



# Drip Irrigation and Its Effect to Water Quality in Aquaponic Systems

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## Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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## ABSTRACT

This study aims to evaluate the effect of drip irrigation on water quality in aquaponics systems. The research was carried out at the Ciparanje Aquaculture Laboratory, Faculty of Fisheries and Marine Sciences, Padjadjaran University. The research method applied is experimental employing Completely Randomized Design (CRD), with six treatments and three repetitions. The treatments in the study included the volume of drip irrigation for *Capsicum frutescens* plants: A (a positive control employing organic liquid fertilizer), B (negative control without employing liquid fertilizer), C (aquaponics drip irrigation with a water volume of 100 ml/day/plant), D (aquaponics drip irrigation with a water volume of 150 ml/day/plant), E (aquaponics drip irrigation with a water volume of 200 ml/day/plant), F (aquaponics drip irrigation with a water volume of 250 ml/day/plant). Parameters observed in this study consist of water quality in the aquaponics system, including ammonia, nitrate, phosphate, dissolved oxygen, temperature, and pH. The resulting data were analyzed by descriptive analysis. The results showed that water quality evaluations performed were still within the recommended standard for fish culture.

**Keywords:** Aquaponics; growth rate; survival rate; water quality.

## 1. INTRODUCTION

The rate of urban regional development, in general, has increased rapidly every year. This could initiate a decrease in environmental quality specifically in the fish farming area, one of which is the decrease in water availability which is crucial for the various cultured fish growth medium [1]. Technological innovation is required to anticipate the aquaculture production decline initiated by land availability lessening and decreasing water quality. One of the technological innovations which capable and is already commonly applied is integrated fish and plant farming through a system termed aquaponics [2].

Aquaponics is a cultivation technology which merges fish and plant farming [3]. This applied technology saves land and water in fish farming, consequently, the aquaponics application may generate profits in two sectors simultaneously, specifically in the fisheries and agriculture sectors. Additional benefits which could be obtained from the aquaponics system application are that it is environmentally friendly and is able to establish a further productive growth environment for fish and plants. One of the reasons is due to this system's capability to produce high-quality fish and plants since the yielded products are free from chemical substances derived from artificial fertilizers, pesticides, and herbicides treatments [4]. Pond water is channeled into plant growing media as a vegetation filter which could cleanse toxic substances contained in the water hence that the water returning to the pond is already clean and suitable for reuse as a fish growth medium [5].

Based on this background, a study which discusses the influence of aquaponic cultivation systems on the culture media water quality is essential to accomplish.

## 2. MATERIAL AND METHODS

### 2.1 Research Interval and Location

This research was performed from March to June 2016 at the Ciparanje Aquaculture Laboratory, Fisheries and Marine Sciences Faculty, Universitas Padjadjaran. In addition, water quality analysis is carried out at the Water Resources Management Laboratory of Fisheries and Marine Sciences Faculty, Universitas Padjadjaran.

### 2.2 Research Instruments and Materials

The instruments employed during this study include burettes, *Winkler* bottles, Erlenmeyer, measuring cups, aquarium cotton, aeration equipment, cemented pond, polybags, plankton nets, water quality measuring devices, and scales. Whereas, the materials utilized were: plant seeds cayenne pepper variety *Nirmala* (*Capsicum frutescens*) (three weeks old); planting medium in the form of *cocopeat* or coconut fiber; commercial feed (brand FF 999) with a crude protein composition of 35%; organic liquid fertilizer (brand Cobra) given every once every 10 days; the test solution used is O<sub>2</sub>, MnSO<sub>4</sub>, H<sub>2</sub>SO<sub>4</sub> reagent for dissolved oxygen titration. A total of 0.5 ml *Nestler* and 1 ml *Siegnel* solution for ammonia test, SnCl<sub>4</sub> solution and (NH<sub>4</sub>)<sub>2</sub>MoO<sub>4</sub> for phosphate test, phenol, and 10% NH<sub>4</sub>OH for nitrate test.

### 2.3 Research Procedures

#### 2.3.1 Cultivation container preparation

The cultivation container applied for this research is one unit of cemented pond measuring 3 m x 2 m x 1.1 m. Preparation of the container includes pond cleaning and drying. After it is dried the pond is subsequently filled with water.

#### 2.3.2 Cayenne pepper planting

The cayenne pepper planting phase begins with seed selection and seeding. Cayenne pepper seeds are immersed in warm water for approximately 30-60 minutes to clean the seeds. Seeding can be completed by using a tub or a tray, polybags, plastic cups, or by plotting the soil. The purpose of seeding is to select the growth of seeds and separate seeds that develop imperfectly due to defects or diseases. In addition, the benefit of seeding is to expect its readiness up until they are resistant enough to be planted in a larger media. Plant seeds that are ready for planting are the seeds that already have four or more leaves. This indicates that the plant is ready to grow and set to be transferred to an extensive planting medium.

#### 2.3.3 Application of aquaponics system

In this study, the cultivation container was in the form of a cemented pond with a size of 3 m x 2 m x 1.1 m containing comet goldfish with a stocking density of 430 fish and a water height of 60 cm. The pond is equipped with an aerator as an

additional oxygen supply and a clear plastic roof to prevent rainwater from entering the aquaponics media. Polybags that already contain cocopeat and cayenne pepper plants are arranged throughout the pond at a distance of 20 cm per polybag. Water from the culture media is streamed by a pump connected to a Parallon pipe which is arranged to follow the shape of the pond (Fig. 1).

### 2.3.4 Drip irrigation research phase

The study was carried out for three months. Water quality measurements such as DO, temperature, pH, phosphate, nitrate, and ammonia as well as the plankton abundance are performed every 7 days. The research was accomplished outdoors, thus the light energy source directly derives from the sun. Cayenne pepper plant productivity data was calculated by measuring plant height and leaves number throughout the study.

## 2.4 Research Methods

The study method was carried out experimentally with a Completely Randomized Design (CRD) consisting of 2 treatments and 6 repetitions. The research treatments performed comprise:

Treatment A = Control (water in the fish pond)  
 Treatment B = Water volume drip 200 ml/day/ plant

## 2.5 Observed Parameters

Water quality measurements performed in this study comprise temperature, pH, dissolved oxygen (DO), nitrate, phosphate, and ammonia. All of the parameter measurements were carried out starting from the initial stage up until the final

stage of the study every 7 days. The method employed for measuring water quality is shown in Table 1.

a. The amount of dissolved oxygen is calculated by employing the following formula:

$$\text{mgO}_2/\text{l} = \frac{(\text{ml titrant}) \times (\text{molarity of thiosulfate}) \times 8000}{(\text{ml sample titrated}) \left( \frac{\text{ml of bottle} - 2}{\text{ml of bottle}} \right)}$$

b. Ammonia concentration is calculated by employing the following formula:

$$A = \frac{\text{sample absorbance}}{\text{standard absorbance}} \times \left( \frac{1000}{25} \times \frac{\text{standard absorbance}}{\text{standard absorbance}} \times 5 \times 10^{-3} \right)$$

$$AC = \frac{\text{conversion table value}}{100} \times A$$

Description:

AC = ammonia concentration (mg/L)

A = ammonia value (mg/L)

TA = total ammonia (mg/L)

c. The phosphate concentration is calculated using the following formula:

$$PC = \frac{\text{sample absorbance}}{\text{standard absorbance}} \times \left( \frac{1000}{25} \times \frac{\text{standard absorbance}}{\text{standard absorbance}} \times 5 \times 10^{-3} \right)$$

Description:

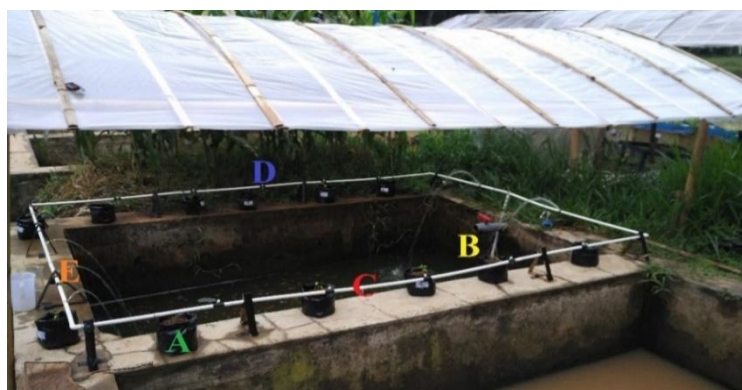
PC = phosphate concentration (mg/L)

d. The nitrate concentration is calculated by employing the following formula:

$$NC = \frac{\text{sample absorbance}}{\text{standard absorbance}} \times \left( \frac{1000}{25} \times \frac{\text{standard absorbance}}{\text{standard absorbance}} \times 5 \times 10^{-3} \right)$$

Description:

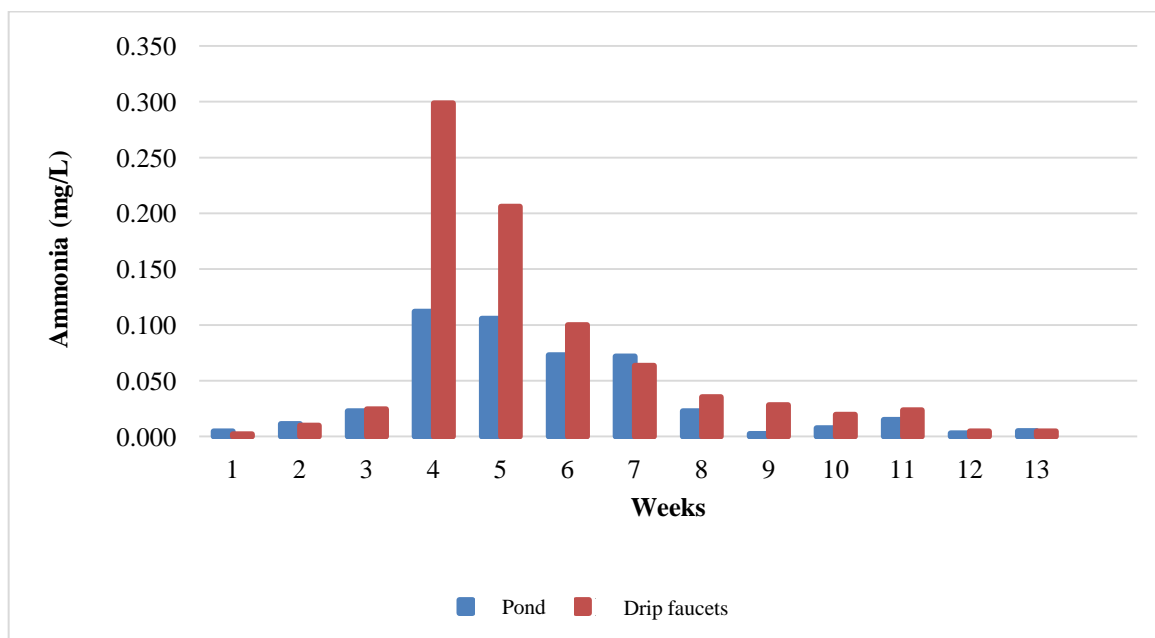
NC = nitrate concentration (mg/L)



**Fig. 1. Aquaponics design (A: polybag (Plant), B: pump, C: Parallon, D: faucet/emitter, E: wood bracket)**

**Table 1. Observed water quality parameters**

No.	Parameters	Measurement Methods
1	Dissolved oxygen	Winkler Method
2	Ammonia	Spectrophotometer
3	Phosphate	Spectrophotometer
4	Nitrate	Spectrophotometer
5	Acidity	pH Meter
6	Temperature	Thermometer



**Fig. 2. Ammonia graph levels during the study**

**2.6 Data Analysis**

Data regarding treatment effects on the value of water quality as well are discussed descriptively.

**3. RESULTS AND DISCUSSION**

**3.1 Ammonia**

Based on the study results, ammonia content originated from two sources, specifically from water contained in the fish rearing pond and drip faucet which flowed in the aquaponic plant system as well. Analysis results (Fig. 2.) indicate that pond's ammonia value is in the range of 0.0002-0.112 mg/L and 0.0002 – 0.299 mg/L in the dripping faucet. Ammonia content in water bodies (ponds) and drip faucets as shown from the results is quite high. According to the quality standard of local Indonesian government regulation (Number 82/2001), the minimum permissible ammonia limit in a fish farming activity is approximately 0.02 mg/L.

Nevertheless, at the 4<sup>th</sup>, 5<sup>th</sup>, 6<sup>th</sup>, and 7<sup>th</sup> weeks of this study, ammonia content appeared to exceed the quality standard limit. A high value of ammonia contained in the dripping faucet could be affected by additional ammonia content which is commonly located at the base of the water compared to the upper part of the water. This could also be instigated by the relatively lesser dissolved oxygen content at the bottom part of the waters, hence the ammonia contained in the bottom part of the waters is most likely greater [6]. The analysis results also show that the ammonia level at the water's bed is not effectively decomposing, which is why the ammonia content of the drop faucet water from the water's bed is higher than that of the water sample taken from the pond's surface. However, as the weeks get further, the ammonia value falls, which is regarded to be a sign that the decomposing bacteria have functioned. It is also possible that the decomposing bacteria did not perform as well in the fourth week, leaving a lot of ammonia that has not been broken down. This decline happens as a result of the ammonia-

decomposing bacteria's already substantial population [7].

### 3.2 Nitrate

During the research period, nitrate content value in waters fluctuated. Water samples in this parameter were procured from ponds and also drip faucets on plants. Analysis results (Fig. 3.) exhibited that pond's nitrate content ranged from 0.027-0.421 mg/L while the nitrate content value running in the dripping faucet ranged from 0.032-0.421 mg/L. This could be caused due to the nitrification processes and the ammonia transformation into nitrates when oxygen is present. Since plants required 0.303 ppm of nitrate for growth in the first few weeks of the study, the nitrate level was insufficient; however, by weeks 9 and 10, the plants' nitrate requirements had been met. The drop in the week after is a result of nitrate being utilized by plants for growth, as the amount of organic matter that decomposes into nitrate is insufficient and only accumulates in the ninth week. According to local Indonesian government regulation (Number 82/2001), the maximum nitrate value contained in waters should not exceed 10 mg/L. Nitrate content in this study was still within safe limits when this measured value was compared with the research data obtained. Excessive nitrate content (>10 mg/L) could initiate rapid algae growth which consequently causes problems regarding water quality [8].

### 3.3 Phosphate

Pond's phosphate content throughout the research period (Fig. 4.) was in the range of 0.024-2.187 mg/L, whereas the drip faucet's phosphate content which streamed through the plants was in the range of 0.077-0.797mg/L. The phosphate content highest increase occurred in the 3<sup>rd</sup> week, 7<sup>th</sup> week, and 10<sup>th</sup> week. This increase is assumed to have occurred due to it coincided with the plankton death phase. The plankton death phenomenon triggers high phosphate content due to the unutilized phosphate compound. Phosphate utilization by plants is considerably low, hence that there is still plenty of phosphate content that accumulates in waters. Based on local Indonesian government regulation (82/2001), the phosphate threshold value in waters is 0.02 mg/L while the phosphate value for plankton growth is in the range of 0.27-5.51 ppm. Phosphate content in the aquaponics system is one of the nutrients for plants, thus phosphate content deficiency will reduce plant productivity [9].

High phosphate content is caused by the decomposition of plankton and an increase in the remaining of fish metabolism because it is not used. Additionally, plants do not use phosphate to its full potential, hence there remains a number of phosphate content that accumulates in the waters. When referring to government regulation (No. 82/2002), phosphate content measured has exceeded the recommended water quality standard threshold, triggering water enrichment which is denoted by pond water turning green due to plankton growth within the pond.

### 3.4 Dissolved Oxygen

Water dissolved oxygen levels during the study fluctuated. The measured dissolved oxygen levels (Fig. 5.) ranged from 3.24 mg/L – 7.4 mg/L. Based on the quality standard, the minimum dissolved oxygen level in fishery waters is 3 mg/L, whereas, in this study, the lowest dissolved oxygen level was 3.24 mg/L which was measured in the 8<sup>th</sup> week. The fluctuations that occurred in the system's dissolved oxygen value are thought to be a result of the organic matter accumulation at the bottom of the water near the pump area. Thus, it interferes with the water flow in the pump circulation. In addition, the system pump is often blocked due to organic matter entering the pump. Therefore, it is better to clean the pump regularly to facilitate the recirculation process. Frequent water addition needs to be performed as well to replace the water used for plants hence, that the water amount in the cultivation media remains stable.

### 3.5 Temperature

Water temperature has an important function for aquatic organisms mainly due to it could affect fish metabolic rate and growth. The optimal temperature will render the fish become more vigorous, and increase their appetite and their metabolism rapidly. The observed temperature during the research period ranged from 25°C-27°C (Fig. 6). The occurrence of temperature fluctuations during the study can be affected by unreliable weather changes. Thus, it affects the research results conducted outdoors. Temperature changes could affect the fish's growth as the optimal temperature could cause digestive enzyme's performance in the fish digestive tract to function at optimum level. This result in the fish's stomach state being empty (hungry) and the fish will vigorously consume feed [10]. Based on [11] the optimum temperature for tropical ornamental fish ranged from 25°C-32°C, therefore, the temperature

during the study was nevertheless in the normal category.

### 3.6 Acidity

Based on the measurement results, the pH value in this study was in the span of 7.3 – 8.06 (Fig. 7.). According to quality standards, a suitable pH for group II fish culture is 6-9 and the optimal pH value is 6-7 [12]. Therefore, the pH value

measured during this research is still within the safe limit. If the pH value is elevated up until it reaches more than 9, subsequently an aquatic environment can be assumed to be severely bad and the odds of fish dying will be extremely high. pH values alteration which occurred every week was presumably due to water quality degradation initiated by feed residues, feces, fish, and plant respiration [13].

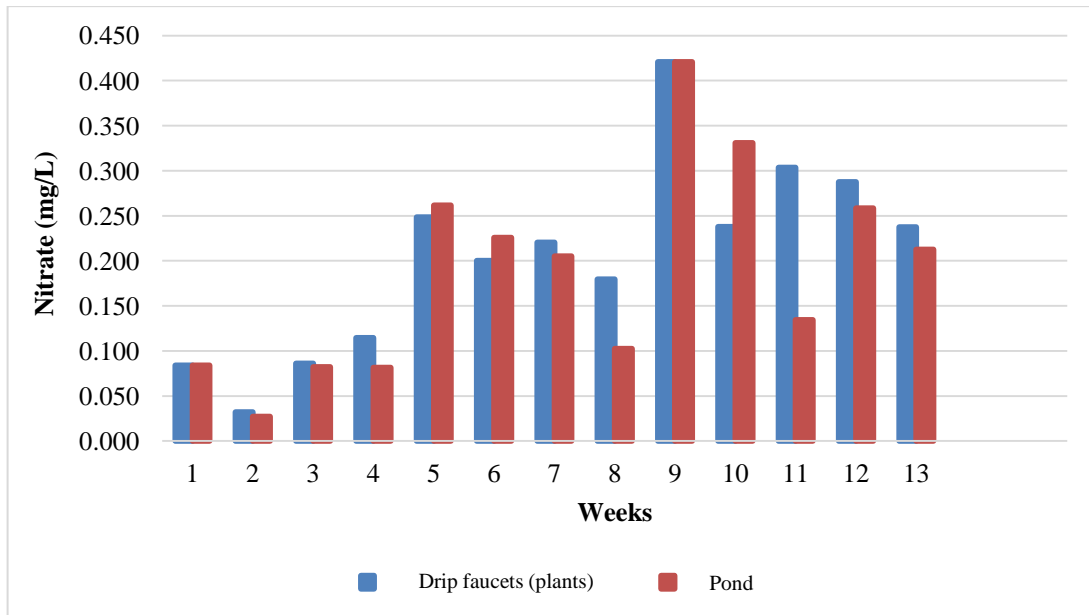


Fig. 3. Nitrate levels graph during the study

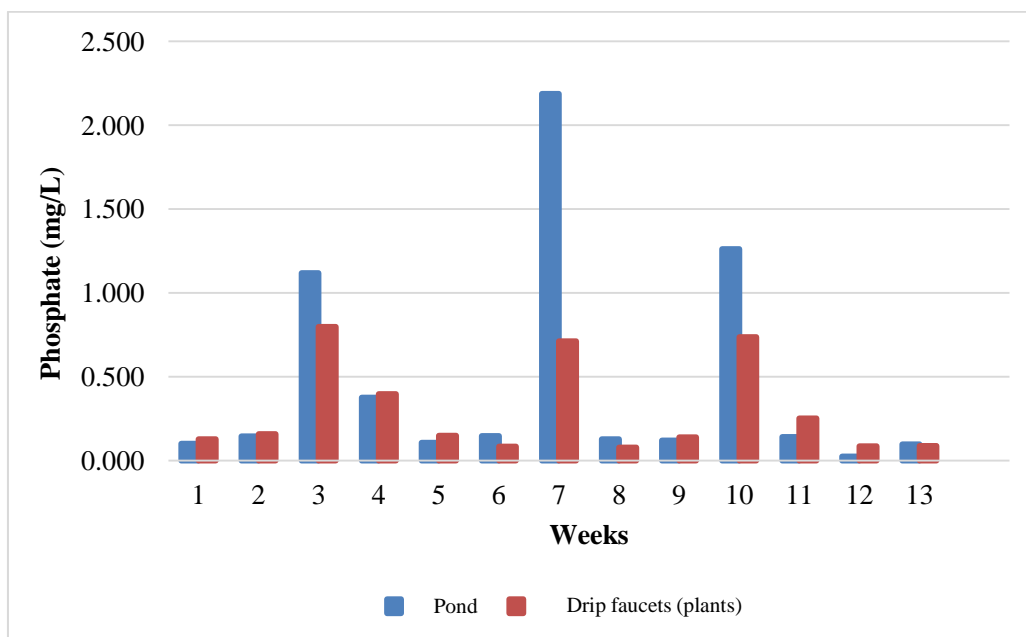


Fig. 4. Phosphate levels graph in water during the study

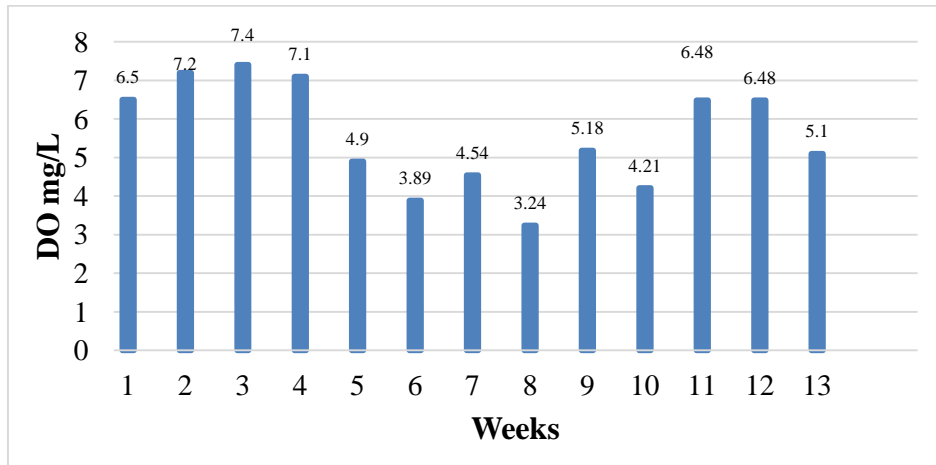


Fig. 5. Dissolved oxygen graph during the study

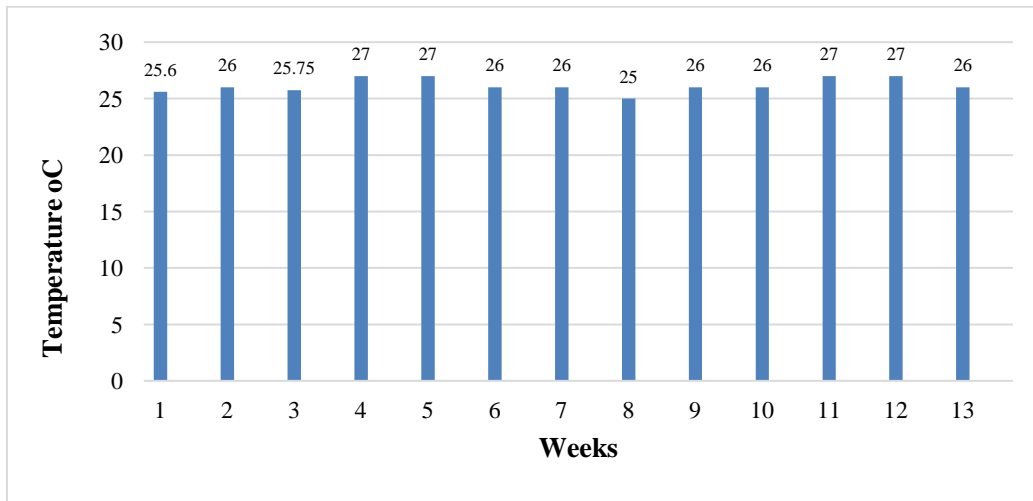


Fig. 6. Graph of temperature during the study

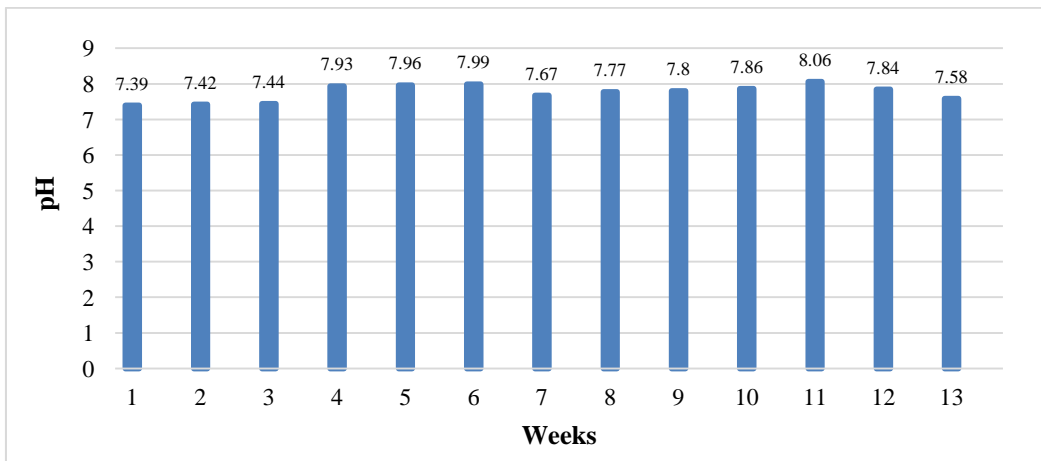


Fig. 7. pH level changes during the study

#### 4. CONCLUSION

Based on the research conducted, the results exhibit that the nitrate, dissolved oxygen, temperature, and pH content measured throughout the research period are however considered safe, even though ammonia and phosphate values have exceeded the threshold for aquaculture activities. Following are a few suggestions that might be made in consideration of the conclusions: the addition of fish stocking density while paying attention to water quality indicators in order to meet plant nutritional needs. Additionally, bacterial testing is required to establish the nitrogen cycle that occurs in the aquaponics system.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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