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Aeration strategy in the intensive culture of tambaqui, *Colossoma macropomum*, in the tropics

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ABSTRACT

As the demand for fish increases and limitations are placed on water use, intensification in closed aquaculture systems could help to increase its sustainable production. The Amazon region stands out for its stable warm climate with fast-growing and resilient fish. This study evaluated the efficacy of two aeration regimes on intensive rearing of tambaqui, *Colossoma macropomum,* in six 46.4-m^3 concrete-wall earthen bottom ponds, with no water exchange. Two aeration regimes were tested: (1) emergency aeration (EA), in which the aeration system was activated with dissolved oxygen (DO) levels below 3 mg L^{-1}; (2) supplemental aeration (SA), with 8 h of aeration every night, and also during days with low solar radiation. Water quality, fish performance and health (haematological and parasitological indicators), aeration use and cost were assessed. Juveniles (44.39 ± 9.72 g, mean weight ± SD) were stocked in six concrete-wall ponds with earthen bottoms at 32,300 ha $^{-1}$ and fed commercial feed (36–32% crude protein) for 17 weeks (122 days). Mean values of the water quality parameters showed no difference between treatments, but occurrences of hypoxia were significantly higher in SA (31 hypoxias with DO < 2 mg L^{-1} and 11 extreme hypoxias with DO < 0.5 mg L^{-1}) than in EA (5 and 0.6 occurrences, respectively). Significantly more erythrocytes were observed in the fish in SA than in EA, which indicates a response to a low DO concentration. The parasitological analyses revealed 100% prevalence of Monogenoidea (Dactylogyridae) in animal gills, with higher abundance in the SA fish. All treatments showed high fish survival rate (99.6 ± 0.8% for EA; 99.3 ± 1.2% for SA) and low FCR (1.22 ± 0.1 for EA; 1.32 ± 0.1 for SA), but weight gain, specific growth rate and yield were higher ($p < .05$) and water use and energy cost was lower ($p < .05$) for EA. In conclusion, the aeration strategy influenced hypoxia frequency and aeration cost, resulting in superior fish performance and health conditions and lower energy cost in EA, which suggests this strategy to be more beneficial for tambaqui production than SA.

1. Introduction

Fish farming intensification is a global need given the growing demand for seafood and the stagnation of capture fisheries (FAO, 2018). However, pond fish production with no water exchange can result in organic loads that must be metabolised by the environment that often becomes unsuitable for the animals due to insufficient water oxygen, predominantly regulated by phytoplankton populations (Tacon and Forster, 2003; Hargreaves, 2006; Boyd, 2017). Thus, high feed supply and the consequent increase in the nutrient load, algal blooms occur and may create oxygen deficits at night (Brune et al., 2003; Alonso-Rodríguez and Páez-Osuna, 2003; Boyd, 2017).

Artificial aeration is a technology that can aid to prevent the hypoxic situation in production systems because it accelerates oxygen transfer between the atmosphere and water (Boyd, 1998). Maintaining water quality improves production, with higher survival and fish growth rates, which may be obtained by applying adequate aeration or aeration strategies (Pawar et al., 2009; Ruiz-Velazco et al., 2010; Torrans et al., 2015).

Tambaqui (*C. macropomum*) has been a target species for which

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aerators in rearing systems have been used. However, technical-scientific information on the feasibility of applying this tool to produce the species is still scarce (Woynárovich and Van Anrooy, 2019). Native to the Amazon and Orinoco Basins, found in Brazil, Bolivia, Columbia, Peru and Venezuela (Araujo-Lima and Goulding, 1997), this species is cultured in most South and Central American countries, and in Caribe and Asia (Woynárovich and Van Anrooy, 2019. Presenting a rapid growth rate (Silva et al., 2007; Almeida et al., 2016), the ability to thrive at high densities (Gomes et al., 2006) and its resilience (Affonso et al., 2002; Oliveira and Val, 2016), interest in tambaqui production is spreading in the tropics.

The resistance of tambaqui to severe hypoxia (DO < 2 mg L^{-1}) is attributed mainly to its morphophysiological adaptations (Saint-Paul, 1984; Val, 1995). However, frequent drops in water dissolved oxygen (DO) can compromise fish homeostasis, as reflected by their performance (Green et al., 2012; Torrans et al., 2015), and can increase their susceptibility to diseases (Wedemeyer, 1996). In this study, the feasibility of applying two aeration regimes in tambaqui production was evaluated after considering fish performance, costs and health, but also the water physical and chemical variables, in intensive pond production with no water exchange.

2. Material and methods

2.1. Fish acclimatisation and experimental units

The experiment was carried out at the Aquaculture Experimental Centre of the INPA (National Amazonia Research Institute) in Manaus, Brazil. This work was previously approved by the Committee for Ethics in Research in the Use of Animals (Comitê de Ética em Pesquisa no Uso de Animais – CEUA) (Proc. num. 029/2015).

Tambaqui were purchased from a commercial fish farm, weighting 1 g and reared in a pond at a density of 12.5 fish m^{-2} until the experiment began. Six 46.4-m^2 concrete-wall earthen bottom ponds (1-m deep) were used as experimental units (EU). Before stocking, EU received 200 g m^{-2} of calcium oxide applied to sides and bottoms as sanitary measure and 600 g m^{-2} of dolomite limestone to raise water hardness and alkalinity and were filled with semi-artesian well water. The water use accounted for initial pond filling, plus pumping water replenishment during the experimental period.

2.2. Experimental protocol

Tambaqui juveniles with initial average weight of 44.39 ± 9.72 g were transferred and acclimated for 2 weeks in the EU at a stocking density of 32,300 fish ha^{-1} (150 fish/EU) and reared for 17 weeks (122 days). Fish were fed commercial extruded feed 6 days a week during the experimental period, being three times daily with 36% crude protein (CP) for the first 60 days to apparent satiation with an upper limit of 4% biomass per day and twice daily with 32% CP for the remaining period with an upper limit of 3% biomass per day. The water DO concentration was measured before feeding. Whenever DO levels were below 3 mg L^{-1}, feeding was suspended to preserve fish health, performance and water quality.

Artificial aeration was supplied by a radial compressor to the EU. Each pond had a 3/4” PVC pipe perforated at seven points (2.5 mm diameter) at 1.5-m intervals, installed longitudinally and centralised at 0.6-m of depth. Two artificial aeration regimes were applied in triplicates: emergency aeration (EA) and supplementary aeration (SA). For the EA treatment, the aeration system was switched on manually whenever critical water dissolved oxygen levels (< 3 mg L^{-1}) were recorded. In the SA treatment, the aeration system was used every night for 8 h (from 10 pm to 6 am), and on the days with low solar radiation (cloudy or rainy days), starting the third week. The duration of aeration used in the EU was recorded daily.

2.3. Water quality monitoring

The water quality variables measured daily were transparency (Secchi disk), dissolved oxygen, pH and temperature using a multiparameter analyser (model Pro1020, YSI Inc., USA) at 6 am and 6 pm, and before aeration started. Every 3 weeks, total ammonia (Verdouw et al., 1978), total hardness, total alkalinity, nitrite and carbon dioxide (Boyd and Tucker, 1992) were measured with water samples collected early morning for immediate processing and analyses.

Based on the tambaqui morphological adaptations after prolonged exposure to low DO concentrations (< 2 mg L^{-1}) in water, three hypoxia categories were established in the present study: level I = DO < 2 mg L^{-1}; level II = DO < 1 mg L^{-1} and; level III = DO < 0.5 mg L^{-1}. Hypoxic situations were counted whenever levels fell in the above-listed categories and were counted as one event that occurred for each day.

2.4. Growth performance and cost

For zootechnical performance evaluation, all fish were counted and weighted in order to determined: feed conversion ratio (FCR) = feed intake/biomass gain, specific growth rate (%) = (ln final average weight - ln initial average weight)/time in days × 100, daily gain = weight gain/time in days, survival (%) = final fish number/initial number of fish × 100, production (ton ha^{-1}) = final biomass/tank surface, water use (m^3 kg^{-1}) = water use/biomass, aeration use (days $cycle^{-1}$) = number of days in which aeration system was used along the 17-week cycle, aeration use (hours $cycle^{-1}$) = total hours of aeration applied in each aeration regime along the 17-week cycle, energy cost (USD kg^{-1} fish) = cost of electric energy/biomass gain; and economic FCR (USD kg^{-1} fish) = cost of feed consumed/biomass gain.

2.5. Fish health assessment

2.5.1. Parasitological analyses: preparation and identification of parasites

Parasitological analyses were performed before (N = 30) and after treatments (N = 10) per EU. In each EU, ten randomly selected fish were euthanised by brain concussion, followed by cranial drilling in accordance with the recommendations of the American Veterinary Medical Association, the AVMA (2013). Gills and gastrointestinal tracts were removed and fixed in 4% formaldehyde (Eiras et al., 2006) and dissected by using a stereomicroscope (Carl Zeiss, Model Stemi 2000-C). Parasites were also fixed in 4% formaldehyde solution. For preservation purposes, specimens were stored in 70% alcohol with 5% glycerine (Amato et al., 1991). The prevalence, intensity, average intensity and average abundance of parasites were calculated according to Bush et al. (1997).

2.5.2. Blood sample collection and determining blood parameters

Blood samples were collected from 10 fish per EU by puncturing the caudal vein using 3-mL syringes rinsed with 10% ethylenediaminetetraacetic acid (EDTA) at the end of the experiment. Haematocrit (Ht%) was measured by the microhematocrit method, the number of erythrocytes (RBC- erythrocytes μL^{-1}) in the citrate formaldehyde solution, using a haemocytometer. The haemoglobin concentration (([Hb] – g dL^{-1}) was recorded by the cyanmethemoglobin method. The haematimetric indices –mean corpuscular volume (MCV fL), mean corpuscular haemoglobin concentration (MCHC%) and mean corpuscular haemoglobin (MCH pg)– were calculated from the Ht, RBC, and [Hb] values according to Wintrobe (1934). Plasma was used for the glucose (mg dL^{-1}) analysis by applying the enzymatic-colorimetric method. The total protein (g dL^{-1}) analysis was performed by the modified biuret method and cholesterol (mg dL^{-1}) was determined by enzyme colorimetric method by using a commercial kit. Analyses were performed in a Spectramax M5 (Molecular Device Inc., USA).

2.6. Statistics

Treatments were compared by a Student's *t*-test, except for the parasitic indices and aeration use, for which a Mann-Whitney analysis was used. The significance level in both tests was 95% ($p < .05$).

3. Results and discussion

3.1. Water quality

The mean values of the physical and chemical water variables during the experiment are shown in Table 1. No significant differences were found between treatments for any evaluated variable. The highest CO_2 concentrations in the two aeration regimes were below the levels considered harmful (Boyd and Tucker, 1992; Oliveira and Val, 2016). The pH and temperature values fell within the suitable range for tambaqui cultivation (Gomes et al., 2006; Oliveira and Val, 2016). The total alkalinity and total hardness levels, even with liming, were moderate, which reflects the buffer system's capacity (Boyd, 2017).

The lack of water dissolved oxygen is the primary limiting factor for productivity increase because of its role in the oxidative process from which fish sources energy (Brune et al., 2003; Hargreaves, 2006; Boyd, 2017). The mean dissolved oxygen concentration was within the comfort zone for the species in both aeration regimes (Val, 1995). However, the morning DO levels gradually declined along the experiment regardless of the aeration regime used as a result of increased feeding rates and biomass (Fig. 2). In SA, despite activating the aeration system at 10 pm, hypoxia events (< 2 mg L^{-1}) were more frequent compared to EA but did not affect fish survival (see Table 2). According to Wedemeyer (1996), Affonso et al. (2012) and Boyd (2017) the effect of the hypoxia varies with the species tolerance and may cause stress and loss of homeostasis. These events were more frequent after algae bloom, observed from weeks 8 and 9 in SA and EA, respectively, which also reduced water transparency (Fig. 1) and its euphotic zone.

Nutrient overload stimulates the proliferation of phytoplankton on the water surface. In the present study, this occurred when feed supply was between 146.9 and 330 kg ha^{-1} d^{-1}, which varied from pond to pond regardless of the aeration regime. For this amount of feed placed in the environment, the amounts of nitrogen were the equivalent to 846 up to 1903 mg N m^{-2} d^{-1}, which exceeded ponds carrying capacity (Hargreaves and Tucker, 2003; Boyd, 2017). After this period, successive blooms took place until the end of the experiment, caused mainly by the high feeding rate. Similar patterns have been reported in intensive outdoor non-water exchange systems, where phytoplankton blooms and crashes have been observed (Burford et al., 2003; Hargreaves, 2006).

Table 1
Water quality variables (mean ± standard deviation) of ponds with *Colossoma macropomum* intensive cultures, without water exchange, but with emergency (EA) or supplementary aeration (SA) regimes, for 17 weeks.

Variables	EA	SA
Carbon dioxide (mg L^{-1})	17.21 ± 4.60	13.79 ± 2.65
Alkalinity (mg $CaCO_3$ L^{-1})	57.48 ± 10.04	50.24 ± 4.62
Total hardness (mg $CaCO_3$ L^{-1})	59.31 ± 5.63	49.64 ± 7.51
Transparency (cm)	21.56 ± 5.69	20.17 ± 1.86
Total ammonia (mg L^{-1})	1.23 ± 0.56	0.96 ± 0.31
Nitrite (mg L^{-1})	0.63 ± 0.38	0.45 ± 0.33
Dissolved oxygen (mg L^{-1})		
Morning	3.87 ± 0.25	3.67 ± 0.18
Afternoon	7.43 ± 0.62	8.16 ± 0.58
pH ($-\log_{10}[H^+]$)		
Morning	7.29 ± 0.04	7.25 ± 0.03
Afternoon	7.89 ± 0.05	7.97 ± 0.21
Temperature (°C)		
Morning	29.86 ± 0.11	29.67 ± 0.08
Afternoon	31.32 ± 0.19	31.15 ± 0.12

Table 2
Growth performance indicators (means ± standard deviation) of tambaqui, *Colossoma macropomum*, reared in ponds with emergency (EA) or supplementary aeration (SA) regimes, for 17 weeks, without water exchange.

Parameters	EA	SA
Initial weight (g)	44.39 ± 9.07	44.39 ± 9.07
Final weight (g)	546.24 ± 34.61[a]	387.25 ± 29.14 [b]
Survival (%)	99.56 ± 0.77	99.33 ± 1.15
FCR	1.22 ± 0.06	1.32 ± 0.06
Specific growth rate (%)	2.06 ± 0.05 [a]	1.77 ± 0.06 [b]
Daily gain (g)	4.11 ± 0.28 [a]	2.81 ± 0.24 [b]
Production (kg ha^{-1})	17,670 ± 1120 [a]	12,515 ± 963 [b]
Water use (m^3 kg^{-1})	0.84 ± 0.06 [a]	1.28 ± 0.06 [b]
Aeration use (days $cycle^{-1}$)	91 ± 5 [a]	108 ± 0 [b]
Aeration use (hours cycle-[1])	908 ± 88.99 [a]	1016.47 ± 6.15 [b]
Energy cost (USD kg^{-1})*	0.34 ± 0.03 [a]	0.54 ± 0.04 [b]
Economic FCR (USD kg^{-1})	0.58 ± 0.03	0.63 ± 0.03

Feed conversion ratio (FCR). Different letters on the same line indicate significant differences ($p < .05$) according to the Student's *t*-test, except for the aeration use indices according to the Mann-Whitney test.
* Aeration system of 9.0 kW per hectare.

The nitrite and total ammonia concentrations gradually rose with increasing biomass but did not differ between aeration regimes. Despite the high level of total ammonia in the system, this was not toxic according to the pH and temperature values. In both EA and SA, tambaqui tolerated total ammonia concentrations of up to 5.89 and 3.93 mg L^{-1}, respectively, which were equivalent to 0.44 and 0.29 mg L^{-1} of unionised ammonia (NH_3). These values are lower than the lethal concentration described for this species (Souza-Bastos et al., 2017). In both treatments, values close to or above 1 mg L^{-1} of nitrite were detected as from week 14, with maxima of 2.92 and 4.74 mg L^{-1} for SA and EA, respectively, which exceed the levels tolerated by this species described in the literature (Costa et al., 2004). This occurs when bacterial oxidation process of nitrite to nitrate is overcome by oxidation of ammonia to nitrite (Ebeling et al., 2006; Boyd, 2017) which indicates nutrient overload in the environment. Despite the high level of this metabolite, fish health was not affected as only 0.6% mortality rate was recorded during the experiment (Table 2). Despite the higher value of this metabolite being recorded in the EA regime, animal performance was not impaired as the zootechnical results were superior in EA than in SA (Table 2).

The ponds with EA were continuously monitored to prevent critical water DO concentrations. However, during periods without aeration, severe hypoxia (OD < 2 mg L^{-1}) occurred in the SA system. The mean frequency of occurrence of hypoxia categories in SA in EA increased in time and were: 30.6 and 6.2 occurrences of level I, 17.7 and 1.7 of level II, and 11.3 and 0.6 of level III, respectively (Fig. 3). These results showed that from culture week 8, critical DO concentrations were reached beyond the operating hours of the SA regime aerators, as reflected by the lower feed consumption and, consequently, worse animal performance (Table 2; Fig. 2). The increasing environment hypoxia frequency also impacts on microorganism and plankton populations, compromising the system capacity to breakdown nutrients (Ebeling et al., 2006; Boyd, 2017), escalating organic matter accumulation.

3.2. Growth performance and costs

The growth performance indicators of tambaqui during the 17-week experimental period are presented in Table 2. The final weight, specific growth rate, daily weight gain and production values were significantly higher, while water use was lower, in EA than in SA. However, the similarity of the FCR suggested that the main effect of SA was lower feed intake, with fish lower energy demand to allow survival under hypoxic conditions (Figs. 2, 3). This has also been reported in other fish species, including channel catfish and hybrid (channel catfish × blue

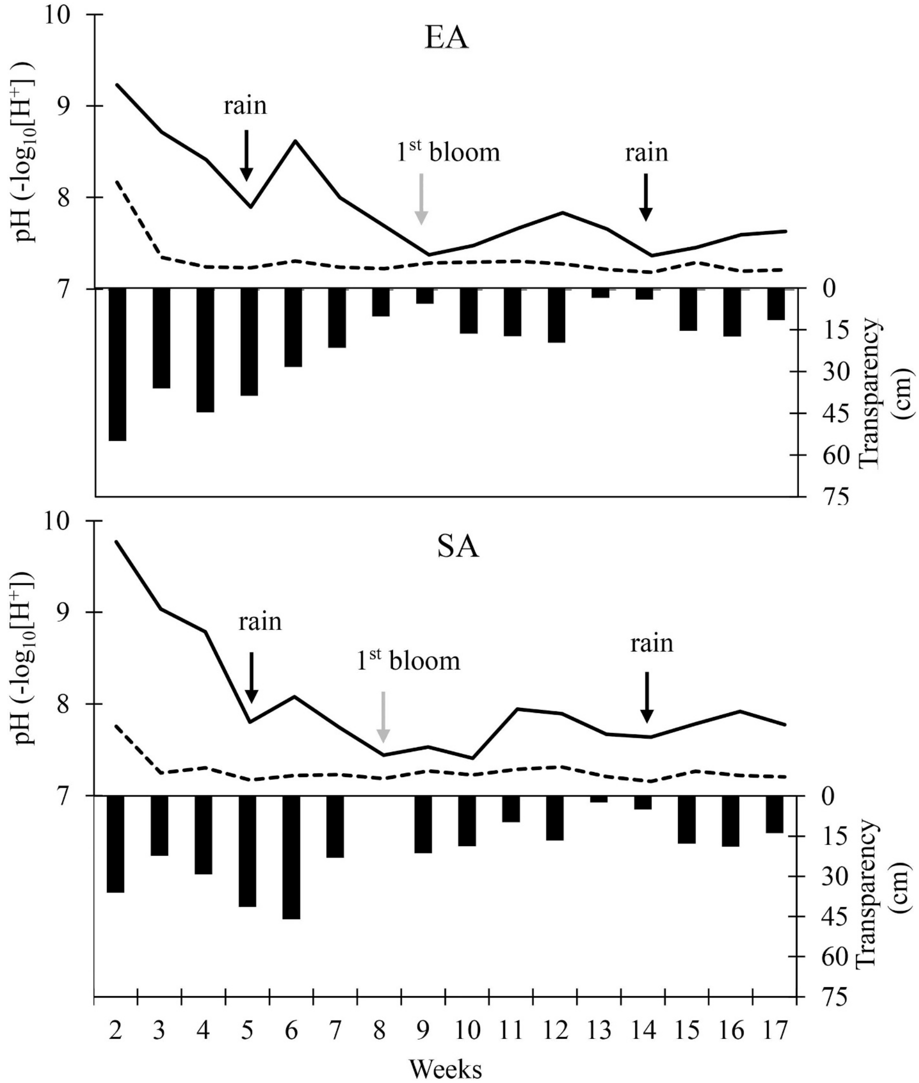

Fig. 1. Minimum and maximum pH and transparency values (means) for ponds with intensive *Colossoma macropomum* culture with no water exchange and emergency (EA) or supplementary aeration (SA) regimes, for 17 weeks.

catfish) (Torrans, 2008; Green et al., 2012; Torrans et al., 2015), rainbow trout (Glencross, 2009), Nile tilapia (Tran-Duy et al., 2012) and Atlantic salmon (Gamperl et al., 2019).

The tambaqui production in the present study achieved similar yields to those of channel catfish reared in aerated ponds, 9 to 23 tons ha^{-1} (Torrans et al., 2015; Kumar and Engle, 2016), and corroborated the results of Izel et al. (2013) for this species pond production of 18.5 tons ha^{-1} in Brazil. These results indicate capacity and potential of tambaqui for intensive pond production (Table 2).

After the 17-week experimental period, the survival rates did not significantly differ between treatments (Table 2). The high survival rate highlights tambaqui resilience to hypoxic conditions and to high ammonia and nitrite levels, under pond culture conditions. These survival rates corroborate those obtained with tambaqui in similar rearing environments (Gomes and Silva, 2009; Costa et al., 2016).

The total use of aeration in EA was significantly lower than in SA, as well as the electric energy cost per kilogram of biomass produced (Table 2). However, the mean daily hours of aeration use were 7.45 ± 0.73 in EA and 8.33 ± 0.05 in SA, with no significant difference. These results demonstrated the poorer growth performance and economic efficiency of the SA regime compared to EA and indicates the marked importance of the normoxia control to produce the species (Torrans et al., 2015; Gamperl et al., 2019).

3.3. Fish health

The parasitological analyses revealed no presence of endoparasites in the gastrointestinal tracts, but ectoparasite Monogenoidea (Dactylogyridae) on the gills. These hermaphroditic parasites, which are frequently described in the literature with the highest prevalence (Godoi et al., 2012; Dias et al., 2015), have a direct life cycle in fish, which facilitates contagion and reproduction (Thatcher, 2006).

In the present study, 100% parasitic prevalence was observed at the beginning and end of the experiment for both treatments (Table 3). Incidence is high in most fish species associated with monogenoids, and parasite intensities of 20–100 per fish are also commonplace (Paperna, 1964; Godoi et al., 2012; Dias et al., 2015). When comparing the parasitic intensity (I) of basal fish with those of regimes EA and SA at the end of the experiment, there were fewer parasites, which was probably related to the higher stocking density in the nursery phase (12.5 fish m^{-2}). Another possibility could be the immune system's increased capacity to protect against pathogens promoted by fish growth during cultivation (Biller-Takahashi and Urbinati, 2014). A significant difference in the mean parasitic intensity (MI) was observed when comparing the parasite load between aeration regimes, with a higher incidence for the animals exposed to SA. This increase could be related to the negative effects of stress during the experiment, probably due to

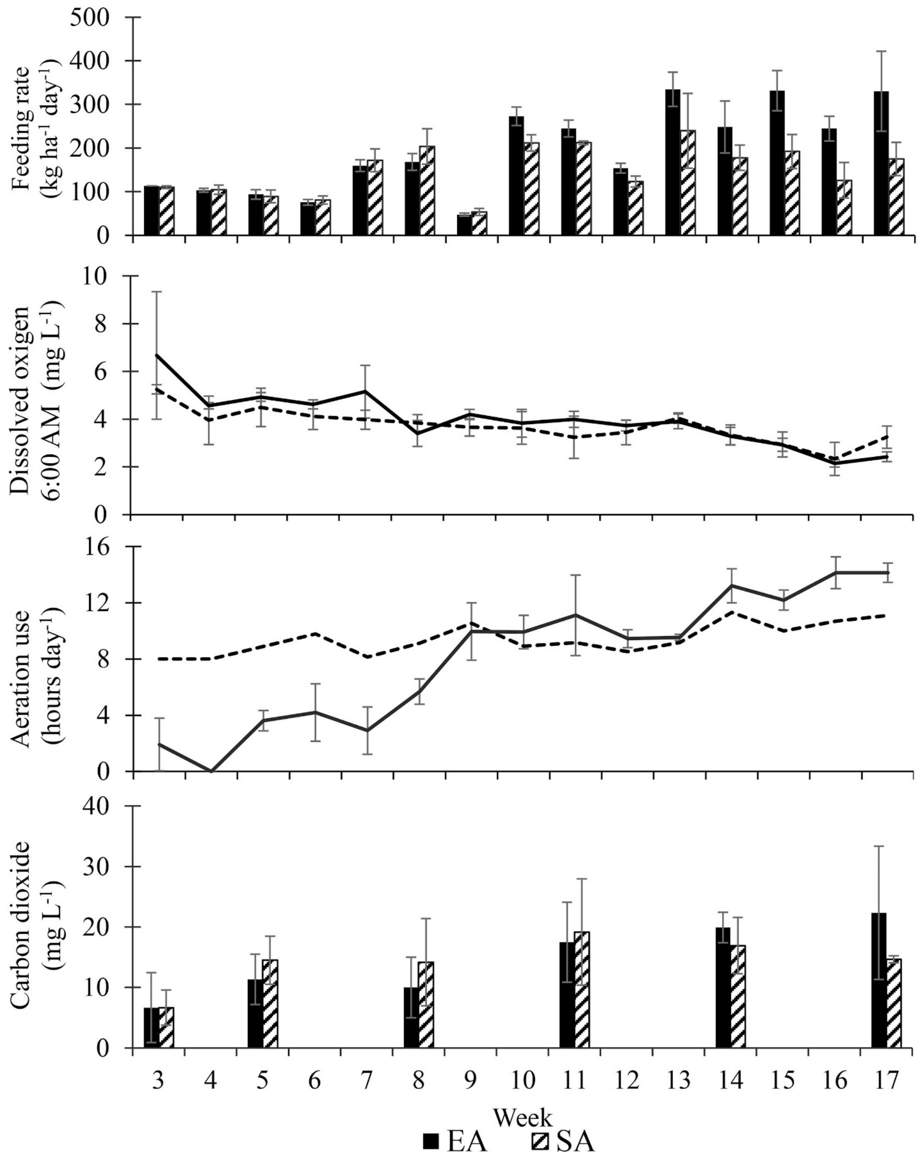

Fig. 2. Feeding rates, dissolved oxygen, aeration use and carbon dioxide along the experimental period in the emergency (EA) and supplementary (SA) aeration regimes in ponds with *Colossoma macropomum* intensive culture with no water exchange.

the more frequent hypoxia occurrences taking place during this treatment (Wedemeyer, 1996; Zanuzzo et al., 2019).

In severe hypoxia cases (< 0.5 mg L^{-1}), tambaqui uses water surface respiration, which involves lower lip protrusion intended to capture the upper water film richer in DO (Saint-Paul, 1984; Val, 1995; Sundin et al., 2000). This behaviour was observed 4.33 times on average in SA and less than once in EA. Under chronic low DO level conditions, fish develop tertiary stress responses, such as immunosuppression, which favour disease manifestation (Wedemeyer, 1996).

Blood parameters have been important indicators in studies to evaluate the efficiency of production systems as they express fish physiological conditions (Foss et al., 2006; Affonso et al., 2012; Gamperl et al., 2019). The haematological parameters of the tambaqui in the present study presented no significant differences between treatments, except for the number of erythrocytes (RBC), which was significantly higher in SA (Table 4). Changes in this parameter can occur in response to stress and could indicate a greater oxygen transport capacity from blood to tissues (Saint-Paul, 1984; Sampaio and Sampaio and Freire, 2016) or anaemia (Heath, 1995). However, the difference in RBC between both regimes did not appear to compromise the efficient transport of oxygen to tissues because fish were not anaemic. This was also confirmed by haematimetric indices MCV, MCH and MCHC, which characterised tambaqui RBC as being normocytic and normochromic (Table 4).

Hyperglycaemia is also an indicative of a response to acute or chronic stress, which occurs due to increasing energy demands (Wedemeyer, 1996; Trenzado et al., 2006; Sampaio and Sampaio and Freire, 2016). In the present study, the fish blood glucose values were not altered, corroborating with the haematological results and the values for total proteins and cholesterol indicating that fish metabolic demands did not increase.

4. Conclusion

The aeration strategy is important for the rearing of tambaqui to the size of the present study, and the emergency aeration regime (at DO < 3 mg L^{-1}) was superior to supplementary aeration in relation to growth performance, economic efficiency and maintenance of fish health. The morphophysiological adaptations of tambaqui to tolerate severe hypoxia conditions and high ammonia and nitrite concentrations confirm this species resilience under intensive culture conditions.

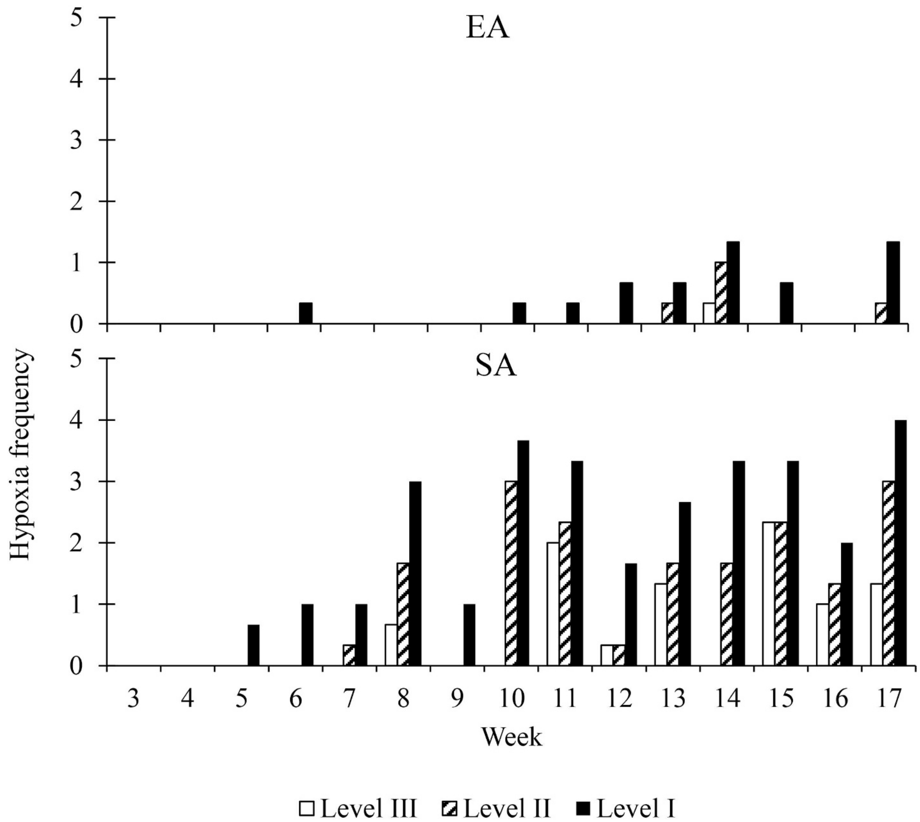

Fig. 3. Level III (DO < 0.5 mg L^{-1}), level II (DO < 1 mg L^{-1}) and level I (DO < 2 mg L^{-1}) hypoxia frequencies along the experimental period in the emergency (EA) and supplementary (SA) aeration regimes in ponds with *Colossoma macropomum* intensive culture with no water exchange.

Table 3
Parasitological indices ± standard deviation of Monogenea (Dactylogyridae) in *Colossoma macropomum* gills from the beginning (A0) and the end of intensive culture without water exchange, and emergency (EA) or supplementary aeration (SA) regimes, for 17 weeks.

Parasitological indices	A0	EA	SA
Prevalence (%)	100	100	100
Intensity	836–102	376–18	350–56
Mean intensity	270.7 ± 164.2^{a}	124.1 ± 95.29^{c}	177.2 ± 71.24^{b}
Mean abundance	270.7 ± 164.2^{a}	124.1 ± 95.29^{c}	177.2 ± 71.24^{b}

Different letters on the same line indicate significant differences ($p < .05$) according to the Mann-Whitney test at 95% significance, $n = 30$.

Table 4
Blood parameters (mean ± standard deviation) of *Colossoma macropomum*, reared in ponds without water exchange, and an emergency (EA) or supplementary aeration (SA) regime.

Blood parameters	EA	SA
Haematocrit (%)	27.1 ± 4.26	25.98 ± 3.94
Red blood cell (10^{6} μL^{-1})	1.19 ± 0.35 ^{a}	1.43 ± 0.42 ^{b}
Haemoglobin (g dL^{-1})	7.19 ± 1.06	7.54 ± 1.10
MCV (fL)	226.04 ± 78.80	215.21 ± 63.75
MCH (pg)	63.56 ± 23.61	58.52 ± 16.72
MCHC (g dL^{-1})	28.77 ± 6.28	27.79 ± 4.85
Total protein (g dL^{-1})	2.89 ± 0.57	2.94 ± 0.6
Glucose (mg dL^{-1})	81.42 ± 32.39	80.39 ± 29.50
Cholesterol (mg dL^{-1})	50.00 ± 10.5	50.2 ± 15.2

Mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin concentration (MCHC). Different letters on the same line indicate significant differences ($p < .05$) according to the Student's *t*-test.

Further studies to evaluate aerations regimes in the production of tambaqui to a larger size may be of interest for aquaculture.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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