



Growth of Striped Catfish Fingerlings (*Pangasianodon hypophthalmus*) in Aquaponic System with Fine Bubbles (FBs) Application

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Authors' contributions

This work was carried out in collaboration among all authors. Author MN designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors ZH, Sumadi and HH managed the analyses of the study. Authors YA and US managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJFAR/2020/v7i230111

Editor(s):

(1) Dr. Vijai Krishna Das, Kamla Nehru Institute of Physical and Social Sciences, India.

Reviewers:

(1) Adel Y. Al-Dubakel, Basra University, Iraq.

(2) Tasmina Akter, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh.

(3) Siti Norita Mohamad, Fisheries Research Institute (FRI), Malaysia.

Complete Peer review History: <http://www.sdiarticle4.com/review-history/58029>

Original Research Article

Received 08 April 2020

Accepted 14 June 2020

Published 23 June 2020

ABSTRACT

This study aims to determine the growth of Striped Catfish fingerlings (*Pangasianodon hypophthalmus*) and using Fine Bubbles (FBs) application with various pressures in the aquaponic system. The study was conducted at the Laboratory of Aquaculture, Ciparanje, Faculty of Fisheries and Marine Sciences, Padjadjaran University from 18th September to 18th October 2019. The method used in this study was the experimental method using Completely Randomized Design (CRD) with four treatments and three replicates. Treatment A: Control (without FBs), Treatment B: FBs with pressure 4.5 atm, Treatment C: FBs with pressure 5 atm, and Treatment D: FBs with pressure 5.5 atm. This research used water spinach as biofilter. The measured parameters in this study were fish growth, plant productivity, and water quality which includes levels of temperature, dissolved oxygen, nitrate, ammonia and phosphate. The results showed that the highest fish specific growth rate in treatment D is $6.68 \pm 0.43\%$ /day with a survival rate of $100 \pm 0.00\%$, the highest plant productivity, with a stem length of 115.03 cm, a weight of 62.75 g, and leaf growth of

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30 strands. While the water quality parameters including temperature, dissolved oxygen concentrations ranged from 24.2-27°C, 7.72-7.94 mg / l, nitrate 0.243-0.602 mg / l, ammonia 0.001-0.010 mg / l and phosphate 0.147-0.229 mg / l respectively.

Keywords: *Fine Bubbles; aquaponic; striped catfish; growth rate; water quality.*

1. INTRODUCTION

Striped catfish is one of the leading freshwater fish commodities that are in demand by Indonesian people because its meat is delicious, easily digestible, and contains calcium, iron, and minerals which are very good for health [1]. The nutritional content of catfish indicates the moisture, protein, fat and ash percentage (%) were 78.29 ± 0.22 , 12.78 ± 0.16 , 16.55 ± 1.52 and 1.78 ± 0.19 , respectively [2]. Striped catfish continue to be developed because it has a high economic value and has the business opportunities for aquaculture. Thus, the production of Striped catfish seedlings must always be fulfilled.

The increased production of Striped catfish is still constrained by limited land and inadequate water quality. Optimal environmental conditions will affect the success of Striped catfish production in aquaculture activities. Aquaculture activities produce solid and liquid waste from manure and fish food waste. Fish waste accumulation can decrease water quality that affects the physiological processes, behavior, growth, and death of fish [3]. Innovation and technological inputs are required to anticipate the decline in aquaculture production and productivity. Technological innovation is needed to overcome these problems, one of the technologies that can be used in aquaponics.

Aquaponics technology is the integration of biological that connects aquaculture with the principle of recirculation with the production of hydroponic plants or vegetables [4]. Aquaponics is a more environmentally friendly technology because this system will decrease nitrogen concentration contained in water in fish care containers because of the presence of biofilter in the form of plants. Water containing nitrogen (ammonia, nitrite, and nitrate) in the fish raising container is channeled to the plants, then used as nutrients [5]. Water containing nitrogen in fish rearing tank will be oxidized through a biological process that is the process of nitrification. Nitrification is an inorganic nitrogen removal process that can occur optimally when sufficient dissolved oxygen needs are met in fish rearing water.

The addition of aeration to the recirculation system can accelerate the process of nitrification. Aeration in aquaculture has the function of dissolving oxygen into the water to increase the concentration of dissolved oxygen and reduce the concentration of unneeded gases dissolved in water and to help the process of stirring the water. One aeration that can be used to increase oxygen concentration is the use of Fine Bubbles applications. Fine Bubbles (FBs) is a technology that produces bubbles of 150-200 nm in size to provide dissolved oxygen for a long time and in a stable condition [6]. The use of FBs application has a positive effect on fish farming activities including fish growth is much faster, fish are not susceptible to disease, and water quality is maintained even in closed pond systems (water is circulated continuously) [7].

FBs generators are designed to control the bubble size distribution by controlling the pressure that enters the generator [8]. The size of the bubbles produced is affected by the combination of pressure and airflow rate used. The size of the bubbles will affect the concentration of dissolved oxygen. The greater the pressure used, the smaller the size of the bubbles produced. The result of Arumugam [9], show that the pressure are 2.6 atm; 3.8 atm; 4.4 atm; and 5.2 atm and dissolved oxygen concentration 7.73 - 8.82 mg / L. While the results of Andinet et al. [10] exhibit that the use of 4.5 atm pressure can increase the concentration of dissolved oxygen to 10 mg / L.

The purpose of this research is to determine the growth of Striped catfish fingerlings (*Pangasianodon hypophthalmus*) using Fine Bubbles application with various pressures in the aquaponic system.

2. MATERIALS AND METHODS

2.1 Research Site

This research was conducted from 18th September to 18th October 2019 at Ciparanje Green House, Faculty of Fisheries and Marine Sciences, Padjadjaran University, Jatinangor, West Java, Indonesia.

2.2 Research Materials

Striped catfish fingerlings used are 2.5 - 4 cm in size with an average weight of 0.2 - 0.5 gram, with a density of fish in rearing containers as 450 fish/container. The plant used in this study was water spinach (*Ipomea reptans*). The seeds of water spinach plants used were 10 days old with husk charcoal media. Water spinach plants placed in aquaponic installations are three stems / pots.

2.3 Research Tools

This study used 3 units of Fine Bubbles Generator with a mixing pump machine of 150 watts capacity, 12 tanks with a volume of 70 cm x 70 cm x 70 cm used as a container for fish raising, 12 pieces of PVC pipe with a diameter of 4" with a total of 19 holes (each with diameter of 6 cm) used as a medium for growing water spinach and 4 tanks with the volume of 70 cm x 70 cm x 70 cm used as a container for Fine Bubbles. Each water tank is filled with a total volume of 150 L. 12 pumps with a size of 90 watts (4 meters) and a size of 25 watts (2 meters) were used to draw water from a fish culture container into a 4" PVC pipe. PVC pipe 4" is placed to drain water and hold water for plants. Total of 228 pieces of plastic cups are used as a place to put plants. Digital scales with an accuracy of 0.1 gram are used to measure the weight of fish and plants. Millimeter block is used to measure fish length and plant height.

2.4 Research Methodology

The method used in this study is an experimental method using a Completely Randomized Design (CRD), with four treatments, repeated three times:

Treatment A: control (without Fine Bubbles, only used aerator)

Treatment B: Fine Bubbles with a pressure of 4.5 atm

Treatment C: Fine Bubbles with a pressure of 5 atm, and

Treatment D: Fine Bubbles with a pressure of 5.5 atm

2.5 Research Procedure

Fish Acclimatization: The fingerlings catfish used in this experiment were obtained from the catfish brood stock originating from Cijengkol-

Subang BPBAT. Fish acclimation was done so that fish can adapt to the new environment and the fingerlings can adjust when subjected to experimentation. Freshly purchased fingerlings are stored in an acclimation container for 1 week so that the fish are not stressed and reduce the value of death. Feeding was carried out routinely ad libitum twice a day (9:00 AM and 3:00 PM) so that the fingerlings continue to get food intake during the adaptation process.

Aquaponics Installation Preparation: The recirculation aquaponics system was installed in such a way, where fish and plants are kept in separate containers placed on multilevel metal shelves. Then, the water in the container where the fish were stored was channeled to the plant container using a 4" PVC pipe. Water from the water spinach outlet comes out of the 4" PVC pipe and into the FBs container. The water that has been processed from the FBs generator will flow back to the fish rearing container with a PVC pipe 1/2" with the pump.

Seeding Seeds: The seeding process was carried out by planting ground water spinach seeds in a tray using husk charcoal. Water spinach was sown for 10 days before it is planted in the growing media in aquaponics.

2.6 Research Implementation

This research was conducted for 30 days. Striped catfish density is 3 fish / L (450 fish in one container). Feeding was done twice a day at 9:00 AM and 3:00 PM with a feeding rate of 5% of the total body weight of fish. The feed used commercial PF-1000 with 39-41% protein. After that, the number of dead fish was counted every day. Weight and length of fish fingerlings measured once a week as many as 45 fish from each fish rearing container. Observation of plants were done once a week by measuring the length of the plant stems and increasing the number of leaves, while the weight of the plants was measured at the beginning and end of the study.

2.7 Observed Parameters

Fish Growth: Fish growth was measured by weighing the weight of the initial and final samples, then measuring the total length of the fish. Specific growth rates are calculated using the following formula [11]:

$$SGR = (\ln(\text{final weight in grams}) - \ln(\text{initial weight in grams}) \times 100) / t \text{ (in days)}$$

The survival rate of catfish fingerlings was calculated using the formula below [12]:

$$SR = \frac{Nt}{N0} \times 100\%$$

Note:

SR : Survival rate (%)

Nt : Number of living fish at the end of treatment (fish)

No : The number of fish at the beginning of treatment (fish)

Water Quality: Water quality observations in this study consisted of measurements of temperature, dissolved oxygen, ammonia, nitrate, and phosphate concentrations in water. Measurement of water quality was an important part of research because good water quality can affect the growth and survival of fish.

Plant Observation: Measuring plant length and increasing the number of leaves were done regularly every 7 days, starting from the beginning of the study until the last day of observation. Plant weight measurements were measured at the beginning and end of the observation.

2.8 Data Analysis

The results of the data were analyzed descriptively through observational studies with supporting data and related literature. Furthermore, the data were analyzed using analysis of variance (F-test) with the confidence level of 95% to determine the effect of each treatment on the length of the plant stem and the addition of leaflets. If there are significant differences between treatments, then the data is analyzed with Duncan's multiple distance test with a level of 5% used Microsoft Excel [13].

3. RESULTS AND DISCUSSION

3.1 Fish Growth

At the beginning of the experiment, the average of the fish used in the research size ranged from

0.2 to 0.5 g with a length of 2.5 - 4 cm and increased after 30 days of cultivation. The results of the study showed weight gain and length of the catfish seeds differed in each treatment. Observation of catfish fingerlings cultivated in the aquaponic system using FBs application with different pressures shows that there are significant differences ($P > 0.05$) in the specific growth rate and growth length. The specific growth rate and the highest growth length are in the treatment of adding applications FBs with a pressure of 5.5 atm (D) of $6.68\% \pm 0.43$ and $2.28 \text{ cm} \pm 0.10$ (Table 1).

The weight and length of catfish fingerlings during the study increased every week. Striped catfish weight gain occurs due to optimal environmental conditions in treatment D. The observations indicate the difference between the use of FBs and without using FBs is very influential on growth, the effect of FBs can increase oxygen concentration so that it affects the physiological effects namely accelerating blood flow, increasing growth and as disinfectant [14].

The application of FBs in aquaponic systems supplies dissolved oxygen with fine sized bubbles that spread evenly in fish rearing containers. The application of microbubbles in fish-raising media increased the concentration of dissolved oxygen while improve water quality and affects faster growth rates [15]. This is in accordance with the study of Ebina et al. [16], who stated that high dissolved oxygen concentrations can enhance growth due to the influence of nano-sized aeration bubbles. Differences in fish growth in each treatment can be seen in Fig. 1.

3.2 Rate of Survival Fish

The survival of fish is one indicator of whether or not the cultivation system is feasible. This is because the survival of fish is related to adequacy of food, the health of the fish, good or poor environmental maintenance such as water quality. The aquaponics system reduces the waste by absorbing the wastewater using plant

Table 1. SGR and total length growth of striped catfish

Treatments	Growth Parameters	
	SGR (%) / day	Total Length Growth
A (Control)	3.82 ± 0.04^a	2.00 ± 0.12^a
B (FBs with pressure 4,5 atm)	6.00 ± 0.71^b	2.51 ± 0.17^b
C (FBs with pressure 5 atm)	5.45 ± 0.33^b	2.47 ± 0.12^b
D (FBs with pressure 5,5 atm)	6.68 ± 0.43^c	2.80 ± 0.10^c

Note: Values followed by the same letter in the same column show no significant difference at the 5% test level

roots so that the remaining absorbed feed undergoes an oxidation process with the help of oxygen and bacteria [17]. Increasing oxygen concentration is an alternative to reducing the concentration of ammonia in waters. The nitrification process is more efficient under conditions of high oxygen tension [18]. High oxygen concentrations can oxidize ammonia so that it does not become toxic in water.

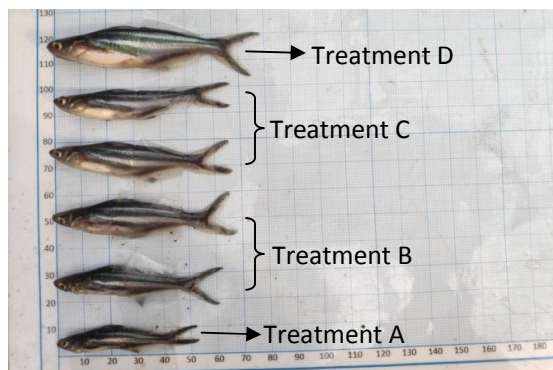


Fig. 1. Fish growth at the end of the study

During 30 days of maintenance, the survival rate of catfish fingerlings showed a different value. The results of the F-test diversity analysis showed that there were significant differences ($P < 0.05$) treatment A with treatments B, C and D. The results showed that the highest rate of survival of catfish was obtained in treatments B and D by 100%, followed by treatment C by 98%, then treatment A was 77% (Table 2).

Table 2. Survival rate of Striped catfish

Treatments	Survival rate (%)
A (Control)	77 ± 4.93 ^a
B (FBs with pressure 4,5 atm)	100 ± 0.00 ^b
C (FBs with pressure 5 atm)	98 ± 1.56 ^b
D (FBs with pressure 5,5 atm)	100 ± 0.00 ^b

Note: Values followed by the same letter in the same column show no significant difference at the 5% test level

The survival percentage of catfish fingerlings in the treatment of adding Fine Bubbles application showed good results with values above 90%. Based on SNI [19] good survival for Striped catfish culture ranges from 80-95%. This is because the treatment using FBs can increase the concentration of dissolved oxygen because the diameter of bubbles is micro and nano, the bubbles present high internal pressure which can significantly increase gas solubility, compared to normal bubbles. FBs bubbles have lower surface

risers in the liquid phase, these bubbles can stay in water for a long time [20].

3.3 Water Quality

Optimal water quality is one of the important requirements in aquaculture, especially in the cultivation of Striped catfish. Water quality in aquaculture containers must be controlled so that it can produce the optimal growth of fish. The results of water quality measurements in this study were the concentration of dissolved oxygen, ammonia, nitrate, and phosphate (Table 3).

Temperature: The results of temperature measurements in all fish treatment containers showed no significant differences. The temperature range during the research can still be tolerated for the survival of catfish. Temperature variability is very important because generally aquatic organisms have a degree of tolerance within a certain range [21]. Optimal water temperature will make fish more active in moving, appetite increases, and metabolic processes increase rapidly.

pH: The results of pH during research is still within normal limits. According to Putra et al. [22], the catfish species can tolerate and live in acidic waters up to pH 5 and can survive in alkaline waters up to pH 9. The pH values have a major influence on the life of aquatic organisms so that the pH of the waters is used as a component to express the merits of the waters.

Dissolved oxygen (DO): Oxygen concentration in treatment A during the study showed the lowest results when compared to treatments B, C, and D using FBs. According to Navisa et al. [23] the smaller the diameter of the bubbles increases the resistance in the bubbles in the water and ultimately increases the gas transfer and solubility of dissolved oxygen. The small diameter of air, nano and micro, is able to increase the surface area of water that coincides with air, making it easier to process the diffusion of air to water. The higher diffusion level will accelerate the process of oxygen saturation. The use of micro-sized bubbles in fish rearing media can increase the concentration of dissolved oxygen accompanied by an increase in water quality in aquaculture containers. The use of FBs application with a pressure of 5.5 atm showed the highest dissolved oxygen concentration ranging from 7.72 - 7.94 mg / L, whereas the

concentration of dissolved oxygen in conventional aquaponic systems in catfish culture ranged from 4.8 to 5.9 mg / L [3].

Ammonia (NH₃): The results of measurement of ammonia concentration during the study fluctuated, the lowest ammonia concentration reduction was found in treatment D, namely 0.001-0.010 mg / L. The decrease in ammonia concentration is caused by the optimal nitrification process. The addition of FBs application increases the concentration of dissolved oxygen which affects the oxidation process and nitrifying bacteria. This may be one of the causes of low ammonia concentration with the addition of FBs, when compared to control treatments. The decrease in ammonia concentration shows the application of FBs works to improve water quality in the aquaponic system through the diffusion of dissolved oxygen in the water. According to Subhan et al. [8], the use of FBs can reduce the concentration of ammonia in the maintenance of catfish seedlings with a decrease in ammonia by 0.0358 ppm / hour / L, FBs technology is able to reduce the concentration of ammonia because air bubbles are produced in the water and are also very small sized. These small, nano and micro sizes are able to accelerate the diffusion of ammonia gas in water to the air surface.

Nitrate (NO₃): Based on the results of nitrate measurements during the study, nitrate concentration values ranged from 0.243 to 0.648 mg / L. The increase in nitrate occurs because the recirculation system works well so that it affects the nitrification process [24]. In addition to the existence of a recirculation system, the use of FBs application by producing high concentrations of dissolved oxygen, also affects the growth and activity of the bacteria *Nitrosomonas* and *Nitrobacter*, so that ammonia will be oxidized to nitrite and then converted to nitrate. Fluctuating nitrate concentrations are thought to be due to the optimal utilization of nitrates by plants. According to Hasan et al. [5] spinach water plants easily absorb inorganic nitrogen, that is the reason it has lush roots. Plants that have lush roots will better absorb nutrients.

Phosphate (PO₄): Phosphate is a form of phosphorus that can be utilized by plants. According to Hasan et al. [5] nutrients in the form of phosphates are more easily absorbed by water spinach plants in the aquaponic system.

The results of phosphate measurements during the study were 0.147 - 0.370 mg / L. The increase in phosphate concentration is because fish have a high appetite so that more waste metabolites are removed, and the concentration of dissolved oxygen decreases. This is consistent with Effendi statement [25], that an increase in fish appetite can cause the release of metabolites to increase, which causes a buildup of impurities, and results in a decrease in dissolved oxygen so that phosphate concentrations will also increase. The existence of phosphate is influenced by the concentration of dissolved oxygen will cause fish metabolism to be stable, so that it can affect the concentration of phosphate produced, this is in accordance with the research that the concentration of phosphate in the addition of FBs treatment has lower concentrations compared to control treatments [26].

3.4 The Growth of the Plant

Plant growth can be seen from the increase in stem height, plant weight, and the number of leaves. All three parameters indicate the ability of plants to absorb and synthesize organic material in water for plant growth. Based on present observations, the water spinach plants grow well based on length, weight and number leaves. Water spinach growth can be seen in Table 4.

Observation of water spinach plant productivity results showed that there were significant differences ($P < 0.05$) in the increase in plant height, plant weight, and the number of leaves, in treatments A with B, C, and D. The results showed that treatment D had the highest productivity with plant height of 115.03 cm \pm 7.01, plant weight of 62.75 g \pm 4.96, and leaf number of 30 strands \pm 0.30. According to Park and Kurata [27], increased growth of water spinach plants in the hydroponic system with the addition of microbubbles has higher growth. A good oxidation process causes sufficient nitrogen concentration and stimulates plant growth.

The results observed during the research, the best plant growth is at the top shelf level. This is because plants get enough light for plants to carry out photosynthesis. Plant growth is influenced by internal and external factors. Internal factors that influence plant growth are related to physiological processes, while external factors that influence are sunlight radiation, water temperature, and nutrient supply [28].

Table 3. Water quality parameters during research

Treatments	Temperature °C	pH	Water quality parameters			
			DO	Ammonia	Nitrate mg/L	Phosphate
A (Control)	24.2-26	7.33-8.16	6.48-7.78	0.009-0.032	0.331-0.587	0.175-0.370
B (FBs with pressure 4,5 atm)	24.8-26.7	7.40-7.83	6.91-7.83	0.003-0.018	0.322-0.648	0.171-0.293
C (F Bs with pressure 5 atm)	25-27	7.13-7.80	7.17-7.89	0.002-0.017	0.334-0.632	0.169-0.272
D (FBs with pressure 5,5 atm)	25.3-27	6.92-7.67	7.72-7.94	0.001-0.010	0.243-0.602	0.147-0.229
Optimal	25-30	6.5-8.5	> 3	< 0,02	20	1

Table 4. The growth of the plant

Treatments	Growth parameters		
	Plant height (cm)	Plant weight (g)	Number of leaves (strands)
A (Control)	79.99 ± 6.92 ^a	42.51 ± 2.79 ^a	18 ± 2.32 ^a
B (FBs with pressure 4,5 atm)	104.60 ± 5.73 ^b	53.14 ± 3.26 ^b	25 ± 3.00 ^b
C (FBs with pressure 5 atm)	95.90 ± 0.96 ^b	51.46 ± 1.42 ^b	24 ± 1.64 ^b
D (FBs with pressure 5,5 atm)	115.03 ± 7.01 ^c	62.75 ± 4.96 ^c	30 ± 0.30 ^c

Note: Values followed by the same letter in the same column show no significant difference at the 5% test level

The increase in weight of spinach plants shows that pollutants (feces and leftover fish feed that are not consumed) originating from fish ponds increase according to fish weight so that the need for nutrients for the growth of water spinach plants can be met [21]. Increasing the number of leaves proves more effective water spinach plants reduce inorganic nitrogen from fish maintenance water. According to Effendi et al. [29] water spinach plants have a faster initial growth rate. These conditions support water spinach plants to grow and absorb nutrients quickly. Absorption of good nutrition will increase the number of cells that will have an impact on increasing plant growth, one of which is the increase in the number of leaves.

4. CONCLUSION

The results showed that the application of Fine Bubbles with a pressure of 5.5 atm (treatment D) increased fish growth, fish survival, and the highest plant growth in the aquaponic system.

ACKNOWLEDGEMENTS

Acknowledgments were conveyed to Hibah Internal Universitas Padjadjaran Tahun Anggaran 2019.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:

The peer review history for this paper can be accessed here:
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