by the national fish farming system (4). Its commercialization has been increasing at an accelerated pace due, mainly, to its adaptability to different environments and growing systems, associated with its metabolic characteristics like rusticity, omnivorous eating habits, rapid growth and efficient induced reproduction handling (5,6).

The adoption of new technologies, developed through research, has played a fundamental role in the evolution of aquaculture (7). Among various technologies aiming to optimize aquaculture productivity, artificial aeration (AE) is the main practice used to insert and promote the dissolution of oxygen (O_2) in water when its concentration shows critical values, causing fish severe stress and even high mortality –''(8). This mechanism, by improving water quality, can positively influence animals productive performance and survival rates, enabling increased environment capacity and fish health –(9,10). Thus, the objective of this work was to evaluate the influence of supplementary artificial aeration on growth performance of Tambaqui in a system with continuous water flow.

Material and method

The experiment was conducted at Ecology Pescados fish farm (Latitude: -02º 46 '48.64''; Longitude: -59º 22' 01.60''), located at Km 11 of Branch Bank - Highway AM 010 Km 127, municipality from Rio Preto da Eva, Amazonas, Brazil.

Animal management

This research used a juvenile batch of 40,000 Tambaqui with an initial average weight of 11.8±3.02 g and standard length of 8.0±3.1 cm, from a fish breeding station in the region. Animals were distributed equally in a randomized design for independent samples, with two treatments and four replicates per treatment, totaling eight experimental units (EU) with 5,000 animals in each EU, in ponds in ponds that measured 40 x 80 x 1.0 m, with a total of 0.32 ha of water extension.

The treatments were distributed in the semi-excavated ponds equipped with supplementary artificial aeration (T1) and without supplementary artificial aeration (T2). The period of operation of the aerators was between 18:00 and 06:00hs. The duration of the experiment was one hundred and twenty days, corresponding to one production cycle of Tambaqui, with biometric measurements at intervals of 30 days.

Pond water was supplied by pumping it from a dam located upstream of the plateau where EU were installed. There was no continuous water renewal; however, there was a replacement of losses through infiltration and evaporation.

Sample size

To calculate the sample size from 5,000 fish in each pond, 135 fish determined a representative sample per EU, using Weyne (2004) methodology:

$$n = \frac{N * z^2 * p * (1-p)}{(N-1) * e^2 + z^2 * p * (1-p)} \quad (1)$$

where n is the size of the sample to be studied; N is the size of the population universe in each nursery (N = 5,000); z corresponds to the 95% confidence level (z= 1.96); and e denotes the error margin (e = 5%); and finally, p indicates the proportion for calculating sample size, considering Silva et al. (2015) study (p=10%).

Feeding

Animals were fed a commercial ration, containing between 28 and 32% of Crude Protein, twice a day equivalent to 3% of fish biomass. The adjustment of feed amount was applied considering biometric measurements of 135, randomly caught, fish in each EU, on each measurement date. Food management is shown in Table 1.

Table 1. Feed management of animals used in the experiment.

Development phase	BP (%)	FR (%)	Time (Days)
1,0 ~ 10,0 cm	32	3	40
10,0 ~35,0 cm	28	3	80

BP: Brute protein; FR: Feed rate in biomass/ day

Fish biometry

Data collection was applied by capturing fish with the aid of knotless multifilament fishing nets, in order to avoid abrasions in animals' teguments.

The productive performance of the animals was evaluated by analyzing the weight (W) in grams, and the standard length (SL) in centimeters, measured with an electronic scale with precision of 1.0 g and an ictiometer with precision of 1.0 mm, respectively. To minimize stress during handling, captured animals were anesthetized in an Eugenol's solution in 65mg*L^{-1} of water(13).

Apparent feed conversion (AFC) is the index of the relationship between the apparent amounts of food offered, converted into biomass. AFC was obtained through the ratio between the amount of feed offered and the fish weight gain (WG) (2):

$$AFC = \frac{Feedoffered(kg)}{WG}(2);$$

The condition factor (K) provides a quantitative parameter of the animal's degree of well-being. The condition factor relates weight and body length, obtained according to Cren (1951) (3):

$$kK\frac{W}{L^b}(3);$$

Where W is the body weight (g); L is determined by the total body length (cm) and b is the regression coefficient of W and L natural logarithm.

Water quality was assessed by analyzing total ammonia (NH_3 and NH_4^+) and nitrite NO_2- (mg*L^{-1}) concentration, collected at fifteen-day intervals at 06:00 and 18:00 hrs. Limnological variables such as pH, electrical conductivity (µS*cm^{-1}), dissolved oxygen (mg*L^{-1}), temperature (°C), and turbidity (cm) were monitored twice a week with the aid of digital equipment and a Secchi disc(15).

Water aeration

Aeration was done by a surface water pumping mechanism (sprinkling) through a centrifugal pump system consisting of a 1.0-horsepower three-phase electric induction motor, coupled to a suction rotor with pipes and polyethylene connectors of 1.0'' diameter (Figure 1), mounted on a floating structure.

The floating structure used as a base for the pumping system was built with a low density polyethylene platform, supported by a set of four 20L plastic buoys, responsible for the base fluctuation, and two lateral floats composed of PVC tubes of 100 mm in diameter and 1.5 m in length, sealed with CAP connectors at the ends, responsible for the stability of the structure, as can be seen in figures 2 and 3.

The set of centrifugal pump systems and floating structure of the experimental aerator is shown in Figure 4.

Standard Oxygen Transfer Rate (SOTR) was measured and expressed in kg OD * h-1, according Boyd (1984) equation (4):

$$SOTR = Kla28xCsxVx10\square3(4);$$

SOTR is defined as standard oxygen transfer rate, in kg of diluted oxygen (DO) per hour (kg/OD*h^{-1}); Kla28 is the oxygen transfer coefficient at 28 Celsius degrees (°C); CS determines the concentration of saturated oxygen at 28 ° C (g*m^{-3}); V informs tank volume where the test was performed (m^3) and 10^{-3} is a constant factor for transforming grams into kilograms (kg*g^{-1}).

To determine the oxygen transfer coefficient at 28°C (Kla28), equation (5) was used:

$$Kla28 = KLaTx1{,}024^{(28-T)}(5);$$

where KLaT is the oxygen transfer coefficient at test temperature per hour of work; and T is the test temperature (°C). Therefore, to estimate KLaT, equation 6 was used:

$$KLaT = \frac{1{,}1}{\left[\frac{(T70 - T10)}{60}\right]}(6);$$

where T70 is the time when the DO reached 70% of the saturation at test temperature and, finally, T10 is the time when the DO reached 10% of the saturation at test temperature.

Then, standard aerator efficiency (SAE) was obtained according to equation (7):

$$SAE = \frac{SOTR}{OEEC}\,(7);$$

by the ratio between SOTR, in kg OD / h-1, and the Operational Electric Energy Consumption (OEEC), in Kw*h^{-1}.

Statistical analysis

To verify variation in water quality and growing performance traits of the animals between treatments, ANOVA with a mixed model was applied. where treatments and collection dates were considered as fixed effects, and the repetitions as random variables. If statistical differences were found, the Tukey test was performed. Previously, data normality and variances homogeneity were verified, with the test of Shaphiro-Wilk, and Levene, respectively. A Pearson correlation was applied to relate W and SL. Statistical analyzes were developed in R software(16), with 5% of statistical significance.

RESULTS AND DISCUSSION

The aerator used in this study offered an oxygen transfer rate of 1.13 ± 11.3 kg O_2*h^{-1}. The variables of water quality did not vary ($p>0.05$) between treatments throughout the experiment, except for electrical conductivity (µS*cm^{-1}) ($p<0.05$), as observed in Table 2.

The quality of the water analyzed in the present study was within the appropriate ranges for the cultivation of the species (17,18). Regarding the pH of the water, this research found its variation between 6.14 and 6.77; within the comfort range for the species. Aride, Roubach e Val (2007) evaluating physiological responses of Tambaqui submitted to different water pH concentrations, verified that there was no mortality of individuals at exposure concentrations ranging from 4 to 8 pH; however, water with a pH close to 8.0 caused changes in hematological parameters. ––Azevedo e Aiub (2012) describe the normal weight development of animals reared in environments with pH values between 6.7 and 9.1; and –Silva e Carneiro (2007) with pH variation of 6.9 and 7.0 in fattening ponds in Tambaqui and a system without water renewal. In addition, the authors report that those values do not negatively influence animal growth, even if other factors can affect those traits.

Water electrical conductivity varied between 39.04 and 47.74 µS*cm^{-1} in the resent research, with similar values as described by Arbeláez-Rojas, Fracalossi and Fim (2002) and Sipaúba-Tavares, Freitas and Braga (1999), around 45 and 49.3 µS/cm in semi-intensive growth systems ponds for Tambaqui and in polyculture with Tambaqui using artificial aeration, respectively.

Both, water electrical conductivity, and turbidity peculiarities found in the present study, corroborate values commonly found in the semi-intensive cultivation of Tambaqui in ponds without continuous water flow, whose main characteristics are high primary productivity, suspended sediments, and high concentrations of dissolved salts(17).

Water transparency in the present study had

Table 2. Mean and standard deviation of water quality variables in the cultivation of Tambaqui (*C. macropomum*) in semi-intensive system without continuous water flow.

	With aeration (T1)	**Without aeration (T2)**
pH	6.77 ± 0.72 a	6.14 ± 0.59 a
Electrical Conductivity (µS/cm)	39.40 ± 4.19 b	47.74 ± 2.94 a
Turbidity (cm)	18.11 ± 1.75 a	23.19 ± 2.91 a
Total Ammonia Nitrogen (mg/L)	129.00 ± 0.16 a	166.00 ± 0.40 a
Nitrite (mg/L)	104.00 ± 0.60 a	75.00 ± 0.01 a
Dissolved Oxygen (mg/L)	7.38 ± 2.58 a	7.20 ± 1.40 a
Temperature (°C)	29.62 ± 0.40 a	29.52 ± 0.51 a

little variation and was similar between treatments ($p<0.05$). These values are in line with those observed by Castro, Souza e Barros (2002) where the average variation is 20.0 cm in depth, in the intensive cultivation of Tambaqui using artificial aeration. Higher transparency values were reported by Fernandes and Menezes (2010), ranging from 37.8 to 56 cm in pond, for Tambaqui growing. (26) highlight that transparency is a good criterion for assessing planktonic density in water in tanks and nurseries, as waters with transparency greater than 60 cm allow the penetration of high volumes of light in the depth, favoring the growth of submerged aquatic plants.

The water transparency values found in the present research are lower than those indicated by Vieira (2017) who claims that the optimum transparency is 40 to 60 cm. This criterion can be used as an indicator of the occurrence of critical levels of dissolved oxygen, but as this parameter had values normal for tropical species, it may not have influenced fish performance. The low values of water turbidity in the present research may be related to the management used in aquaculture systems, since emptying procedures allow the formation of stable aggregate soils and, as a consequence, less dispersion of fine particles into the water, which did not occurr in this research since the tanks did not have a continuous flow of water(28).

Total ammonia ($NH3^+$ and $NH4^+$) concentration varied below the critical levels for the species. Araújo-Lima e Gomes (2010) reported that Tambaqui can tolerate concentrations of up to 0.46 mg / L of non-ionized ammonia (NH3), the most toxic form, without compromising its growth. The values of total ammonia observed in the present study were 0.129 mg / L at T1 and 0.166 mg / L at T2. These values are within the concentration ranges described by –Silva e Carneiro (2007); as well as by Sipaúba-Tavares, Freitas e Braga (1999) with concentrations between 0.1 to 0.3 mg/L and 0.018 to 0.028 mg/L, respectively. Nitrite (NO^2) concentrations varied from 0.075 to 0.089 mg/L. –Costa et al. (2004) report that Tambaqui is sensitive to the effects of nitrite, where the lethal concentration (CL_{50}) occurs around 0.13 $mg*L^{-1}$. Therefore, values found in the present study are below the lethal levels for the species.

According to –Silva e Carneiro (2007), dissolved oxygen concentrations below 2.0 mg/L affect Tambaqui growth. Thus, as observed in the present research, oxygen supply provided by the supplementary artificial aeration in T1 contributed substantially to the maintenance of the highest concentration levels, providing greater availability of oxygen for the animals' comfort zone. Water temperature showed constant variation in both treatments, with a minimum of 28.15 °C and a maximum of 29.48 °C in T1, and a minimum of 28.25 °C and a maximum of 30.75 °C in T2.

The productive performance variables of the animals evaluated in the present experiment are summarized in Table 3.

For W, the present research observed that

Table 3. Means and standard errors of the productive performance variables of Tambaqui (*C. macropomum*), cultivated in a semi-intensive system without continuous water flow, for a period of 120 days. Amazonas, Brazil.

Trait	Colect	With aeration (T1)			Without aeration (T2)			p value
Weight (gr)	1	51.40 ± 0.87	**E**	**b**	64.46 ± 0.83	**E**	**a**	0.0001
	2	105.38 ± 1.83	**D**	**b**	125.53 ± 1.81	**D**	**a**	0.0001
	3	152.10 ± 3.22	**C**	**a**	154.04 ± 3.12	**C**	**a**	0.6664
	4	228.93 ± 4.68	**B**	**b**	264.69 ± 4.62	**B**	**a**	0.0001
	5	341.91 ± 6.33	**A**	**a**	303.56 ± 6.43	**A**	**b**	0.0001
Length (cm)	1	12.88 ± 0.08	**E**	**b**	13.73 ± 0.08	**E**	**a**	0.0001
	2	14.39 ± 0.09	**D**	**b**	15.25 ± 0.09	**D**	**a**	0.0001
	3	16.56 ± 0.14	**C**	**a**	16.42 ± 0.13	**C**	**a**	0.4622
	4	18.36 ± 0.14	**B**	**b**	19.30 ± 0.14	**B**	**a**	0.0001
	5	21.15 ± 0.14	**A**	**a**	21.23 ± 0.14	**A**	**a**	0.7030
Biomass (kg)	1	5.23 ± 0.36	**C**	**b**	7.09 ± 0.36	**B**	**a**	0.0217
	2	12.44 ± 0.74	**C**	**a**	15.15 ± 0.74	**B**	**a**	0.0600
	3	17.64 ± 2.63	**BC**	**a**	19.05 ± 2.63	**AB**	**a**	0.7252
	4	27.17 ± 3.83	**B**	**a**	32.20 ± 3.83	**A**	**a**	0.4045
	5	41.83 ± 7.46	**A**	**a**	36.02 ± 7.46	**A**	**a**	0.6117
Feed Convertion (FC)	1	1.8000 ± 0.001	**A**	**b**	1.09 ± 0.001	**A**	**a**	0.0001
	2	0.9438 ± 0.001	**B**	**a**	0.9242 ± 0.001	**B**	**b**	0.0001
	3	0.9077 ± 0.001	**C**	**a**	0.8961 ± 0.001	**C**	**b**	0.0001
	4	0.8879 ± 0.001	**D**	**a**	0.8786 ± 0.001	**D**	**b**	0.0001
	5	0.8709 ± 0.001	**E**	**b**	0.8825 ± 0.001	**E**	**a**	0.0001
k Factor	1	35.22 ± 2.68	**A**	**a**	36.10 ± 1.41	**B**	**a**	0.7653
	2	10.84 ± 0.49	**B**	**b**	44.12 ± 3.09	**A**	**a**	0.0001
	3	0.13 ± 0.01	**C**	**b**	0.78 ± 0.05	**D**	**a**	0.0001
	4	0.39 ± 0.02	**C**	**b**	3.33 ± 0.27	**CD**	**a**	0.0001
	5	0.57 ± 0.04	**C**	**b**	8.87 ± 0.78	**C**	**a**	0.0001

there is a variation between treatments in each data collection (p <0.05). It was found that in the first two, as well as in the fourth evaluation, T2 had higher weights (p<0.05), whereas in the third, weights did not differ among treatments (p>0.05). Therefore, in the final weighing could be noted greatest weight in T1 (p<0.05). The same variation was observed in the animals' SL. The correlation between both traits was positive, high and significant in T1 [0.92675; 0.0001] and in T2 [0.82277; 0.0001].

The difference in the final average weight between treatments shows the influence of supplementary artificial aeration on Tambaqui growth. Likewise, noting that the biomass (kg) in T1 proved to be 13.88% higher than in T2 at the end of the experiment. These results correspond to a productivity yield (kg/ha) of 5361.71 in T1 and 4171.84 in T2, representing an average biomass increase of 1189.87 kg/ha.

–''Boyd (1998), conducting productivity studies with channel catfish using nocturnal artificial aeration, describes relationships similar to those observed in the present study, where he obtained a higher biomass yield using only emergency artificial aeration (O2>2.0 mg/L). The authors found a difference in productivity, which corresponds to a 24.01% increase in biomass, similar to that obtained in the present study. The same positive relationship between the use of aeration and improved productivity in aquaculture was observed by Henares (2011) farming shrimp (*Macrobrachium amazonicum*), noting an increase in final biomass yield from 972 kg/ha in cultivation without aeration to 1131 kg/ha in cultivation with artificial night aeration.

The relatively low values of food conversion indices in the present study can be attributed to Tambaqui ability to filter and use plankton as natural food supplement to its diet, especially in the development phase. Costa (2013) in a study evaluating the plankton contribution to Tambaqui juveniles productivity, reports that even at high stocking densities, plankton accounted for 7.7 to 26.4% in the participation of body biomass.

This research showed that in T1, the FC index was higher than in T2 at 5th harvestand not before (p<0.05) with T2 characterized by having better feed conversion. Gazzola (2003) points out that in hypoxia environments, which is a frequent condition in fish farms, especially at night, body tissues allocate a lot of energy to physiological and behavioral mechanisms attempting to regulate metabolism to this adverse environmental conditions and, consequently, the extra expenditure of this energy reduces reserves for body synthesis, resulting in lower body weights. Correa, De Sousa e Martins-Junior (2018) indicate that low animal weight, as a consequence of low fish growth rates, can occur when the dissolved oxygen level is low, causing the animal to stay at the surface of the water, in an attempt to capture more oxygen and, when the condition is critical, it can develop labial prolapse in wich the animal slows down its growth rate and is more susceptible to diseases; a fact that did not occur in this experiment, evidenced in T1 where there was aeration and higher final weights.

The AFC is directly related to the amount of food that the fish eats and the efficiency in its transformation into body tissues (35). AFC in the present study is consistent with the findings in other Tambaqui researchs. Miguel et al. (2019) found values ranging from 1.15 to 1.29, indicating that the FC ratios of omnivorous fish can approach 2:1, because these species develop in aquatic mediums difficulting the obtaining of precise FC estimates, suggesting interaction between the food offered to the animals and the primary production developed in the nurseries, as consequence of previous fertilization.

In the present research, AFC values decreased as the animals grew, this reflects the efficiency of the nutritional regime in a semi-intensive rearing system. The fact that the present study showed AFC rates lower than 1, could indicate the use of certain amounts of natural food, in volumes recommended for Tambaqui growth, and its adequate use.

Although the AFC indices differ significantly from each other during the experiment (p<0.05), the trend towards their improvement when using supplementary artificial aeration at the end of the growth period was evident. This difference, under an economic approach, can significantly indicate high influence on production costs composition, since variables that conform, AFC are directly related to the costs and expenses of commercial production in Tambaqui.

As revised in the present research, meat fish production in tropical aquaculture systems plays a significant role in global food security, due to their environmental peculiarities, offering the ideal conditions for rapid fish growth, due to higher temperatures, but these systems also require careful management, especially in terms of water quality –(37). One of the most critical factors in optimizing fish production in ponds is aeration, that in consequence adequates the oxygen levels to its essential level; maintaining fish health, promoting feed conversion efficiency and preventing stress, which leads to higher mortality rates (38,39). Thus, proper aeration not only supports fish metabolism but also facilitates the breakdown of organic matter, reducing the risk of water pollution within the pond ecosystem, as found in the current research where Growth traits were influenced by aeration.

In tropical aquaculture, aeration is particularly crucial due to the rapid rate of biological activity in warm waters, warmer temperatures reduce the solubility of oxygen in water, leading to potential oxygen depletion (40); influencing the decline in oxygen availability; it can severely affect fish growth and health, especially in systems with high stocking densities where oxygen demand is already high (41). Therefore, mechanical aeration is often introduced to enhance oxygenation in ponds, particularly during the night when photosynthesis ceases, and oxygen consumption by fish and bacteria increases.

Aeration technologies vary significantly across different tropical systems. Paddlewheel aerators, for example, are commonly used in Southeast Asia for shrimp and tilapia farming –' —(42). In contrast, in Latin American countries, diffused air aerators are more frequently utilized (43). The type of aeration system chosen depends on several factors, including pond size, stocking density, and the species being cultured. Other aeration methods include vertical pump aerators, which are used in both India and parts of Africa, and surface aerators, which are common in small-scale fish farms across South America.

In Brazil, a tropical aquaculture leader, paddlewheel aerators have been particularly effective in tilapia farming systems, where high biomass production demands efficient oxygenation (44). Similarly in other countries, as in Thailand, floating aerators have been adopted in large-scale catfish farms due to their ability to aerate large surface areas and create currents that evenly distribute oxygen throughout the water column (45).

Indonesia, another major tropical aquaculture producer, has seen significant success with aspirator aerators in the cultivation of Pangasius and Catfish, with systems that, not only provide oxygenation but also assist in mixing the water, which helps prevent stratification and ensures that waste products are more evenly dispersed (46). Additionally, in Egypt, bubble diffusers are commonly employed in intensive systems to raise oxygen levels efficiently in dense fish populations (47).

In Africa, the use of aeration systems, particularly in Kenya and Uganda, has expanded in recent years with the adoption of solar-powered aerators. These systems are cost-effective and particularly suited to areas where electricity supply is unreliable, making them a sustainable option for small-scale farmers (48,49). In Nigeria, aerators powered by renewable energy sources, such as wind and solar, have been introduced to improve the production of catfish, which is a staple in the country's diet(50).

Although aeration systems are crucial for maintaining optimal oxygen levels in aquaculture ponds, these systems' cost can be impossible to afford for many small and medium-scale farmers in tropical regions. High energy consumption, maintenance costs, and the initial capital investment required for high-efficiency aerators often limit their widespread adoption, especially in low-income countries (51,52). Consequently, the development and implementation of low-cost aeration technologies are essential for improving the efficiency of meat fish farms.

Cheaper aeration systems, such as wind-powered or solar-powered aerators, can significantly reduce the operational costs of aquaculture farms while maintaining adequate oxygen levels for fish production (53). Additionally, the adoption of low-cost aerators has been shown to improve the financial viability of small-scale farms, allowing farmers to increase production without the need for expensive energy sources(54).

To further improve the efficiency of meat fish farms, research into innovative and affordable aeration systems must continue. Local adaptations, such as using locally available materials to construct aerators, can make these technologies more accessible to farmers. Moreover, the integration of renewable energy sources into aquaculture practices not only reduces costs, but contributes to the sustainability of the industry by minimizing its carbon footprint.

CONCLUSION

Supplementary artificial aeration improves the productive performance of Tambaqui (*Colossoma macropomum*). The application of this strategy can efficiently improve production systems of this species.

REFERENCES

1. Silva ACC, Barros AF de, Mendonça FMF, Gama KF da S, Marcos R, Povh JA, et al. Performance and economic viability of tambaqui, Colossoma macropomum, selectively bred for weight gain. Acta Amaz. 2020;50(2):108–14.

2. Falconer L, Hjøllo SS, Telfer TC, McAdam BJ, Hermansen Ø, Ytteborg E. The importance of calibrating climate change projections to local conditions at aquaculture sites. Aquaculture. 2020;514:734487.

3. Nguyen Van Huong. Economic analysis of small scale freshwater aquaculture production and its product marketing channels in agro-aquaculture system in Hai Duong province, Vietnam [Internet]. Gembloux Agro-Bio Tech - Université de Liège, Gembloux, Belgique; 2020 [cited 2020 Nov 17]. Available from: https://orbi.uliege.be/handle/2268/247570

4. FAO. Yearbook. Fishery and Aquaculture Statistics 2018/FAO annuaire. Statistiques des pêches et de l'aquaculture 2018/FAO anuario. Estadísticas de pesca y acuicultura 2018 [Internet]. FAO; 2018 [cited 2020 Nov 13]. Available from: http://www.fao.org/documents/card/en/c/cb1213t

5. Mendonça PP, Ferreira RA, Vidal Junior MV, Andrade DR, Santos MVB, Ferreira AV, et al. Influência do fotoperíodo no desenvolvimento de juvenis de tambaqui (Colossoma Macropomum). Archivos de Zootecnia. 2009;58(223):323–31.

6. Santos EL, Soares ACL, Tenório OLD, Soares EC, Silva TJ, Gusmão Júnior LF, et al. Desempenho de tambaquis (Colossoma macropomum) submetidos a restrição alimentar e a realimentação em tanques-rede. Arquivo Brasileiro de Medicina Veterinária e Zootecnia. 2018;70(3):931–8.

7. Kumar G, Engle C, Tucker C. Factors Driving Aquaculture Technology Adoption: FACTORS DRIVING AQUACULTURE TECHNOLOGY ADOPTION. J World Aquacult Soc. 2018;49(3):447–76.

8. Boyd CE. Pond water aeration systems. Aquacultural Engineering. 1998 Jul 1;18(1):9–40.

9. Izel-Silva J, Ono EA, de Queiroz MN, dos Santos RB, Affonso EG. Aeration strategy in the intensive culture of tambaqui, Colossoma macropomum, in the tropics. Aquaculture. 2020 Dec;529:735644.

10. Rogers GL. Aeration and circulation for effective aquaculture pond management. Aquacultural Engineering. 1989 Jan 1;8(5):349–55.

11. Weyne GR de S. Determinação do tamanho da amostra em pesquisas experimentais na área de saúde. Arquivos Médicos do ABC. 2004;29(2).

12. Silva CA da, Fujimoto RY, Silva CA da, Fujimoto RY. Crescimento de tambaqui em resposta a densidade de estocagem em tanques-rede. Acta Amazonica. 2015 Sep;45(3):323–32.

13. Vidal LVO, Albinati RCB, Albinati ACL, Lira AD de, Almeida TR de, Santos GB. Eugenol como anestésico para a tilápia-do-nilo. Pesquisa Agropecuária Brasileira. 2008 Aug;43(8):1069–74.

14. Cren EDL. The Length-Weight Relationship and Seasonal Cycle in Gonad Weight and Condition in the Perch (Perca fluviatilis). The Journal of Animal Ecology. 1951 Nov;20(2):201.

15. Feiden IF, Oliveira JDS de, Diemer O, Feiden A. Qualidade da água, capacidade de suporte e melhor período para criação de peixes em tanques-rede no reservatório de Salto Caxias. Eng Sanit Ambient. 2015 Dec;20(4):589–94.

16. R Core Team. R: A Language and Environment for Statistical Computing [Internet]. Vienna, Austria: R Foundation for Statistical Computing; 2023. Available from: https://www.R-project.org/

17. Cavero BAS, RUBIM MAL, MARINHO-PEREIRA T. Criação comercial do tambaqui Colossoma macropomum (Cuvier, 1818). In: Manejo e sanidade de peixes em cultivo [Internet]. 1a Edição. Macapá: Embrapa Amapá; 2009 [cited 2021 Jan 11]. p. 33–46. Available from: https://core.ac.uk/reader/15448070#page=33

18. Kubitza F. Qualidade da água no cultivo de peixes e camarões. F. Kubitza; 2003.

19. Aride PHR, Roubach R, Val AL. Tolerance response of tambaqui Colossoma macropomum (Cuvier) to water pH. Aquaculture Research. 2007;38(6):588–94.

20. Azevedo JC, Aiub JA da S. Avaliação da qualidade da água utilizada nos viveiros de tambaquis (Colossoma macropomum) na região de Cáceres – MT. 40 REVISTA DE BIOLOGIA E CIÊNCIAS DA TERRA. 2012;12(2):7.

21. SILVA C, CARNEIRO P. Qualidade da água na engorda de tambaqui em viveiros sem renovação da água. [Internet]. Empresa Brasileira de Pesquisa Agropecuária – EMBRAPA Tabuleiros Costeiros.; 2007. Available from: http://www.cpatc.embrapa.br/publicacoes_2007/f_18_2007.pdf

22. Arbeláez-Rojas GA, Fracalossi DM, Fim JDI. Composição corporal de tambaqui, Colossoma macropomum, e matrinxã, Brycon cephalus, em sistemas de cultivo intensivo, em igarapé, e semi-intensivo, em viveiros. Revista Brasileira de Zootecnia. 2002 Jun;31(3):1059–69.

23. Sipaúba-Tavares LH, Freitas AM, Braga FMS. The use of mechanical aeration and its effects on water mass. Revista Brasileira de Biologia. 1999 Feb;59(1):33–42.

24. Castro ALC, Souza N, Barros LCG. Avaliação do sistema de produção de Tambaqui intensivo em viveiro de terra

com aeração. Embrapa Tabuleiros Costeiros; 2002.

25. Fernandes TRC, Menezes B. TAMBAQUI (Colossoma macropomum, CUVIER, 1818) EM DIFERENTES TEMPOS DE. Bol Inst Pesca. 2010;36(1):8.

26. Júnior EF de M, Cordeiro GL, Silva MJL da. Qualidade da água em viveiros de tambaqui Colossoma macropomum (Cuvier, 1818), em São Gabriel da Cachoeira, Amazonas, Brasil. REVISTA IGAPÓ-Revista de Educação Ciência e Tecnologia do IFAM. 2018;12(1):22–31.

27. Vieira J. Níveis de proteína bruta no desempenho de juvenis de tambaqui criados em tanques-rede durante a fase de recria. Revista Nutritime [Internet]. 2017;14(02). Available from: http://nutritime.com.br/arquivos_internos/artigos/Artigo_420.pdf

28. Sipaúba-Tavares LH, Celeste CC, Braga FM de S. Efeito do óxido de cálcio sobre variáveis limnológicas em viveiros de criação de Piaractus mesopotamicus (pacu) e Colossoma macropomum (tambaqui). Boletim do Instituto de Pesca. 2018 Oct 30;32(2):191–8.

29. Araújo-Lima CARM, Gomes L de C. Tambaqui (Colossoma macropomum). In: Baldisserotto, B; Gomes, L de C Espécies nativas para piscicultura no Brasil. 2da ediçao. Embrapa Amazônia Ocidental (CPAA); 2010. p. 175–204.

30. Costa OTF da, dos Santos Ferreira DJ, Presti Mendonça FL, Fernandes MN. Susceptibility of the Amazonian fish, Colossoma macropomum (Serrasalminae), to short-term exposure to nitrite. Aquaculture. 2004 Apr 5;232(1):627–36.

31. Henares MNP [UNESP. Cultivo de camarão com aerador e substrato artificial, identificação de bactérias da wetland construída para o tratamento do efluente [Internet] [Tese de Doutorado]. [São Paulo]: UNESP; 2011 [cited 2021 Jan 12]. Available from: https://repositorio.unesp.br/handle/11449/100159

32. Costa JI da [UNESP. Avaliação econômica e participação do plâncton no cultivo de tambaqui em viveiros com diferentes densidades de estocagem [Internet] [Dissertação de Mestrado]. [São Paulo]: UNESP; 2013. Available from: https://repositorio.unesp.br/handle/11449/96669

33. GAZZOLA AC. Efeito da amônia e do oxigênio dissolvido na sobrevivência [Internet] [Dissertação de Mestrado]. [Santa catarina]: UNIVERSIDADE FEDERAL DE SANTA CATARINA; 2003. Available from: https://repositorio.ufsc.br/bitstream/handle/123456789/85945/193967.pdf

34. CORREA R de O, de SOUSA A, Martins Junior H. Criação de tambaquis. Embrapa Amazônia Oriental-Fôlder/Folheto/Cartilha (INFOTECA-E) [Internet]. 2018; Available from: https://www.infoteca.cnptia.embrapa.br/infoteca/bitstream/doc/1094579/1/CriacaodeTambaquisAINFO.pdf

35. Santos EL, Soares ACL, Tenório OLD, Soares EC, Silva TJ, Gusmão LF, et al. Desempenho de tambaquis (Colossoma macropomum) submetidos a restrição alimentar e a realimentação em tanques-rede. Arq Bras Med Vet Zootec. 2018 Jun;70:931–8.

36. Miguel CB, Cruz WD, Bonifácio AD, Reis FA, Fialho AP. Residuo de cervejaria na a alimentacao de Tambaqui *Colossoma macropomum* (CUVIER, 1818). Boletim do Instituto de Pesca [Internet]. 2019 Apr 17 [cited 2021 May 31];24(Especial). Available from: https://209.124.77.230/index.php/bip/article/view/1386

37. Dantas DP, Flickinger DL, Costa GA, Moraes-Valenti P, Valenti WC. Economic effects of production scale, use of agricultural greenhouses, and integration of tropical aquaculture species when farming in a subtropical climate. Aquacult Int. 2022 Apr 1;30(2):547–79.

38. Kusumah BR, Kostajaya A, Supriadi D, Nugraha EH, Siskandar R. Engineering of Automatically Controlled Energy Aeration Systems for Fisheries Cultivation Pools. In: Aquacultura Indonesiana [Internet]. 2020 [cited 2024 Oct 17]. p. 74. Available from: https://aquasiana.org/index.php/ai/article/view/207

39. Yongphet P, Ramaraj R, Whangchai N, Quaye EK, Wang D, Dussadee N. Modeling and implementing the use of aeration to increase water temperature and dissolved oxygen in greenhouse aquaculture cages. Aquacultural Engineering. 2020 Nov 1;91:102119.

40. Altieri AH, Johnson MD, Swaminathan SD, Nelson HR, Gedan KB. Resilience of Tropical Ecosystems to Ocean Deoxygenation. Trends in Ecology & Evolution. 2021 Mar 1;36(3):227–38.

41. Ali B, . A, Mishra A. Effects of dissolved oxygen concentration on freshwater fish: A review. Int J Fish Aquat Stud. 2022 Jul 1;10(4):113–27.

42. Roy SM, Tanveer M, Machavaram R. Applications of gravity aeration system in aquaculture—a systematic review. Aquacult Int. 2022 Jun 1;30(3):1593–621.

43. Nguyen NT, Vo TS, Tran-Nguyen PL, Nguyen MN, Pham VH, Matsuhashi R, et al. A comprehensive review of aeration and wastewater treatment. Aquaculture. 2024 Oct 15;591:741113.

44. Suriasni PA, Faizal F, Panatarani C, Hermawan W, Joni IM. A Review of Bubble Aeration in Biofilter to Reduce Total Ammonia Nitrogen of Recirculating Aquaculture System. Water. 2023 Jan;15(4):808.

45. Whangchai N, Klahan R, Balakrishnan D, Unpaprom Y, Ramaraj R, Pimpimol T. Development of aeration devices and feeding frequencies for oxygen concentration improvement in 60-tones freshwater recirculating aquaculture and biofloc ponds of Asian seabass (Lates calcarifer) rearing. Chemosphere. 2022 Nov 1;307:135761.

46. Wiratama N, Uchuwittayakul A, Susanto Y, Utari HB, Muna N, Satriagasa MC. Mapping spatial analysis of fish disease incidence and antibiotic resistance trends in selected provinces of Indonesia. IOP Conf Ser: Earth Environ Sci. 2024 Sep 1;1392(1):012004.

47. Fouda T, Elrayes AE, Elhanafy AE. A STUDY ON MICRO BUBBLES AERATION METHOD ON WATER TURBIDITY AT AQUACULTURE EARTHEN PONDS UNDER DIFFERENT

OPERATIONAL PARAMETERS. 2022;22(3).

48. Fouda T, Elrayes AE, Elhanafy AE. THE EFFECT OF AERATION METHOD ON NILE TILAPIA GROWTH, WATER QUALITY INDICATORS AND ENVIRONMENTAL IMPACT. 2023;23(1).

49. Tien Nguyen N, Tran-Nguyen PL, Vo TTBC. Advances in aeration and wastewater treatment in shrimp farming: emerging trends, current challenges, and future perspectives. AQUA - Water Infrastructure, Ecosystems and Society. 2024 Apr 6;73(5):902–16.

50. Omofunmi OE, Esan OJ. Development of A Cascade Aeratror for Small and Medium Fish Farmers in Nigeria. ASRIC JOURNAL ON AGRICULTURAL SCIENCES. 2023;195.

51. Dong Z, Wang Y. Optimization of power load and energy consumption in industrialized recirculating aquaculture system. IET Conference Proceedings. 2023 Sep 19;2023(12):79–82.

52. Liu S. Design of high efficiency and energy saving aeration device for aquaculture. AIP Conference Proceedings. 2017 Mar 13;1820(1):040006.

53. Parra L, Sendra S, Garcia L, Lloret J. Smart Low-Cost Control System for Fish Farm Facilities. Applied Sciences. 2024 Jan;14(14):6244.

54. Laktuka K, Kalnbalkite A, Sniega L, Logins K, Lauka D. Towards the Sustainable Intensification of Aquaculture: Exploring Possible Ways Forward. Sustainability. 2023 Jan;15(24):16952.