Application of FLOCponics to improve water quality (phosphate, sulphate, calcium, potassium)

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Abstract. FLOCponics is a biofloc-based F&D (flood & drain) aquaponics system that can improve water quality, including phosphate, sulfate, calcium, and potassium values. This study aims to obtain optimal water quality so that tilapia (*Oreochromis niloticus*) and pakcoy plants (*Brassica rapa* L.) can grow fast and have high survival rates. The FLOCponics series consists of fish tank (FT), mechanical filter (MF), biofilter (BF), sum tank (ST), and hydroponics bed (HB). In general, the concentrations of sulfate, calcium, and potassium are still within the acceptable quality standard intervals, except for phosphate concentration. The study results show that the application of FLOCponics technology can improve water quality, which is indicated by good plant growth (absence of yellowing, wilting, and lack of nutrients). The same is true for fish, characterized by high growth and survival rates.
Key Words: *Brassica rapa*, biofloc-based F&D aquaponics, tilapia.

Introduction. In Indonesia, aquaculture is the primary driver of economic growth in the fisheries sector (Zulkarnain et al 2013). The problem of limited land in urban areas lead to agricultural land to be converted into commercial spaces (Sudarmo 2018). In rural areas, conventional aquaculture is in great demand, but the problems arising are solid waste and liquid waste originating from feces and fish feed residue (Deswati 2021a, 2021b). The accumulation of these wastes can cause a decrease in water quality which affects the physiological processes, behavior, growth, and mortality of fish (Effendi et al 2015a). One of the innovative solutions to deal with limited land in urban areas and water quality problems from aquaculture waste is to apply aquaponic system technology.

The aquaponics system is an integrated system between aquaculture and hydroponics (Stathopoulou et al 2018; Deswati et al 2018, 2019), using a recirculation system (Yanong 2003; Deswati et al 2021b), so that plants can utilize the nutrients contained in water (Effendi et al 2015b; Deswati 2021b, 2021c). The advantages of aquaponic technology are that it saves land and water use, is environmentally friendly, produces organic fertilizers for plants, creates quality food products with high nutritional value, and can improve the economy (Deswati et al 2020a). Deswati et al 2020b have reported that aquaponic systems are more effective in managing residual aquaculture waste to improve water quality than conventional aquaculture systems.

The type of aquaponics used is Flood and Drain (F&D), where plants get water, oxygen, and nutrients through pumping from the sum tank (ST), which is pumped to the hydroponics bed so that it wets plant roots. After a short time, water, and nutrients, will fall back to ST. The advantage of the F&D hydroponic system is that plants receive a regular supply of water, oxygen, and nutrients (Deswati et al 2020c, 2021b).

In this study, FLOCponics technology was applied to obtain optimal water quality, namely a biofloc-based F&D aquaponics system. FLOCponics has advantages compared to conventional aquaculture, including reducing inorganic and organic nitrogen waste from feed residues and fish waste, and can provide additional high protein feed for fish to increase growth and feed efficiency (Adharani et al 2016; Sudaryati et al 2017). Deswati et al (2020d) have reported a comparison of the use of FLOCponics technology (biofloc in aquaponics system) with no use of biofloc, where the use of biofloc is better in improving water quality supported by no yellowing of plants due to lack of nutrients and can reduce the number of dead fish. The use of biofloc technology in aquaponic systems can support the growth and survival of fish, plants, and bacteria.

The fish used is *Oreochromis niloticus*, which has a relatively fast growth rate, tolerance for poor water quality, high salinity, high water temperature, low dissolved oxygen, high ammonia concentration, and tilapia is suitable for cultivation in this tropical area (Deswati et al 2020d, 2020e). Tilapia is a freshwater fish ideal for cultivation using biofloc technology (Deswati et al 2021b, 2021c, 2021d).

The hydroponic plant used in this study is pakcoy (*Brassica rapa* L.) because it has high commercial value, fast harvest time, and suitable nutrients for human health (Deswati et al 2018). Pakcoy is a vegetable with a good source of vitamins and minerals because it contains β-carotene, 53 mg vitamin C and 102 mg Ca in 100 g fresh weight (Priadi & Nuro 2017).

Millamena (2002) found that plants can grow optimally if the needs of macro and micronutrients are met. In previous studies, heavy metal detoxification (Fe, Zn, Cu) was carried out in the FLOCponics system, which integrated tilapia and samhong mustard, with concentrations of Cu (0.0036-0.02260 mg/L), Fe (0.5269-1.1013 mg/L), and Zn (0.0215–0.2581 mg/L), with the fast growth rate of tilapia and samhong mustard and high fish survival rate (>95%) (Deswati et al 2020c). Because there are still few studies on macronutrient elements in the FLOCponics systems, in this study, we assess water quality improvement using the Flockponics system.

Material and Method. The research was carried out from January to May 2022. The manufacture of aquaculture systems was carried out at Freshwater Aquaculture Center, Padang, Indonesia. Sample analysis was carried out at the Applied Analytical Laboratory of the Department of Chemistry, Andalas University, Basic and Central Laboratory of Andalas University.

Instruments. The tools used in this study were Atomic Absorption Spectrophotometer (AAS) (Perkin Elmer AA-100), UV-Vis Spectrophotometer (PAN analytical), analytical balance (Shimadzu), fish tank (FT, 1 unit), mechanical filter (MF, 1 unit), biological filter (BF, 1 unit), sum tank (ST, 1 unit), hydroponic bed (HB), water pump, high blower, PVC pipe and glassware commonly used in laboratories.

Materials. The materials used in this study were pakcoy seeds (35 units), fish feed, growing media (hydroton, pumice stone, and red brick), tilapia (200 fish, 5-6 cm), water (0.88 m^3), bacteria biolacto, banana, pineapple, egg, vitamin C, vitamin B complex, bread tape yeast, sugar, Yakult, molasses, distilled water, and chemicals.

FLOCponics system. The FLOCponics system consists of FT, MF, BF, ST, and HS (Figure 1). FT (90 cm high and 120 cm in diameter), MF (110 L), BF (110 L), ST (110 L), and HB with growing media (hydroton, pumice stone, and red brick). FT was filled with water (0.88 m^3) and fish were put in (200 fish, 5-6 cm long). The MF is filled with a circular plastic filter (3 cm thick, two units) to filter the sediment. BF consists of (i) aeration stone, (ii) plastic filter, and (iii) bio-ball.

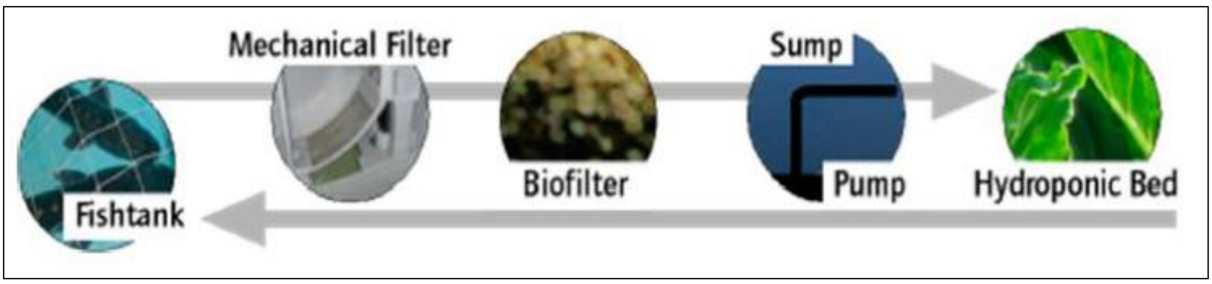

Figure 1. Layout of the FLOCponics system.

The water flow is regulated in a RAS (Recirculating Aquaculture System). Water from the FT has flowed to MF, BF, ST, and HB, and recirculation is carried out continuously, assisted by a pump. Oxygen needs, especially in FT and BF, are equipped with a high blower.

FLOCponics bacteria breeding. Bacterial breeding ingredients are biofloc bacteria (100 g), banana (255 g), pineapple (300 g), eggs (3 units), vitamin C (150 mg), vitamin B complex (3 tablets), yeast tape (4 g), bread yeast (6 g), sugar (750 g), Yakult (455 mL). Then a gallon containing water (19 L) was provided as a container for bacterial breeding. Ingredients such as bananas, vitamin C, vitamin B complex, and tape yeast are mashed using a blender and placed in a clean container. Then the pineapple is blended and placed in a clean container, then bread yeast is added. Then egg yolks, sugar, mashed ingredients, and biofloc bacteria are added to the gallon. After that, the aerator was installed (high blower) and was closed tightly so that no air enters. Bacterial seeding was carried out for one week with a fermentation process. The successful breeding process was indicated by the slightly fermented yeast odor with a new yellow color.

Stages of application of biofloc nutrition per week. The biofloc nutrient added to the FT, namely dolomite lime (50 g), was weighed, dissolved in water (50 mL), put into the fish pond, and waited for 30 minutes. Salt (250 g) was put into the pool, waited for 30 minutes, and 75 mL of molasses and water were each put for bacteria cultured with various variations every week, namely: 100, 150, 200, 250, 300, and 350 mL.

Hydroponic plant preparation. The hydroponic plant used in this system is pakcoy (*Brassica rapa*). Pakcoy seeds were sown for 1 week using rockwool media which had been cut into pieces (1x1) cm in size. After 1 week, the pakcoy plants were transferred to the hydroponic circuit (HS)

Aquaponic system analysis. The analysis carried out on the FLOCponics system analyzes water quality (phosphate, sulfate and Ca and K). Water samples were taken from 3 places, FT, BT, and HB. Water sampling was carried out on days 0, 7, 14, 21, 28, and 35. Fish and plant growth measurement was carried out from day 0 to day 35.

Results and Discussion

FLOCponics analysis. In this study, weekly biofloc nutrition was intended to increase C/N>15 (Hargreaves 2006) to produce high quality and quantity that promotes survival, growth, and immune activity (Panigrahi et al 2018; Deswati et al 2022). Furthermore, strong and even aeration was carried out (> 4 mg/L) (Gunarto & Suwoyo 2008) because tilapia requires oxygen for metabolism and the bacterial population requires oxygen to degrade waste and reproduce.

The biofloc nutrition added to FLOCponics consists of a consortium of biofloc bacteria (*Lactobacillus* spp.), dolomite lime, salt, and molasses. *Lactobacillus* spp. is a heterotrophic bacterium that converts nutrients into bacterial biomass that can be used as fish feed. Munawaroh et al (2013) reported that *Lactobacillus* spp. is a lactic acid bacterium capable of degrading amino acids into N elements. Heterotrophic bacteria can form flocs and synthesize PHB compounds (polyhydroxybutyrate) as polymer bonds between microbial floc-forming substances (Putri et al 2015; Ekasari et al 2015). Ekasari (2015) and Deswati et al (2022) reported that probiotic bacteria produce enzymes capable of breaking down complex compounds into simple ones to be ready for use by fish. The bacteria contained in probiotics have a mechanism to produce several enzymes to increase nutrition. These enzymes will help hydrolyze feed nutrients (complex molecules), such as breaking down carbohydrates, proteins, and fats into simpler molecules that facilitate digestion and absorption in the digestive tract.

Molasses is a by-product of the sugar-making process, containing much glucose, fructose, and sucrose. Microorganisms can utilize the addition of molasses as a source of carbohydrates (Rochani et al 2016). Adding element C (carbohydrates) into the FT increases the C/N ratio. It stimulates the growth of bacteria that will utilize nitrogen in microbial protein (Avnimelech 2018), adding dolomite to FT to increase pH stability. Dolomite in water can bind CO_2 to HCO_3, which functions as a buffer system for changes in pH because tilapia can grow optimally at pH 7-8 and *Lactobacillus* spp. bacteria at pH 6.5 (Faridah et al 2019; Gunarto & Suwoyo 2008; Deswati et al 2022). The addition of salt aims to regulate the osmotic pressure of the liquid, regulate the balance (buffer) in the fish body, and regulate the immune system to inhibit the growth of bacteria, fungi, and viruses that attack fish (Syufy 2018; Deswati et al 2022) and prevent fish from getting sick, not experiencing stress.

Growing media analysis. In this study, the growing media used were pumice, hydroton, and red brick. Cohen et al (2018) found that pumice consists of SiO_2, AIO_3, CaO, MgO, NaO, and I. The presence of silica and calcium oxide elements is thought to be used as a substrate by consortium bacteria that can convert ammonia into nitrate, which plants then utilize nutrients. A consortium of bacteria operated purmice as a substrate (Elman et al 2020) and as an adsorbent and filtrate in fishery wastewater treatment (Luthfi et al 2019). Hydroton is an inorganic growing medium made of heated clay capable of storing nutrients longer, easily absorbed, and has good air circulation for plant roots (Deswati et al 2021b, 2022). Broken red brick serves as a substrate for attaching roots and can store water. The smaller the size of the red brick shards, the better the absorption capacity of water or nutrient solution, and the smaller the size can make air circulation and air humidity around the roots better (Tiya et al 2019).

Phosphate concentration analysis. Phosphorus (P) is a macronutrient needed by fish and plants in large amounts. Phosphorus in water is in the form of phosphate ions. Phosphate serves to help plants at the beginning for the formation and development of young roots and leaves. Fish and plants are deficient in phosphate, resulting in slower growth (Zainuddin 2010). However, the concentration of phosphate absorbed by fish and plants in excessive amounts will be toxic. High phosphate concentrations in the waters will trigger the eutrophication process, which is detrimental to the continuity of the aquaculture process (Pratama et al 2015), such as mass fish deaths in Lake Maninjau. The acceptable phosphate quality standard for cultivating freshwater fish and plants in the aquaponics system is 1.0 mg/L (Government Regulation of the Republic of Indonesia Number 22 of 2021, class 3).

Based on Figure 2, phosphate concentration on days 0-35 in the FT (fish tank) increased, presumably from the fish feed. The increase in the concentration of feed given is directly proportional to the increase in fish weight and maintenance time so that uneaten feed remains and fish metabolic waste is produced in feces. The primary source of high phosphorus in aquaponic cultivation is fish feed, and phosphorus in water is phosphate ions (Hlordzi et al 2020). Nugroho et al (2014) and Ade Lestari et al (2015) reported that fish feed dissolved in water would release nitrate and phosphate into the waters. In addition to fish feed, fish waste will also be degraded and produce nitrate and phosphate, which then dissolves into the water. Nugroho et al (2014) reported the concentration of P in the feed ranged from 0.96%. The feed given every day is not all eaten by the fish, but 10-15% will fall to the bottom of the water, settle and dissolve, releasing P into the water. The study found that the phosphate concentration in the FT was 1.4409-17.8925 mg/L.

At BF, the phosphate concentration on days 0-35 tends to increase, presumably because the ability of the MF (mechanical filter) is not optimal to reduce the phosphate concentration due to not changing water and cleaning the MF base so that dirt builds up and clogs the filter. Ade Lestari et al (2015) found that filters had a significant effect on decreasing phosphate concentrations. Furthermore, Rahman et al (2021) stated that most of the dissolved phosphate would be deposited and adsorbed in the bottom sediments of the water. In an anaerobic atmosphere, phosphate trapped in the sediment is slowly released. It will be released back into the water, increasing the availability of dissolved phosphate. The study found that phosphate concentration in BF was 1.2258-20.10753 mg/L.

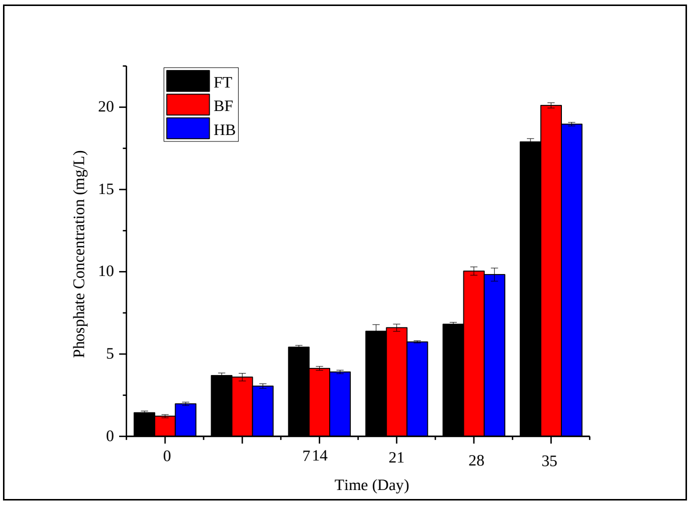

Figure 2. Phosphate concentration (mg/L) in different days.

During the study, the phosphate concentration in HB increased because the rhizosphere microbial activity in the roots was not optimal in breaking down orthophosphate compounds into simple phosphate compounds, which are nutrients for plants (Dwi Adi Suastuti et al 2015). The absorption of phosphate by plant roots affects phosphate concentration because phosphate is a macronutrient nutrient needed by plants in large quantities for the growth process (Zainuddin 2010). The phosphate concentration during the study on HB was 1.9785-18.9677 mg/L.

Based on the study results, the phosphate concentration in FT, BF, and HB has exceeded the standard quality interval allowed for freshwater fish and plant cultivation in aquaponic systems < 1.0 mg/L (Government Regulation of the Republic of Indonesia Number 22 of 2021 class 3). However, there was no significant negative impact on fish and plants, where plant growth could grow well, and not many fish died. Chaney et al (1982) reported that high phosphorus concentrations would harm Fe and Zn deficiency.

Analysis of sulfate concentration. The sulfate ion is one of the macronutrient elements needed by plants in large quantities for plant growth and development. Sulfate (SO_4^{2-}) is an anion that occurs naturally in aquatic environments (Karjalainen & Mikko 2021). Sulfate ion (SO_4^{2-}) is a form of dissolved sulfur in perfectly aerated waters, while in anoxic waters, sulfur accumulates in the form of H_2S (Purwanta & Firdayati 2002). Sulfur is absorbed by plants in the form of sulfate ions so that the leaves turn green. The sulfate ion is a component of amino acids, deficiency of sulfate ion results in impaired plant growth such as paler plant leaves. Sulfate occurs naturally in the aquatic environment but, at high concentrations, can be toxic to freshwater aquatic life (Karjalainen & Mikko 2021). In general, waters contaminated with wastewater have high sulfate concentrations, presumably because they have been infected by sewage. Sulfate waste can cause odor and corrosion in wastewater pipes due to reducing SO_4^{2-} to S^- under anaerobic conditions and H^+ ions to form H_2S. Hydrogen sulfide, which has a high concentration, will interfere with the respiration of aquatic organisms, causing stress and susceptibility to disease (Boyd 2014).

Based on Government Regulation of the Republic of Indonesia Number 22 of 2021 class 3, the sulfate quality standard for cultivating freshwater fish and plants in the aquaponic system is ≤ 300 mg/L. The sulfate ion concentration obtained during the study can be seen in Figure 3.

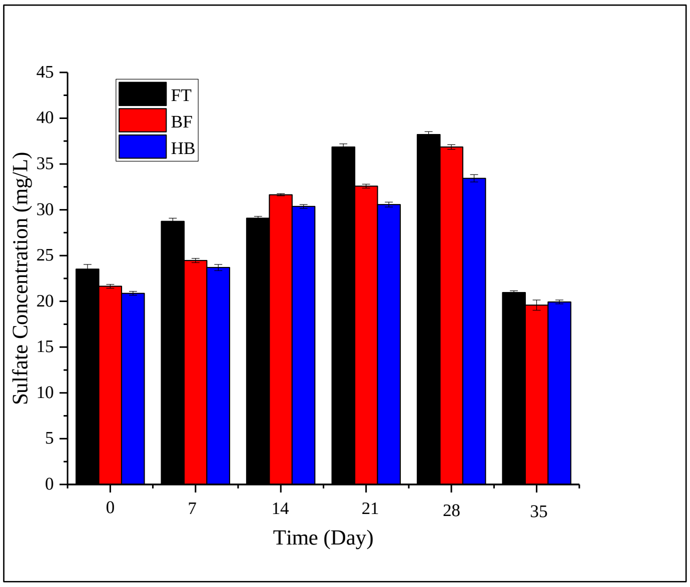

Figure 3. Sulfate concentration (mg/L) in different days.

In FT, the sulfate concentration increased on days 0-28, presumably because of the increase in the amount of feed given every week, which resulted in an increase in aquaculture waste in the form of fish feces and fish feed residues. Furthermore, fish culture waste accumulates metabolic products (H_2S, sulfate, NH_4^+, PO_4^{3-}, etc.) (Choi et al 2020). However, on day 35, the sulfate concentration decreased and was relatively stable in FT, BF, and HB. From day 0 to day 35 at FT, the sulfate concentration was 20.957-38.222 mg/L.

In BF, the sulfate concentration on days 28-35 decreased, presumably because, in BF, there were nets, circular plastics, and bio-balls that functioned as substrates (for bacterial growth and development) and absorbed sulfate ions to reduce sulfate in aquaculture waters. In BF, bacteria form a biofilm layer, where microorganisms can decompose organic pollutants in water (Suryawan 2016). Under anaerobic conditions, it will create H_2S gas, and if the dissolved oxygen (DO) concentration is high, it will convert H_2S gas into sulfate (SO_4). During the study, the sulfate concentration in BF was 19.5897-36.855 mg/L.

In HB, sulfate concentrations decreased on days 28-35, presumably because hydroponic plants had functioned as biofilters so that the water returning to the FT had optimal water quality (Zidni et al 2019). Plants absorb sulfate ions as macronutrient elements so that the leaves are greener (Susilawati 2019). The sulfate concentration in HB was 19.9316-33.436 mg/L during the study.

Based on the study results, the sulfate concentration is within the standard quality interval allowed for the cultivation of freshwater fish and plants in the aquaponics system of 300 mg/L (Government Regulation of the Republic of Indonesia Number 22 of 2021, class 3). Although the sulfate concentration is high in the water, it does not cause negative effects because sulfate is inert, non-toxic, and non-volatile. As the concentration of sulfate in the body of fish and plants increases, the effect will be felt in the long term (Choi et al 2020). Water with a sulfate concentration of 300-400 mg/L has a bitter taste that can cause catharsis, dehydration, and stomach irritation. At concentrations of sulfate > 1000 mg/L it causes diarrhea. In addition to the effect on health, the sulfate concentration is converted to hydrogen sulfide under anaerobic conditions, resulting in scale formation and a foul odor in the exhaust pipe (Choi et al 2020).

Analysis of calcium concentration. Calcium is an essential mineral for fish and plants, required in large amounts. Fish absorb calcium through the gills and skin, and plants absorb calcium in the form of Ca^{2+} (Sari & Ginting 2013). Fish needs the mineral calcium to form bones and tissues. Calcium minerals for plants play a role in creating cell structures (cell walls and membranes) and dividing new cells. Calcium is also an enzyme cofactor in plants.

Besides, calcium in the roots will regulate the uptake of other cations by plants (Sari & Ginting 2013). Excess calcium concentration has an impact on plants and fish. If the calcium concentration exceeds the permissible tolerance limit, it causes plant and fish toxicity so that it can inhibit growth. It can meet calcium needs by adding dolomite lime (Hastuti et al 2014). In waters designated for drinking water, the concentration of calcium minerals should be < 75 mg/L. Calcium concentrations in freshwater are usually < 15 mg/L (Kravchenko et al 2015). The results of the analysis of calcium concentration in water during the study can be seen in Figure 4.

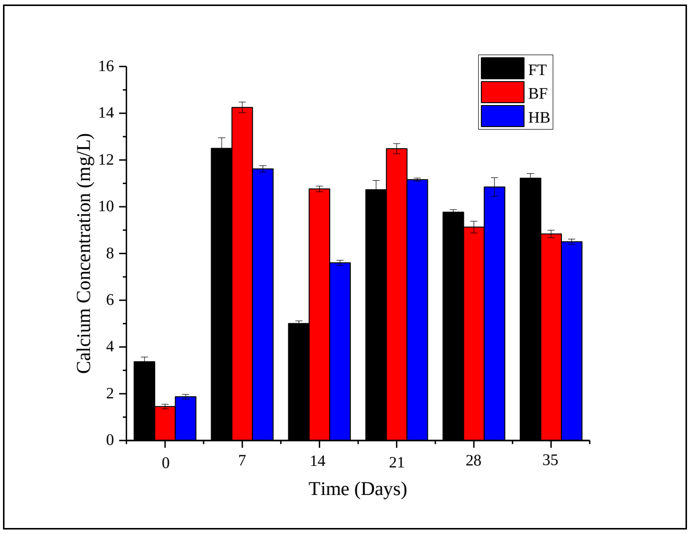

Figure 4. Calcium concentration (mg/L) in different days.

At FT, the calcium concentration increased on days 7, 21, and 35. The primary source of calcium in aquaponic cultivation is dolomite lime. Hastuti et al (2014) reported that the addition of lime could meet calcium requirements. It is suspected in this study that dolomite lime is the most significant contributor to the calcium concentration in FLOCponics system. Dolomite lime can supply metallic elements with valence two, such as Ca^{2+}. However, on day 14 and day 28, the sulfate concentration decreased, presumably due to the absorption of Ca by fish, so that fish could utilize Ca^{2+} levels to maximize growth (Hastuti et al 2014). Calcium is a macronutrient element for fish growth that functions to form bones, soft tissues, and regulatory processes in the body and maintain acid-base balance in the fish body. The amount of calcium absorbed in the body depends on calcium concentration in the fish's body. If the calcium in the feed decreases, calcium absorption from the aquatic environment will increase (Hadie et al 2010). Calcium is an essential mineral needed to form bones and fish skeletons (Ummari et al 2017). From the results of the study, the calcium concentration in the FT was 3.369-12.499 mg/L.

In BF, calcium concentration on the 7th, 14th, and 21st days increased. It was suspected that the filter had not worked optimally, namely the presence of lime at the bottom of the BF, which caused the calcium concentration to increase. From the results of the study, the concentration of calcium in BF was 1.452-14,251 mg/L.

In HB, calcium concentration decreased on days 7, 14, 21, 35, presumably because some of the calcium had been absorbed by plants for growth (Sari & Ginting 2013). Suryantini et al 2020 reported that calcium is a nutrient that plays a crucial role in the formation (of new shoots, root tips, and leaves) and increases the absorption of nitrogen in the form of nitrate. On day 28, the calcium concentration increased, presumably because the metal attached to the plant roots was carried back by water in the water recirculation process (Suryantini et al 2020). Calcium concentration in HB during the study was 1.8716-11.6198 mg/L.

Based on the description above, the calcium concentration in FT, BF, and HB is still within the permissible interval, < 500 mg/L (Minister of Health Regulation No. 416 of 1990). This condition indicates that FLOCponics is suitable for cultivating freshwater fish and plants. Lestari et al (2020) asserted that if the calcium concentration is too high in the waters, it will result in hypercalcemia, an excess of calcium in the blood. The body's ability to regulate calcium concentrations is disrupted.

Potassium concentration analysis. Potassium is a macronutrient needed in large amounts by plants and fish. Potassium plays a role in forming starch, activating enzymes, opening stomata (regulating respiration and evaporation), controlling plant physiological processes, regulating cell metabolic processes that affect the absorption of other elements, increasing resistance to drought, disease and regulating root development (Setianingsih et al 2018). If the water's potassium concentration in the waters is insufficient, the osmoregulation mechanism will be disrupted, eventually impacting fish growth (Lestari et al 2020). The chemical reaction of potassium acts as an enzyme in accelerating the breakdown of complex protein compounds as the main ingredient in the formation of tilapia body tissues. Also, it serves as the homeostasis of ions and nerves that work in the fish body (Lestari et al 2020). At low concentrations, the metal is needed by living organisms for growth and development, but when the metal will turn into poison when the concentration increases. Potassium deficiency in water can cause decreased osmoregulation ability because enzyme activity is directly related to potassium concentration. Optimal potassium mineral in the medium affects the isosmotic pressure between body fluids and their environment. If the potassium concentration in the water is insufficient, then osmoregulation will be disrupted and impact the growth process (Roy et al 2007). The analysis of potassium concentration during the study can be seen in Figure 5.

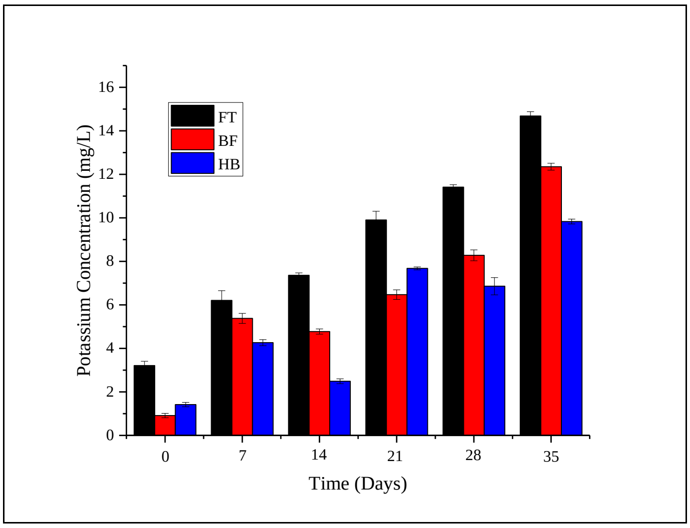

Figure 5. Potassium concentration (mg/L) in different days.

The potassium concentration presumably increased during the study because fish feeding increased with increasing fish mass, so fish waste, feces, and uneaten fish feed residue increased. Potassium concentrations in FT, BF and HB during the study were 3.21-14,682 mg/L, respectively 0.914-12.351 mg/L, 1.419-9.831 mg/L.

In HB, the decrease in potassium concentration was higher than in FT and BF, presumably because pakcoy plants utilized potassium as nutrients for growth. Potassium functions in photosynthesis, accumulation, translocation, transport of carbohydrates, opening and closing of stomata, or regulating water distribution in tissues and cells. However, on day 21, the potassium concentration in HB was higher than BF. It was suspected that metal elements attached to plant roots were carried back by water during the recirculation process (Deswati et al 2019).

Based on the study results, the potassium concentration obtained was still in the optimum allowed interval of <5.05 mg/L (Yang & Kim 2020). Potassium deficiency will cause lower water absorption to reduce immunity to disease; leaves that look older and leaf edges curl inward. In dicotyledonous plants, the leaves have burning spots, while in monocotyledons, there are dead leaves at the tips and edges (Junge & Antenen 2020). In the study, the growth of lettuce was excellent, and found no old leaves and dead leaf edges. Its growth can be seen on the 35th day as long as it has green leaves with an average height of 20 cm, a leaf width of 11 cm, and the number eight strands of leaves. In this situation, lettuce can be produced and is suitable for consumption.

Fish and plant analysis. In this study, the length growth rate of tilapia (3.0812 %), the growth rate of fish weight (6.1812%), and survival (95.6%) were determined. This condition indicates that FLOCponics technology (integration of biofloc and aquaponics) can improve water quality and increase growth rate and survival to increase fish production. This finding is in line with the results of the study by Deswati et al (2020c) that tilapia cultivation in the FLOCponics system obtained a growth rate of fish length of 2.9254% and a growth rate of fish weight of 5.1426%.

The planting media used in this study were hydroton, pumice, and red brick, which are expected to provide nutrients, and air and not suppress root growth (Elman et al 2020). The study results showed that the color of the leaves did not turn yellow, and there were no wilted or dead leaves. It indicates the success of the FLOCponics system. The phosphate concentration has exceeded the quality standard, but the growth of pakcoy plants can grow optimally, characterized by the absence of yellowing, shriveled plant leaves.

The water quality in the fish culture tanks also does not show an excess of phosphate, which is indicated by the absence of algae blooms in the waters. It does not hinder sunlight penetration, which is beneficial for aquatic ecosystems.

The sulfate concentration is below quality standards, but the nutrients are sufficient for optimal plant growth. This condition is characterized by the absence of signs of sulfate deficiency, including chlorosis of young leaves, followed by yellowing of old leaves, stunted growth, and reduced tillers.

The concentration of Ca metal is below quality standards. Still, the nutritional requirements for plant growth have been met, indicated by optimal plant growth and no lack of Ca metal, such as stunted plant growth, necrotic growth on the edges of young leaves or curved leaves, and finally, the death of terminal shoots and root tips.

According to Somerville et al (2014), solid fish waste contains almost all the nutrients needed by plants, both macro and microelements. Some nutritional elements are very limited in numbers, such as potassium (K), calcium (Ca), and iron (Fe), so it can lead to nutritional deficiencies. The lack of these elements is due to the composition of fish feed, which provides all the nutrients needed by fish to grow, but does not necessarily contain all the components required by plants.

Conclusions. It can be concluded that: (i) the phosphate concentrations in FT, BF and HB are 1.4409-17.8925 mg/L, 1.2258-20.1075 mg/L, 1.9785-18.9677 mg/L; (ii) the sulfate concentrations in FT, BF and HB are 20.957-38,222 mg/L, 19.5897-36.855 mg/L, 19.9316-33.436 mg/L; (iii) the calcium concentrations in FT, BF and HB are 3.369-12,499 mg/L, 1.452-14,251 mg/L, 1.8716-11.6198 mg/L; (iv) the potassium concentrations in FT, BF and HB are 3.21-14.682 mg/L, 0.914-12.351 mg/L, 1.419-9.831 mg/L. In general, the concentrations of sulfate, calcium and potassium are still within the permitted quality standard intervals, except for phosphate. In the future, FLOCponics technology can be applied because a consortium of biofloc bacteria can improve water quality and increase production.

Acknowledgments. This research was supported by the Andalas University, Primary Research Scheme of Publication Research Cluster of Andalas University Professor in Research Contracts: T/4/UN.16.17/PT.01.03/Pangan-PDU-KRP1GB-Unand/2022, April 8, 2022.

Conflict of interest. The authors declare that there is no conflict of interest.

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Received: 04 June 2022. Accepted: 05 July 2022. Published online: 06 February 2023.
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How to cite this article:
Deswati, Tetra O. N., Yusuf Y., Dewi P., Pardi H., 2023 Application of FLOCponics to improve water quality (phosphate, sulphate, calcium, potassium). AACL Bioflux 16(1):483-495.