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Study of Ammonia, Phosphate, Nitrate and Catfish (Clarias Sp) Production on Aquaponics and Conventional Systems in Archipelagic Dry Land Areas

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A R T I C L E I N F O

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A B S T R A C T

This study aims to determine ammonia, phosphate and nitrate catfish (Clarias sp) farming water in aquaponics systems with conventional systems and determine catfish farming production aquaponics systems and conventional systems. The main parameters observed are ammonia, phosphate, nitrate and fish production while supporting parameters are temperature, pH, DO, SR and fish growth. The results of the independent t test showed that the value of ammonia, phosphate nitrate and nitrate in the aquaponic system was lower ($P<0.05$) than the conventional system, while fish production in the aquaponic system was higher ($P<0.05$) than the conventional system. This research shows that aquaponic systems are suitable for development in the archipelagic dry land area.

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INTRODUCTION

Catfish (Clarias sp) farming is one type of aquaculture business that is developing today. Catfish is one of the many fishery orgnisms that has animal protein that is much loved by the people of Indonesia. This is because catfish is easy to obtain, relatively cheap, and has a high protein content and relatively lower fat (Setiadi et al., 2019). Aquaculture water contains organic waste in the form of remnants from fish digestion and remnants of inedible feed. The greater the production capacity of a cultivated area, the greater the organic waste produced, so that organic waste is wasted into the waters is also greater. Organic waste from cultivation will cause new environmental problems, related to the large amounts of nitrogen (N) and phosphorus (P) discharged into waters (Abraham et al., 2018). Aquaculture water that contains organic waste if left unchecked will cause pollution that has a negative impact on the environment. The negative impact of organic discharges of aquaculture around experiencing aquatic fertility problems or eutrophication with the category of eutrophic waters towards hypereutrophic (Sikora et al., 2019).

In organic waste waters this toxic nitrogen is found in the form of ammonia or nitrate. Ammonia is converted into nitrite (NO_2) by nitrosomas bacteria, then continued by nitrobacter bacteria to remodel nitrite (NO_2) into nitrate (NO_3). Nitrate (NO_3) is what will be used by plants for their growth. From this process, ammonia of harmful origin is converted into beneficial for plants thanks to the role of nitrifying bacteria (Liang & Chien, 2013). In archipelagic dryland areas, with limited water resources and dry environments, catfish aquaculture water management becomes a more complex challenge. Dry land in NTT also has the advantage of having sunlight that shines for 9 months so that the existing sunlight can help the photosynthesis process in plants properly (Lee et al., 2022). Thus, it is very supportive of the aquaponics system because the vegetables planted can grow optimally.

The solution to the existing problem is to apply an aquaponics system. The aquaponics system is one of the innovative solutions in catfish farming in dryland areas of the archipelago. Aquaponics system is a cultivation system that combines cultivation systems and plants (Eissa et al., 2015). The main mechanism in aquaponics is the conversion of organic waste of aquaculture water (NH_3) produced by fish into nitrate (NO_3) which can then be used to grow plants so as to create a more sustainable environment and reduce negative impacts on the environment (Yep & Zheng, 2019). One of the plants used is the water spinach plant. According to Endut et al., (2016) water spinach plants are able to reduce ammonia levels in waters. Aquaponics technology is able to produce fish optimally on narrow land and limited water sources, including in urban areas. Aquaponics systems can save water use in fish farming activities by up to 97% and can maintain the water quality of budiaya media, this is due to the interaction between fish and plants that can create a more productive environment than conventional methods (Gupta & Huang, 2014). In conventional systems, aquaculture water is directly discharged into the environment without any treatment. Cao et al., (2007) stated that wastewater from aquaculture activities has the potential to boost organic matter content drastically and can then affect water quality and eutrophication or excessive phytoplankton growth causing imbalances in waters. In contrast to aquaponics systems that are mutually beneficial for plants and fish. Plant nutrition can be obtained from feces and fish food residues that settle to the bottom of the pond, resulting in water with quality that meets standards for fish farming (Goddek et al., 2019).

Based on the explanation above, it seeks to prove the results of the influence of aquaponics systems and conventional systems on aspects of ammonia, phosphate, nitrate and catfish production. The purpose of this study was to examine aspects of ammonia, phosphate, nitrate and catfish production (*Clarias* sp) in aquaponics and conventional systems in dry land areas of the archipelago.

LITERATURE REVIEW

Setiadi et al, (2019), "Efforts to Improve Productivity and Water Quality of Catfish Farming (Clarias sp.) on Tidal Aquaponics Systems through the Application of Different Filtration". The results showed that the application of three filters such as settling tanks, semi-anaerobic, and aerobic in this aquaponics system can improve fish and vegetable production and water quality under optimal conditions. A study written by Eissa et al., (2015) found that aquaponics systems can improve water quality significantly compared to traditional systems. This shows that aquaponics is a more environmentally friendly and sustainable option for fish and plant farming.

Research written by Cao et al., (2007) entitled "Environmental Impact of Aquaculture and Countermeasures to Aquaculture Pollution in China". Emphasizing the importance of sustainable aquaculture to meet global protein needs. Aquaponics systems offer innovative solutions to overcome these problems by combining fish and plant farming in one efficient and environmentally friendly system. Goddek et al., (2019) "Aquaponics Innovative Solutions to Future Food Challenges". Explain that aquaponics can help improve food security, reduce environmental impact, and increase people's access to fresh and nutritious food. This shows that aquaponics has great potential to be an innovative solution to address the various challenges facing the food system today.

Research Sikora et al, (2019) "Utilization of Fish Organic Waste for Soil Fertility". Shows that dumbo catfish organic waste has a high concentration of nitrogen and phosphorus, so it can be used as an organic fertilizer rich in important nutrients for plants. This shows that aquaponics can be an integrated and sustainable system, with waste from fish farming being processed into resources that benefit plants.

METHODOLOGY

The aquaponics system is carried out systematically and has sequential stages, while the stages in the aquaponics system carried out in this study can be seen in Figure 1.

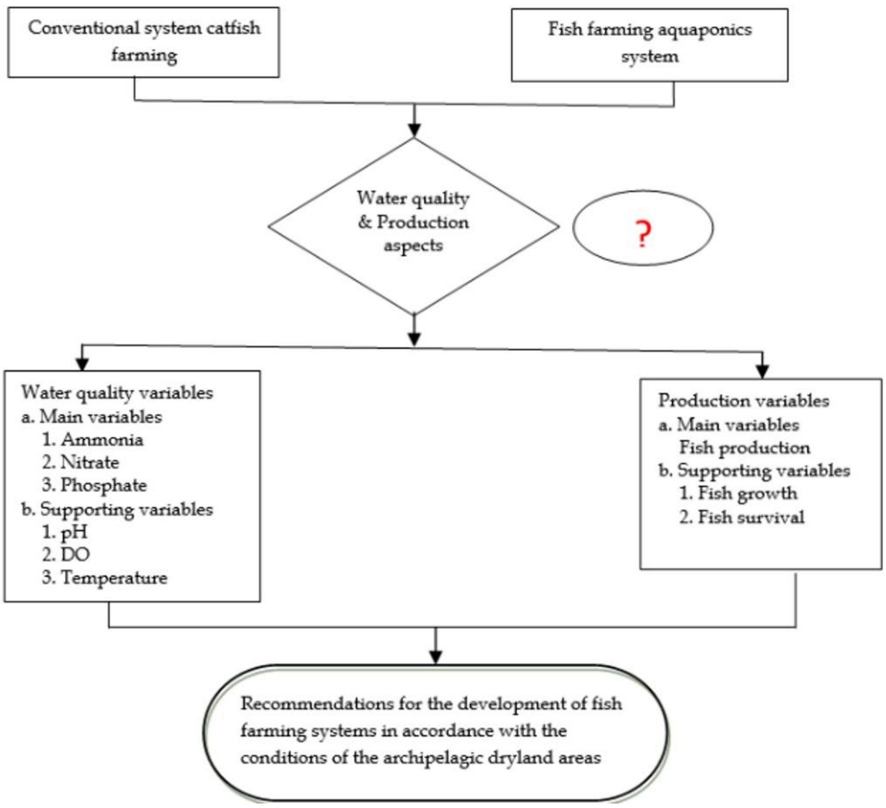

Figure 1. Conceptual Framework

This research has been carried out for 3.5 months or (105 days), namely from August to November 2023, located at UPT. Lab. Dryland Fisheries Islands Nusa Cendana University. This study used a randomized design complete with two treatments (aquaponics system and conventional system) with six repeat units. Each repetition is placed randomly to obtain The experimental design used is a Complete Randomized Design (RAL). The materials used in this study were catfish fry weighing ± 2.80 gr with a length of 7-9 cm and water spinach vegetables. The number of fish per container is 350 heads with a total number of 4200 heads.

Fish stocking is carried out after the fish have been acclimatized and the aquaponics series has been operationalized for 3 days. The feed given is in the form of commercial feed that has 31% protein. Feeding is carried out as much as 5% by weight of fish biomass. The frequency of feeding is 2 times a day, namely in the morning at 8 o'clock and in the evening at 4 o'clock. Feeding by stocking thoroughly on the surface of the pond. Water changes are carried out in conventional tubs once a week by making a 30% change, while in aquaponics systems during maintenance no water changes are made, except for those lost due to evaporation.

Taking and checking water quality samples for supporting variables both temperature, pH, and DO for aquaponics and conventional ponds are taken once a week and the measurement time is morning at 8 and 4 pm. Direct sampling at the research site. While the main variables ammonia, phosphate, nitrate for aquaponics and conventional ponds were carried out twice, namely week-1 and week 3. Production variables were carried out 1 time, namely at the end of the study. For water sampling in 12 ponds. Water samples were taken as much as 2 L on the surface layer (±50 cm on the surface) using a water sampler. Furthermore, the sample was analyzed in the laboratory of the Faculty of Fisheries, University of Muhammadiyah Kupang to find out whether it crossed the threshold or not. The variables observed are in the form of quality variables of the main aquatic environment, namely ammonia (NH_3), phosphate (P), nitrate (NO_3) and fish production. Meanwhile, the supporting variables of water quality are temperature, pH, DO, absolute growth of fish and fish survival.

a. Analysis of Ammonia, Phosphate and Nitrate

Analysis of ammonia, phosphate and nitrate was carried out in the laboratory using spectrophotometric method (SNI 06-6989.30-2005 for ammonia; SNI -5-6989.31-2005 for phosphate and SNI 06-2480-1991 for mitrate).

b. Production of catfish

Catfish production is calculated as follows (Zonneveld & Metz, 1991):

$$\text{Catfish production (kg/m}^2\text{/cycle)} = \frac{1000}{catfish\ pond\ area}\ x\ (Bt - Bo)$$

where:
Bt = Catfish weight at the end of the study (g)
Bo= Catfish weight at the beginning of the study (g)

c. Pertumbuhan mutlak ikan

Absolute growth can be calculated by the formula (Effendi, 1979):

$$W = W_t - W_o$$

where:
W = Absolute growth (g)
Wt = Catfish weight at the end of the study (g)
Wo = Catfish weight at the beginning of the study (g)

d. Catfish Survival

Catfish survival is calculated by the following formula (Ransum & Yang, 2016):

$$SR = \frac{Nt}{No} x\ 100\ \%$$

where:
SR = Survival rate (%)
No = The number of catfish at the beginning of the study (Individual)
Nt = The number of catfish at the end of the study (Individual)

Data on ammonia, phosphate, nitrate and catfish production were analyzed using t-test, while supporting data were analyzed descriptively. All data analysis used SPSS (Statistical Package for the Social Sciences 24) software.

RESEARCH RESULT

a. Ammonia, Phosphate and Nitrate

The presence of ammonia, phosphate, nitrates comes from the activity of catfish waste metabolites such as feces and urine, as well as inedible feed residues. The measurement results of ammonia, phosphate and nitrate are presented in Table 1.

Table 1. Ammonia (mg/L), phosphate (mg/L) and nitrate (mg/L) levels in aquaponics and conventional systems.

Variable	System	Week		Quality Standards
		1	3	
Ammonia	Aquaponic	0.003 ± 0.001	0.015 ± 0.002	<1 (Somerville *et al.*, 2014)
	Conventional	0.003 ± 0.001	0.042 ± 0.003	
Phosphate	Aquaponic	0.009 ± 0.003	0.051 ± 0.006	0.2 mg/L (Strauch *et al.*, 2019)
	Conventional	0.009 ± 0.003	0.163 ± 0.037	
Nitrate	Aquaponic	0.178 ± 0.041	0.316 ± 0.054	< 10 mg/L (Yosmaniar *et al.*, 2021)
	Conventional	0.178 ± 0.041	0.630 ± 0.092	

Independent t test results showed that ammonia. phosphate. and nitrate in aquaponics systems significantly lower ($P<0.05$) than in conventional ponds. Average ammonia concentration in the aquaponics system at 0.015 mg/L compared to the conventional system at 0.42 mg/L. The same was the case with Average phosphate in the aquaponics system at 0.051 mg/L, while in the conventional system at 0.163 mg/L. Similarly, average nitrate concentration in the aquaponics system at 0.316 mg/L, and in conventional system of 0.630 mg/L.

b. Production of catfish

Based on the results of the study showed that the results of both treatments of the aquaponics system had higher catfish production than conventional systems. The average value of catfish production in conventional aquaponics systems during the study is presented in Table 2.

Table 2. Average production value (kg/m^2) of catfish in aquaponics and conventional systems

No	System Aquaculture	Production (kg/m^2)

1	Aquaponic	22.149 ± 0.469
2	Conventional	18.119 ± 0.568

Independent t test results showed that catfish production was significantly higher ($P<0.05$) in aquaponics system treatment (22,149 kg/m^2) than production in conventional system treatment (18,119 kg/m^2). Although the aquaponic system does not apply water changes until the end of the study, the biofilter components in the aquaponic system are proven to support fish production optimally.

c. Absolute Growth

The value of the absolute growth rate of catfish during aquaponics system research is higher than conventional systems. The average results of measuring catfish growth at the beginning and end of the study are presented in Table 4.

Table 4. Growth of Early Weight and End weight of Catfish (Clarias sp) in Aquaponics Systems and Conventional Systems.

System	Initial Weight (g)	End Weight (g)	Absolute Growth (g)
Aquaponic	13.588 ± 0.829	102.184 ± 1.632	88.597 ± 1.875
Conventional	13.528 ± 1.002	86.002 ± 1.651	72.475 ± 2.272

The results showed that catfish growth in aquaponics systems was higher (88,597g) compared to conventional systems (72,475g). However, the aquaponic system does not apply water changes until the end of the study, the biofilter components in the aquaponic system are proven to support fish growth optimally.

E. Sintasan ikan

Survival rate is the percentage of organisms that live at a certain period of time. Survival is calculated by comparing the number of living organisms at the end of the study with the number of organisms at the beginning of the study. The average results of survival rate (SR) measurements of catfish raised with aquaponics systems and conventional systems at the beginning and end are presented in Table 5.

Table 5. The Average Survival Rate of Catfish at the Aquaponics and the Conventional Systems.

System	Initial Number (fish)	End number (fish)	Survival Rate (%)
Aquaponic	2100 ± 0.000	1732 ± 12.323	82.477 ± 3.520
Conventional	2100 ± 0.000	1509 ± 33.110	71.858 ± 9.460

The highest catfish survival rate was obtained in fish raised in aquaponics systems (82,477%) compared to conventional systems (71,858%). Although the aquaponic system does not apply water changes until the end of the study, the biofilter components in the aquaponic system are proven to support catfish survival rate optimally.

C. Other Water Quality

Water quality is one of the factors supporting fish growth in aquaculture systems. In this study, water quality has been observed as supporting data, namely temperature, pH, and DO. The following results of water quality measurements are presented in Table 3.

Table 3. Water quality parameters in aquaponics systems and conventional systems

Parameter	**System**		**Quality Standard**	**Literature**
	Aquaponic	Conventional		
Temperature (℃)	27.6 ± 0.514	26.3 ± 1.230	22-34℃	(Hargreaves & Tucker, 2003)
pH	6.8 ± 0.424	7.2 ± 0.508	6.5- 9.0	(Baldisserotto. 2001)
DO (mg/L)	8.2 ± 0.447	7.1 ± 0.458	> 3 mg/L	(Boyd et al., 2018)

The results showed that in the aquaponics system the values of temperature (27.6 ± 0.514 ℃), pH (6.8 ± 0.424), and DO (8.2 ± 0.447 mg/L), while in conventional systems temperature (26.3 ± 1.230 ℃), pH (7.2 ± 0.508), and DO (7.1 ± 0.458 mg/L). The average value of these three parameters is still within the tolerance value in catfish farming.

DISCUSSION

Ammonia in aquaponics systems is lower than conventional systems. This is thought to be because the water quality in the aquaponics system can be maintained. In maintaining water quality. The aquaponics system is supported by the filter in it. Treatment with aquaponics systems at ammonia concentrations is lower than conventional system treatment. It is suspected that water spinach plants are able to reduce ionized ammonia in the form of (NH^{4+}) in water and ammonia that has been nitrified into nitrates which are used for growth. The roots of water spinach plants have a big role in the utilization of nitrogen in water so that ammonia that is ionized in the form of (NH^{4+}) and that has been nitrated can be used by water spinach plants for growth. The roots of the plant will absorb ammonia in the water from the cultivation container. then it will be converted into nitrate after undergoing an oxidation process with the help of oxygen and bacteria (Effendi et al., 2015).

High ammonia concentrations can cause an increase in pH in ponds. on the other hand, increasing temperature will also increase ammonia concentrations in fish holding ponds (Datta. 2012) further (Li et al.. 2020) adding that the nitrification process becomes hampered because it is triggered by low temperatures in aquaculture containers, resulting in high ammonia concentrations. Unlike conventional ponds, ammonia is higher. This is due to being in a conventional pool system. There is no change of water during maintenance, as a result there is a buildup of fish metabolic waste (feces) and inedible fish food resulting in ammonia accumulation in the pond and can be toxic to fish. As a result of high ammonia, fish appetite decreases because the water in conventional ponds does not experience recirculation or special treatment. Decreased of water quality can also affect fish appetite. Because when appetite decreases, feed intake into the body is reduced (Joshua et al., 2017).

The increase in phosphate in conventional systems during the study is thought to be due to the accumulation of fish metabolic waste and also inedible feed residue. According to (Rafiee & Saad. 2005), the high concentration of phosphate comes from the excretion of fish in the form of faeces. So that phosphate settles to the bottom and accumulates in the cultivation water. Phosphate from fish feed will be used by fish according to the needs of the body. while unutilized phosphate will be excreted by fish in the form of feces (Powers, Hughes & Soares., 1998). Increased feed residue and accumulated metabolite waste can cause an increase in phosphate, causing water quality to decrease. The excessive presence of phosphorus accompanied by the presence of nitrates can stimulate an explosion of algae growth in waters that can use large amounts of oxygen, resulting in a decrease in dissolved oxygen levels. Orthophosphates are inorganic compounds that can be utilized directly by aquatic plants such as water spinach for growth. Based on Jeschke et al. (1997) phosphate content is needed by plants for stem development. root. and leaves. If the phosphate content is low, it will inhibit root growth. trunk. petioles. and leaves. According to Nozzi et al. (2018) Decrease in phosphate content in aquaponics system with maintenance of water spinach plants causes low biomass value at the end of maintenance. According to Zainun (2018) orthophosphate concentration is influenced by temperature and pH. The concentration of orthophosphate will increase with an increase in temperature and a decrease in pH.

From the results of observations on the treatment of aquaponics systems, there was a decrease in nitrate concentrations contained in fish rearing media caused by the absorption of plant roots (Yep & Zheng, 2019). Plants in the aquaponics system provide the role of biofilters by utilizing nutrients derived from cultivated organic waste. Plant roots are also a medium for adding nitrifying bacteria. which helps reduce ammonia and provides the nitrates plants need. According to Deswati et al. (2018) nitrates are absorbed by plants through the roots as a natural fertilizer for growth.

Increased survival value is high in the treatment of aquaponics systems so that the final population of fish largely determines the amount of harvested/final fish production. According to Rajuansah et al. (2021) that the increasing need for feed, it can cause a decrease in water quality caused by increased metabolite discharges in cultivation containers. and will cause ammonia levels in the water to be high. This circumstance leads to decreased appetite of fish. As a result, survival and growth also decrease.

The highest temperature in aquaponics systems has increased and tends to be more stable (Yang & Kim. 2020). This thing. Due to the role of the recirculation system and biofilter where water is pumped from fish rearing media and then mechanical friction occurs between water particles. Planting media and plant roots so that the water temperature in the pond can increase and tends to be more constant. Temperature that fluctuates too much will affect the metabolic system of fish. In low temperature conditions will affect the immunity or immunity of fish. and in conditions of temperature that drops suddenly will result in red blood cell degeneration so that the process of respiration, namely breathing or oxygen uptake, will be disrupted (Meidiana et al., 2022). In addition, the optimum media temperature affects the performance of digestive enzymes and effective metabolism.

The pH value of water will affect the oxidation process of organic matter. phytoremediation process. and plant growth (Hoarau et al., 2018). According to Robles-Porchas et al. (2020) states that acidic pH conditions can inhibit the proliferation process of nitrifying bacteria. This condition will inhibit the release of bacteria to fecal residues and feed residues in fish farming media. In addition, according to Zou et al. (2016) observed that plants obtain better development in aquaponics systems with a pH of 6-7 water. Most microbes exist in the hydroponic layer. The large number of microbes in hydroponics makes it the main site of nitrogen transformation.

The decrease in dissolved oxygen during observations on conventional systems is thought to be due to the accumulation of feces and residual feed. the process of decomposition by myroorganisms. utilization of oxygen by fish. and increased water temperature (Mallekh & Lagardère, 2002). Beat with the aquaponics system, oxygen levels increase due to the ability of water spinach plants to grow faster than other plants, affecting better absorption of inorganic nitrogen so that water quality becomes better. This affects the dissolved oxygen content in fish farming media. According to Andriani et al. (2023) The dissolved oxygen content in maintenance media plays a role in the oxidation and reduction process of organic and inorganic matter by nitrifying bacteria to reduce the pollution load on cultivation containers. If the oxygen content in fish rearing media is low, there will be competition for oxygen demand between fish and bacteria that decompose organic matter.

The growth of catfish in aquaponics system treatment is higher than conventional system treatment. This is influenced by the use of a recirculation system using water spinach plants as a biofilter has a significant influence on absolute weight growth. The high growth of fish in the aquaponics system is thought to be due to the influence of the filtration system and biofilter of water spinach plants. Water spinach which is a plant absorbs excess nutrients in water in the form of ammonia which has been broken down into nitrates. where this can improve the quality of water entering the cultivation pond (Qiu et al., 2014).

The survival rate (SR) value is low in conventional systems due to mortality due to water quality and mutual prey. According to (Siregar, 2021). The survival rate of fish can also be affected by factors inside and outside the fish. The inner factor consists of the age and ability of the fish to adapt to the environment. External factors consist of abiotic conditions including food availability and quality of living media. The process of improving water quality can affect the survival of catfish. According to Andriani et al. (2021) Catfish survival in aquaponics ponds is higher than conventional or no aquaponics systems. Water quality plays an important role, especially in cultivation activities. Deterioration in water quality can result in death. stunted growth. the onset of disease. and reduction of feed conversion rate. According to Naomi et al. (2020) Catfish enlargement ponds with aquaponics systems are better than conventional systems. This condition is caused by the presence of a recirculation system. Thus triggering the rate of decomposition and nitrification. High or low ammonia levels and pond water quality greatly affect fish production size and fish survival rate. Similarly, the survival rate of the fish.

CONCLUSIONS AND RECOMMENDATIONS

1. Ammonia, phosphate and nitrate in aquaponics systems showed that lower than conventional system. Average ammonia concentration in the aquaponics system at 0.015 mg/L compared to the conventional system at 0.42 mg/L. The same was the case with Average phosphate in the aquaponics system at 0.051 mg/L, while in the conventional system at 0.163 mg/L. Similarly, average nitrate concentration in the aquaponics system at 0.316 mg/L, and in conventional system of 0.630 mg/L.
2. Catfish production was significantly higher in aquaponics system treatment (22,149 kg/m^2) than production in conventional system treatment (18,119 kg/m^2). Although the aquaponic system does not apply water changes until the end of the study, the biofilter components in the aquaponic system are proven to support fish production optimally.

ADVANCED RESEARCH

1. Further research needs to be done on the effect of the aquaponics system on the growth of fish with different plants and different fish so that the aquaponics system can be a problem solving in fish farming activities. and the application of aquaponics systems directly to the community.
2. Aquaponics system can be applied in catfish farming activities because with the aquaponics system we can save water use as a maintenance medium because the use of an aquaponics system can improve the quality of maintenance water so that it is more efficient in water use (does not change water during maintenance).

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REFERENCES

Abraham, T. J., Mallick, P. K., & Paul, P. (2018). African catfish Clarias gariepinus farming practices in North and South 24 Parganas districts of West Bengal. India. *Journal of Fisheries*. *6*(1). 579. https://doi.org/10.17017/jfish.v6i1.2018.280

Andriani, Y., Hasan, Z., Zidni, I., Nurruhwati, I., Iskandar., I. & Kusumoputra, R. (2021). The effectiveness of filters on catfish Clarias gariepinus fry performance in the aquaponic system. *Jurnal Akuakultur Indonesia*. *20*(2). 101–114. https://doi.org/10.19027/jai.20.2.101-114

Andriani, Y., Zahidah, Z., Anando, D, A. & Pratama, R., I. (2023). Productivity of comet goldfish (Carassius auratus) cultured in aquaponics system using fine bubbles (FBs). *Aceh Journal of Animal Science*. *8*(3). 121–128. https://doi.org/10.13170/ajas.8.3.31827

Baldisserotto, B. L. V. F. (2001). Survival and growth of silver catfish larvae exposed to different water pH. *Aquaculture International*. *9*(1). 73–80. https://doi.org/10.1023/A:1012512211898

Boyd, C. E., Torrans, E. L. & Tucker, C. S. (2018). Dissolved Oxygen and Aeration in Ictalurid Catfish Aquaculture. *Journal of the World Aquaculture Society*. *49*(1). 7–70. https://doi.org/10.1111/jwas.12469

Cao, L., Wang, W., Yang, Y., Yang, C., Yuan, Z., Xiong, S. & Diana, J. (2007). Aquaculture Pollution in China Subject Area 5.1: Microbial studies and technologies supporting waste disposal. management. and remediation of municipal and industrial hazardous wastes Environmental Impact of Aquaculture and Countermeasures to Aquaculture. *Environmental Science and Pollution Research-International*. *14*(7). 452–462. http://crsps.net/wp-content/downloads/AquaFish/Inventoried 10.29/8-2007-4-47a.pdf

Datta, S. (2012). Management of Water Quality in Moldova. *Respiration*. *6*(December 2012). 602. http://link.springer.com/10.1007/978-3-319-02708-1

Deswati, Febriani, N., Pardi, H. Yusuf., Y. & Suyani., H. (2018). Applications of aquaponics on pakcoy (Brassica rapa L) and Nila fish (Oreochromis niloticus) to the concentration of ammonia. nitrite and nitrate. *Oriental Journal of Chemistry*. *34*(5). 2447–2455. https://doi.org/10.13005/ojc/340529

Effendi, H. AmalrullahUtomo. B, Maruto Darmawangsa., G. & Aprianti Hanafiah, D. (2015). Wastewater Treatment Of Freshwater Crayfish (Cherax quadricarinatus) Culture With Lettuce (Lactuca sativa). *International Journal of Applied Environmental Sciences*. *10*(1). 409–420. http://www.ripublication.com

Eissa, I.. El-Lamie. M.. Hassan. M. & El Sharksy. A. (2015). Impact of Aquaponic System on Water Quality and Health Status of Nile Tilapia Oreochromis niloticus. *Suez Canal Veterinary Medicine Journal. SCVMJ*. *20*(2). 191–206. https://doi.org/10.21608/scvmj.2015.64627

Endut, A., Lananan, F., Abdul Hamid, S. H., Jusoh. A. & Wan Nik, W. N. (2016). Balancing of nutrient uptake by water spinach (Ipomoea aquatica) and mustard green (Brassica juncea) with nutrient production by African catfish (Clarias gariepinus) in scaling aquaponic recirculation system. *Desalination and Water Treatment*. *57*(60). 29531–29540. https://doi.org/10.1080/19443994.2016.1184593

Goddek, S., Joyce, A., Kotzen, B. & Burnell, G. M. (2019). Correction to: Aquaponics Food Production Systems (Aquaponics Food Production Systems. (2019). (1-620). 10.1007/978-3-030-15943-6). In *Aquaponics Food Production Systems: Combined Aquaculture and Hydroponic Production Technologies for the Future*. https://doi.org/10.1007/978-3-030-15943-6_25

Gupta, B. & Huang, B. (2014). 701596. *International Journal of Genomics*. *2014*.

Hargreaves, J. A., & Tucker. C. S. (2003). Defining loading limits of static ponds for catfish aquaculture. *Aquacultural Engineering*. *28*(1–2). 47–63. https://doi.org/10.1016/S0144-8609(03)00023-2

Hoarau, J., Caro, Y., Grondin, I., & Petit, T. (2018). Sugarcane vinasse processing: Toward a status shift from waste to valuable resource. A review. *Journal of Water Process Engineering*. *24*(May). 11–25. https://doi.org/10.1016/j.jwpe.2018.05.003

Jeschke, W. D., Kirkby, E. A., Peuke, A. D., Pate, J. S., & Hartung, W. (1997). Effects of p deficiency on assimilation and transport of nitrate and phosphate in intact plants of castor bean (Ricinus communis L.). *Journal of Experimental Botany*. *48*(306). 75–91. https://doi.org/10.1093/jxb/48.1.75

Joshua, O., Adogbeji, P. & Author, C. (2017). Factors Affecting Feed Intake in Cultured Fish Species: a Review. *Animal Research International*. *14*(2). 2697–2709. www.zoo-unn.org

Lee, H. J., Choi, K. Y., Chiang, M., H. & Choi, E. Y. (2022). Photosynthesis. Growth and Yield Characteristics of Peucedanum japonicum T. Grown under Aquaponics in a Plant Factory. *Journal of Bio-Environment Control*. *31*(1). 67–76. https://doi.org/10.12791/ksbec.2022.31.1.067

Li, S., Duan, H., Zhang, Y., Huang, X., Yuan, Z., Liu, Y. & Zheng, M. (2020). Adaptation of nitrifying community in activated sludge to free ammonia inhibition and inactivation. *Science of the Total Environment*. *728*. 138713. https://doi.org/10.1016/j.scitotenv.2020.138713

Liang, J. Y., & Chien, Y. H. (2013). Effects of feeding frequency and photoperiod on water quality and crop production in a tilapia-water spinach raft aquaponics system. *International Biodeterioration and Biodegradation*. *85*. 693–700. https://doi.org/10.1016/j.ibiod.2013.03.029

Mallekh, R. & Lagardère, J. P. (2002). Effect of temperature and dissolved oxygen concentration on the metabolic rate of the turbot and the relationship between metabolic scope and feeding demand. *Journal of Fish Biology*. *60*(5). 1105–1115. https://doi.org/10.1006/jfbi.2002.1918

Meidiana, A., Prayogo & Rahardja, B. S. (2022). The effect of different stocking densities on ammonia (NH3) and nitrate (NO3) concentration on striped snakehead (Channa striata) culture in the bucket. *IOP Conference Series: Earth and Environmental Science*. *1036*(1). https://doi.org/10.1088/1755-1315/1036/1/012109

N,Y. Zainun., M, M. S. (2018). Council for Innovative Research. *Journal of Advances in Mathematics*. *10*(February 2014). 1201–1229.

Naomi, M., Hasan, Z., Sumadi, Hamdani, H., Andriani. Y., & Subhan, U. (2020). Growth of Striped Catfish Fingerlings (Pangasianodon hypophthalmus) in Aquaponic System with Fine Bubbles (FBs) Application. *Asian Journal of Fisheries and Aquatic Research*. *7*(2). 1–9. https://doi.org/10.9734/ajfar/2020/v7i230111

Nozzi, V., Graber, A., Schmautz, Z., Mathis, A., & Junge, R. (2018). Nutrient management in aquaponics: Comparison of three approaches for cultivating lettuce. mint and mushroom herb. *Agronomy*. *8*(3). https://doi.org/10.3390/agronomy8030027

Powers Hughes, K., & Soares, J. H. (1998). Efficacy of phytase on phosphorus utilization in practical diets fed to striped bass Morone saxatilis. *Aquaculture Nutrition*. *4*(2). 133–140. https://doi.org/10.1046/j.1365-2095.1998.00057.x

Qiu, W., Wang, Z., Huang, C., Chen, B., & Yang, R. (2014). Nitrate accumulation in leafy vegetables and its relationship with water. *Journal of Soil Science and Plant Nutrition*. *14*(4). 761–768. https://doi.org/10.4067/s0718-95162014005000061

Rafiee, G., & Saad, C. R. (2005). Nutrient cycle and sludge production during different stages of red tilapia (Oreochromis sp.) growth in a recirculating aquaculture system. *Aquaculture*. *244*(1–4). 109–118. https://doi.org/10.1016/j.aquaculture.2004.10.029

Rajuansah, R., Junaidi, M., & Hari Setyono, B. D. (2021). The Solid Influence of Spread on the Growth and Survival Rate of Sea Worm's (Nereis sp.). *Jurnal Biologi Tropis*. *21*(1). 248–254. https://doi.org/10.29303/jbt.v21i1.2504

Ransum, P., & Yang, H. (2016). *1 *. 1 . 2. 1*(April). 1–11.

Robles-Porchas, G. R., Gollas-Galván, T., Martínez-Porchas, M., Martínez-Cordova, L. R., Miranda-Baeza, A., & Vargas-Albores, F. (2020). The nitrification process for nitrogen removal in biofloc system aquaculture. *Reviews in Aquaculture*. *12*(4). 2228–2249. https://doi.org/10.1111/raq.12431

Setiadi, E., Taufik, I., Widyastuti, Y. R., Ardi, I., & Puspaningsih, D. (2019). Improving productivity and water quality of catfish. Clarias sp. cultured in an aquaponic ebb-tide system using different filtration. *IOP Conference Series: Earth and Environmental Science*. *236*(1). https://doi.org/10.1088/1755-1315/236/1/012026

Sikora, J., Niemiec, M., Szeląg-Sikora, A., Mudryk, K., Kurpaska, S., Latała, H., & Rorat, J. (2019). Evaluation of the properties of waste from African catfish (Clarias Gariepinus B.) farming in the context of using it for agricultural purposes. *IOP Conference Series: Earth and Environmental Science*. *214*(1). https://doi.org/10.1088/1755-1315/214/1/012034

Siregar, A. Z. (2021). *The Growth Production Paddy and Tilapia sp with Legowo Row Planting System Support of Security Food and Maritime in Indonesia*. *3*. 388–395. https://doi.org/10.5220/0010043503880395

Somerville, C., Cohen, M., Pantanella, E., Stankus, A., & Lovatelli, A. (2014). Small-scale aquaponic food production- Integrated fish and plant farming. *FAO Fisheries and Aquaculture*. 262.

Strauch, S. M., Bahr, J., Baßmann, B., Bischoff, A. A., Oster, M., Wasenitz, B., & Palm, H. W. (2019). Effects of ortho-phosphate on growth performance. welfare and product quality of juvenile African catfish (Clarias gariepinus). *Fishes*. *4*(1). https://doi.org/10.3390/fishes4010003

Yang, T., & Kim, H. (2020). *horticulturae E ff ects of Hydraulic Loading Rate on Spatial and Temporal Water Quality Characteristics and Crop Growth and Yield in Aquaponic Systems*. 1–23.

Yep, B., & Zheng, Y. (2019). Aquaponic trends and challenges – A review. *Journal of Cleaner Production*. *228*. 1586–1599. https://doi.org/10.1016/j.jclepro.2019.04.290

Yosmaniar Y, Sumiati T., & Mulyasari, M. (2021). Growth Performance and Survival Rate of Catfish (Pangasius sp) with the Application of the Nitrifying and Denitrifying Bacteria. *IOP Conference Series: Earth and Environmental Science*. *934*(1). https://doi.org/10.1088/1755-1315/934/1/012004

Zonneveld, C., & Metz, J. A. J. (1991). Models on butterfly protandry: Virgin females are at risk to die. *Theoretical Population Biology*. *40*(3). 308–321. https://doi.org/10.1016/0040-5809(91)90058-N

Zou, Y., Hu, Z., Zhang, J., Xie, H., Guimbaud, C., & Fang, Y. (2016). Effects of pH on nitrogen transformations in media-based aquaponics. *Bioresource Technology*. *210*(3). 81–87. https://doi.org/10.1016/j.biortech.2015.12.079