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The Performance of Water Quality in Tilapia Pond Using Dutch Bucket and Deep Flow Technique

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ABSTRACT
Water recirculation is one of the advantages of the aquaponics system, water from fish ponds flows to the plants then returned to the fish. The aquaponics system can improve the quality of pond water, thereby increasing the survival rate and growth of fish, which in turn can increase the productivity of fish farming. This study aimed at comparing two aquaponics methods, Deep Flow Technique (DFT) and the Dutch Bucket System (DBS), on their merits at improving pond water quality and tilapia survival rate. The two. The research method used was field experiments and each treatment had three replications and was observed for 30 days. The water quality parameters observed were temperature, dissolved oxygen, pH, the amount of dissolved solids, NH_3, and NO_3 levels. The result of this study is that the water quality in DBS ponds is better than in DFT ponds. The survival rate of the fish receiving water filtered by DBS is 1% higher than the fish receiving water filtered by DFT. This showed that the existence of a biological filter in the form of plants and a mechanical filter in the DBS installation helped in improving water quality and the survival rate of tilapia.

INTRODUCTION

According to data from the **Indonesian Central Statistics Agency (2013)**, Indonesia's population will continue to rise to 305 million in 2035 or an increase of about 2.9 million per year. The Head of the Center for Education and Training of the Indonesian Central Bureau of Statistics Drs. Razali Ritonga, M.A. **(Gloria, 2017)** refered to that this growth rate is far greater than the world population growth rate. Thus, The main question is how could we meet the basic needs of such large population, whereas, one of the most basic needs is food.

The aquaponics system could be the answer to provide two food stuff income in one time, fish and vegetables. Which is faster and healthier to meet the human needs in food and nutrition. As it integrates fish farming with hydroponics. The water of the aquaponic system circulates from the fish pond to the plant growing medium and back.

Previous studies **(Farida *et al.*, 2017; Azhari and Tomasoa, 2018; Pamula *et al.*, 2019)**, showed that the advantage of aquaponics system is improving the quality of pond water, since before returning to the pond, water passes through plant roots which act as a biological filter, thereby increasing the survival rate and growth of fish, which in turn it can increases the productivity of fish farming.

There are many types of aquaponics systems, such as, floating systems; Nutrient Film Technique (NFT); Deep Flow Technique (DFT); and Dutch Bucket System (DBS). The first three methods solely use plants as a biological filter, where water passes only through the plant's root system. Meanwhile, DBS not only uses plants as biological filters, but also uses mechanical filters such as small pebbles, broken tiles, or hydrotons. However, there has been no research on the quality of the water produced by this DBS method. Based on this background, in this study the authors compared two aquaponics methods, namely DBS and DFT to determine water quality and fish survival rate.

The DFT method was chosen to represent the most used aquaponics technique because DFT and DBS have almost the same working principle. In this study the authors used tilapia (*Oreochromis niloticus*) as a sample, because tilapia, a freshwater fish, is in high demand in the market. The high market demand is causing Tilapia farmers to increase the number of farmed Tilapia, this has an impact on the density of the Tilapia population in one square meter of pond and increased feed input as well. High density and increased feed can cause water quality to decline, resulting in decreased fish survival. Research from **(Marlina and Rakhmawati, 2016)** showed that the aquaponics system can reduce ammonia levels in tilapia fish ponds and increase the survival rate of tilapia.

MATERIALS AND METHODS

Study area

The experiment was conducted from May to June 2020 in Kanigoro, Blitar, East Java, Indonesia. Two concrete ponds with a size of 7 x 3.5 m, and 0.8 m water level were used, or about 19.6 m^3 of water.

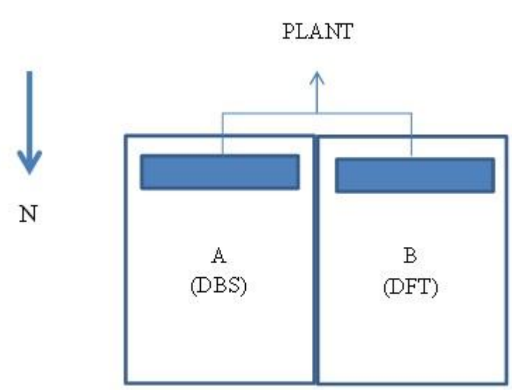

Figure 1. Pond layout

Procedures

Aquaponics installation

The DBS installation uses 10 buckets. Each bucket was filled with a 10 cm netpot, with the planting medium in the form of hydrotons, in each planting medium there were five rockwool, each rockwool contained three water spinach (*Ipomoea aquatica*) seeds.

Figure 2. DBS installation

Meanwhile, the DFT installation uses 3 PVC pipes with diameter 6.35 cm. Each pipe has 19 holes of 5 cm to put the netpot. Each netpot was filled with two rockwool, each rockwool contained three water spinach plant seeds.

Figure 3. DFT installation

Before moving to the DBS and DFT installations, water spinach seeds were sown in rockwool media for seven days, sprayed with water and has been placed in a place exposed to sunlight every day.

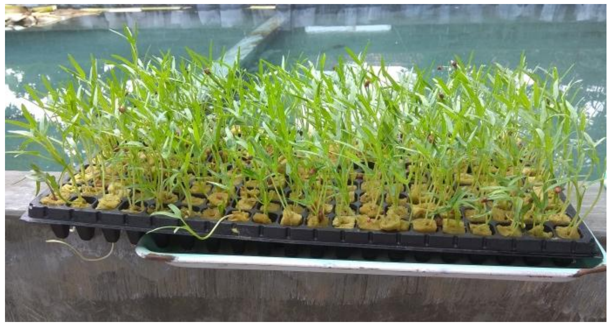

Figure 4. Water spinach seedling

Fish culture

Tilapia with average of 4.47 cm in total length and 21.6 g in body weight was used. Stocking density was 25 fish m^{-3} or 490 fish in each pond. Feeding dose was three times a day for 30 days as much as 3% of the biomass of the fish. Pellets contain 29% of protein.

Water quality parameters and fish survival rate

The observed water quality parameters were temperature (digital thermometer), dissolved oxygen (YSI 550-A), pH (pH-ATSC 211R), total dissolved solids (Thermo Scientific Elite-CTS), ammonia, and nitrate level (Sera test kit). These parameters were measured in situ at 12:00 PM with three replications of measurement in each pond. The survival rate of tilapia using the **Goddard (1996)** method:

$$\mathbf{SR} = (\mathbf{Nt} / \mathbf{N0})\ \mathbf{x}\ \mathbf{100}$$

Where:

SR: Survival Rate (%)

Nt: Number of living tilapia at the end of experiment

No: Number of tilapia at the beginning of experiment

Data analysis

Comparison of data was used to determine which methods gave the best water quality and fish survival rate.

RESULTS

Water quality

The average of water quality parameters of 2 ponds were shown in Table 1, with optimal range for Tilapia. Graph for each water quality parameter were shown in Fig.5, Fig. 6, Fig. 7, Fig.8, Fig.9, and Fig. 10. Observation was done for 30 days at 12 PM.

Table 1. The average of water quality parameters during 30 days of culture period

Parameter	Unit	Treatment		Optimal range
		DBS	DFT	
Temperature	ºC	28	28	25 - 32 [a]
Dissolved oxygen	mg/L	8.1	7.1	≥ 3 [a]
pH	-	7.9	8.4	6.5 - 8.5 [a]
Total dissolved solids	mg/L	242.7	332.6	1000 [a]
Ammonia	mg/L	0.033	0.092	≤ 0.1 [b]
Nitrate	mg/L	17	27.3	≤ 20 [c]

Note: [a] Wijayanti et al. (2019), [b] Setiadi et al. (2018), [c] Kabalmay et al. (2017)

Temperature

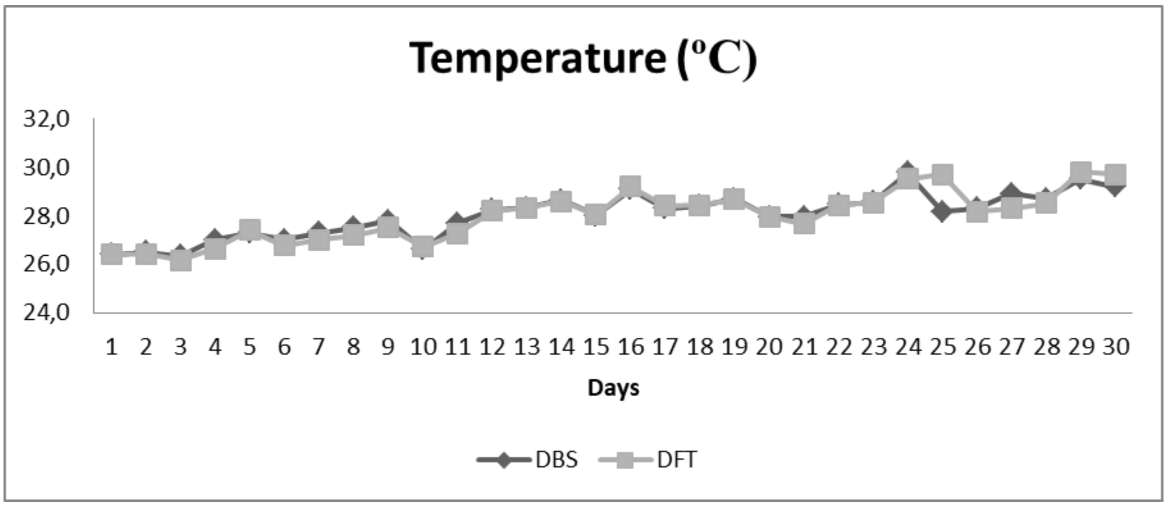

Figure 5. Temperature data during the observation period

- **Dissolved oxygen**

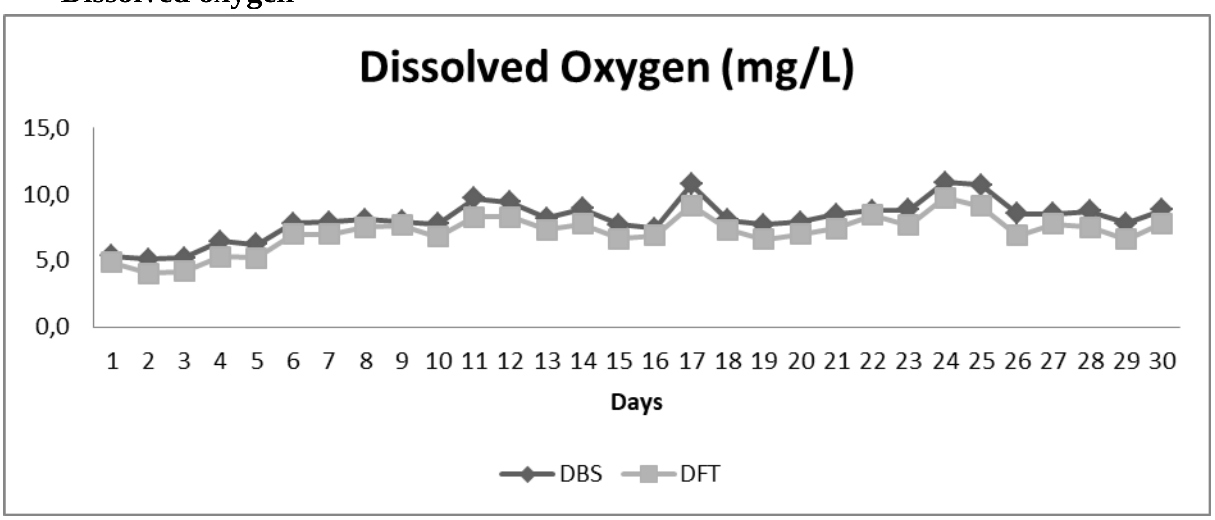

Figure 6. Dissolved oxygen data during the observation period

- **pH**

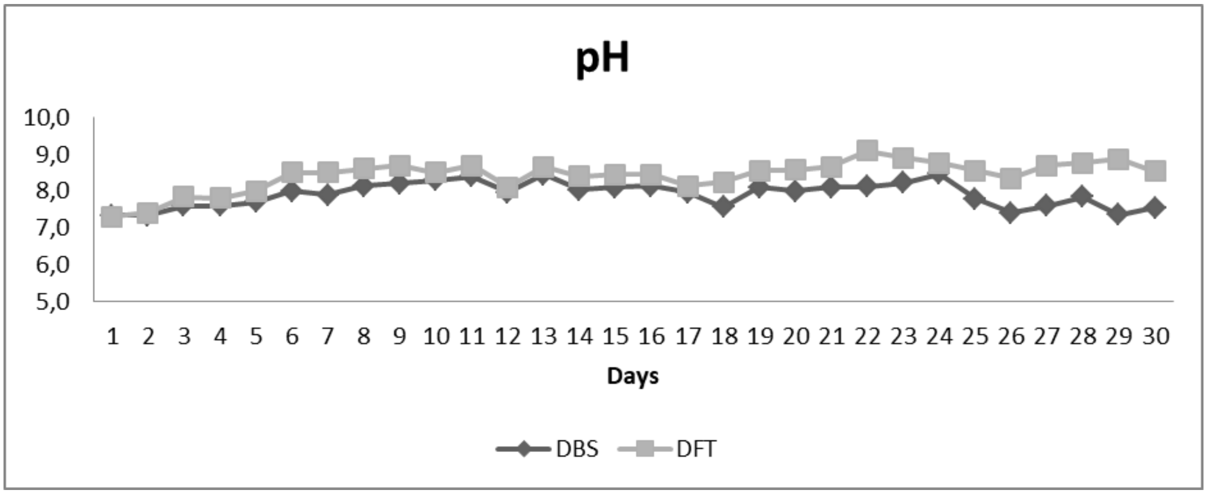

Figure 7. pH data during the observation period

- **Total dissolved solids (TDS)**

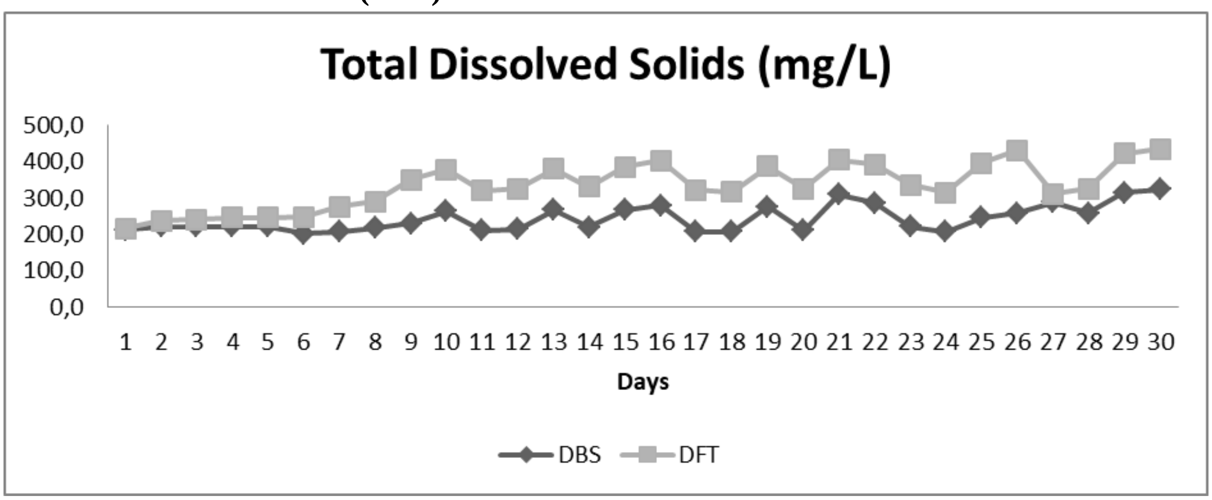

Figure 8. Total dissolved solids data during the observation period

- **Ammonia**

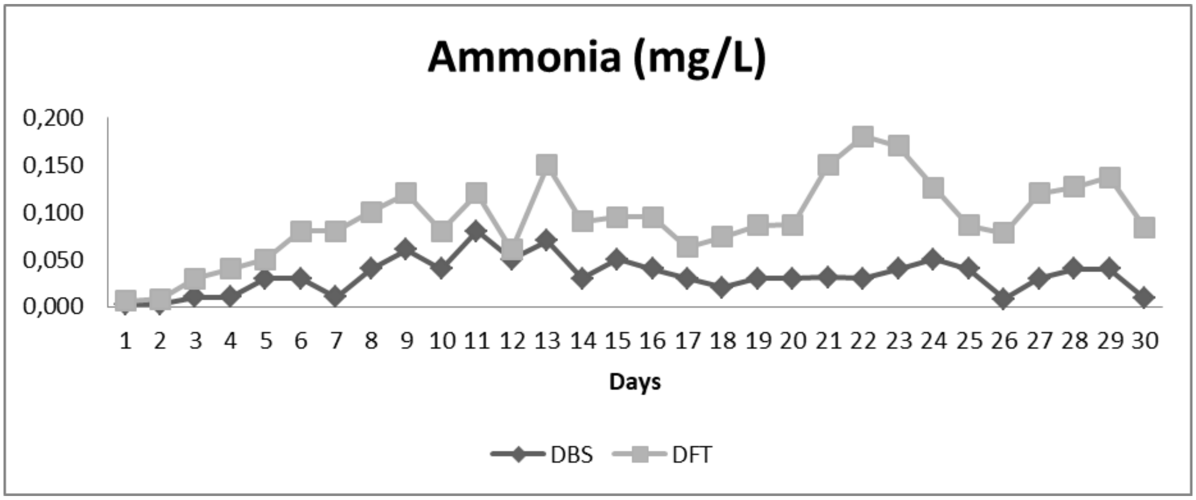

Figure 9. Ammonia data during the observation period

Nitrate

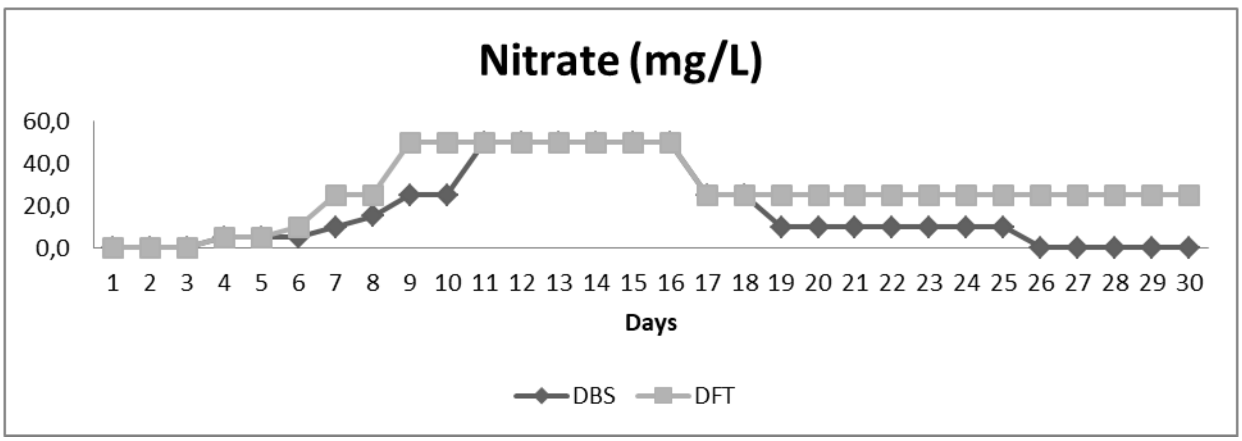

Figure 10. Nitrate data during the observation period

- **Survival rate**

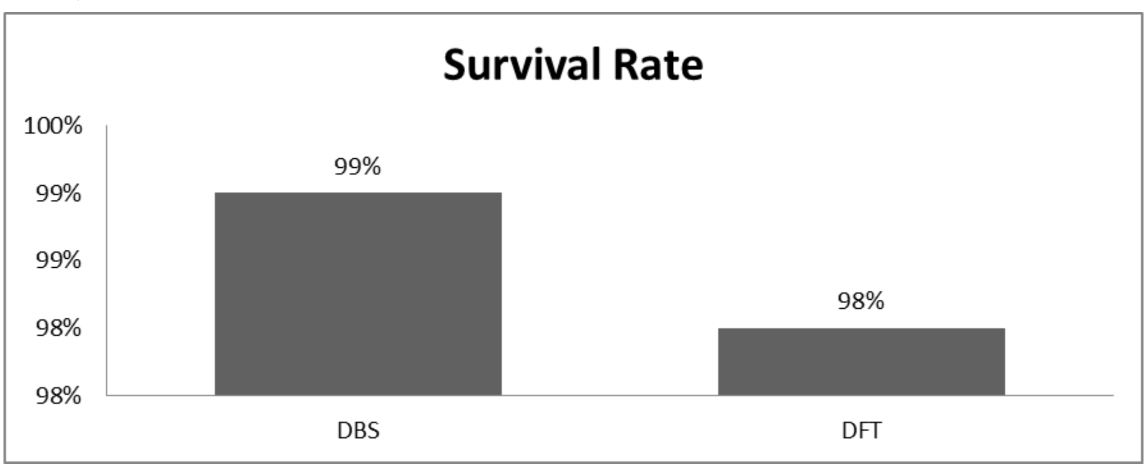

Figure 11. Survival rate data during the observation period

DISCUSSION

As mentioned by **Diem *et al.* (2017)**; **Setiadi *et al.* (2018), and Estim *et al*. (2019)** that aquaponics can improve water quality so that fish survival can be increased compared to conventional fish farming. The recorded temperature data showed that with an average of 28ºC there is no difference in temperature between the two ponds. These ponds are located close to each other and affected by the same environmental conditions. The observation began in May 2020, which a transition period, from wet season to dry season, characterized by cold temperature in the morning and hot in the afternoon. Hence, in the beginning of observation the temperature was on 26ºC even though the measurement was performed at 12:00 PM. The temperature continues to increase during the observation period.

Although the water temperature quite fluctuated day by day, but it was in the optimal range for Tilapia's growth. **Sallenave (2016)**, explained that temperature is important not only for fish itself in aquaponics system, but also for the plant growth and the optimum performance of biofilter (nitrifying bacteria). Tilapia as warmwater species can grow maximally at 27-29ºC. The best temperature for vegetables to grow is 21-25ºC. While, nitrifying bacteria could perform optimally at temperature from 27-30ºC.

Figure 6 showed that the dissolved oxygen in DBS pond was higher than in DFT pond. The average concentration of dissolved oxygen during the observation period was amounted to 8.1 mg/L in DBS and 7.1 mg/L in DFT. These data were obtained every day at 12 PM, as the highest point of dissolved oxygen, due to photosynthesis process during the day by the phytoplankton and water spinach, which contribute to the dissolved oxygen in the pond. **Boyd *et al.* (2017)** stated that phytoplankton photosynthesis and mechanical aeration are major sources of oxygen in ponds; respiration by fish and by microorganisms in the water column and sediment is the key drain for oxygen. Night time is the most critical time for dissolved oxygen, but with aquaponics system that pumps water from ponds to plants every 45 minutes, and operates for 15 minutes, can help to add dissolved oxygen in the water, so that dissolved oxygen does not reach below 3 mg / L.

As mentioned by **Wahab *et al.* (2018)**, that dissolved oxygen is affected by some factors, including the amount of dissolved particles. DBS pond has higher average of dissolved oxygen due to the amount of dissolved particles in DFT pond was more than DBS (Figure 8). The DBS system used hydrotons as a growing medium for water spinach that also played a role in filtering dissolved particles in the DBS pond.

The pH data showed that in DBS pond has lower pH than in DFT pond. In DBS the average pH was 7.9, while in DFT the average pH during the observation was 8.4. Nevertheless these both pH were in the optimum range that Tilapia can tolerate. Water pH is an element that influences the stress response and development of fish. The hydrogen ion (H^+) concentration in the water influences survival, development and responses to reproduction (**Lemos *et al.*, 2018**).

The pH value of water is influenced by several factors; some are the level of CO_2 in the water, the level of dissolved salts, and the decomposition of organic matter in the pond. During the day, phytoplankton and plants use CO_2 to carry out photosynthesis, so that CO_2 would decrease, and H^+ ions produced by CO_2 would also decrease, which causes pH to increase and become alkaline (**Yang and Kim, 2020**). This explains why there was a lower pH for DBS than for DFT. It indicated that the TDS in DFT was greater than DBS when viewed from the Total Dissolved Solids (TDS) data in Figure 8. This demonstrated that the DFT has many dissolved particles or solids which lead to the rising of pH value.

Tyson *et al.* (2004) in **Blanchard *et al.* (2020)** recommended pH from 6.5-8.5 for aquaculture system and 5.5-6.5 for hydroponics system. As the nitrifying bacteria have optimum performance in pH above 6.5, to convert ammonia into nitrate. Aquaponic is a recirculating system, which three aspects of this system (fish, plant, bacteria) rely on the same recirculating water. Thus, maintaining the water quality such as pH is very important for this system.

The recorded data showed that the average level of TDS in DFT was 90 mg/L higher than in DBS (Table 1). The lower quantity of dissolved solids in DBS was due to the use of growing media (hydrotons) as a mechanical filter, so that particles of solids that pass through it can be filtered and the water becomes clearer. While the DFT method only uses plants as a biological filter, it does not contribute much to the reduction of solid waste particles from fish.

To determine the amount of dissolved substances in water, both organic and inorganic, it is important to examine the quantity of dissolved solids. The pH and dissolved oxygen levels in pond water could be influenced by the amount of dissolved solids that were too high, which would in turn affect the growth of cultured fish, aquatic plants, algae and bacteria (**Scanell and Duffy, 2007**).

Excreted ammonia in aquaponic systems is 90% from fish (**Timmons *et al.*, 2002**). To prevent ammonia and nitrite toxicity, ammonia was oxidized into nitrite (NO_2^-) and nitrate (NO_3^-) by ammonia-oxidizing bacteria (AOB) and nitrite-oxidizing bacteria (NOB) respectively. Nitrate is assimilated by aquaponic plants that increase the efficiency of nitrogen usage (NUE) and eventually create healthier habitats for fish in aquaculture tanks (**Lam *et al.* 2015; Wongkiew *et al.* 2017**).

With an average value of 0.033 mg/L, the ammonia content of DBS ponds was lower than that of DFT ponds, while DFT ponds had an average ammonia content of 0.092 mg/L. Levels of ammonia are influenced by fish metabolism. The DBS method, which is not only a plant-based biological filter, but also a hydrated mechanical filter, plays a role in reducing ammonia levels in the pond.

Zahidah *et al.* (2018) disclosed that the ammonia level in the filtered fish pond was lower than in the filterless fish pond. With an average of 91.53%, filter utilization in the recirculating aquaculture system will minimize the total amount of ammonia. The efficacy of reducing the amount of ammonia has been determined by the filter mechanism and the type of filter used.

Aquaponics is a system for vegetable production which integrates the increasing technology of soil-free plants and aquaculture. Plants remove nutrients and convert metabolic products from waste water that may be harmful to fish. Because of the reuse of waste and nutrients in the resulting effluents from fish growth, it is a friendly approach for the environment (**Pantanella *et al.* 2010**). Contamination of surface water and groundwater by nitrate (NO_3^-) is a global problem, primarily due to overuse of fertilizers and discharge of human and animal waste (**Wu *et al.* 2020**).

The nitrate concentrations in the DFT pond were higher than in the DBS pond and, after the 17^{th} day of observation, were constantly at 15 mg/L. While DFT also has a plant to absorb the concentration of nitrate in water, the water from the DFT pond was sometimes trapped in the installation of the DFT pipe, so less water recirculated to the pond. On day 4 until day 16 of observation, there was an increasing amount of nitrate, this is believed, plant root was not fully formed, so the nitrate was not properly absorbed, as observed in the **Djokosetiyanto *et al.* (2006)** experiment.

Observation data showed that tilapia survival was 1% higher in DBS ponds than in DFT ponds. Four fish were found dead in the DBS pond and eight fish died in the DFT pond during the experiment, out of 490 fish at the beginning of the study. At the beginning and at the end of the observation period, several deaths occurred. The dead fish were marked by the presence of a white portion of one part of their bodies which later spreads gradually across the whole body, decreasing appetite, swimming less agile, and mucus on their gills. These fish were most probably killed by a bacterial infection. At the end of the study period, DBS pond conditions appeared to be better than that of DFT ponds.

Diem *et al.* (2017) concluded that the tilapia survival rate can be improved by the recirculation system in aquaponics. Meanwhile, **Estim *et al.* (2019)** said that although the survival rate of tilapia was not significantly affected by aquaponics method, changes in parameters of water quality showed that the decrease in nutrient levels was caused by the use and absorption of plants for their development. The developed Aquaponics system showed that it was not only ideal for integrated plant biomass production systems, but also was useful for the reuse of nutrient-rich water available in aquaculture systems.

CONCLUSION

This study showed that, due to the growing media used by the DBS system (hydrotons) as mechanical filters, the aquaponics pond using the Dutch Bucket system has better water quality than that of the Deep Flow Technique system. In this case, the DBS method has two benefits at the same time: a biological filter (plants) and a mechanical filter (growing media in the form of hydration). Meanwhile, DFT only has a biological filter, namely plants that help absorb nitrates for fish.. Moreover, in DBS ponds, the survival rate was 1% higher than in DFT ponds. Further research on the DBS system is required, especially with different types of plants or rising media, knowing that the DBS system can improve water quality better than other aquaponics systems. In addition, in order to improve water quality, fish and plant development, attention should be paid to the number of occupancy facilities in the pond area.

REFERENCES

Azhari D. and Tomasoa A.M. (2018). Kajian Kualitas Air dan Pertumbuhan Ikan Nila (*Oreochromis niloticus*) yang Dibudidayakan dengan Sistem Akuaponik. [Study of Water Quality and Growth of Tilapia (*Oreochromis niloticus*) Cultivated by Aquaponics System]. Jurnal Akuatika Indonesia 3(2):84-90. https://doi.org/10.24198/jaki.v3i2.23392

Blanchard C.; Wells D.; Pickens J. and Blersch D. (2020). Effect of pH on cucumber growth and nutrient availability in a decoupled aquaponic system with minimal solids removal. Horticulturae 6(1). DOI: 10.3390/horticulturae6010010

Blidariu F.; Radulov I.; Lalescu D.; Drasovean A. and Grozea A. (2013). Evaluation of Nitrate Level in Green Lettuce Conventional Grown under Natural Conditions and Aquaponic System. Scientific Paper: Animal Science and Biothecnologies 46(1).

Boyd C.E; Torrans E.L. and Tucker C.S. (2017). Dissolved Oxygen and Aeration in Ictalurid Catfish Aquaculture. Journal of the World Aquaculture Society 49(1). https://doi.org/10.1111/jwas.12469

Diem T.N.T.; Konnerup D. and Brix H. (2017). Effects of recirculation rates on water quality and *Oreochromis niloticus* growth in aquaponic system. Aquacultural Engineering. 78 B: 95-104. https://doi.org/10.1016/j. aquaeng.2017. 05. 002.

Djokosetiyanto D.; Sunarma A. and Widanarni. (2006). Changes of ammonia, nitrite and nitrate at recirculation system of red tilapia (*Orechromis* sp.) rearing. Jurnal Akuakultur Indonesia 5 (1): 13-20. https://doi.org/10.19027/jai.(5)13-20

Estim A.; Saufie S. and Mustafa S. (2019). Water qulity remediation using aquaponics sub-systems as biological and mechanical filters in aquaculture. J of Water Process Engineering 30:1-10. DOI:10.1016/J.JWPE.2018.02.001Corpus ID: 134704463

Farida N.F.; Abdullah S.H. and Priyati A. (2017). Analisis Kualitas Air pada Sistem Pengairan Akuaponik. [Analysis of Water Quality in Aquaponic Irrigation

System]. Jurnal Ilmiah Rekayasa Pertanian dan Biosistem 5(2): 385-394. https://doi.org/10.29303/jrpb.v5i2.54

Gloria [Internet]. **(2017).** Penduduk Indonesia Mencapai 305,7 Juta di Tahun 2035. [Indonesia's Population Reaches 305.7 Million in 2035]. Yogyakarta (Indonesia): UGM.ac.id; [updated 2017 August 22; cited 2020 Dec 22] Available from: https://ugm.ac.id/id/berita/14575-penduduk-indonesia-mencapai-305-7-juta-di-tahun-2035

Goddard S. (1996). Feed management in intensive aquaculture. Chapman and Hall. New York.

Indonesian Central Statistics Agency. **(2013).** Proyeksi Penduduk Indonesia. [Indonesia Population Projection 2010-2035]. Badan Pusat Statistik Indonesia.

Kabalmay A.A.; Pangemanan N.P.L. and Undap S.L. (2017). Pengaruh Kualitas Fisika Kimia Perairan Terhadap Usaha Budidaya Ikan di Danau Bulilin Kabupaten Minahasa Tenggara. [The effect of physicochemical quality of waters on aquaculture in Bulilin Lake, Southeast Minahasa Regency]. Budidaya Perairan 5(2): 15-26.

Lam S.S.; Ma N.L.; Jusoh A. and Ambak M.A. (2015). Biological nutrient removal by recirculating aquaponic system: Optimization of the dimension ratio between the hydroponic & rearing tank components. International Biodeterioration & Biodegradation 102: 107-115. https://doi.org/10.1016/j.ibiod.2015.03.012.

Lemos C.H.D.P.; Ribeiro C.V.D.M.;, de Oliveira C.P.B; Couto R.D. and Copatti C.E. (2018). Effects of interaction between pH and stocking density on the growth, haematological and biochemical responses of Nile tilapia juveniles. Aquaculture 495:62-67. https://doi.org/10.1016/j.aquaculture.2018.05.037

Marlina E. and Rakhmawati. (2016). Kajian Kandungan Ammonia pada Budidaya Ikan Nila (Oreochromis niloticus) Menggunakan Teknologi Akuaponik Tanaman Tomat (Solanum lycopersicum). [Study of Ammonia Content in Tilapia (Oreochromis niloticus) Cultivation Using Aquaponic Technology of Tomato Plants (Solanum lycopersicum)]. In: Fakultas Perikanan dan Ilmu Kelautan UNDIP, Prosiding Seminar Nasional Tahunan Ke-V Hasil-Hasil Penelitian Perikanan dan Kelautan. ISBN 2339-0883.

Pamula O.Y.T. and Prayogo, S. (2019). Optimization on survival and growth rate of African catfish (*Clarias* sp.) using water spinach (*Ipomoea aquatic*)-based aquaponic system. AACL Bioflux 12(2): 716-723.

Pantanella, E., Cardarelli, M., Colla, G., Rea, E. and Marcucci, A. (2010). Aquaponics VS Hydroponics: Production and Quality of Lettuce Crop, ISHS Acta Horticulturae 927: XXVII International Horticultural Congress on Science and Horticulture for People (IHC2020)International Symposium on Greenhouse 2010 and Soilless Cultivation, pp. 1-8

Paudel S.R. (2020). Nitrogen transformation in engineered aquaponics with water celery (Oenanthe javanica) and koi carp (*Cyprinus carpio*): Effects of plant to fish biomass ratio. J Aquaculture 520. https://doi.org/10.1016/j.aquaculture. 2020. 734971.

Sallenave R. (2016). Important water quality parameter in aquaponics system. NM State University, New Mexico.

Scanell P.K.W. and Duffy L.K. (2007). Effect of total dissolved solids on aquatic organism: a review of literature and recommendation for Salmonid species. American Journal of Environmental Sciences 3 (1): 1-6.

Setiadi E.; Widyastuti Y.R. and Pribadi T.H. (2018). Water quality, survival, and growth of red tilapia, Oreochromis niloticus cultured in aquaponics system. In: E3S Web of Conference 47: 1-8. https://doi.org/10.1051/e3sconf/20184702006

Timmons, M.B.; Ebeling, J.M.; Wheaton, F.W.; Summerfelt, S.T. and Vinci, B.J. **(2002)**. Recirculating Aquaculture Systems, 2nd. ed. Cayuga Aqua Ventures, Ithaca, NY.

Wahab N.A.; Kamarudin M.K.A.; Toriman M.E.; Ata F.M.; Juahir H.; Ghazali A. and Anuar A. (2018). The evaluation of dissolved oxygen (DO), total suspended solids (TSS) and suspended sediment concentration (SSC) in Terengganu River, Malaysia. International Journal of Engineering and Technology, 7: 44-48

Wijayanti M.; Khotimah H.; Sasanti A.D.; Dwinanti S.H. and Rarassari M.A. (2019). Pemeliharaan Ikan Nila (*Oreochromis niloticus*) dengan Akuaponik di Desa Karang Endah, Kecamatan Gelumbang, Kabupaten Muara Enim Sumatra Selatan. [Culturing of nile tilapia (*Oreochromis niloticus*) with aquaponic system in Karang Endah Village, Gelumbung District, Muara Enim Regency South Sumatera]. Journal of Aquaculture and Fish Health Vol. 8 No. 3: 139-148

Wongkiew S.; Hu Z.; Chandran K.; Lee J.W. and Khanal S.K. (2017). Nitrogen transformations in aquaponic systems: A review. J Aquaculture Engineering 76: 9-19. https://doi.org/10.1016/j.aquaeng.2017.01.004.

Wu H.; Dong Y.; Gao L.; Song X.; Liu F.; Peng X. and Zhang G.L. (2020). Identifying nitrate sources in surface water, regolith and groundwater in a subtropical red soil Critical Zone by using dual nitrate isotopes. CATENA. https://doi.org/10.1016/j.catena.2020.104994

Yang T. and Kim H.J. (2020). Characterizing nutrient composition and concentration in tomato-, basil-, and lettuce-based aquaponic and hydroponix system. J Water 12(5):1-27. https://doi.org/10.3390/w12051259

Zahidah H.; Rjibbusalam; Ine M. and Yuli A. (2018). Novel mechanical filter for reducing ammonia concentration of Silver Barb culture in a recirculating aquaculture system (RAS). Research Journal of Chemistry and Environment 22:319-324.