Enhancing Tilapia Growth in Modern Aquaponics Through IoT Integration

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Article Information

Received: 15-11-2023
Revised: 30-11-2023
Published: 15-12-2023

Keywords
Aquaponics, IoT, Fisheries

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Abstract

Aquaponics is a system recognized as an innovative method of sustainable food production that combines fish cultivation with agriculture simultaneously. Aquaponics is able to overcome problems in urban areas which require land for farming and fish cultivation. The aim of this research is to implement an IoT system in aquaponics that is connected to various sensors, such as Ph sensors, TDS sensors, temperature sensors and turbidity sensors to monitor water quality conditions in tilapia habitats. The results of this research show that implementing an IoT system in aquaponics can overcome environmental monitoring and control problems effectively. By using methods in the aquaponics system and using the IoT system in collecting data so that it can respond to environmental changes quickly and precisely. This system helps increase tilapia fish growth and plant productivity in a modern aquaponics system. This research demonstrates the great potential of IoT technology in increasing efficiency and productivity in aquaponic cultivation, so it can push the fisheries sector in a more advanced and competitive direction. So that we can face the challenges of food security and move towards more environmentally friendly, efficient solutions for future sustainability.

1. Introduction

One of the problems in urban areas is food security [1]. In line with the regulations stipulated by the Minister of Maritime Affairs and Fisheries of the Republic of Indonesia Number 17/ PERMEN-KP/2020 concerning Strategic Plans. Ministry of Maritime Affairs and Fisheries 2020-2024, stated that the strategic target of fulfilling fish consumption per kilogram per capita in 2020 is targeted at 56.39 kilograms, and in 2021 it is 58.08 kilograms. Of course, with this target, efforts are needed to supply fish to the community so that sufficient quantities are met, especially in areas that do not have fishing areas *(land lock)* like the sea. Alternative sources of supply of fishery products are expected to come from freshwater fish cultivation activities through fish cultivation systems in ponds or aquaponics [2].

Cultivation and rearing of freshwater fish generally requires land as a location for development. The need for food is increasing, but limited land in urban areas is a problem for city residents because they cannot garden and raise fish. The only use of narrow land is through an aquaponics system. The basic concept of aquaponics is that waste produced by fish (for example, fish waste) becomes a source of nutrition for plants. Plants then take these nutrients, clean the water, and return them to the aquaculture system for reuse by fish [3].

One type of fish that is easy to cultivate in an aquaponics system is tilapia. Parrot fish *(Oreochromis niloticus)* is one type of fish that is widely consumed and is quite economical [4]. This tilapia also contains nutrients needed by the human body such as carbohydrates, protein, fat, calcium, phosphorus and iron [5]. Apart from that, tilapia is also one of them superior commodities in national programs [6]. Fish contribute N or P elements from feces and fish food waste, bacteria convert fish food waste and feces into nitrate, a substance that functions as a source nutrients for plants, while plants supply water free of toxic metabolic waste gases which are very necessary for pet fish during the maintenance period, through the process of using nitrogen (NH3-N, NO2-N and NO3-N) and carbon dioxide (CO2) which are produced from fish farming. Fish excrete 80-90% of ammonia through the osmoregulation process while feces and urine excrete 10-20% of total ammonia nitrogen. Total ammonia-nitrogen (TAN) consists of non-ionized ammonia (NH3) and ionized ammonia (NH4) which is the result of protein metabolism [7]. Apart from the limited land in urban areas for cultivating tilapia, there are also problems experienced by farmers when cultivating tilapia either on a large scale or in an aquaponic system. The problems include unstable freshwater temperatures for tilapia so that tilapia growth is hampered. The sensitivity of water to the value of solid particles in the water must be stable and the pH of the water and the level of water turbidity also influence the growth rate of tilapia [8].

Based on the problems that have been raised, a technological approach is needed to solve these problems. The technology used is based on integrated IoT (Internet of Things), namely a monitoring and control system to support the growth of tilapia in a modern aquaponics system. The system is equipped with sensors that can measure water pH, water temperature and water density which can be monitored in real time using mobile devices such as website-based smartphones. Having a monitoring and control system can make it easier for fish farmers to monitor and take early action if aquarium water conditions are abnormal, thereby reducing the risk of crop failure. Apart from IoT technology, there is also a portable system for determining the position of aquaponics (for example, it can be inside or outside the house).

1.1 Literature Review

Many studies have been carried out to provide solutions. One of the research that has been carried out is the Smart Growbox System Design, an IoT system that uses an Arduino Uno as a microcontroller and then an Ethernet shield is installed so that it can function as a cloud server for the IoT system [9]. The use of IoT in aquaponics uses Raspberry Pi as a supporting platform for IoT or as a receiving server for sensors and several other sensors to read data, several sensors used such as light, ultrasonic and temperature sensors [10]. There is research on measuring pH and water temperature in an IoT system using the DS18B20 sensor. The water pH monitoring system in aquaponics uses Arduino Uno which does not use an Android-based monitoring system [11]. Apart from that, there was research on a remote monitoring system for the temperature of Bangkok tilapia ponds using the Internet of Things (IoT) based on the ESP8266 MCU node, which was carried out by [12]. There is research that uses a water quality monitoring system in freshwater fish ponds based on measuring water pH, water turbidity and water temperature based on a mobile website using Arduino Uno and WiFi 8266 as a microcontroller [13] . Research on this system can monitor pool water conditions automatically and in real time using a mini computer, namely Raspberry Pi, with the development of Internet of Things technology [14].

Apart from that, there are related researchers, namely IoT technology for monitoring the quality of water for cultivating catfish using a pH meter sensor and a waterproof DS18B20 sensor [15]. Design of a Temperature Control System, Dissolved Oxygen, Total Dissolved Solid Water and Fish Feed in Aquaponic Tilapia Cultivation using Esp8266 as a microcontroller and DS18B20 sensor to measure water temperature [16]. The research title is Automation of Aquaponic Choy Sum and Nile Tilapia Using Arduino Microcontroller. The main tools used to build this automation include Arduino ESP-32, GY-302 Ambient Light Intensity Sensor, DFRobot Gravity Analog pH sensor, DS18B20 temperature sensor, DC motor 3-6V DC R140, relay module6 Channel 12V, RTC DS130 module and SR04 ultrasonic sensor [17].

2. Research Methods

Aquaponics research was conducted by Fitri et al entitled "Managing the Environment Through Education on Aquaponic & Hydroponic Cultivation as an Alternative Solution for Utilizing Land for the Community of Perlang Village, Bangka Belitung" in this research, observations were made for 1 x 24 hours on Friday, 18 February 2022 in the province of Bangka Belitung which is the largest tin producing area in Indonesia. Perlang village is a village in the Lubuk Besar sub-district of the Bangka Belitung Islands. Perlang Village has rich and varied natural resources, including the industrial, agricultural, mining, capture fisheries, aquaculture and tourism sectors. According to Law no. 23 of 1997 concerning Environmental Management [18]. The living environment is the unity of space with all objects and the unity of living creatures, including humans and their behavior, which supports the life and welfare of humans and other living creatures. Humans as environmental authorities on earth play a major role in determining environmental sustainability [19]. Therefore, the results obtained from this research are that the village has potential land for making aquaponics, but it is hoped that the community will have the innovation to develop hydroponics or aquaponics at a more modern level to support the economy and food needs of the Perlang village community in the future. Based on these problems, IoT technology is needed to solve problems and problems from the results of observations made and support Indonesia's program for industrial revolution 4.0 which was also conveyed by the Minister of Industry Airlangga Hartarto. He said that Indonesia can compete with other countries in the industrial sector, Indonesia must also follow trends. "Industrial Revolution 4.0 is a transformation effort towards improvement by integrating the online world and production lines in industry, where all production processes run with the internet as the main support" [20].

Hardware design begins with creating an NFT (Nutrient film engineering) module. NFT is a system that uses a nutrient solution 'film'. The film or thin layer is a nutrient solution 1-3 mm thick, pumped and flowed through the plant roots continuously at a flow speed of around 1-2 liters per minute [21]. According to S. Wibowo and A. Asriyanti, the more sloping the gutter, the greater the plant productivity. The advantages of using this method include that it makes it easier to control the root area of plants, water needs are met well and easily, nutritional uniformity and the level of concentration of nutrient solution required by plants can be adjusted to the age and type of plant, low maintenance, relatively better protected from pests and diseases. and does not require special fertilization. Meanwhile, in aquaculture, the author uses the sump filter method to drain water into the bucket tube, but replaces the camber with a bucket tube, then the water that has flowed into the bucket tube will be pumped up to drain the water into the aquaponics pipe [22].

This research uses an ESP32 microcontroller and Arduino UNO as well as several sensors such as pH sensor, TDS, DS18B20. There are also several supporting components such as Power Supply, Step Down, Relay, Aquarium Heater.

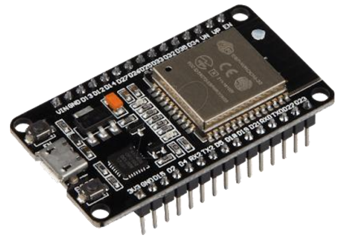

Fig. 1 ESP 32.

As a microcontroller, the ESP32 is used to control various electronic devices and other sensors, as in Fig 1.

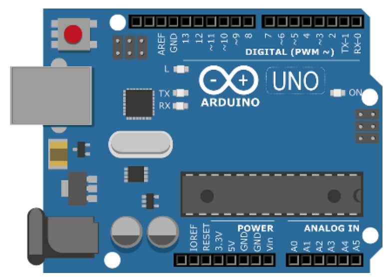

Fig. 2 Arduino UNO.

As an Arduino UNO microcontroller, it is used to send pH sensor values to the ESP32 which will then be displayed on the website, as in Fig 2.

Fig. 3 Sensor pH.

This sensor is used to measure the extent to which a solution is acidic or basic by measuring the concentration of hydrogen ions (H+) in the solution. The optimal water pH level for tilapia habitat is between 6-8, as in Fig 3.

Fig. 4 Sensor TDS.

This tool is used to measure the levels of dissolved substances in tilapia water. TDS concentration can be an important indication of the cleanliness and health of water. The optimal level of dissolved solids for tilapia habitat is -+ 300 ppm, as in Fig 4.

Fig. 5 Sensor Suhu DS18B20.

This tool is used to measure the temperature in water in aquaponics to increase the survival of tilapia fish and the growth of tilapia fish in aquaponics, by monitoring the temperature in water that has been filtered by filter buckets and plant roots, the optimal temperature for tilapia habitat is 28-35oC, as in Fig 5.

Fig. 6 Heater Akuarium.

This tool is used to heat the water in the aquarium so that if the temperature is <=28 degrees Celsius then this tool will optimize it to a temperature of -+ 33 degrees Celsius. The right temperature is important for fish health and growth, as in Fig 6.

Fig. 7 Relay.

Relays are used to connect or disconnect the flow of electricity in a circuit when certain control signals are applied to it, as in Fig 7.

Fig. 8 Stepdown LM2596

This tool is used to lower or reduce a higher input voltage to a lower output voltage level according to the set configuration, as in Fig 8.

Fig. 9 Power Supplay.

Power Supply which functions as a source of all overall power from the components so that the electronic circuit can work. Power Suppy is an important component in designing a tool, as in Fig 9.

Fig. 10 Arduino IDE

The Arduino IDE is used to create programs for this modern aquaponics system, as in Fig 10.

Fig. 11 Fritzing.

Fritzing is used as a place to create a schematic of a modern aquaponics equipment circuit, as in Fig 11.

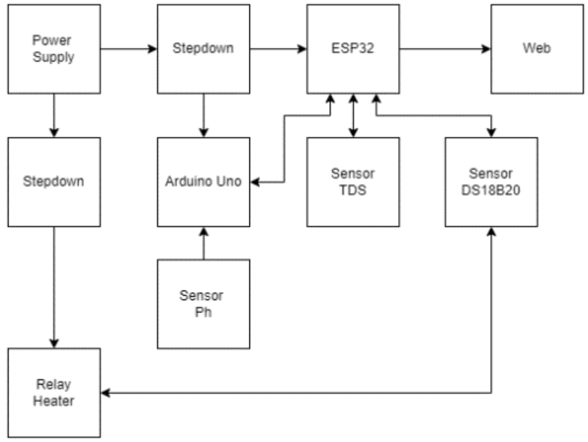

Fig. 12 Blok Diagram

The Block Diagram is a series that explains the outline of the design in this research. The mechanism of how the tool works to achieve pH, TDS and water temperature values, as in Fig 12.

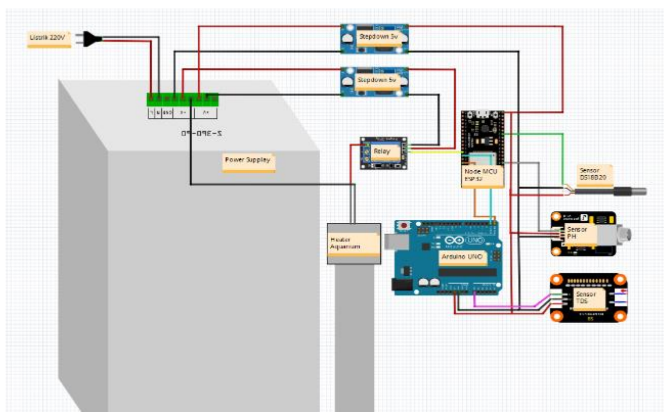

Fig. 13 Set of tools.

The schematic description of the tool circuit is as follows:

1. 12V 20A Power Supply is used as a tool to convert AC current to DC.

2. Stepdown LM2596 is used as an electrical voltage reducer.

3. Node MCU ESP 32 is used as a microcontroller to be connected to the sensor and functions as a Wi-Fi signal receiver that the user connects to the device via the internet network.

4. Arduino UNO is used to send serial Ph sensor data to the ESP32 so that the Ph value can appear on the website.

5. Relays are used for microcontroller controlled automatic switches.

6. The pH sensor is used to detect the pH of the water in the tilapia aquarium.

7. The TDS sensor is used to detect ppm of water in tilapia aquariums.

8. The DS18B20 sensor is used to measure the temperature of the water in the tilapia aquarium.

9. Aquarium heaters are used as aquarium water heaters to stabilize the water temperature in the tilapia aquarium.

Fig. 14 Flowchart of How the System Works in the Process of Displaying Data to a Smartphone.

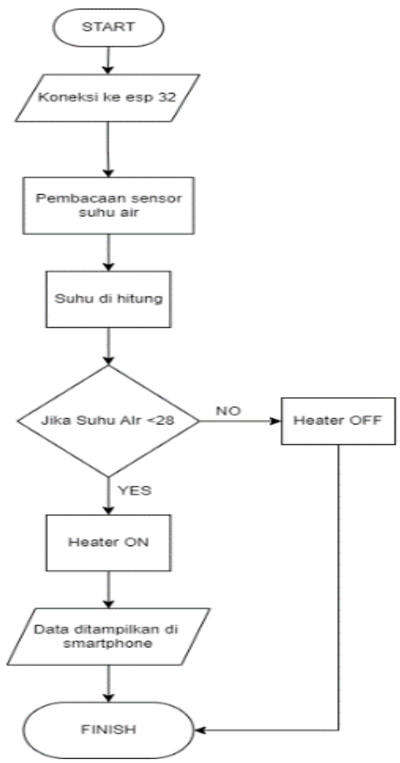

Fig. 15 Flowchart of How the System Works in the Temperature Monitoring Process Tilapia Fish Water.

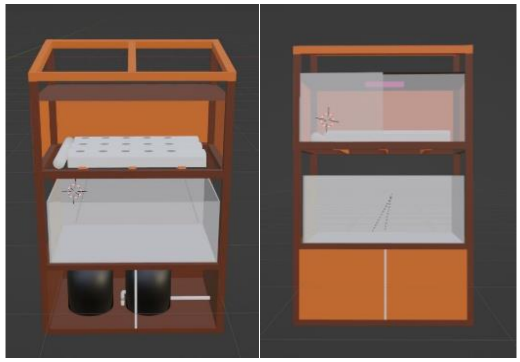

Fig. 16 Open and Closed Front View Tool Designs.

Fig. 17 Tool Designs Top View and Back View.

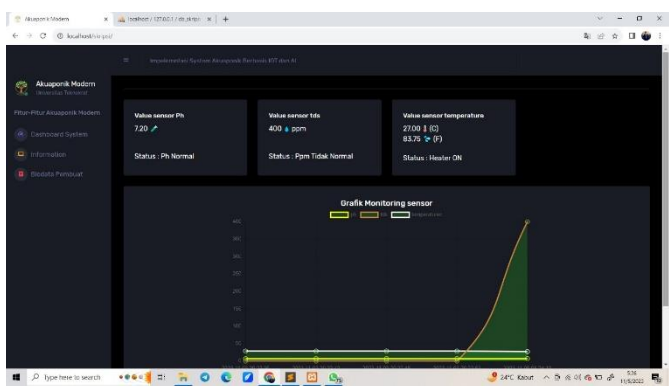

Fig. 18 Display of Sensor Data on the Web.

3. Result and Discussion

In this chapter the author will explain the results of testing the tool that has been designed along with a discussion to find out the results of the tool plan and implementation carried out. The table and discussion below is data from sensors implemented in IoT systems in modern aquaponics:

The pH sensor is used to maintain environmental conditions in the tilapia aquaponics system. With good monitoring, environmental conditions can be maintained within the optimal range for the growth and health of fish and plants. The pH sensor testing was carried out for 5 days by taking sensor data once a day which can be seen in Table 1.

Table 1. Ph sensor test results

Measurement Time	Ph Value	Fish Condition	Information
Day 1	7,2	Healthy	Ph in Optimal Range.
Day 2	7,5	Healthy	Slight increase in Ph, but still in the good range.
Day 3	7,8	Healthy	Ph continues to increase, action is needed.
Day 4	8,1	Stressed fish	Ph is too high, needs to be lowered immediately.
Day 5	7,7	Fish Recovered	Ph is returned to optimal range.

The TDS sensor is used to measure solid particles in tilapia water. With good monitoring, the water conditions given to the tilapia will encourage growth and make the tilapia healthy. TDS sensor testing was carried out for 5 days by collecting sensor data once a day which can be seen in Table 2.

Table 2. Tds sensor test results

Measurement Time	TDS Value (ppm)	Fish Condition	Information
Day 1	300	Healthy	TDS Level in Optimal Range.
Day 2	350	Healthy	Improvement in good range.
Day 3	400	Stressed fish	TDS is increasing, needs to be reduced immediately.
Day 4	380	Healthy	TDS decreases in good range.
Day 5	300	Fish Recovered	TDS is returned to the optimal range.

The DS18B20 temperature sensor is used to monitor and control the water temperature in the tilapia aquaponics system with heater action when the temperature is below 28°C. With good monitoring, water temperatures can be maintained within the optimal range for the growth and health of fish and plants. DS18B20 sensor testing was carried out for 5 days which can be seen in Table 3.

Table 3. ds18b20 sensor test results

Measurement Time	Water Temperature	Action Heaters	Condition Fish	Information
Day 1	28 **°C**	Off	Healthy	Doptimal water temperature without heating.
Day 2	25 **°C**	On	Healthy	The waterfall temperature is below the ideal range. Heater is activated.
Day 3	28 **°C**	Off	Healthy	The water temperature has been adjusted back to the optimal range.
Day 4	30 **°C**	Off	Healthy	The water temperature remains within the optimal range without heating.
Day 5	27 **°C**	On	Healthy	Water temperature is less than optimal. Heater is activated.

4. Conclusions

This research has investigated the implementation of the Internet of Things (IoT) system in modern aquaponics cultivation to increase the growth of tilapia (Oreochromis niloticus) and plant productivity. The results of this research reveal several important aspects that can be concluded that the implementation of the IoT system in aquaponics allows real-time monitoring of environmental parameters such as air temperature, level of dissolved particles in the air, and air pH. This increases the efficiency of monitoring aquaponic conditions. With accurately collected data, farmers can take quicker and more appropriate action when there are changes in environmental conditions. Better control helps prevent extreme jawing that can negatively impact fish and plant growth. And implementing IoT can help ensure that environmental parameters are always within the optimal range according to the needs of tilapia and plants. This has the potential to increase productivity and quality of agricultural products. This research also confirms that IoT technology can play an important role in improving hunting in aquaponic cultivation. By avoiding wasting resources and reducing risks to the environment, aquaponics becomes more environmentally friendly. This system is also a promising first step in integrating more sophisticated technologies such as artificial intelligence (AI) and machine learning in aquaponic cultivation. This provides opportunities for further improvements in aquaponic cultivation.

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