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pH Monitoring and Nutrient Control in IoT-Based Hydroponic Water Storage Tanks Using ESP 32 Microcontroller

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Abstract

Hydroponic plants are a soilless farming method that is increasingly popular due to its efficiency in using resources and increasing crop yields. One important aspect of hydroponic cultivation is monitoring and controlling pH and nutrients in plant nutrient solutions. In this research, researchers developed a pH and nutrient monitoring system as well as an automatic nutrient addition controller in hydroponic reservoirs using a TDS meter sensor, pH meter, and Internet of Things (IoT) technology with an ESP32 microprocessor. The aim of the research is to monitor pH, nutrients, and automatically control nutrients in real-time so that farmers are more efficient in monitoring. The ESP32 microprocessor is used as the brain of the system which can measure the pH and nutrient levels in the nutrient solution. Data generated by the ESP32 microprocessor is sent via the WiFi network to the Firebsae website for remote monitoring. The research results show that this monitoring system is able to measure and monitor pH and nutrient levels accurately. The conclusion from this research is that the automatic monitoring and controller tool designed can work well with sensor reading accuracy reaching 90-95%. With this tool, farmers become more efficient in monitoring and plant growth becomes more because nutritional needs are always met.

Keywords: *Hydroponic Plant Monitoring, TDS Meter sensor, pH Meter Sensor, IoT (internet of think).*

1. Introduction

Hydroponics is a form of agricultural cultivation without the use of soil. Therefore, hydroponics is an agricultural activity carried out using water as a medium to replace soil. Therefore, hydroponic farming systems can utilize limited land. Hydroponic farming does not require large areas of land (Roidah, 2014). [1].

With the advancement of technology, researchers are utilizing the Internet of Things (IoT) for agricultural development and making it easier for farmers to monitor pH and nutrients so that plant intake can be accurately controlled. The tools used to monitor changes in pH and nutrients include pH meters and TDS meters. These sensors will read changes in pH and nutrients in reservoirs in real time, making it easier for farmers to control the nutrient content of the water. [2].

The Internet of Things (IoT) is a futuristic concept where an object can transmit data via the internet without requiring a human connection. The IoT itself has an ecosystem consisting of smart objects, smart devices, and smartphones. The Internet of Things (IoT) can simplify all human tasks, including monitoring or controlling something using only a smartphone or gadget. This website uses Firebase as a database to store data received from sensors connected to the main microcontroller. The data received by Firebase as a database is sent to the API (Application Programming Interface) for processing so that it can be viewed directly on the website. The data received includes water quality, nutrients, and pH. (Pratama et al., 2023) [3].

Therefore, this study aims to design and implement a pH monitoring and nutrient controller system in a hydroponic reservoir using an ESP 32 microcontroller. In addition to monitoring changes in pH and nutrient values, this tool is also designed to automatically control nutrient addition so that plant nutritional needs are always met. It also conducts testing and analysis of implementation results. This research is expected to contribute to the development of more efficient and optimal hydroponic cultivation technology.

2. Literature Review

Previous research conducted by Ayuningtyas Putri M, Hadi Zakaria with the title "Design of an Android-Based Hydroponic Plant Water and Nutrition Monitoring System Using Nodemcu ESP32 on Lettuce Plants". The water quality and nutrient monitoring system for lettuce plants using a microcontroller made from several nodemcu sensors that have been integrated with an android application at Afflaha Farm, replaces the monitoring system that currently still uses manual monitoring or monitoring that comes directly to the site. If we do not monitor regularly and carefully, plant growth will immediately be seen to be suboptimal so that it can affect the quality of the lettuce plants. This system is expected to make it easier for farmers to get information on water pH levels and nutrient levels quickly, and can make it easier for farmers to monitor remotely using only a smartphone via an android application connected to the internet. This research produces an android-based hydroponic nutrient monitoring system with the aim of saving farmers time to monitor nutrients and control them via an android-based application remotely. [10]

Previous research conducted by Dhodit Rengga Tisna, Berlian Juliartha, Tamara Maharani, and Hasnira entitled "Method of Improving Accuracy of Arduino-Based TDS Sensors for Water Nutrients Using Linear Regression" (TDS). Water quality plays a crucial role in aquaculture. One factor determining water quality is the TDS (Total Dissolved Solids) content. Therefore, a TDS meter with high accuracy is needed to accurately measure the quality of various types of water. In this research, a prototype capable of measuring TDS levels in water was developed. This prototype consisted of a TDS sensor device, an Arduino Uno, and an LCD to display the measured water quality readings. To ensure the prototype's accuracy could match that of commercial TDS meters, the researchers incorporated a linear regression algorithm into the Arduino TDS program. Experimental results showed that the prototype's accuracy increased from 77% to 98.3%, nearly approaching the precision of typical commercial TDS meters. [11]

This research aims to design and implement a pH monitoring system and nutrient controller in a hydroponic reservoir with an ESP 32 microcontroller, in addition to monitoring changes in pH and nutrient values, this tool is also designed to automatically control the addition of nutrients so that plant nutritional needs can always be met, as well as to conduct testing and analysis of implementation results. This research is expected to contribute to the development of more efficient and optimal hydroponic cultivation technology.

3. Research Methods

In this study, entitled "Ph and Nutrient Monitoring in IoT-Based Hydroponic Water Storage Tanks with an ESP 32 Microcontroller," the method used in this study is to collect monitoring and controller data based on real-time pH and TDS sensor readings.

The system block diagram is shown in Figure 1. The ESP 32 [4] acts as the main controller in this system, processing inputs according to the programming algorithm entered into the ESP 32. This system uses a pH sensor [5] to read pH, a TDS sensor [6] to read nutrient levels in the water, and a 4-channel relay [7] that is used as an automatic switch on the pump. A 16x2 I2C LCD screen [8] is used for monitoring. The power supply [9] serves as a power supply for all components used. The power supply used is 12V. Android is used to display the monitoring data.

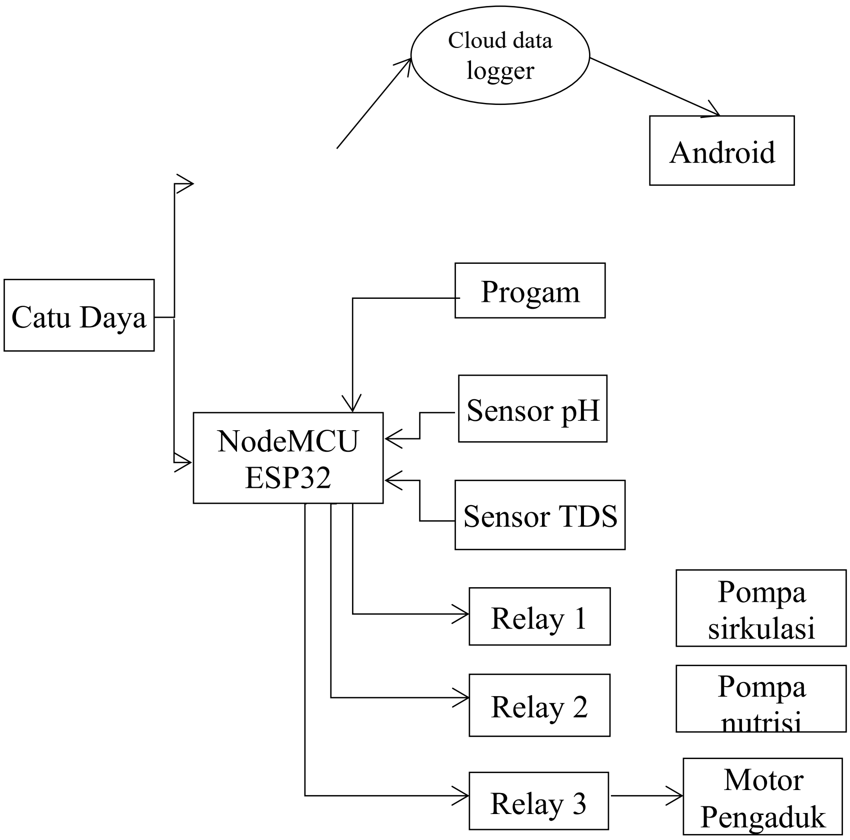

Figure 1: System Block Diagram

The system schematic circuit is shown in Figure 2, while the system flow diagram is shown in Figure 3. The system works from the initial stage of reading the nutrient and pH levels on the sensor. Then the sensor reading results are displayed on the LCD and the firebase website. The data from the nutrient level reading results is also used as a relay controller for the circulation pump and the nutrient pump that has been set, if the nutrient level is more than 500 ppm then the circulation pump will work and the nutrient pump is off. If the nutrient level is below 500 ppm then the circulation pump will be off and the nutrient pump will work.

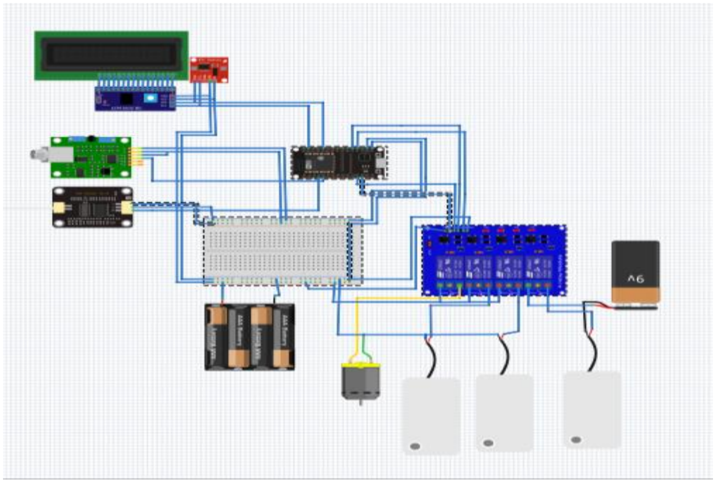

Figure 2: Schematic circuit of the system

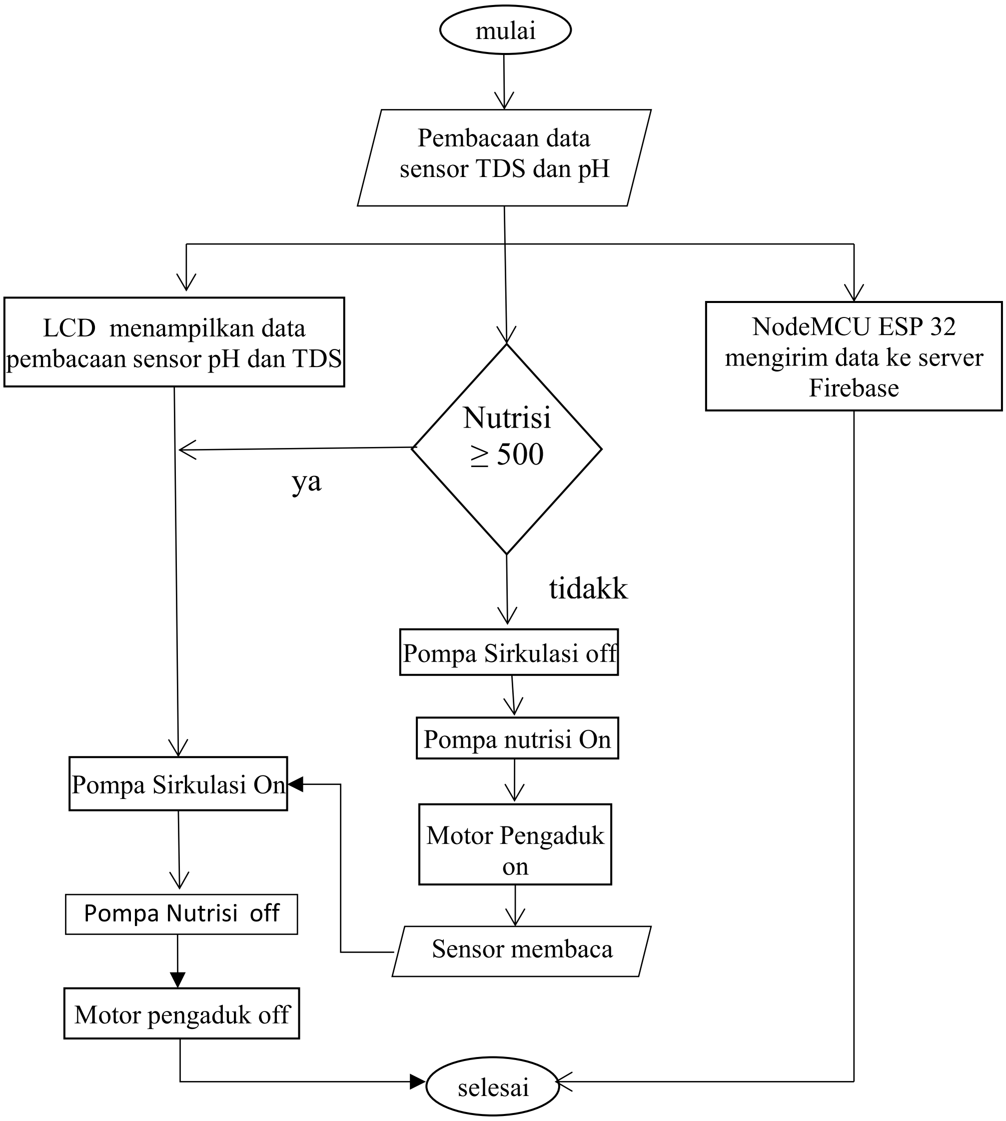

Figure 3: System Flowchart

4. Results

A hydroponic plant monitoring system was developed to simplify the care of hydroponic plants, with the goal of producing high yields and avoiding pests. To determine the yields of the plants using the monitoring system, researchers observed leaf growth to achieve optimal results. Table 1 shows the monitoring of leaf length development of hydroponic bok choy plants over a five-day period

Table 1: Monitoring Hydroponic Development.

Tanaman yang diuji	Monitoring Perkembangan Panjang Daun Tanaman Hidroponik Pakcoy (cm)					
	Hari ke 1	Hari ke 2	Hari ke 3	Hari ke 4	Hari ke 5	Rata-rata
1	3	3,3	3,5	4	4.8	0,42
2	3,1	3,3	3,6	4	4,7	0,38
3	3	3,2	3,5	3,9	4,5	0,34
4	2,9	3,1	3,4	3,7	4,3	0,28
5	3	3,2	3,5	4,1	4,8	0,4

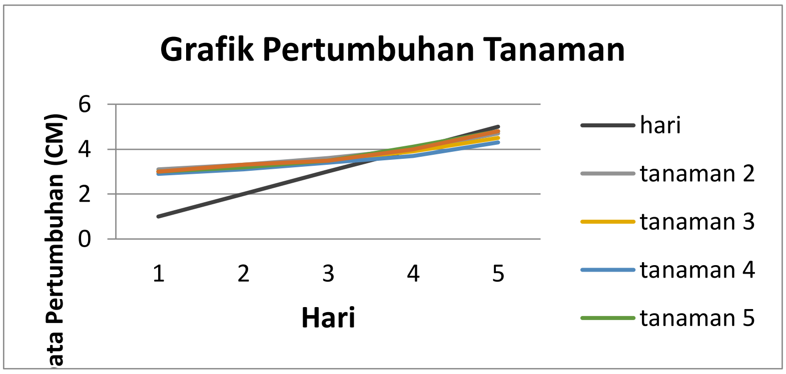

Figure 5: Plant Growth Graph

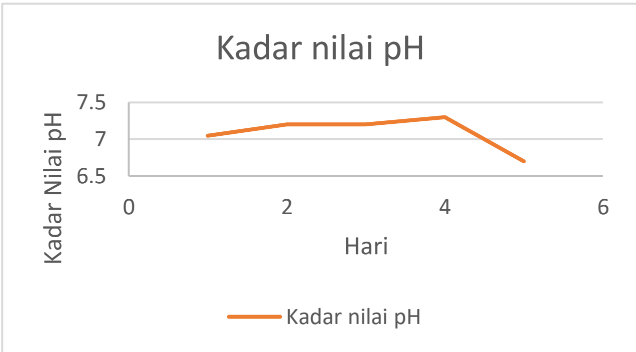

Figure 6: pH Graph

From the results of the plant monitoring tests carried out for five days on hydroponic pakcoy plants, researchers summarized the results of monitoring pH and nutrient levels in the following table.

Table 2: Monitoring Result Data

Hari	Waktu monitoring	Kadar nilai pH	Kadar nilai Nutrisi (PPM)
Senin, 4/09/2023	09.00	7,05	874
Selasa, 5/09/2023	09.00	7,2	733
Rabu, 6/09/2023	09.00	7.2	557
Kamis, 7/09/2023	10.00	7.3	805
Jumat, 8/09/2023	10.00	6.7	535

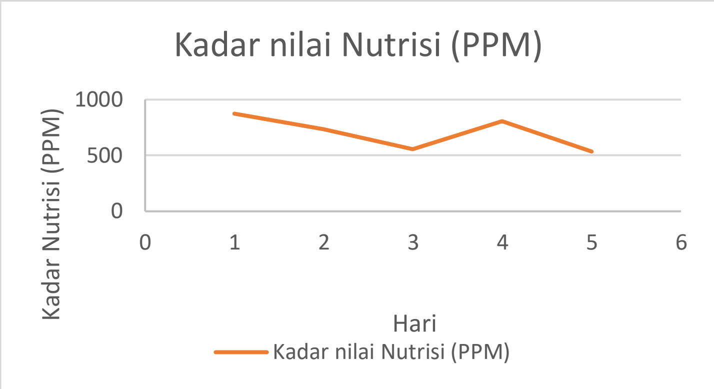

Figure 7: Graph of Nutrient Content (PPM)

The graph in Figure 6 shows that the pH levels on days 1-5 are stable, as they still meet the recommended water pH for bok choy, which is 6.5-7. On the first day, the water pH read 7.05, an appropriate level for bok choy. On the second day, the water pH in the reservoir read 7.2, a level considered safe for bok choy. On days 3-5, the pH monitoring readings were stable at 7.2 and 7.3, with a slight decrease on the fifth day, reaching 6.7. The five-day test results indicate that the change in pH readings is due to changes in water temperature in the reservoir.

The graph in Figure 7 shows the nutrient levels during the five-day test. On the first day, the nutrient level read 762 ppm, indicating good monitoring. On the second day, the nutrient level read 719 ppm, a decrease due to plant uptake. On the third day of monitoring, changes in nutrient levels began to show a significant reduction. It can be concluded that on the third day, the plant's nutrient needs began to increase as the plants began to grow larger. For more details, see Figure 4.14. Monitoring on the fourth day showed that the nutrient level was 805 PPM. On the fourth day, the nutrient monitoring increased, indicating that the automatic nutrient increase controller was working properly. When the nutrient reading was less than the set level, the controller would automatically fill the reservoir with nutrients. On the fifth day, the monitoring system was observed to be working properly, with the nutrient level reading 535 PPM.

5. Discussion

Tests showed that the system operated effectively as designed. All sensors operated with a high level of accuracy. The results of the five-day test of the automatic hydroponic plant monitoring and controller on bok choy (pak choy) plants indicated that using the monitoring system significantly facilitated plant care for farmers. The automatic nutrient addition controller system consistently met the plants' nutritional needs, resulting in optimal plant growth.

6. Conclusion and Suggestions

Based on the results of the analysis and discussion of pH monitoring and nutrient controllers in IoT-based hydroponic water reservoirs with ESP 32 microcontrollers, several conclusions can be drawn as follows:

1. The IoT-based hydroponic pH and nutrient monitoring system uses pH and TDS sensors controlled by an ESP 32 microprocessor. The microprocessor is then connected to a Firebase web API key to send data. The sent data will then be displayed on the website.
2. With the implementation of IoT-based hydroponic monitoring tools, hydroponic farmers find it easier to check plant nutrition by simply monitoring it via the website.
3. Test results from the automated nutrient addition control system design demonstrated satisfactory performance. The nutrient requirements of the hydroponic bok choy plants were met during the five-day test.

Suggestions for further researchers are to add an automatic controller for adding raw water so that the water in the reservoir can always be stable at a predetermined water level. The website display can be developed by adding a feature to set the nutrient levels needed by plants. so that if the tool is used for other hydroponic plants, it can easily regulate the nutrient levels automatically. For hydroponic gardens that use greenhouses, a DHT sensor can be added which functions as a temperature and humidity regulator in the greenhouse space.

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