KINERJA KUALITAS AIR DAN PRODUKTIVITAS KANGKUNG DALAM SISTEM AKUAPONIK MENGGUNAKAN *FINE BUBBLES* (FBS)

WATER QUALITY AND WATER SPINACH PRODUCTIVITY IN AQUAPONIC SYSTEMS USING FINE BUBBLES (FBS)

Zahidah[1], Yuli Andriani[1], Drian Alif Anando[1],Sofiya Hasani[2], Rusky I. Pratama[1]

[1]Fisheries of Departement, Faculty of Fisheries and marine, Universitas Padjadjaran Bandung-Sumedang KM.21 Jatinangor, Sumedang, West Java, Indonesia
[2] Agrotechnology of Departement, Faculty of Science and Technologhy UIN Sunan Gunung Djati, AH. Nasution Street no. 105, Bandung, West Java, Indonesia

[*]Corresponding Author: zahidah@unpad.ac.id

Accepted : 01 December 2022 / Agreed : 23 December 2022

ABSTRAK

Fine bubbles (FBs) merupakan teknologi baru dalam sistem akuaponik yang diharapkan mampu meningkatkan produksi ikan dan tanaman. Penelitian ini bertujuan untuk menentukan pemberian tekanan *fine* bubbles (FBs) yang dapat meningkatkan kualitas air dan produktivitas kangkung dalam sistem akuaponik. Penelitian dilaksanakan pada bulan Januari – Maret 2022 di *Green House* Ciparanje Fakultas Perikanan dan Ilmu Kelautan Universitas Padjadjaran, Jatinangor. Penelitian ini menggunakan metode eksperimental Rancangan Acak Lengkap (RAL) dengan empat perlakuan dan tiga ulangan. Perlakuan yang digunakan adalah pemberian tekanan FBs masing-masing 0 atm (A), 5,25 atm (B), 5,5 atm (C), 5,75 atm (D). Parameter kualitas air yang diukur terdiri atas parameter fisika (suhu) dan kimia (oksigen terlarut, pH, amonia, dan nitrat). Hasil penelitian menunjukkan pemberian tekanan FBs 5,75 atm menghasilkan suhu berkisar 24,4℃ - 26,5℃, kandungan oksigen terlarut sebesar 7,83 mgL^{-1}, pH 6,98 – 8,07, konsentrasi amonia 0,002 mg L^{-1}, yang berpengaruh pada pertumbuhan ikan yang baik serta konsentrasi nitrat 0,316 mg L^{-1} yang berpengaruh pada produktivitas tanaman yang lebih tinggi, menghasilkan pertumbuhan tinggi tanaman 128,83 cm, bobot tanaman 140,60 g, dan jumlah daun 284 helai.

Kata kunci: akuaponik, fine bubbles, kangkung, kualitas air

ABSTRACT

The fine bubbles (FBs) is a new technology in aquaponic system that is expected to improve the fish and plant productivity. This study aimed to determine the application of fine bubbles pressure in improving water quality and water spinach in an aquaponic system. The research was conducted from January to March 2022 at Ciparanje Green House, Faculty of Fisheries and Marine Sciences, Universitas Padjadjaran, Jatinangor. This study used an experimental method of Completely Randomized Design (CRD) with four treatments and three replications. The treatments used were FBs pressure of 0 atm (A), 5.25 atm (B), 5.5 atm (C), 5.75 atm (D). The water quality parameters measured consisted of physical (temperature) and chemical (dissolved oxygen, pH, ammonia, and nitrate) parameters. The results showed that

Cite this as: Zahidah., Andriani, Y., Anando, D. A., Hasani, S. & Pratama, R.I. (2022). Water quality and water spinach productivity in aquaponic systems using fine bubbles (FBS). *Jurnal Agro*, *9*(2), 252-264. https://doi.org/10.15575/21491

the pressure of FBs 5.75 atm generated temperatures ranging from 24.4°C - 26.5 °C, dissolved oxygen content of 7.83 mg L^{-1}, pH 6.98 – 8.07, ammonia concentration 0.002 mg L^{-1} which affected on good fish growth and nitrate concentration 0.316 mg L^{-1} which affected higher plant productivity, resulting plant height of 128.83 cm, a plant weight of 140.60 g, and the number of leaves of 284 leaves.

Keywords: aquaponics, fine bubbles, water spinach, water quality

INTRODUCTION

Aquaculture activities can initiate ammonia and organic matter waste accumulation originating from feed excess and fish feces in water resulting in water quality decrease. One solution that can be taken to solve this problem is by applying aquaponics technology. In the aquaponic process, plants utilize nutrients derived from leftover feed and fish feces. The remaining feed manure and fish urine contain nutrients can be used as fertilizer for plants in the hydroponic subsystem (Sumiarsih, 2021). Plants in the aquaponic system can reduce ammonia by absorbing aquaculture waste water using plant roots, hence that the absorbed ammonia undergoes an oxidation process. With the help of oxygen and bacteria, ammonia is converted into nitrate which is then utilized by plants as a source of nutrition (Badiola et al., 2012).

Water spinach (*Ipomea reptans*) is a plant that can be grown in aquaponic cultivation employing simple planting systems and media. Water spinach plants in the aquaponic system can reduce ammonia by absorbing aquaculture waste water using plant roots, thus the absorbed ammonia undergoes an oxidation process (Zahidah et al., 2018).

Physical and chemical factors are essential to be considered in maintaining aquaponic system water quality, one of which is oxygen (Arthanawa et al., 2021). Aquaponic activitiy is capable to affect the decrease in water oxygen levels, thus the aquaponic system requiries a supplier of micro-sized air bubbles that can maximize gas exchange (FAO, 2014), that have a large surface area, to maximize gas exchange process and release oxygen into the water better than ordinary bubbles (Silaban et al., 2012).

Fine Bubbles (FBs) technology is a renewable technology that can be implemented in aquaponic activities since it is capable to increase fish productivity and the aquaponic system efficiency. FBs produce 150-200 nm bubbles to provide dissolved oxygen for an extensive period and under stable conditions (Andinet et al., 2016). The FBs aeration system can significantly increase the activity of Ammonia Oxidizing Bacteria (AOB) and Nitrite Oxidizing Bacteria (NOB) to accelerate biological activity in waters. Optimal aeration system is essential as it affects the comet fish fry growth performance in aquaponics system. The purpose of this study was to determine the water quality and water spinach productivity by employing fine bubbles (FBs) technology with various pressures in an aquaponic system.

MATERIAL AND METHOD

The aquaponic research was carried out from January to March 2022 at the Ciparanje Green House, Faculty of Fisheries and Marine Sciences, Universitas Padjadjaran, Jatinangor. The water quality analysis were done at the Laboratory of Aquatic Resources, Faculty of Fisheries and Marine Sciences, Universitas Padjadjaran. As much as 1200 comet fish fry were used as test sample's fish in this study measuring 8-11 cm originated from fish farmers in Tanjungsari, Sumedang. This study employed a completely randomized design (CRD) with four treatments and repeated three times. The treatment applied was the application of FBs pressure in fish rearing tanks, consisted of:

A: Control (without FBs pressure)
B: FBs with a pressure of 5.25 atm
C: FBs with a pressure of 5.5 atm
D: FBs with a pressure of 5.75 atm

Fish Acclimatization

Comet fish seed were first acclimatized in a fiber tank for seven days prior initiating the study. Fish acclimatization was carried out to provide fish adequate time in adapting with the new environment and well acclimated when the experiment is performed. The stocking density of fish in each rearing tank was 100 fish. Feeding was given three times a day using the *ad-satiation* method, specifically feeding the fish until they were full at 07 AM, 11 AM and 04 PM.

Aquaponic Installation Preparation

Recirculation system was installed with separate fish and plant containers and assembled of multilevel iron shelves. The water in the fish rearing tanks was channeled into the plant containers using a 4-inch PVC pipe. The water from the water spinach outlet emerged from the 4-inch PVC pipe and enters the FBs container. The water that had been pumped from the FBs generator was returned to the fish rearing tank by a 0.5-inch PVC pipe.

Seeding Water Spinach Seeds

The seeding process was carried out by planting water spinach seeds in containers with rice husk charcoal as media. Water spinach was sown for 10 days before being planted in aquaponic media.

Data Analysis

Water quality parameters measured included: dissolved oxygen (mg L^{-1}), ammonia, and nitrate (mg L^{-1}). Water samples for water quality analysis originated from: water in rearing tanks, water spinach outlets from each rearing tank, as well as water in pump containers and FBs that passed biofiltration for each treatment. However, specifically for the dissolved oxygen concentration parameter, the sample was taken from the outlet of the FBs hose, except without FBs (pump) the sample water was obtained from the pump container. Parameters used in measuring water quality are listed in Table 1.

Table 1. Methods and measurement period of observation parameters

Parameters	Unit	Method	Measurement Period
Dissolved oxygen	(mg L^{-1})	DO Meter	Every week
Ammonia	(mg L^{-1})	Spectrophotometer	Every week
Nitrate	(mg L^{-1})	Spectrophotometer	Every week

Observation of plant growth was carried out by means of sampling every seven days. The number of plants observed was seven plants in each treatment. Plant growth was measured by measuring the height using a ruler and counting the increase in the number of leaves. Measurement of plant growth was carried out at the beginning of the study, namely when the plant seeds were transferred to the plant growth medium until 4 weeks. Observation of plant height gained can be measured employing the formula (Ogunji et al., 2008) as follows:

Plant Height = Final Height – Initial Height

Observation of plant weight improvement can be measured with the formula (Ogunji et al., 2008):

Plant Weight = Final Weight – Initial Weight

Observation of the increase in the number of leaves can be measured by the formula (Ogunji et al., 2008):

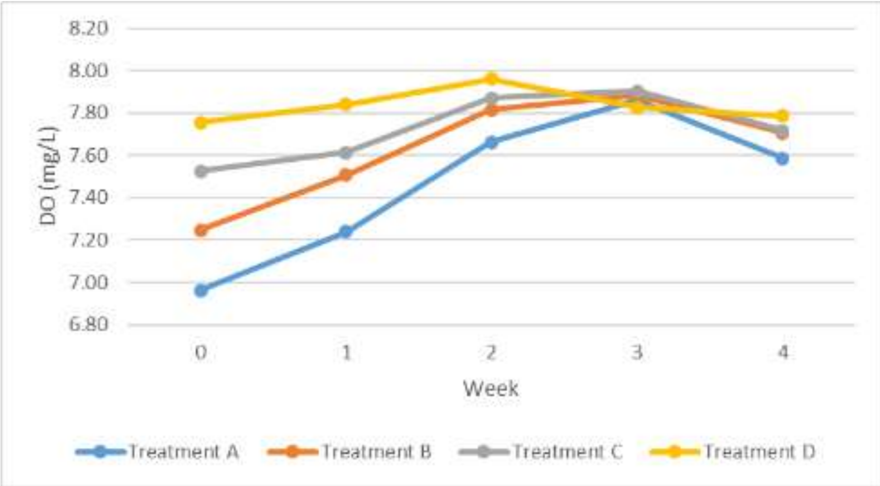
Number of Leaves = Number of Final Leaves - Number of Initial Leaves

The effect of treatment on water quality (DO, ammonia, and nitrate) was analyzed descriptively and presented in tables and graphs with range values and subsequently compared with the Indonesian National Standard (SNI) and government regulation (PP RI No. 82/2001 Class III). The effect of the treatment given to the height and weight growth, also number of leaves of the water spinach was analyzed using variance with the F-test at 95% confidence level. If there was a significant difference between the treatments, then the test was resumed with Duncan's multiple range test with 95% confidence level.

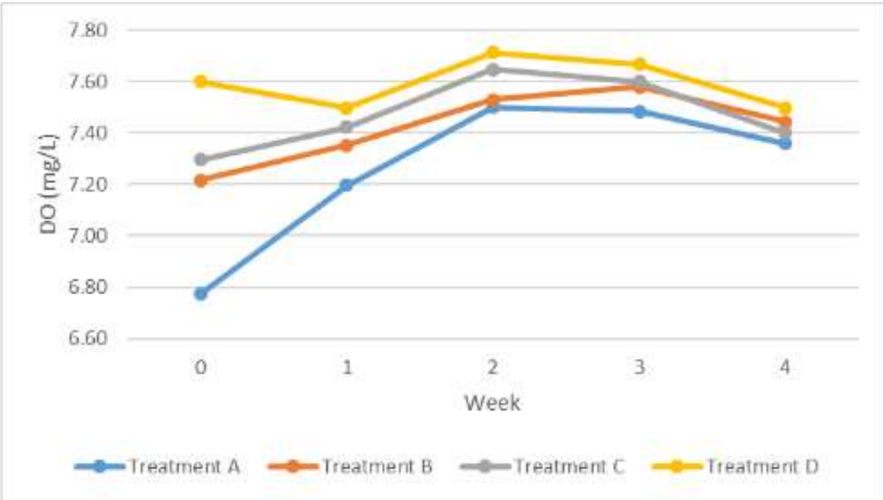
RESULT AND DISCUSSION

Dissolved Oxygen

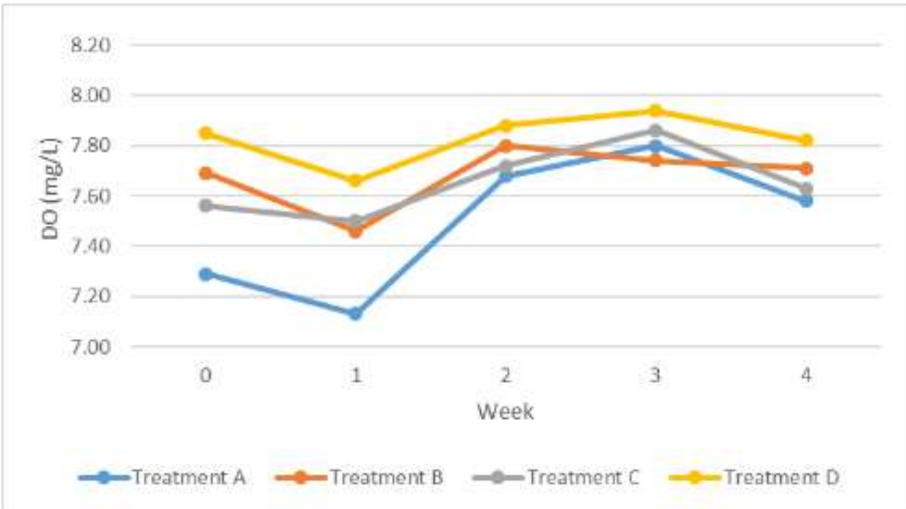
The results of dissolved oxygen measurements showed that the dissolved oxygen value in the fish-rearing container (Figure 1a) ranged from 6.96 – 7.96 mg L^{-1}, at the water spinach outlet (Figure 1b) ranged from 6.77 – 7.71 mg L^{-1} and at pump containers and FBs (Figure 1c) ranged from 7.13 – 7.94 mg L^{-1}. Changes in dissolved oxygen values during research can be seen in Figure 1.



(a)



(b)



(c)

Figure 1. Changes in dissolved oxygen (DO) value during research. Rearing containers fish (a), water spinach outlet (b), and pump containers and FBs (c))

Figure 1a showed that the dissolved oxygen value in the comet seed rearing container exhibited a decrease in the fourth week in treatments A, B, and C. The highest average dissolved oxygen value in the comet seed rearing container was in treatment D which was 7.83 mg L^{-1} and the lowest value was found in treatment A of 6.96 mg L^{-1}, then increased gradually in treatment B of 7.63 mg L^{-1} and treatment C of 7.73 mg L^{-1}. The treatment using the FBs application had a higher average dissolved oxygen value compared to the treatment without FBs (control). Figure 1c displayed that the average value of dissolved oxygen is higher in the FBs container with treatment D (pressure 5.75 atm) which is equal to 7.83 mg L^{-1}.

Ammonia (NH_3)

The measurement results during the study showed that the ammonia concentration values in the fish rearing tanks (Figure 2a) ranged from 0.001 – 0.023 mg L^{-1}, at the water spinach outlet (Figure 2b) ranged from 0.002 – 0.019 mg L^{-1}, as well as in the pump containers and FBs (Figure 2c) ranged from 0.001 – 0.021 mg L^{-1}. The concentration of ammonia in the fish rearing tanks decreased until the fourth week compared to the ammonia concentrations at the water spinach outlet as well as pump containers and FBs which fluctuated. The value of ammonia concentration with the highest average was found in comet seed rearing media in treatment A, which was 0.023 mg L^{-1}, and the lowest value was in treatment D of 0.002 mg L^{-1}, then slightly increased in treatment B of 0.016 mg L^{-1} and treatment C of 0.013 mg L^{-1}. Changes in ammonia concentration during the study can be seen in Figure 2.

Figure 2c showed that treatment D ammonia concentration value at the water spinach outlet increased in the second week, this was in accordance with treatment D pH value which also increased in the second week. According to Norberg-King et al. (2005) the concentration of un-ionized ammonia (NH_3) in water increases along with the rising in pH values. The lowest ammonia concentration value was showed in treatment D (FBs pressure 5.75) at the end of the observation, which was 0.002 mg L^{-1}. The high dissolved oxygen in the FBs container could be utilized by nitrifying bacteria in oxidizing ammonia, thus the ammonia value was lower compared to the container without FBs (control).

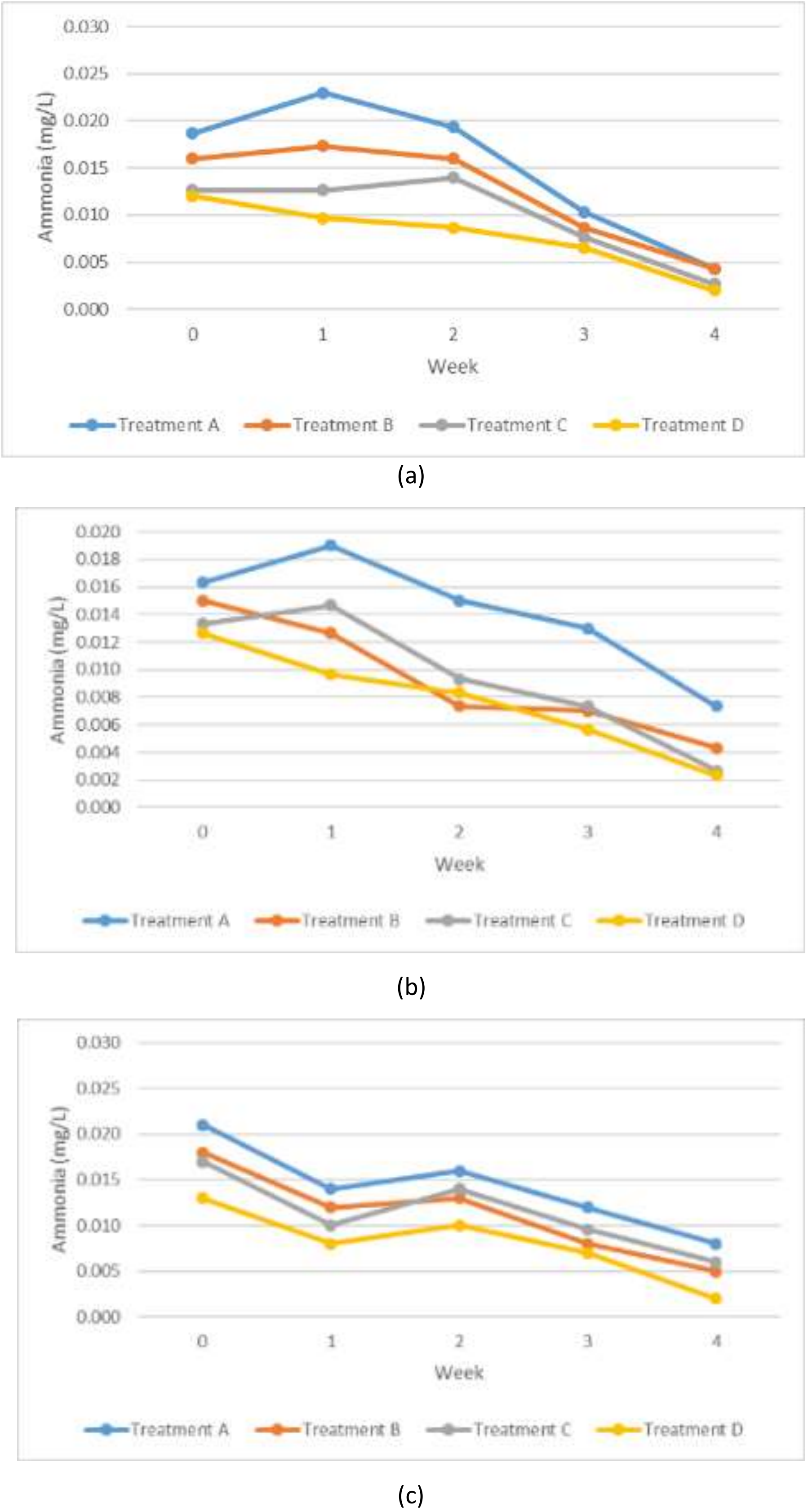
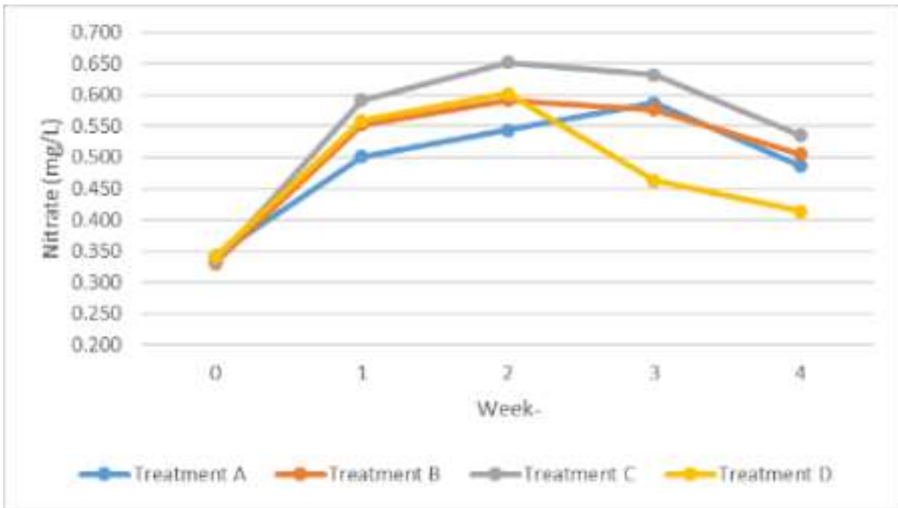


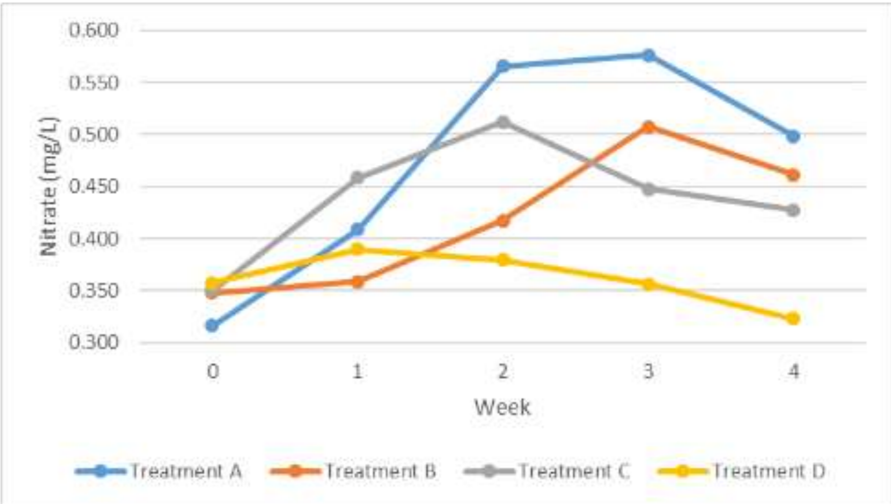
Figure 2. Changes in ammonia concentration (NH_3) during Research. Fish rearing containers (a), water spinach outlets (b), and pump containers and FBs (c)).

Nitrates (NO_3)

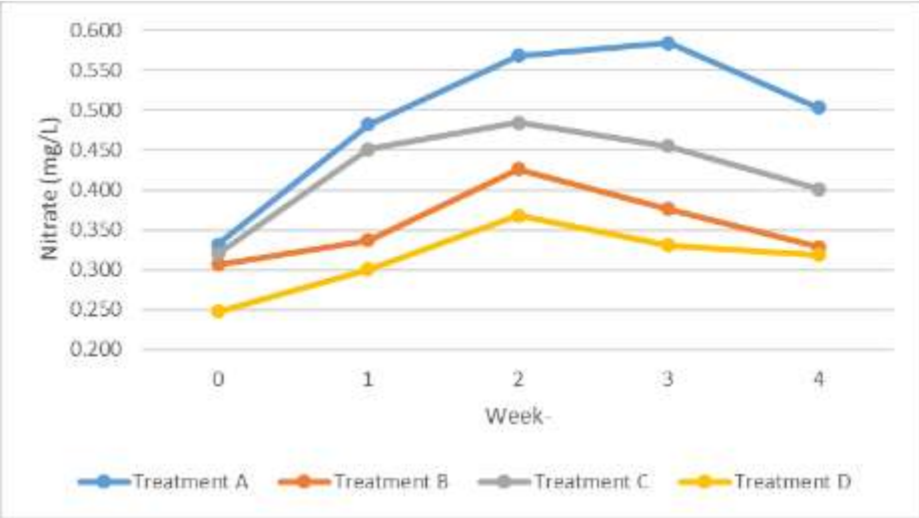
The results of measurements of nitrate concentrations showed that the values for fish rearing media (Figure 3a) ranged from 0.331 – 0.652 mg L^{-1}, at the water spinach outlet (Figure 3b) the values ranged from 0.316 – 0.576 mg L^{-1} and at the pump container and FBs (Figure 3c) ranged from 0.301 – 0.584 mg L^{-1}. Concentrations measured in fish rearing containers, water spinach outlets as well as pump media and FBs fluctuated until the fourth week. Changes in nitrate concentrations during the study can be seen in Figure 3.



(a)



(b)



(c)

Figure 3. Changes in nitrate concentration (NO_3) during research on containers. Fish rearing containers (a), water spinach outlet (b), pump container and FBs (c).

Based on Figure 3a, treatment D (FBs pressure 5.75 atm) exhibited the lowest nitrate concentration during the second to fourth week observation. This indicated that nitrate was well absorbed by the roots of water spinach, and this absorption was further increased if water spinach had dense roots with high oxygen utilization for root growth and respiration. Plant roots are also an additional site for nitrifying bacteria in reducing ammonia and producing nitrate which is a nutrient for plants.

The nitrate concentration at the outlet of the water spinach tended to increase in the first week to the third week in treatments A, B and C, except for treatment D which decreased in the second to fourth weeks. Figure 3c shows the lowest concentration of nitrate in treatment D in the first to fourth weeks. Denitrifying bacteria used dissolved oxygen to reduce nitrate in waters.

Plant Growth

The results of Duncan's Multiple Test analysis for height, weight, and number of leaves parameters of water spinach can be seen in Table 2. The results of Duncan's Multiple Test at the 95% confidence level showed that growth in height, weight, and number of leaves in each parameter of treatment A was significantly different with treatments B, C, and D. The highest plant growth was found in treatment D with the weight, height and number of plants leaves on each parameter of 140.60 g, 128.83 cm and 284 leaves respectively. The growth chart of water spinach can be seen in Figure 4.

Table 2. Growth of water spinach various FBs pressures at week 5

Treatment	Plant Growth		
	Weight (g)	Height (cm)	Number of Leaves
A (Control)	79.66 ± 2.34 [a]	108.77 ± 2.22 [a]	51 ± 3.77 [a]
B (5.25 atm)	124.31 ± 0.78 [b]	114.97 ± 3.12 [b]	146 ± 1.83 [b]
C (5.5 atm)	128.48 ± 1.14 [b]	119.63 ± 1.57 [c]	188 ± 7.00 [c]
D (5.75 atm)	140.60 ± 6.57 [c]	128.83 ± 1.90 [c]	284 ± 6.93 [d]

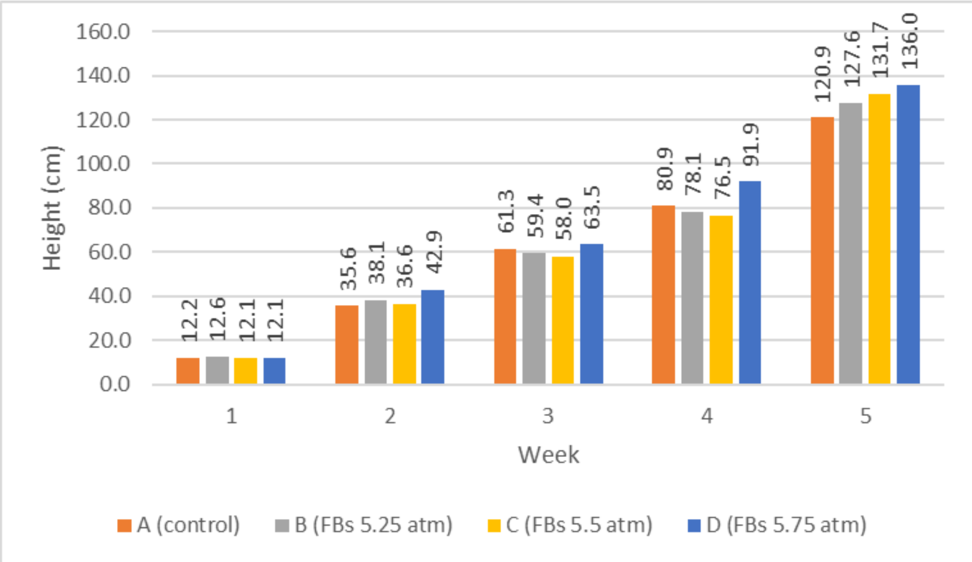


Figure 4. Plant height growth during the study.

Based on the analysis, dissolved oxygen in the comet seed rearing containers decreased at the fourth week in treatments A, B, and C. This was due to the fish seeds growth which still possessed active tissues in their metabolic processes, thus they required more oxygen consumption, along with an increase in fish body weight during the fish seed rearing period (Sataloff et al., 2001). Changes in dissolved oxygen values also occured due to the utilization of dissolved oxygen by aquatic plants (Roy, 2021). Dissolved oxygen concentration was still in an appropriate range for the water spinach growth. According to FAO (2014) aquatic plants require high levels of DO > 3 mg L^{-1} in water and plant roots require oxygen. Without oxygen, plant roots can deteriorate and die and grow fungus. Plant roots function as a growing medium for nitrifying bacteria which also require dissolved oxygen to oxidize ammonia (Wahyuningsih, 2015).

The treatment using the FBs application exhibited a higher average dissolved oxygen value compared to the treatment without FBs (control). Figure 1c shows that the average value of dissolved oxygen was higher in the FBs container with treatment

D (pressure 5.75 atm) which was equal to 7.83 mg L^{-1}.

Nitrate concentration in comet seed rearing containers increased from the first week to the second week. This could happen due to the increased activity of NOB bacteria (Nitrite Oxidizing Bacteria) in oxidizing nitrite. Nitrates in water have lower toxicity to fish compared to nitrites and ammonia. Nitrogen waste is toxic towards fish at certain concentrations. However, ammonia is about 100 times more toxic than nitrate (Wahyuningsih et al., 2020). According to Scabra et al. (2021), plants in the aquaponic system take part in absorbing the most nitrate and in addition less ammonia and nitrite from aquaculture waste. Nitrate as a nutrient for plants is absorbed through plant roots, nevertheless nitrate concentrations that exceed the limit can be toxic to plants (Meegoda, 2018).

The use of FBs can generate more oxygen bubbles and a very small bubble's size compared to ordinary aeration (Serizawa, 2017). FBs in an aquaponic system can increase the concentration of dissolved oxygen in water which is useful for plant roots respiration and ammonia oxidation by nitrifying bacteria in plant roots to produce nitrate which is an essential nutrient for plant growth (Zahidah et al., 2018). High plant roots growth can be beneficial as a location to live and develop nitrifying bacteria, where plant roots with suitable oxygen availability will assist respiration and absorption of phosphorus, nitrate and potassium ions. Nitrate also facilitate enzyme's function activities that take part in photosynthesis and plant respiration. Plant roots perform aerobic respiration, an important process of releasing energy required for root and plant growth which has an important function in burning carbohydrates in food into energy (Endut et al., 2016).

CONCLUSION

Applying FBs pressure of 5.75 was the best treatment which produced temperatures ranging from 24.4℃ - 26.5℃, dissolved oxygen content of 7.83 mg L^{-1}, pH 6.98 – 8.07, ammonia concentration of 0.002 mg L^{-1}, which exhibited an effect on appropriate fish growth and a nitrate concentration of 0.316 mg L^{-1} which showed an effect on higher plant productivity which resulted in a height growth of 128.83 cm water spinach plants, a weight growth of 140.60 g, and number of leaves growth of 284 leaves.

REFERENCES

Andinet, T., Kim, I., & Lee, J. (2016). Effect of microbubble generator operating parameters on oxygen transfer efficiency in water. *International Conference on Environmental Science and Technology,* 3994, 1–9.

Arthanawa, N., Astiko, Yana., Darmawan, I Ketut., Situmeang, Y. P., & Sudita, I. D. N. (2021). Utilization of biofloc system catfish pond waste nutrients in the cultivation of kale, spinach, pakcoy, and lettuce using the aquaponic system. *SEAS (Sustainable Environment Agricultural Science),* 5(1), 66–71.

Badiola, M., Mendiola, D., & Bostock, J. (2012). Recirculating aquaculture systems (RAS) analysis: Main issues on management and future challenges. *Aquacultural Engineering,* 51, 26–35.

Effendi, H., Amarullah, B., Darmawangsa, U. B., & Karo, M. (2016). Fitoremediasi limbah budidaya ikan lele (*Clarias* sp.) dengan kangkung (Ipomoea reptans) dan pakcoy (Brassiica rapa chinensis) dalam sistem resirkulasi. *Jurnal Ecolab*. 47-104.

Endut, A., Jusoh, A., Ali, N., Wan Nik, W. B., & Hassan, A. (2016). Effect of flow rate on water quality parameters and plant growth of water spinach (*Ipomoea aquatica*) in an aquaponic recirculating system. *Desalination and Water Treatment*, 5 (5), 19-28.

FAO (Food and Agriculture Organization). (2014). *Calculating the amount of ammonia and biofilter media for an aquaponic unit.* FAO. Retrieved from http://www.fao.org/publications/card/en/c/90bb6bfe-1ac3-4280-857e1c5a20404b38/

Meegoda, J. N., Hewage, S.A., & Batagoda, J. H. (2018). Stability of anobubbles. *Environmental Engineering Science*, 35(11), 1216 – 1227.

Nugroho, R. A., Pambudi, L. T., & Haditomo, A. H. C. (2016). Application of aquaponics technology in freshwater fish farming to optimize production capacity. *Fisheries Scientific Journal,* 8(1), 46-51.

Ogunji, J., Toor, R. S., Schulz, C., Kloas, W. (2008). Growth performance, nutrient utilization, of nile tilapia orheochormis niloticus fed housefly manggot meal diets. *Tourkish Journal of Fisheries and Aquatic Science*, 8, 141 – 147.

Patty, S. I. (2018). Oksigen terlarut dan *apparent oxygen utilization* di perairan selat lembeh, sulawesi utara. *Jurnal Ilmiah Platax*, *6*(1), 54–60. http://lipi.go.id/publikasi/21573.

Roy, S.M., Jayraj, P., Machavaram, R., Pareek, C.M., & Mal, B. C. (2021). Diversified aeration facilities for effective aquaculture systems—a comprehensive review. *Aquaculture International*, 29, 1181–1217.

Sataloff, R. T., Johns, M. M., & Kost, K. M. (2019). *Efek Perbedaan Salinitas Dan Temperatur Air Terhadap Pertumbuhan Dan Efisiensi Pakan Ikan Nila Gift (Oreochromis sp.)*.

Scabra, A. R., Marzuki, M., Setyono, B. D. H., Diniarti, N., & Mulyani, L. F. (2021). Aplikasi teknologi mikrobubble pada petani ikan nila di desa bayan. *Indonesian Journal of Fisheries Community Empowerment*, *1*(1), 36–43.

Serizawa. A. (2017). *Fundamentals and Applications of Micro/Nano Bubbles. Internasional Symposium on Application of High Voltage, Plasmas and Micro/ Nano Bubbles to Agriculture and Aquaculture*, 5-7 January. Rajamangala University of Technology Lanna Chiang Mai. Thailand.

Silaban, T. F., Santoso, L., & Suparmono. (2012). In improving the performance of water filters to reduce ammonia concentration in maintenance of carp (*Cyprinus carpio*). *E-Journal of Aquaculture Engineering and Technology,* 1 (1), 47-56.

Sumiarsih, E. (2021). Analysis of water quality in layer cage with aquaponic system in PLTA kota panjang, kampar district. *IOP Conference Series: Earth and Environmental Science,* 695(1), 1–7.

Wahyuningsih, S., Effendi, H., & Wardiatno, Y. (2015). Nitrogen removal of aquaculture wastewater in aquaponic recirculation system. Aquaculture, Aquarium, Conservation & Legislation

International Journal of the Bioflux Society, 8(4), 491–499.

Wahyuningsih, S., Gitarama, A. M., & Gitarama, A. M. (2020). Amonia pada sistem budidaya ikan. *Syntax Literate; Jurnal Ilmiah Indonesia*, 5(2), 112. https://doi.org/10.36418/syntax-literate.v5i2.929

Widayat, W., Suprihatin, S., & Herlambang, A. (2018). Penyisihan amonia dalam upaya meningkatkan kualitas air baku pdam-ipa bojong renged dengan proses biofiltrasi menggunakan media plastik tipe sarang tawon. *Jurnal Air Indonesia*, 6(1). https://doi.org/10.29122/jai.v6i1.2456

Zahidah, Dhahiyat, Y., Andriani, Y., Sahidin, A., & Farizi, I. (2018). Impact of redWater system (RWS) application on water quality of catfish culture using aquaponics. *IOP Conf. Series: Earth and Environmental Science,* 139, 1-8.