Automatic controlling system and IoT based monitoring for pH rate on the aquaponic system

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Abstract. Aquaponics is an opportunity for cultivating plants and fish. Plants use nutrients from fish feces and the fishes use clean water after being filtered by plant roots. The results of fish metabolism, food residue, and temperature change will affect the pH rate. An automatic control system and monitoring pH rate on aquaponics system is designed to maintain the pH rate within a certain range. The method used is a literature study to find the basic theory in designing a control system and monitoring water pH levels. Afterward, it’s necessary to find out the arising problems. The next step to do is designing the system, starting from flow diagrams to system design. The last step to do is simulating the tools that have been designed and then testing the system. Based on the results, it can be concluded that the system could maintain the water condition automatically in pH range from 6.3 to 7.7. The average error found in this sensor was 0.67\%, the average decrease in water pH level was 0.023 per day, and the controlling interval was every 42 seconds, the success rate of sending monitoring data was 100\% in which the data was sent every 1 minute in 1 hour.

1. Introduction
Aquaponics is a combination and improvement of aquaculture and hydroponic systems. Aquaponics integrates closed circulation of fish farming combined with plants. In this process, plants take benefits of nutrients from fish feces. When fish food is left in the pond, it will be toxic for the fish [1-2]. Plants take benefits of nutrients from fish feces, while the fish uses clean water filtered by the plant roots. In this system, the Deep Flow Technique (DFT) method is used where the water from the pond will drain 3-5 cm of plant roots, and with a certain slope, the water will flow again into the fishpond. pH is known as the main variable in aquaponics since it affects many water quality parameters. Acidic solutions have a lower pH, while basic solutions have a higher pH. At room temperature (25 °C), pure water is neither acidic nor basic and has a pH of 7 [3]. Too acidic or alkaline water can interfere with plant growth. Fluctuations in the pH value of water will also affect the condition of the fish. So that water pH must always be controlled based on the pH requirements for fish and plants. The ideal pH for lettuce plants is in the range 6.0 - 7.0, while the optimal pH for catfish is in the range of 6.5 - 8.

Several factors can affect the pH rate on an aquaponic system such as fish feces, sunlight, etc. Temperature plays a significant role in pH measurements. As the temperature rises, molecular vibrations increase which results in the ability of water to ionize and form more hydrogen ions; as a result, pH will drop [4-5]. To increase and decrease pH, it can be done by dissolving pH up / pH down with water then...
slowly entered into the fishpond until pH changes as desired. In this case, pH control of the aquaponic water is less effective if done manually by humans. It needs a control system that can automatically regulate pH levels in aquaponic water [8-10].

Based on the description above, it has been designed as an automation system for controlling water pH levels in DFT aquaponics systems. The system will pump the alkaline solution/acid solution to work so that the desired pH value is obtained. The control system used is Arduino Uno as a microcontroller where the pH sensor is input, while the pump is an actuator in the control system. The pH sensor output can later be monitored from Antares IoT Platform. Plants and fishes used in this system are Lettuce (Lactuca Sativa) and Catfish (Clarias sp.).

2. Design of the system

![Overall System Design](image)

Figure 1. Overall System Design.

Figure 1 explains the overall system design. The fish tank, growing tray, filter and pump work as an aquaponics system. The hardware used is Arduino Uno as a microcontroller, pH sensor as input, relay connected to the pump as an actuator, and Wemos D1 Mini as an Arduino connector with the internet via WiFi media so that the sensor reading data can be accessed through the Antares platform. Pump 1 and 2 will drain the liquid of pH up or pH down as needed. The liquid will be flowed by the pump back to the aquaponic media so that it can maintain the condition of the water pH level.

2.1. Software design

![Software design](image)

Figure 2. Software design.
The software design is divided into 2 processes, namely the system control process and the sending data process to Antares as can be seen in Figure 2. Before the data can be sent, the system first reads and controls the pH level of the water if the conditions do not match the maximum limit or maximum pH level of water. After the pH level of the water meets the desired conditions, the system will switch to the sending data process to get to the Antares platform using the MQTT protocol.

3. Analysis

3.1. pH Sensor Calibration
This test is carried out to calibrate the pH sensor used so that the output of the pH sensor is following the pH meter. The sensor calibration process is done by collecting sensor voltage data with the results of pH meter readings that are sold in the market; thus, the reading of the pH meter results is considered correct. The test is carried out to see systematic errors which can be formulated as follows:

\[
\text{error} = |X - Xi| \% \quad (1)
\]

\[
\text{error} = \left| \frac{(X - Xi)}{X} \times 100\% \right| \quad (2)
\]

Where X is the reference data and Xi is the actual data.

Thus, it can be concluded to find error and error percentage in this system, the formulas used are:

\[
\text{Error} = | \text{pH Meter Value} - \text{pH Sensor Value} | \quad (3)
\]

\[
\% \text{error} = \left| \frac{(\text{pH Meter Value} - \text{pH Sensor Value})}{\text{pH Meter Value}} \times 100\% \right| \quad (4)
\]

Besides, an analysis of the response time of the pH sensor was carried out. Response time is an observation of system output response to changes in time. It is observed starting from the input/disturbance/load signal changes until the response is entered in the steady-state [6-7].

![Figure 3. Characteristics of pH sensor voltage with pH meter readings.](image-url)
As illustrated in Figure 3., it can be seen that the greater the voltage received by the pH sensor, the higher the pH level of the water or the more alkaline water conditions. Calibration results data shows pH meter and pH sensor readings so that the error of pH sensor readings can be compared with the reference of pH meter. Calibration results data is the average error rate of the pH sensor reading of 0.045 in the pH unit or 0.67%. Figure 5. shows the response time of the pH sensor in which the difference in the pH sensor reading with the previous reading affects the response time of the pH sensor. The greater the difference in reading the pH sensor with the previous reading, the greater the response time sensor and vice versa. The average sensor response time is 42 seconds.

3.2. Pump Calibration

![Figure 6. Comparison between pump output and pump specifications output.](image)
This test is carried out to calibrate pump so that the pump can release the volume of water according to the desired volume of water output. In the results of testing the pump output comparison with the output there should be little difference with the specifications of the pump. But after the calibration process, the test results above show that the pump can work in accordance with the desired output.

3.3. pH up
This test was conducted to find the appropriate dose of PH up liquid use in each desired pH range. A tub filled with 4 liters of water and then observe the change of pH rate for each addition of 6 ml of liquid pH up. The pH up liquid used is a liquid that has been diluted with water on a scale of 1/100.

From the results of these tests, it can be seen to increase the pH from 6.3 to 6.5. It takes 36 ml of pH liquid up with a dilution scale of 1/100. So that in 36 ml of liquid pH up on a scale of 1/100 there is 0.36 ml of liquid pH up is pure or equal to 3.6 ml of liquid pH up on a scale of 1/10.

From the test results it can be calculated to increase the pH from 6.3 to 6.5 in the following equation:

\[
\frac{\text{pH up solutions volume (testing)}}{\text{total volume (testing)}} = \frac{\text{pH up solutions volume (aquaponic system)}}{\text{total volume (aquaponic system)}}
\]  (5)

\[
\frac{3.6 \text{ ml}}{4078 \text{ ml}} = \frac{x \text{ ml}}{400000 \text{ ml}}
\]  (6)

So that from the test results the pump will drain 353 ml of pH up liquid to increase pH levels from 6.3 to 6.5 in 400,000 ml of aquaponic media.

3.4. pH down
This test is carried out periodically by looking at the comparison of time between the RTC and the national standard time and processed by looking at the performance of the RTC accuracy whether the pump can work based on the set point time.
This test is conducted to find the right dose of pH down liquid usage in each desired pH range. A tube is filled with 4 liters of water and the change of pH rate for each addition of 6 ml of liquid pH down is observed. The pH down liquid used is a liquid that has been diluted with water on a scale of 1/100.

From the results of this test, it can be seen that to reduce the pH from 7.7 to 7.5, it takes 54 ml of liquid pH down with a dilution scale of 1/100. Therefore, in 54 ml of liquid pH up on a scale of 1/100,
there is 0.54 ml of pure liquid pH up or equal to 5.4 liquid pH up on a scale of 1/10. The results of this test can be calculated to reduce the pH from 7.7 to 7.5 using the following equation:

\[
\frac{\text{pH up solutions volume (testing)}}{\text{total volume (testing)}} = \frac{\text{pH up solutions volume (aquaponic system)}}{\text{total volume (aquaponic system)}}
\]  

(7)

\[
\frac{5.4 \text{ ml}}{4400 \text{ ml}} = \frac{x \text{ ml}}{400000 \text{ ml}}
\]  

(8)

Therefore, the pump will drain 524 ml of pH down liquid to reduce pH levels from 7.7 to 7.5 in 400,000 ml of aquaponic media.

3.5. Monitoring data

This test is conducted to determine the success rate of Wemos in sending data to get to the IoT platform where the results of sending data can be seen on the Antares platform.

**Figure 8.** The results of monitoring data from Antares IoT platform.

The data sent is the result of reading the pH sensor and TDS sensor. Based on the test results of sending data to the Antares platform, the results of the success of sending data to all samples is obtained. This shows that Arduino Uno and Wemos D1 Mini can perform properly.

3.6. Characteristics of the aquaponics system

**Figure 9.** Characteristics of pH rate on aquaponics system.
From the observation for 30 days, the data show that the average change in pH level of water per day was 0.023 in pH units. At the beginning of the system implementation, the pH level of the water in the pond was 7.7. The pH level is the maximum pH level determined by the system so that the system automatically ejects the liquid pH down on the first day and successfully decreases the pH according to the target, which is 7.5. Changes in pH levels of water tend to go down every day due to the results of the fish metabolism dissolved in water, making the water more acidic. However, the condition of the pH of the water tends not to change significantly in 1 day. It takes ± 25 days for the pH of the pond to drop naturally from levels pH 7.5 to 7.2.

4. Conclusion
1. The system can maintain pH rate on aquaponic system in the range of 6.3 - 7.7.
2. The system can transfer pH up and down fluids automatically. The pump will drain pH up liquid of 353 ml when the pH reaches 6.3 and the pump will drain the pH down liquid of 524 ml when the pH condition reaches 7.7.
3. The whole system is running well as monitored through the Antares platform with data transmission intervals every 1 hour.
4. Aquaponics has characteristics where the pH of water tends to increase due to fish yield. In this case, the average value of pH of water every day is 0.023. However, at night, the pH level of water increases by 0.1 and decreases during the daytime, which is caused by increased nighttime temperature conditions.

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