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Natural control of pH and temperature levels for an aquaponics system

Arman V. Atienza, Mark B. Gonda, Carlo Magno A. Salazar, Anton Louise P. de Ocampo*
Batangas State University - Alangilan, Batangas City, Philippines

ABSTRACT

Aquaponics is the combination of aquaculture (fish farming) and hydroponics (soil-less plant culture). Aquaponics answers the need for a sustainable food source with high production density considering the increasing human population. However, such system needs constant monitoring and proper intervention to maintain their productivity. The pH and temperature levels are crux parameters in a successful aquaponic system. The proposed method aims to control the pH and temperature levels naturally without the use of chemicals and synthetic materials that may affect health after consuming products from the aquaponic system. The closed-loop control system automatically checks and maintains the pH levels and temperature of nutrient-enriched water solutions used in aquaponics. Temperature and pH level sensors interfaced with a microcontroller regulate actuators and pumps for water circulation. Two circulating paths for water maintain the pH and temperature in the system: one that passes through a coral-filled container and the other passes through a collection of driftwood. Coral and driftwood served as controlling agents for lowering and raising the pH level of the water. Water cools down by stagnating for several hours in an insulated container. The pH and temperature measurements showed that the system was able to maintain desired levels. It took around 3.3 hours for the system to reach the target temperature, 19 hours to lower the pH level from an initial value of 7.7 to 6.5, and about 23 hours from 5.5 to 6.5. Controlling pH levels and temperature in an aquaponics system can be done using natural agents which impose no harm both to the fish and plants.

Keywords: aquaponics, closed-loop control system, pH level, water temperature

1. Introduction

Food security is a major consideration related to the increasing world population. Aquaponics is one of those technologies that both the agriculture sector and scientific community see to have potential in securing food for the future [1-3]. Aquaponics gives a practical and sustainable food creation system [4,5]. It is a closed-loop system consolidating the components of aqua-farming and hydroponics which could add to resolving sustainability issues [6].

The Philippines is also on the track to modernizing and further developing its horticulture industry, with both the public authority and private firms empowering the utilization of cutting-edge innovations and shrewd cultivating practices to raise agricultural yield [7,8]. It is also worth mentioning that aquaponics can be done in urban communities by practicing urban farming [9,10]. An aquaponic system is a bio –incorporated system that re-courses water from fish tanks through a tank-farming system to create high-worth agricultural yields [11-16]. Fish will process food and discharge their wastes into the water. Their discharge is separated into nitrates and nitrites [17], which become supplements for the plants. The water will be recycled all through the system. The plants can be utilized as a bio channel to eliminate squanders or uneaten fish feed in water to establish a sound climate. Thus, soil and mineral composts are not required in aquaculture beds as yields acquire supplements from the fish water through their underlying foundations [18]. Subsequently, benefiting both the fish and yield [19]. However, the balance between fish and plants is crucial. Any disturbance in the growing parameters between fish, germs, and plants may result in the generation of ammonia or nitrite that could be lethal to the fish [20].

Plants, fishes, and microorganisms, each have distinctive pH levels to live, but there is a narrow range where they agree without having negative effects on either of them. So, it is necessary to keep the aquaponics system at optimal levels of growing parameters. Plants prefer pH levels between 5.5 to 7.0 while fishes prefer 6.0 to 9.0. This ends up with most of the aquaponics systems falling within a pH scope of 5.5-7.5 which is normal for plants and fishes [21-23]. Temperature also plays a vital role because it must be maintained between 18 to 30 ^{o}C [24-26].

The challenge in implementing aquaponics is maintaining the optimal levels of pH and temperature, naturally. The use of chemicals to adjust pH or cooler/heaters to regulate temperature is discouraged so as not to add up to wastes to be processed. So, there is a need for a system that provides the necessary treatment concerning the controlling and monitoring of pH and temperature using natural methods to keep up with the life of plants and fish. The goal of this experimental research was to create and provide a working

*Corresponding author
Email address: antonlouise.deocampo@g.batstate-u.edu.ph

model of an automated aquaponics system that uses natural ways of controlling the desired parameters (pH and temperature).

2. Materials and methods

The aquaponics system model or setup developed in this study followed the Conceive, Design, Implement and Operate (CDIO) framework as shown in Figure 1.

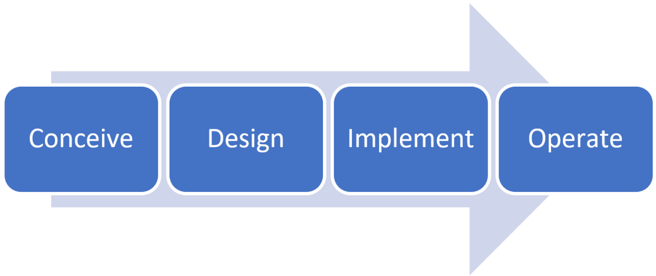

Figure 1. CDIO framework adopted in the study.

The main considerations in the development of the aquaponics system include the optimal pH and temperature levels, and the natural agents that can be used to correct these parameters when the system strays away from the optimal ranges. Based on the pieces of literature reviewed, the optimal range for pH adopted in this study is 6.0 to 7.0 while the temperature is between 18 to 28 °C. The natural agents for correcting pH levels was also identified, i.e., driftwood for lowering pH levels while corals and eggshells for increasing pH levels.

After identifying the requirements, next in the workflow is the aquaponics system design which includes the drawings and schematics, calculations, and algorithm development for the automated measurement and control. The aquaponics system consists of a 2.4 x 1 x 1.2 $ft.^3$ grow bed for plants, a 2.1 x 1 x 1.4 $ft.^3$ fish tank, a sump tank, a tank with corals, a tank with driftwood, and a tank for the water reserve as in Figure 2.

The system uses a 200 gal/h submersible pump with a stature limit of 1.95 m a set of solenoid valves to control the discharge of water from the grow bed, fish, coral, and driftwood tanks to the reservoir. Also, the system is equipped with pH and temperature sensors to constantly monitor these parameters. There are three pH sensors and one temperature sensor that simultaneously send measurements to the controller. The five solenoid valves interfaced using relays, allow the discharge of water from the grow bed to the other tanks. The schematic diagram showing connections of the solenoid valves, sensors, and pump to the controller is shown (Figure 3).

An ATMega328p (Arduino Mega) microcontroller runs the algorithm for the control of the pump and solenoid based on the sensor measurements. The algorithm requires the controller to obtain measurements of pH and temperature levels for both the grow bed and the fish tank. If the water in both the grow bed and the fish tank is normal, the controller will not initiate any operation, otherwise, the pump will run and slowly replace the water in the grow bed and in the fish tank with the reserved water. The reserved water is maintained at optimal pH and temperature levels. If the pH level is too low, the water from the grow bed and fish tank will be discharged to the tank with corals to increase pH. Otherwise, the water is discharged to the tank with driftwood to lower the pH levels. After pH correction, the water is placed in a sump tank for temperature adjustment before finally transferring it to the reserved tank (Figure 4).

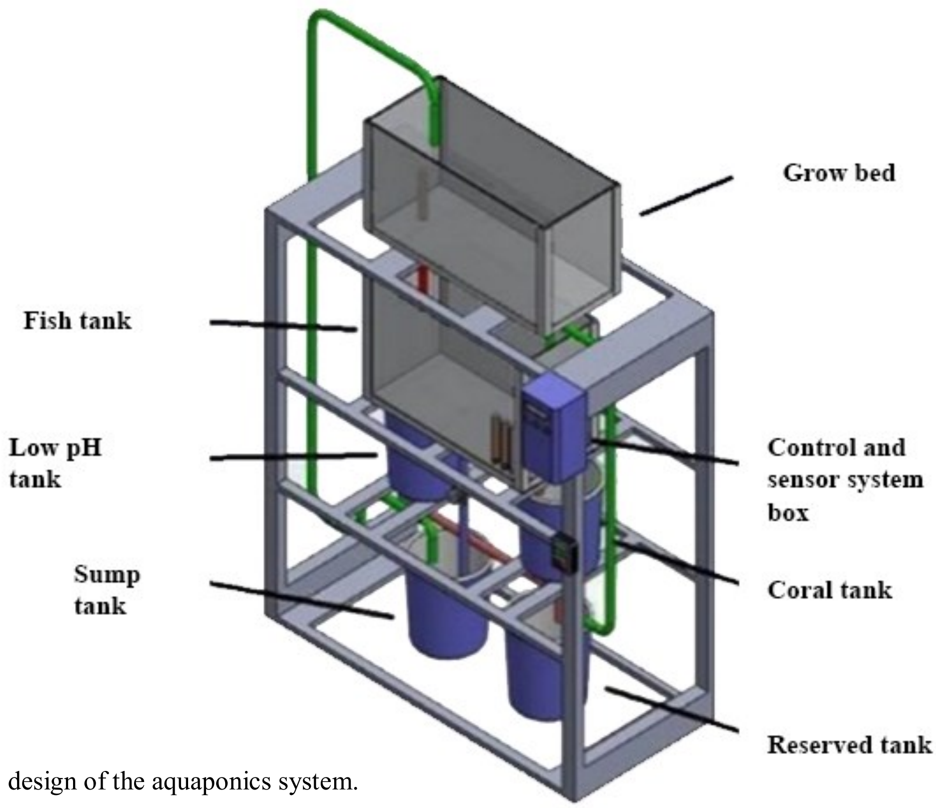

Figure 2. The 3D design of the aquaponics system.

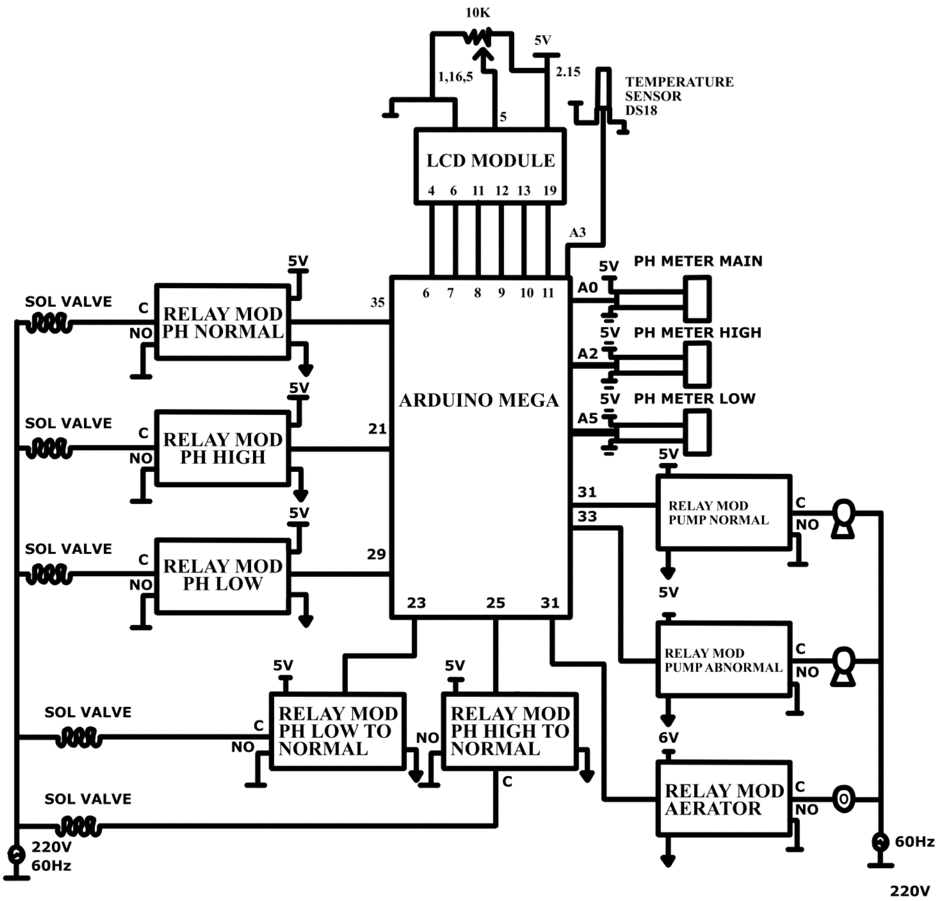

Figure 3. The schematic diagram of the aquaponics system showing its key components.

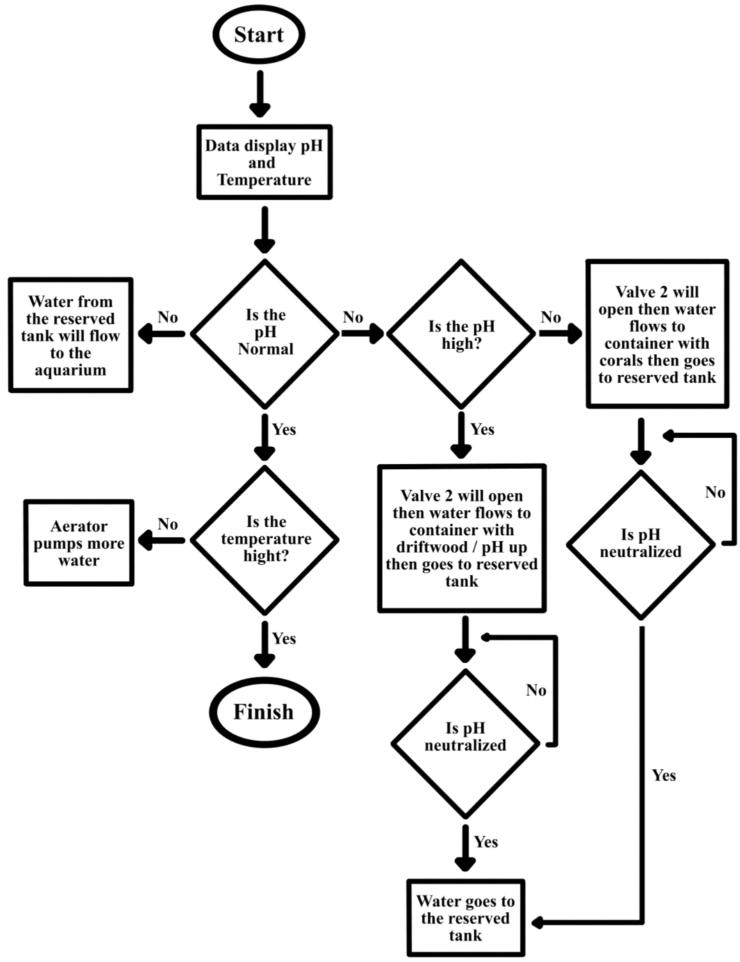

Figure 4. Flowchart summarizing the algorithm performed by the controller.

To test the operation of the aquaponic system, water samples with varying pH and temperature levels are used. Potassium hydroxide is used to obtain a water sample with a 7.9 pH level while phosphoric acid is added to neutral water to obtain a pH level of 5.8. Sample water heated to 35 °C is used for testing the process for temperature adjustments.

3. Results and discussion

The actual aquaponics system is installed at Batangas State University located in Alangilan, Batangas City. Since the ambient temperature rarely goes below 18 °C, a heater is not needed in the system. From the 35 °C initial temperature of the water sample, it took the system 3.3 hours to obtain the desired temperature level of 23 °C as shown in the smoothed temperature response in Figure 5.

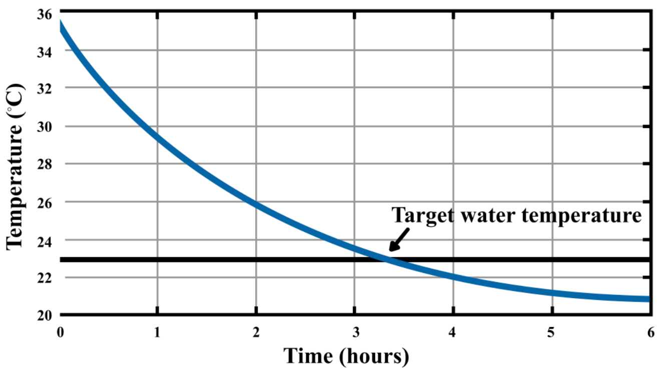

Figure 5. Smoothed temperature response showing the elapsed time before reaching the target temperature.

The aquaponics system is initiated with the sample water with a pH level of 7.9 placed in the grow bed and fish tank. After the controller has obtained the sensor measurements, the water is started to get discharged to the tank with driftwood while the pump is running to replace the discharged water with that contained in the reserved tank. The water in the tank with driftwood normalizes to a pH level of 6.5 after about 19 hours in contact with the pH-lowering natural agent as shown in Figure 6.

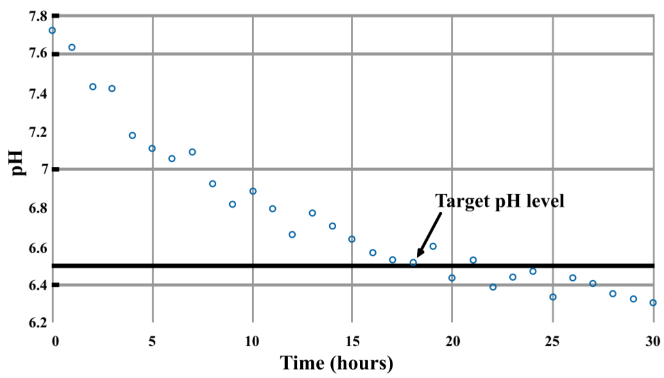

Figure 6. The pH level response with driftwood showing the elapsed time before reaching the target pH value.

Similarly, to test the correction of pH level from a low of 5.5 to the normal value of 6.5, the low pH water sample is placed in the grow bed and the fish tank. Once the controller receives sensor measurements, the low pH water will be discharged to the tank containing corals and eggshells. The time elapsed before the natural agents increase the pH level from 5.5 to 6.5 is about 23 hours as in Figure 7.

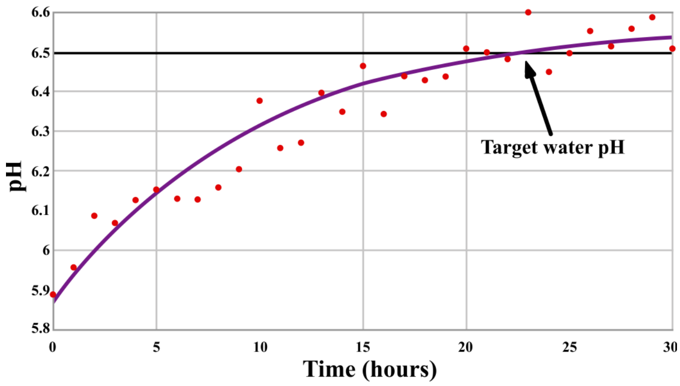

Figure 7. The pH level response with corals showing the elapsed time before reaching the target pH level.

4. Conclusions

Controlling pH levels and temperature in an aquaponics system can be done using natural agents which impose no harm both to the fish and plants. The use of corals and driftwood to maintain pH levels and a dark container for cooling water proved to be a viable solution in an aquaponic system. The proposed system obtained the desired levels of temperature and pH. In future work, fish feeding behavior as well as the ammonia and nitrates concentration levels can also be investigated to provide more accurate interventions to the system. Also, other system designs to reduce settlement time for pH and temperature levels can be explored.

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