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Water Quality Monitoring and Control System for Tilapia Cultivation Based on Internet of Things

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Abstract

This research analyzes the quality of water for tilapia habitat which is a type of brackish water fish that is currently widely cultivated by pond farmers. This fish is the choice because of its flexibility regarding habitat. However, despite having flexibility in terms of habitat, each harvest of tilapia that lives in a different habitat will produce tilapia with different quantity and quality. Currently, many tilapia farmers still carry out the cultivation process using traditional methods using ponds. Kuala Kerto Village, Lapang District, North Aceh is one of the locations where many tilapia fish farmers use ponds as a habitat for this fish. Not infrequently, changes in natural conditions such as rain and floods have an impact on tilapia fish ponds in this village. Thus, crop yields are very varied, often even resulting in losses. One of the reasons for this is that there is still minimal use of technology in tilapia cultivation in this village. The design of a water quality monitoring and control system for IoT-based tilapia cultivation in this research was carried out to help the problems of tilapia pond farmers. Through this research, a tool was produced in the form of a prototype IoT device that can be used to monitor and control water quality in tilapia fish ponds. This device utilizes several sensors such as turbidity sensors, ammonia sensors, salinity sensors, pH sensors, and several other sensors as data takers which will later be transmitted and displayed via a web application. Research and development of this device uses the R&D method, namely research and development.

Keywords: *Tilapia, IoT, Control, Water, Monitoring.*

1. Introduction

Tilapia is a species of fish that has high economic value among Indonesian people, and is one of the freshwater fish that is widely cultivated as well as having a high value in terms of economy and potency [1]. To get the desired results from cultivating tilapia, several requirements must be met, one of which is a pond for cultivation with water conditions that support this fish to live and develop. Water quality requirements for growing tilapia include appropriate water temperature, acidity level, ammonia and nitrite levels, dissolved oxygen, and water that is not cloudy or contaminated with chemicals [2].
The condition of water is not regularly monitored by tilapia farmers, so that the harvest results are not as expected. Various kinds of water condition problems, such as water turning cloudy, changing water pH, ammonia levels not meeting standards, as well as several other problems faced by tilapia fish farmers in Kuala Kerto village, Lapang District, North Aceh Regency, affect the quality of fish and yield capacity. The harvest was not as expected of the approximately 30,000 tilapia seeds that were sown at the beginning, after 68-70 days, it turned out that the average weight of adult tilapia fish did not reach 200 grams, and were not yet suitable for harvest. The longer the harvest period, the more expenses will increase for raising tilapia fish. Several solutions have been implemented, such as adding several substrate to prevent livable condition for the fish. However, they are often not cost-efficient and there was no significant effect on water quality and fish growth after the use of different substrate combinations [3]. To prevent for a longer harms, the farmer should ensure the height and the quality of water [4].

The location of the fish pond, which is quite far from residential areas, makes regular monitoring of the pond difficult. The use of supporting tools to prevent crop failure, such as using water replacement pumps during the cultivation of tilapia, is still very limited and requires significant costs. Other anticipatory measures, such as when the pond water appears murky, are only addressed by settling the sludge. Ideally, if turbidity measurements were conducted, earlier preventive actions could be taken, such as adding coagulants to clarify the water on a larger scale. Therefore, designing a measuring tool that uses several sensors to meet the suitability parameters for tilapia ponds is considered necessary to help address some of the problems faced by tilapia farmers in Kuala Kerto Village, Lapang District, North Aceh Regency.

2. Literature Review

2.1. Tilapia

Tilapia (Oreochromis) is classified as an *euryhalin*e fish based on its lifestyle, meaning it can live in a wide range of salinity levels. Its distribution is quite broad, covering rivers, lakes, reservoirs, swamps, and brackish water. The wide habitat range and tolerance to salinity can significantly influence the physiological processes in this fish. Growth is a process of increasing length and weight of an organism, which can be observed through changes in size and weight over time. The quality and quantity of feed affect the growth of tilapia, as do the age and quality of the water [5].

2.2. Node MCU ESP32

The ESP32 is a chip with 2.4 GHz WiFi and Bluetooth, designed with 40 technology for optimal durability and radio performance, showcasing resilience, versatility, and reliability in various applications and power scenarios [6] The ESP32 is a microcontroller module with dual-mode features, namely WiFi and Bluetooth, used to make it easier for users to develop various application systems and projects based on IoT (Internet of Things). It is a microcontroller introduced by Espressif Systems and is the successor to the ESP8266. The ESP32 has many additional features and advantages compared to the previous generation. It includes a faster CPU core, improved WiFi, more GPIO pins, support for Bluetooth 4.2, and low power consumption, making it ideal for creating various electronics projects based on the Internet of Things (IoT).

2.2. State of the Art

The research on an IoT-based monitoring and control system for water quality in tilapia farming is supported by several previous studies. The foundational research, which is relevant and serves as a reference, can be seen in the following table.

Table 1. State of The Art

No	Author	Title	Year	Result
1	Nur Sholikin, Imam Abdul Razaq, Mohamad Iqbal, Noor Yulita Dwi Setyaningsih	Control of pH Levels and Water Height in Tilapia Ponds Based on IoT	2021	This study aimed to create an automation prototype for monitoring pH levels and water height in ponds online via Thinger.io. The results showed a sensor error of 0.07% with 99.93% accuracy for water height, and an error of 0.02% with 99.98% accuracy for water pH.
2	Miftahul Jannah, Zulpikar, Muliani, (Department of Aquaculture, Malikussaleh University)	The Application of Aquaponics Technology with Different Substrate Combinations on Water Quality and Growth of Tilapia	2021	This study aimed to determine the effects of different substrate combinations on water quality, growth of tilapia (Oreochromis niloticus), and lettuce. The results indicated that different substrate combinations did not have a significant effect on water quality and fish growth. The best water quality was found in treatment D (rockwool and rice husk charcoal) with ammonia content of 0.09 mg/L, nitrate 13.45 mg/L, temperature 28.84°C, pH 7.29, and DO 5.75 mg/L.
3	Galih Rezza Fernandez, Khilda Afifah, Novi Prihatiningrum	Monitoring and Control System for Water Quality and Height in Tilapia Ponds Based on Internet of Things	2022	This study aimed to design a device for monitoring water height in tilapia ponds. The results showed that the device operated with a sensor reading accuracy of 96%, allowing users to monitor the pond condition through an application and control the filling and drainage pumps as commanded.
4	Munirul Ula, Rizal Tjut Adek, Bustami, Sibbran Mulaesyi, Muhammad Bayu Juhri (Department of Informatic Engineering, Malikussaleh University)	A Monitoring System for Aquaponics Based on Internet of Things	2022	This research developed a smart aquaponics system using a mobile application accessible via the internet. The results showed that the aquaponics monitoring system functioned well.
5	Mohamad Syaipul Anwar, Ulinnuha Latifah	Design of an IoT-Based Water Quality Monitoring Application for Tilapia Farming Using Android Studio	2022	This study aimed to design a device for monitoring water quality in tilapia farming. The results indicated that the application performed well, with data on the microcontroller, database, and application achieving 100% accuracy.

2.3. Design of the Device

The results of the analysis using experiments on pond water with several supporting sensors were used to design and assemble a prototype system. This process led to the development of a prototype for an IoT-based water quality monitoring and control system for tilapia farming, which then the visual block language used by user to build applications by dragging and dropping components into the design view [7]. As for the accuracy and connection between database and microcontroller would be controlled by the microcontroller [8].

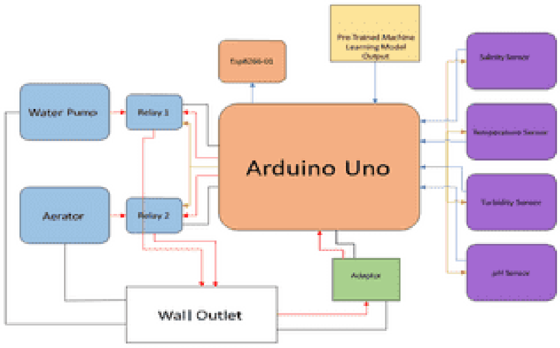

Fig 1. Design of Prototype System

3. Result and Discussion

Here is an overview of the water quality monitoring device for tilapia ponds that has been designed:

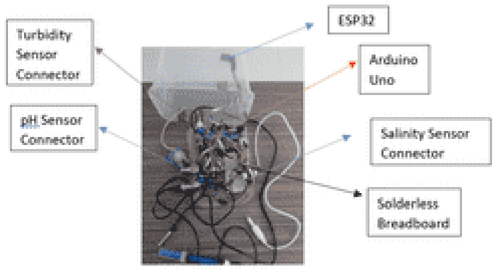

Fig 2. Pond Water Quality Measurement Device

From the image above, it can be seen that each sensor is connected to the Arduino Uno and ESP32 modules using connectors. The Arduino Uno module serves as the main module for decision-making and logic, while the ESP32 module functions as the communicator for transmitting information via the internet. So as to preserve the purity and circulation of water, the waterlevel sensor should be at a perfect measurement success rate [9].

3.1. Operation, Testing and Performance of The Water Quality Monitoring Device

Here is a simplified explanation of how the device works; The sensors detect real-time water conditions, including pH levels, water turbidity, water temperature, and salinity. The values obtained by the sensors are sent to the Arduino, which then transmits the data to the web system. The Arduino processes this data to provide the necessary commands to maintain a healthy aquatic ecosystem for tilapia. Performance is the result achieved by a system. The real condition will be achieved after the system being processed [10]. As for the testing, it is carried out on each part of the sensors and electronic circuits contained in the design of this IoT-based system [11]. Hence, The performance of this device is as follows:

1. This device uses sensors to detect water quality by measuring the pH level, temperature, turbidity, and salinity of the water.
2. The device is equipped with IoT connectivity, allowing for remote, real-time monitoring via the internet. The monitoring results are displayed on a website, enabling farmers to view the pond conditions from anywhere and at any time.
3. The device is expected to improve the quality of harvests for farmers and reduce the risk of crop failure caused by undersized tilapia. Efficient use of this device is a key factor in helping farmers enhance their harvest outcome.

3.2. Water Quality Testing

After designing the system, the device, and testing both the device and the system, the final phase of this research is testing the water quality in the tilapia pond located in Kuala Kerto, North Aceh. The reason for the testing run is to ensure the feasibility of the system which has been built [12]. Below is an overview of the data collection process, which involves placing the device in the tilapia pond:

Fig 3. Water Quality Data Collection

The image above shows the process of collecting water quality data from the tilapia pond. This data collection was conducted after the water quality measurement device was placed in the pond. Each sensor must be placed in water that can cover a larger area and provide more representative information regarding water conditions at various points [13].Periodically, the data read by the device is displayed on the website that has been designed. Below is the website interface displaying the water quality data captured by the sensors on the device:

ID	Date / Time	Temperature (°C)	Turbidity	pH	Salinity (ppm)
300	2024-08-17 00:00:00	30.39	412.23	7.44	3950.82
299	2024-08-16 23:00:00	29.87	369.67	6.89	4090.62
298	2024-08-16 22:00:00	30.18	314.56	7.71	4152.89
297	2024-08-16 21:00:00	29.84	490.98	8.23	4038.55
296	2024-08-16 20:00:00	29.99	356.29	7.34	4321.47
295	2024-08-16 19:00:00	30.02	413.77	8.12	4196.82
294	2024-08-16 18:00:00	30.55	328.84	7.22	4059.74
293	2024-08-16 17:00:00	29.95	349.23	7.98	4214.55
292	2024-08-16 16:00:00	30.14	385.66	8.02	3871.26
291	2024-08-16 15:00:00	30.45	456.12	7.55	3995.01
290	2024-08-16 14:00:00	30.22	360.00	8.30	4112.78
289	2024-08-16 13:00:00	30.01	318.90	7.02	4001.56
288	2024-07-28 00:00:00	30.39	412.23	7.44	3950.82
287	2024-07-27 23:00:00	29.87	369.67	6.89	4090.62
286	2024-07-27 22:00:00	30.18	314.56	7.71	4152.89

Fig 4. Pond Water Quality Data Display

Based on the image above, the data used includes temperature, pH, salinity, and turbidity, with 300 data points collected over one month and a fluctuation rate of 5%. If the sensor shows that the water temperature is too high or too low, the automatic system will be able to adjust to these conditions [14]. Below are the data obtained from each sensor used.

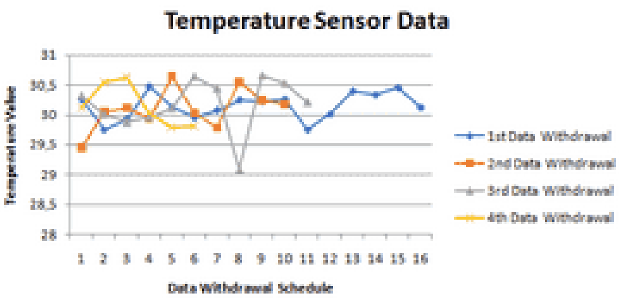

Fig 5. Temperature Sensor Data

According to the Indonesian National Standard (SNI) issued by the National Standardization Agency (BNS), the optimal temperature for tilapia farming ranges between 25–35 degrees Celsius. The higher the water temperature, the lower the oxygen solubility and the higher the toxicity. The increase in water temperature in tilapia ponds is influenced by environmental factors such as weather and wind conditions [15]. Therefore, the relay system started the water circulation once the sensor value was under standard [16].

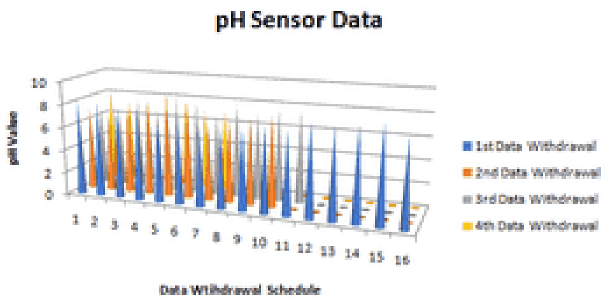

Fig 6. pH Sensor Data

Based on the data obtained in the graph above, the optimal pH range for water quality in aquaculture is between 6.5 and 9, which supports the growth and development of fish. Water with a pH lower than 6 inhibits the survival of microorganisms. A pH value above 10 can be lethal to fish, while a pH below 5 can significantly hinder fish growth [17]. In order for the fish to produce well in the water, unpaired test at a real level of 5% at the average pH in the pool should be homogeneous or equal [18].

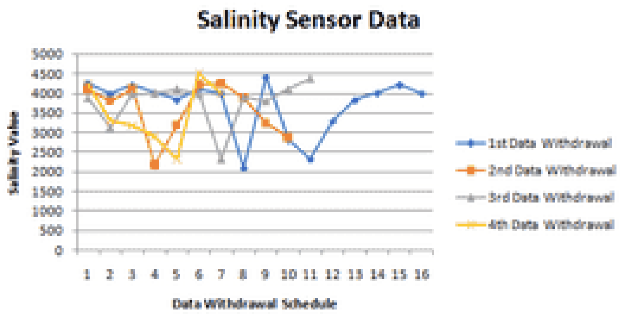

Fig 7. Salinity Sensor Data

The salinity levels for freshwater range between 0–5 ppt, brackish water typically ranges between 6–29 ppt, and seawater ranges between 30–40 ppt [19]. The value of the salinity should be 4,5 ppt in order for the fish to have longer growth as well as better weight. At the same time, the movement of the fish would be more active [20].

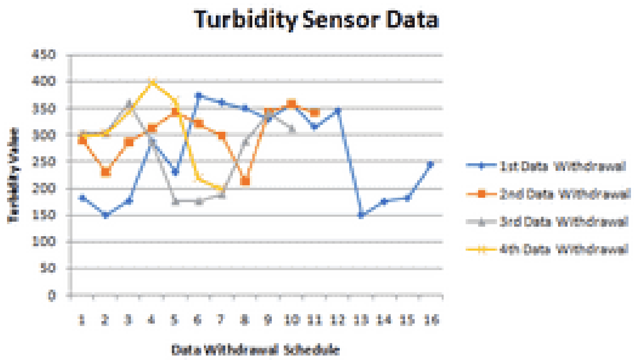

Fig 8. Turbidity Sensor Data

Based on the image, changes in turbidity values are not significantly different from previous values. Water is considered turbid when it contains many suspended particles that give it a muddy and dirty appearance.

From the analysis of the four sensor graphs, several actions need to be taken by pond farmers to achieve optimal tilapia growth. These actions include opening water channels, cleaning the pond, and managing the spacing of fish stocking and feedin.

4. Conclusion

Based on the results of the research, it can be concluded that:

1. The IoT-based water quality monitoring and control system for tilapia farming can be designed using PHP programming language and the Laravel framework. Data storage is managed with MySQL, and Visual Studio Code is used to write and manage the web interface and integrate it with the database.
2. Functional testing of the system and hardware is conducted by connecting the designed website with the device. The sensors on the device are placed in the pond water, and the sensor data is then displayed on the website.
3. Water quality testing using the IoT-based monitoring and control system for tilapia farming is performed by placing the designed device in the tilapia pond located in Kuala Kerto. The data collected by the device over the set duration is retrieved and displayed on the website when the device is connected via USB.

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