Implementation of Fish and Plant Nutrition Technology On Aquaponic Systems

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Abstract

Catfish farming often faces challenges due to high stress levels in fish caused by instability in water pH and temperature, which disrupt metabolism, reduce appetite, and harm their health. This can lead to nutrient deficiencies for plants in aquaponic systems, causing ecological imbalances. Many farmers still rely on instinct to monitor pond conditions, making it difficult to detect changes in pH, temperature, and nutrient levels promptly, resulting in suboptimal water conditions and high fish mortality rates. To address this, a device equipped with sensors for real-time monitoring of pH, water temperature, and nutrient levels is necessary, helping farmers maintain ecological balance and reduce fish mortality. This research aims to ease catfish farming by integrating an automatic feeding system controlled by a servo and RTC and monitoring critical parameters like pH, temperature, and plant color through Thingspeak. Using the prototype method, the system was developed with ESP32, Arduino Microcontroller, pH sensor, DS18B20 temperature sensor, TCS3200 color sensor, buzzer, and servo. The aquaponics system design included scheduled nutrient supply for fish feed and an accurate feeding process activated at 12:00 PM, running the servo for 2 seconds with a buzzer alert. Testing confirmed the sensors' ability to transmit data to Thingspeak and display it via LCD. However, the temperature sensor requires periodic calibration, as weather conditions significantly influence readings. During the rainy season, the lowest temperature recorded was 27.10°C, while the highest temperature during summer reached 29.32°C, demonstrating the system's adaptability across seasons.

1. Introduction

The main challenges in catfish farming often stem from the instability of pH levels and water temperature, which lead to fish stress, reduced metabolism, and decreased appetite. These conditions directly impact fish health and disrupt aquaponic systems by creating ecological imbalances, such as a lack of nutrients for plants

(Rahmanto et al., 2021). Most farmers still rely on intuition to monitor water quality, causing delays in detecting changes in pH, temperature, and nutrient levels. This often results in suboptimal water conditions, ultimately leading to high mortality rates in catfish. To address this issue, an automated sensor-based device capable of real-time water quality monitoring is needed to maintain ideal conditions for both fish and plant growth.

Aquaponics, an integration of aquaculture and hydroponics, is a relevant solution for optimizing water resource utilization. In this system, fish metabolic waste and leftover feed are processed into natural fertilizers for plants, simultaneously reducing water consumption and environmental pollution (Zulhelman et al., 2017; Zidni et al., 2019). Aquaponics has proven to be more efficient in nutrient utilization by maintaining clean water in fish ponds and ensuring it remains free from harmful substances (Cohen et al., 2018). However, the success of this system heavily depends on stable pH levels, water temperature, and proper feed management (Fathulloh & Budiana, 2015). Additionally, optimal water circulation is required to support the balanced growth of fish and plants.

Previous studies have demonstrated the effectiveness of various technologies in supporting aquaponic systems. Color sensors can assess plant fertility based on changes in leaf color (Octavia, 2018), while pH sensors are effective for monitoring water quality, as seen in fish farming practices in Jejangkit Village, Kalimantan (Pratomo, 2020). Furthermore, Arduino-based technology has been successfully applied to reduce manual labor in aquaponic systems, such as in chili pepper and catfish farming in Kandri Village (Setiawan, 2020). Rozie (2021) proposed a Fuzzy Inference System to optimize water pump power based on ammonia levels and temperature, enhancing system efficiency. With the implementation of automated feeding technology, ecosystem balance in aquaponics becomes easier to achieve, as fish nutrition can be managed on a scheduled basis (Wijaya & Widodo, 2021).

Based on these findings, the development of an aquaponic system integrating pH, water temperature, nutrient sensors, and automated feeding mechanisms offers a promising solution to improve the productivity and efficiency of both fish and plant farming. This research aims to design technology that supports farmers in maximizing sustainable food production while minimizing environmental impacts. With this approach, aquaponic farming can become a model for modern agriculture that is environmentally friendly, efficient, and supportive of food security.

1.1 Literature Review

In this research, the author needs literature obtained from previous research. The literature review is in table 1.1

Table 1.1. Literature review

Literature	Writer	Year	Title
Literature 1	Zulhelman, Haidar Afkar Ausha, Rachma Maharani	2017	Smart Aquaponics System Development
Literature 2	Anang Burlian, Yuri Rahmanto, S. Samsugi, Adi Sucipto	2021	Automatic Control System for Aquaponics Based on Arduino R3 Microcontroller
Literature 3	Fachrul Rozie, Iwan Syarif, M. Udin Harun Al Rasyid, Edi Satriyanto	2021	Aquaponic System for Catfish Farming and Hydroponic Water Spinach Plants Based on IOT and Fuzzy Inference System
Literature 4	Nuris Dwi Setiawan	2020	Design of an Aquaponic Care System for Cayenne Pepper Plants and Catfish Using Arduino Based on the Internet of Things

Literature 5	Adi Pratomo, Agus Irawan, Mey Risa	2020	Prototype of Water Ph Quality Monitoring System in Aquaponic Ponds to Maintain Food Security
Literature 6	Windy Oktavia, Fauzan Masykur, Angga Prasetyo	2018	Indicator System on Leaves Using Color Sensor Based on AT-Mega32 Microcontroller
Literature 7	Mohamed Farag Taha, Gamal ElMasry, Mostafa Gouda, Lei Zhou, Ning Liang, Alwaseela Abdalla, David Rousseau, Zhengjun Qiu	2022	Recent Advances of Smart Systems and Internet of Things (IoT) for Aquaponics Automation: A Comprehensive Overview
Literature 8	Haryanto, M Ulum, A F Ibadillah, R Alfita, K Aji, R Rizkyandi	2019	Smart aquaponic system based Internet of Things (IoT)

1.1.1 Literature 1

Research conducted by Zulhelman (2017) entitled "Development of a Smart Aquaponics System". This research focuses on developing an automation system using an Android application to increase efficiency and control in aquaponic cultivation. The program used to create this application uses C language in the Arduino IDE and Java language for Android applications. System design involves component analysis and selection of appropriate devices to control and monitor pH levels and water levels. The design stage includes installing hardware such as Arduino Uno, pH meter V1.0, RTC, I2C LCD, water temperature sensor, and ultrasonics. Arduino IDE software is used to create programs that facilitate visualization of sensor data. From the experimental results, this system was successfully tested directly and in real-time using embedded technology. Automatic monitoring in aquaponic systems is integrated with an Android application, allowing users to easily monitor water conditions. The conclusions from the results of this trial provide a positive contribution in supporting the effectiveness and accuracy of aquaponic monitoring.

1.1.2 Literature 2

In research conducted by Rahmanto (2021) entitled "Automatic Control System for Aquaponics Based on the Arduino Uno R3 Microcontroller". A technology was created that has an automatic system for DFT aquaponics that can regulate water circulation scheduling, which uses the RTC DS3231 module. Several other components such as switch buttons, relays, Arduino Uno R3, LCD I2C, and water pump. The DS3231 RTC module provides a time scheduling function to the Arduino, which then controls the relay module to activate the water pump. The water pump is set to operate for 5 hours, followed by a 1 hour shutdown period. When the time shows 00:00 on the LCD screen, the relay will automatically activate, turning on the water pump until 5 am. After that, there is a 1 hour break, and then the water pump is active again from 6 am to 11 am, and so on. The results of this research indicate that the application of the automatic circulation control method in the DFT aquaponics system is more efficient and saves electricity compared to the circulation method which is not yet automatic in controlling the pump on and off cycle.

1.1.3 Literature 3

Research conducted by Rozie (2021) entitled "Aquaponics System for Farming Catfish and Hydroponic Water Spinach Plants Based on IOT and Fuzzy Inference System". This research aims to develop an intelligent system for aquaponic cultivation practices by utilizing Internet of Things (IoT) technology. This system is equipped with various types of sensors to monitor and control water quality. The Fuzzy Inference System (FIS) algorithm is applied to regulate the speed of pool water circulation, with the aim of reducing electrical power consumption in the pump. In addition, this equipment is equipped with an automatic fish feeding service that can be programmed according to needs. Monitoring of this aquaponic system can be done via the web and Android-based smartphone. The results of comparative testing of decisions between experts and the FIS system regarding water circulation speed show an accuracy level of 83.33%. In addition, testing the accuracy of automatic feeding equipment compared to manual feeding showed an accuracy rate of 90.97%.

1.1.4 Literature 4

In research conducted by Setiawan (2020) entitled "Design of an Aquaponic Care System for Cayenne Pepper Plants and Catfish Using Arduino Based on the Internet of Things". An Aquaponic Treatment system using Arduino has been designed which has helped the people of Kandri village carry out water maintenance in fish ponds. This tool is designed to provide information to the owner regarding the pool temperature, water turbidity, and the acidity level (pH) of the water in the fish pond automatically. All these conditions will be automatically monitored, and notifications will be sent and displayed on the LCD screen. This aims to ensure optimal growth of aquaponic plants, so that the results are good and safe for human consumption. The test results from this research show a value of 37, indicating that the system is categorized as "Very Effective." The comparison was made with the previous system used in the Semarang Aquaponics Tourism Village. The main difference lies in the use of a new system which is equipped with a monitor to monitor the level of turbidity, pH and water temperature in the catfish pond.

1.1.5 Literature 5

Research conducted by Pratomo (2020) entitled "Prototype of Water pH Quality Monitoring System in Aquaponic Ponds to Maintain Food Security". A prototype system has been designed using an Android application as a solution to the obstacles faced by the community in fish farming, especially related to the problem of fish deaths which are often caused by changes in acidity levels in pond water. The test results from this research show that the Arduino-based water pH monitoring tool can operate optimally when integrated with an Android application. Water pH measurement data can be wirelessly sent to the Android application via Bluetooth technology. The calibration process is carried out by comparing the pH value measured by the sensor device with the pH measured using the pH tester pen. The results of data analysis show that the standard deviation ranges from 0.1 to 0.3. Differences in measurement results can be overcome by adjusting the resistance of the variable resistor in the circuit or adjusting the offset voltage in the program.

1.1.6 Literature 6

Research conducted by Octavia (2018) entitled "Indicator System on Leaves Using a Color Sensor Based on the AT-Mega32 Microcontroller". This research discusses how to determine the fertility level of pak choy vegetables, and it is proven that using a color sensor is the right solution. This can be related to the plants in aquaponics so that the author can find out the level of fertility in the plants, if the vegetables are not suitable or less fertile, this means that the process of using nutrients from fish ammonia which produces bacteria in the form of nitrites in the pond on the plants is still less effective. The results of this research are that the sensor can read colors and produce output in the form of frequency and LED light according to the desired procedure. The average distance consistency in leaf color readings should be less than 6.5 cm. If the distance is taken further, the resulting frequency will be longer. If the leaf frequency is ≤21.5 Hz, the sensor will indicate that the leaf condition is not suitable with an output in the form of one red LED and the message "NOT VALUE (TT)" on the LCD. From the research above, the author intends to carry out this research so that the system can be better or more optimal and can determine the pH level of the water and the fertility level of the plants, making it easier for farmers to care for aquaponics.

1.1.7 Literature 7

Research conducted by Taha (2022) entitled "Recent Advances of Smart Systems and Internet of Things (IoT) for Aquaponics Automation: A Comprehensive Overview". This research focuses on developing an automation system using an Android application to increase efficiency and control in aquaponic cultivation. This system involves component analysis and selection of appropriate devices to control and monitor pH levels and water levels. Apart from that, previous researchers used the Fuzzy Inference System (FIS) algorithm to regulate the speed of water circulation and automatic feeding. Their tests demonstrated a level of accuracy in regulating water circulation and feeding rates. However, this journal does not provide a detailed explanation of how Android applications are used to control aquaponic systems and does not provide sufficient information about the level of complexity of developing these applications.

1.1.8 Literature 8

Research conducted by Haryanto (2019) entitled "Smart aquaponic system based on Internet of Things (IoT)". This research aims to improve efficiency and quality in aquaponic cultivation through the use of technology. The journal focuses more on monitoring water quality and nutrients using temperature, pH and ultrasonic sensors. As well as providing valuable insight into the implementation of technology in aquaponic farming to increase productivity and sustainability.

1.2 Research Synthesis

In this research, the author applies concepts to the literature obtained from previous research and aims to support the author's research. The previous research that is relevant to this research is:

Table 1.2. Research Synthesis

Literature	Compare	Contras	Criticize	Summarize	Synthesis
Literature 1	In their second research, they used IoT technology to monitor water pH, and also focused on the efficient use of nutrients, only the author added sensors that could monitor plant health as well.	The difference is in the use of RTC, previous researchers used RTC on water pumps to control water circulation while the author only used automatic feeding.	There are still several disadvantages to manual aquaponic systems such as dependence on electricity, high investment, and maintenance skills required.	This research aims to develop a microcontroller-based smart aquaponics system that is able to control and monitor water pH, temperature and water level automatically.	According to Zulhelman (2017), by combining microcontroller technology, pH sensors, temperature sensors and water level sensors, this research succeeded in creating a smart aquaponics system that can automatically regulate environmental conditions for efficient growth of fish and plants.
Literature 2	In the research conducted, the author focused on using RTC to schedule and regulate fish feeding times automatically in an aquaponic system. This is different from previous research which emphasized more on regulating	The difference is that previous research focused more on regulating water pumps in the symbiosis of fish and vegetables, which aims to reduce electricity waste and care	This research does not provide an in-depth explanation regarding the advantages or disadvantages of using the DS3231 RTC module to regulate water pump timing compared to using RTC to regulate water	This research succeeded in creating an automatic system for DFT aquaponics that can regulate water circulation scheduling using the RTC DS3231 module.	Integrating a water pump control system with automatic feeding using RTC offers an efficient solution for water and nutrient management in aquaponics. Future enhancements could include additional sensors for

	water circulation.	for plants and fish ponds.	circulation scheduling.		comprehensive environmental monitoring.
Literature 3	Both studies have similarities in the samples used, namely using catfish and water spinach plants.	Previous researchers focused more on using telegram bots and sensors to monitor catfish pond water conditions automatically and in real-time. Meanwhile, the research carried out by the author used the ESP-32 Cam so that it could be more effective in monitoring the water conditions of catfish ponds.	In this study there is no clear criticism.	This research develops an IoT and FIS aquaponic system for cultivating catfish and hydroponic kale plants, channeling fish waste to the kale plants.	Previous research can prove that the aquaponics system using the fuzzy algorithm method is very effective in monitoring and regulating environmental parameters and providing feed automatically, and can also increase efficiency and productivity in fish and plant cultivation.
Literature 4	This research has the same sample, namely using catfish.	The difference lies in the research system, namely the previous research was still manual for monitoring water temperature and pH via a 16x2 LCD, while the research carried out by the author did not use an LCD and instead used web thingspeak and esp-32 Cam for overall monitoring.	In previous research, this system was very ineffective because aquaponics were still maintained manually and only relied on the LCD. This means that monitoring can only be done if the owner is at home.	This research develops smart technology to provide nutrition to fish and plants in aquaponics, automating the process of monitoring and providing nutrition for optimal conditions.	Previous research integrated pH, turbidity, and temperature sensors with an Arduino control system, overcoming the problem of manual monitoring and management of aquaponic nutrients. This solution is more efficient and sustainable, improving nutrient use and plant and fish health.

Literature 5	The similarity lies in the purpose of using a pH sensor, namely to prevent fish deaths caused by changes in the acidity level of pond water (Pratomo et al., 2020).	Previous research has been more limited to monitoring pH and water temperature, while your research involves color sensors to assess plant fertility, scheduled nutrient treatments, and the use of IoT technology to monitor and manage the aquaponics system as a whole.	Previous researchers only paid attention to pH and water temperature, ignoring other factors that affect the overall health of plants and fish. Plants must also be considered to maintain food security.	Previous research designed a prototype system for monitoring the pH quality of water in ponds in order to reduce problems, namely preventing fish deaths.	This research is an advancement from previous research with the integration of more sophisticated sensory and automation technology to increase the efficiency of aquaponic cultivation. This solution offers increased productivity and ecological balance with a focus on scheduled nutrition, use of color sensors and IoT technology.
Literature 6	The similarity in this research focuses on the application of the TCS230 color sensor to assess vegetable quality.	The difference is in the system, namely previous research does not contain IoT elements in terms of vegetable quality research, and the author will apply that system.	This research is still in the simulator stage, with several obstacles that need to be fixed. Although simulators provide the advantage of concept testing before physical implementation, there are limitations that need to be overcome.	Previous research focused on evaluating and improving the quality of pak choy vegetables through the use of color sensors and microcontrollers as a solution to optimize growth, plant health, and create an efficient system	Based on previous research which focused on assessing the quality of vegetables using color sensors, the author got a new idea by combining color sensors in the research conducted by the author creating the potential for a more comprehensive solution in aquaponic cultivation.
Literature 7	There are similarities between previous researchers, namely using the TCS3200 color sensor,	The difference lies in the system used, namely using an Android application as a user interface to	This research does not provide an adequate picture of the level of complexity of application	This research develops an automation system for aquaponic cultivation using C language, Java language, and	From a review of the author's research, it is concluded that the use of technology in aquaponic cultivation is

	DS18B20 temperature sensor, and pH Meter sensor to monitor water and plant conditions in the aquaponic system and also integrating IoT technology to send sensor data to the Thingspeak cloud.	monitor and control the aquaponics system. Previous researchers also applied it use of the fuzzy inference system (FIS) algorithm.	development, leaving uncertainty regarding how complicated the development process is.	the Fuzzy Inference System (FIS) algorithm, but does not explain the use of the Android application in detail or the complexity of its development.	expanded through the integration of microcontrollers and separate sensors. This innovative approach allows automation of the cultivation process and remote control of the system, demonstrating progress in this field.
Literature 8	Previous researchers focused on temperature, pH and ultrasonic measurements in smart aquaponic systems. Meanwhile, the author's research adds an automatic system to fish feed scheduling to control the nutritional effectiveness of the fish nitrification process.	Previous researchers focused on monitoring water and nutrients with temperature, pH and ultrasonic sensors. Meanwhile, the author's research emphasizes scheduled nutrition and evaluation with color sensors, as well as introducing the RTC DS3231.	Although previous researchers have made important contributions in understanding and monitoring aquaponic conditions, further emphasis is needed on the implementation of technologies to increase the efficiency of nutrient use and automatic monitoring of environmental conditions.	Previous research emphasized increasing the efficiency and quality of aquaponic cultivation through technology by monitoring water quality and nutrients using temperature, pH and ultrasonic sensors. Contribute to the sustainability of aquaponic farming	From the comparison, the author's research integrates scheduled nutrition technology and color sensors in expanding the contribution to previous research. It is hoped that this will improve nutritional efficiency, environmental monitoring, and the productivity and sustainability of aquaponics.

2. Research Methods

In this research, the author used an experimental method that involved direct implementation at the research location. This research process consists of several stages, starting from literature study, designing and manufacturing software and hardware, testing, data collection, to analysis of results. A literature study was carried out by summarizing information from journal articles, books and direct interviews at research locations relevant to this topic. Using an experimental approach, the authors created a tool that can efficiently feed plants and fish through an aquaponic system (Rahmanto et al., 2021). In the research, Figure 3.3 below is a picture of the experimental method that the author used.

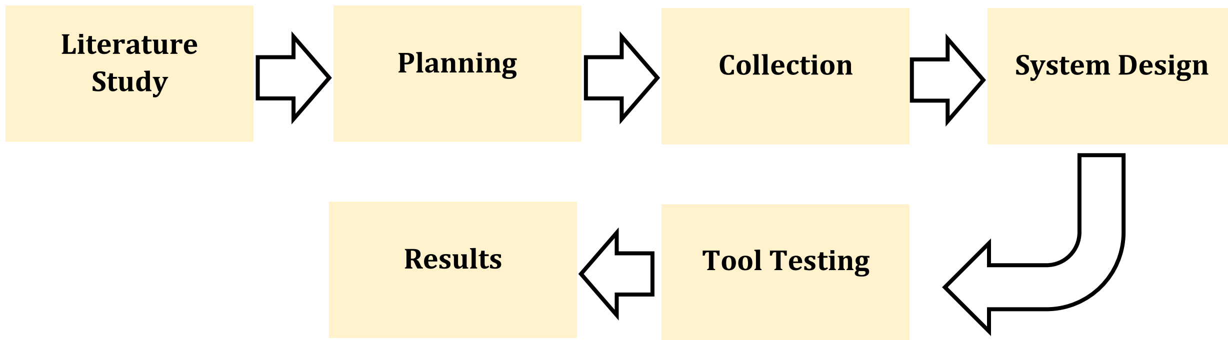

Fig 2.1. Experimental Method

2.1 System Development Methods

The author uses the prototype method for an approach that can be used in device development to produce iterative development. The process begins by gathering requirements from users, especially users

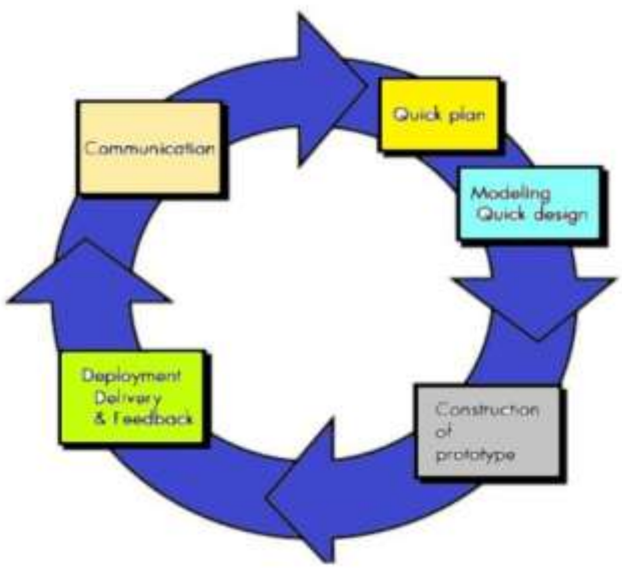

Fig 2.2. Prototype Method

an Internet of Things-based aquaponics system that is being developed. The next step is to prepare a design which will later be evaluated before being completely produced. It should be noted that the prototype is not final, but rather an entity that needs to be evaluated and adjusted. All changes can occur during prototyping to meet user needs and at the same time, provide developers with a deeper understanding of user needs (Rahayu et al., 2018).

1. Communication: Communication in software development involves meetings with users to identify software needs known at that time, as well as to describe the domain where further definition will be carried out in the next iteration.

2. Quick Plan: Efficient planning involves iterative implementation in prototyping with a process that occurs quickly. Next, modeling is carried out through a "rapid design" process.

3. Quick Plan Modeling: In this stage, a quick design model is used to visualize previous planning using draw.io, namely through a flowchart. This flowchart aims to clearly illustrate the function of the system and devices being developed.

4. Construction of Prototype: At the prototype creation stage in the rapid design process, it is carried out based on a representation of the software aspects that will be visible to the user.

5. Deployment Delivery & Feedback: Submitting and providing feedback on prototype development, then handed over to the user to evaluate the prototype that has been previously created. Feedback provided by users will be used as a basis for improving requirements specifications. The iteration process occurs when development makes improvements to the prototype based on the feedback received.

2.2 Data Collection Methods

Data collection is a stage in this research which is carried out to obtain information regarding the implementation of fish and plant nutrition technology in aquaponic systems, as well as identifying problems in this research.

2.3 Literature Study

In this research, the researcher conducted a literature study by collecting data from several books, journals, scientific articles and news which can be used as a theoretical basis related to the research problem that the researcher is conducting or discussing.

2.4 Interview

In this study, the researcher consulted with the supervisor, as well as Cultivating Fish and Plants in Buckets Lele Pak Juli.

2.5 Observation

At the observation stage, researchers will make direct observations at the research site, namely budikdamber lele in the Tanjung Senang area, Kec. Tj. Happy, Bandar Lampung City. Observations aim to collect field data that is not obtained from literature studies.

2.6 Planning

Planning is a process that starts from determining overall research objectives. Carrying out tools and materials collection, research stages, and data collection.

2.7 System Design

In making system design tools, it is very necessary, because system design is one of the basics before being implemented in the form of a tool. System design is something that is absolutely essential for a programmer or engineer to do because it really determines the success or failure of the tool that will be created. If all stages are carried out well and meet the specified standards, starting from making the flow diagram, to the tool components to be used, then the results will definitely match the drawing at the beginning of making the tool. When a stage is missed, the results obtained will not be optimal or satisfactory to what was expected.

2.8 Tool Design

Tool design is a visual representation of the tool architecture created, used to understand the physical structure of the planned system. The aim of tool design is to provide an overview of the shape of the tool to be designed, acting as a guide in the tool making process.

Fig 2.3. Tool Design

The way this system works is more aquaponic monitoring by controlling the feed schedule using an RTC DS3231 and a buzzer as an indicator of the effectiveness of the servo in feeding fish. There are 3 sensors, namely the TCS3200 color sensor to determine the nutritional effectiveness of the fish nitrification process. DS18B20 temperature sensor to determine temperature levels in pool water, Ph Meter sensor to measure acid-base levels in pool water. These three sensors will send their data to the Thingspeak cloud.

2.9 Block Diagram

A block diagram is a visual representation used to illustrate the relationships and interactions between the components of various systems or processes. In a block diagram, the main components are represented by geometric shapes, such as boxes or rectangles, and the relationships between them are explained using arrows or lines. Block diagrams aim to simplify system complexity and visualize the flow of information, signals, or functions between various components. Details of the block diagram explained can be found in figure 2.4

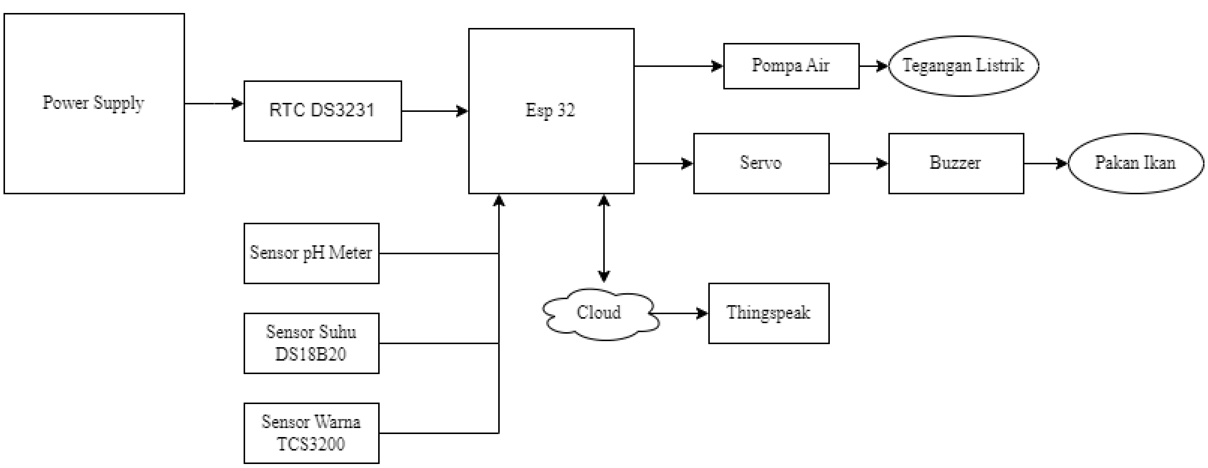

Fig 2.4 Block Diagram

2.10 Flowchart

Flowchart is a form of diagram used to describe the workflow or algorithm of a process. This diagram consists of symbols representing the steps in a process or algorithm, which are connected by lines to show the sequence and flow of these steps. Flowcharts function as a guide for writers in determining the sequential steps of a process that will be executed by the microcontroller. The following is a flowchart that I used as a reference in this research:

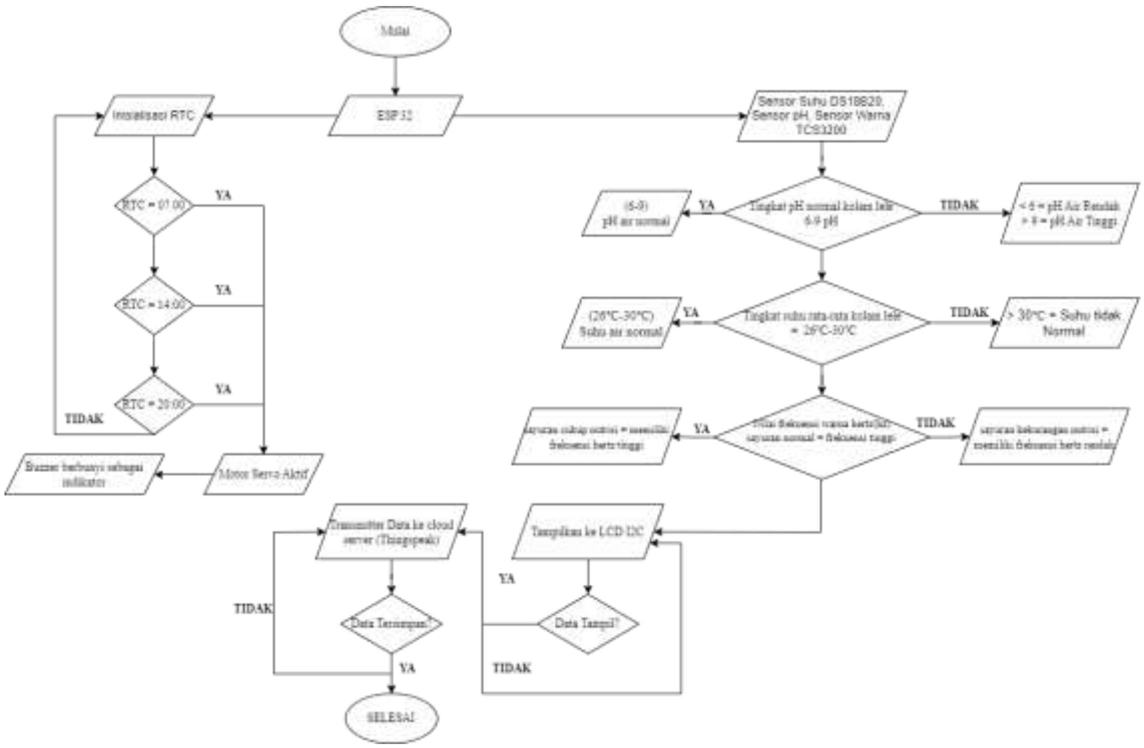

Fig 2.5 Block Diagram

2.11 Schematic device circuit

Below is a schematic series of all the tools that will be used with the aim of minimizing errors in component installation and making system testing easier. The following is a schematic series of tools in the picture 2.5

2.12 Schematic device circuit

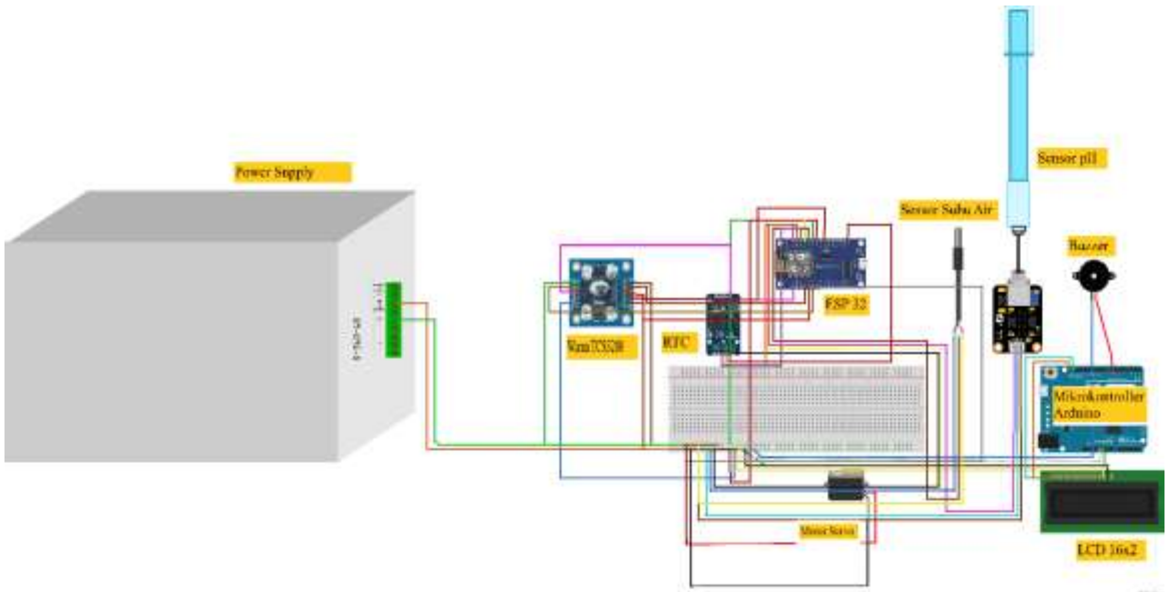

Fig 2.6 Tool Schematic Design

After successfully collecting materials and tools, the next step is to implement the tools that have been made. In this phase, the design results that have been prepared will be applied to become a real system. Implementation is carried out in two stages, namely implementation on software and implementation on hardware.

2.12.1 Software Implementation

In this research, the implementation process involves saving the program that has been created into the Arduino Uno and NodeMCU ESP 32 using software. The author uses Arduino IDE as the main software using the C programming language. After completing program writing, this research involves the compilation stage to ensure program errors. If the program does not experience errors, then the next process is to upload the program to the Arduino Uno and NodeMCU ESP 32. After successfully saving the program on the two devices, they will automatically send the sensor reading results to Thingspeak as an output of sensor data values. Thus, these steps guarantee the successful implementation of the program on hardware and ensure the transfer of sensor data to thingspeak for further analysis.

2.12.2 Hardware Implementation

Hardware implementation is the final stage in system design that will be carried out in this research, where at this stage all sensors and components will be installed in this aquaponics system in accordance with the schematic series of tools that have been created. The sensors that will be installed are the pH meter sensor, TCS3200 color sensor, and DS18B20 temperature sensor. Meanwhile, the components that will be installed include ESP 32, RTC DS3231, power supply and other components used to support the operation of the tool. After the sensors and components are installed, the next step is to install the aquaponic technology system according to the design previously explained.

2.13 Tool Testing

In this research, tool testing will use a black box testing approach, where at this stage the author tests the hardware without having knowledge of the internal details or hardware design. This testing aims to ensure that the hardware functions according to specifications.

3. Result and Discussion

3.1 Results of aquaponic technology system design

In this section the author will explain the results of testing the tool that has been designed along with a discussion to find out whether the results of the tool design and implementation are in accordance with the required data. The initial step is to carry out testing of several components.

Fig 3.1 Tool Design Results.

In table 4.1, the design of this tool as the appearance and function of the design of the research tool is the central point of the microcontroller and ESP 32 to run the design tool section which can function as a trial test in terms of making research tools. The following is the tool design in table 3.1

Table 3.1 Tool Design

No	Tool Name	Function
1	DS18B20 water temperature sensor	In this test, the DS18B20 temperature sensor was used to measure the water temperature in the aquaponic pond.
2	Servo Motor	This tool functions to feed fish at certain hours, regulated by RTC automatically.
3	Ph sensor	A tool used to measure the level of acidity and alkalinity in aquaponic pond water.
4	Component box	The function of electronic components or equipment can refer to various types of boxes or containers used to protect, organize, or manage various types of devices or components.

5	I2C LCD	Functions to display actual Ph sensor data, water temperature and color from the aquaponic system.
6	Tarpaulin	As a place to tamp water for fish ponds
7	Filter housing	As a container for bioball and bio sponge filter media as pool water filtration
8	TCS3200 color sensor	This tool can determine the value of color levels in kale plants.

In table 3.1 above, the results of designing a fish and plant nutrition system in aquaponics use four sensors, namely buzzer, water temperature, pH, and TCS3200 color sensor. When the internet hotspot is turned on, the IP is obtained from ESP 32 which will be connected to the hotspot connection and the data from the three sensors will automatically be transmitted to Thingspeak and the data will also appear on the I2C LCD screen. in the fish feeding system, it is set at 07:00 in the morning, 12:00 in the afternoon and 05:00 in the afternoon.

3.2 Testing pH and temperature sensors for aquaponics

pH sensor testing is carried out by measuring and detecting water in aquaponic ponds. Below is a picture of how to measure water pH and water temperature.

Fig 3.2 pH Sensor Testing

Fig 3.3 Temperature and pH Sensor Testing

In figure 3.2 is the result of pH sensor measurements from the first experiment, the pH sensor was tested and in figure 3.3 for the second experiment the temperature and pH sensors were carried out in conditions when the water was cloudy. The following is a picture of the reading results of the two sensors above.

Fig 3.4 Results of reading pH and temperature values

From the reading results, the pH and temperature values are shown in table 4.2 below.

Table 3.2 Results of reading pH and temperature values

Ph value	Temperature Value
6.87	28.31

In monitoring water quality and temperature trials, this allows you to identify changes in the acidity level or water quality on the pH meter sensor and the temperature on the temperature sensor.

3.3 Test water temperature analysis in aquaponic ponds

Measurements are carried out to determine how the water temperature is developing and an effective temperature value is needed for fish ponds due to inadequate weather changes. The measurement results are shown in the table 3.3

Table 3.3 Temperature Analysis

No	Date	Time	Temperature (°C)
1	28-05-2024	08:51	29.25
2	-	10:02	29.38
3	-	13:42	29.45
4	-	15:20	29.20
5	-	17:40	29.01
6	29-05-2024	09:35	29.18
7	-	10:25	29.32
8	07-06-2024	18:37	27.10
9	08-06-2024	14:04	27.22
10	-	15:08	27.17
11	-	17:15	28.31
12	19-06-2024	06:25	27.69

The table above is an analysis of water temperature in fish ponds which records temperature values at various times and dates. The goal is to monitor temperature changes periodically to evaluate environmental conditions in the aquaponic system. Recorded temperature data provides information about daily and long-term fluctuations that can affect fish health and aquaponic plant growth. In addition, this table is also used to monitor the efficiency of the temperature regulation system, ensuring the water temperature remains optimal for aquaponic biota.

3.4 Testing the effectiveness of the fish feeding system

Aquaponics system with automatic fish feeding 3 times a day. This system provides feed at 07:00 in the morning, second at 12:00 noon, and third at 17:00 in the afternoon. To find out how effective this will be, do it on 50 catfish in an aquaponic pond. Table 3.4 below is the data on the timing of automatic fish feeding.

Table 3.4 Temperature Analysis

No	Time	Servo	Indicator
1	07:00:10 WIB	Open	Buzzer On
2	07:00:12 WIB	Close	Buzzer Off
3	12:00:10 WIB	Open	Buzzer On
4	12:00:12 WIB	Close	Buzzer Off
5	17:00:10 WIB	Open	Buzzer On
6	17:00:12 WIB	Close	Buzzer Off

3.5 TCS3200 color sensor measurements on kale plants

There are 2 sensors used to test kangkong plants in aquaponics, to get effective results the distance between the sensors and the plants must be closer. There are RGB values in this sensor system which are between values. The highest green determines the dark/dark green color because according to expert sources, on average, all dark green vegetables have good nutrition. The following is table 3.5 of the test below.

Table 3.5 Color Sensor Testing on Water Spinach

No	Color Sensor 1			Color Sensor 2		
	Red	Green	Blue	Red	Green	Blue
1	85	118	145	86	119	146
2	135	200	180	324	388	344
3	138	183	125	324	384	344
4	133	173	122	313	388	344

- Sample 1:

  Color Sensor 1: Shows RGB values (85, 118, 145), indicating a green color that is not too bright.
  Color Sensor 2: RGB values are nearly the same (86, 119, 146), indicating consistent results between the two sensors.

- Sample 2:

  Color Sensor 1: Shows RGB values (135, 200, 180), the color is brighter green than sample 1.
  Color Sensor 2: Higher RGB values (324, 388, 344), indicating possible differences in calibration or measurement conditions.

- Sample 3:

  Color Sensor 1: RGB values (138, 183, 125), more natural green color.
  Color Sensor 2: RGB values are almost similar to sample 2 in sensor 2 (324, 384, 344), consistency in results is high.

- Sample 4:

  Color Sensor 1: RGB values (133, 173, 122), showing green with medium intensity.
  Color Sensor 2: High RGB values (313, 388, 344), consistency between samples 3 and 4 in sensor 2.

The RGB values produced from both sensors indicate that there are slight variations in the measurement results which could be caused by differences in sensor calibration or environmental conditions. A lack or excess of certain nutrients can change the color of kale leaves. For example, a lack of nitrogen can cause the leaves to become paler or yellow, while an excess of nitrogen can result in darker leaves. This will be reflected in the color intensity values (e.g. RGB values) measured by the color sensor.

3.6 Transmit sensor data to ThingSpeak

Testing sending data to the Thingspeak cloud to ensure whether the sensor data has successfully formed a graph and displayed the sensor data correctly. The following is a graphic image along with test data.

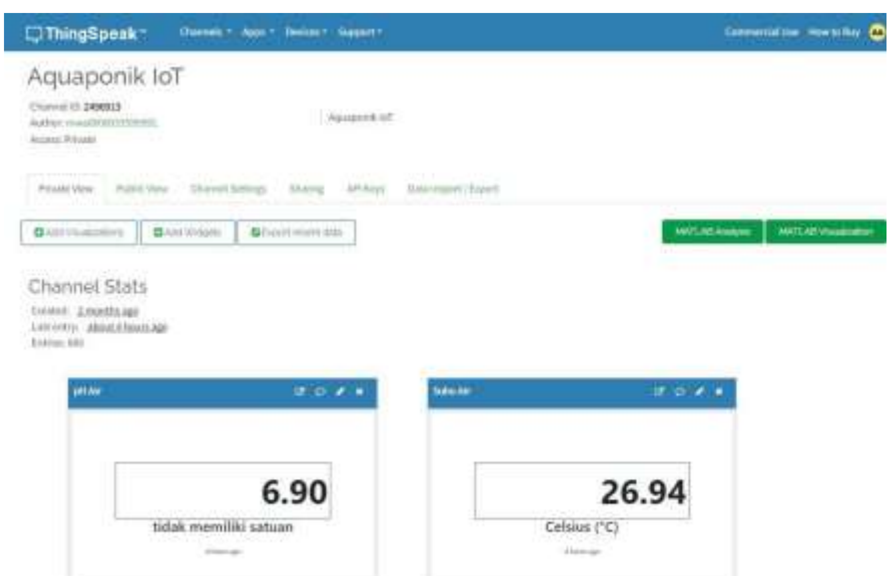

Fig 3.5 Thingspeak Temperature and pH Data

The image displays pH sensor measurement data and water temperature displayed numerically via the ThingSpeak platform, with a pH value of 6.90 and a temperature of 26.94°C. A pH value of 6.90 indicates slightly acidic water conditions, which are still within the optimal range of 6.0 to 9.0 for catfish cultivation, thus supporting optimal fish metabolism and growth. The water temperature of 26.94 degrees Celsius also fits the ideal range of 25 to 30°C for catfish, ensuring that the biological activity and health of the fish is maintained. This stable water condition is very important in an aquaponic system, because it not only affects catfish, but also kale plants which depend on nutrients from fish waste that are processed into a form that can be absorbed. In an aquaponics system, proper water conditions support a symbiosis between fish and plants, where kale plants help filter and clean the water, creating a better environment for catfish. Data from sensors displayed in real-time via ThingSpeak enables continuous monitoring of water conditions, so that any significant changes can be immediately identified and addressed. With this accurate data, decisions regarding system management can be made more precisely, ensuring the balance of the aquaponic ecosystem and the success of cultivating catfish and kale plants.

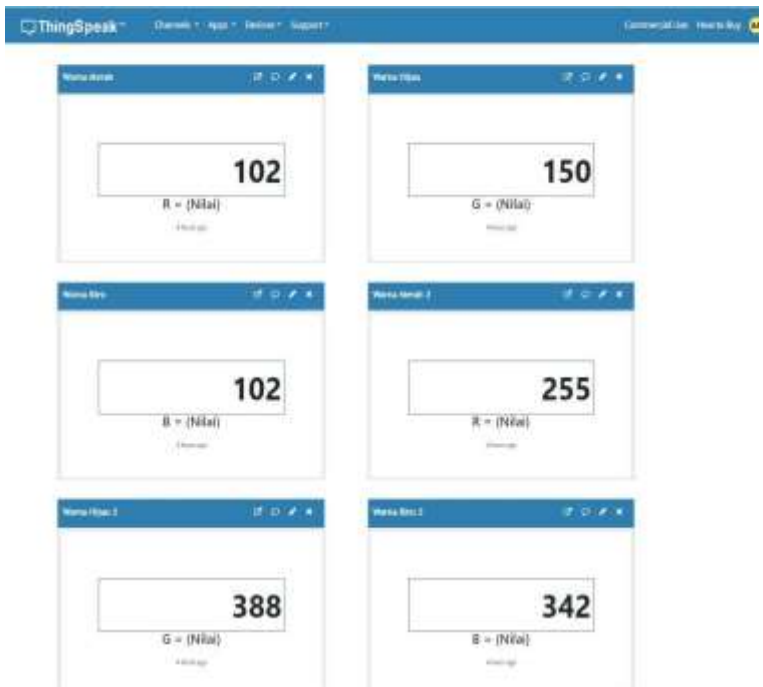

Fig 3.6 RGB Sensor Numerical Data (Color)

The image shows the display of numerical data from two RGB color sensors on kale leaves displayed on the ThingSpeak platform, where the first sensor records the value (102, 150, 102) and the second sensor records the value (255, 388, 342). The main purpose of this numerical display is to monitor and analyze the color intensity differences detected by two different sensors in real-time, which is an important indicator for assessing the health and nutritional condition of kale plants in an aquaponic system. Displays in ThingSpeak allow researchers to access data directly and continuously, ensuring that any changes in plant conditions can be immediately identified and responded to. Significant differences in RGB values between two sensors can also indicate variations in lighting, leaf quality, or the accuracy of the sensors themselves, so this data is very useful for calibration and optimization of monitoring systems. Thus, the main benefit of this display is to provide accurate and real-time data to support appropriate management decisions in managing aquaponic systems, ensuring kale plants get the best conditions for growth and health, as well as assisting in thesis research to understand the dynamics of aquaponic ecosystems.

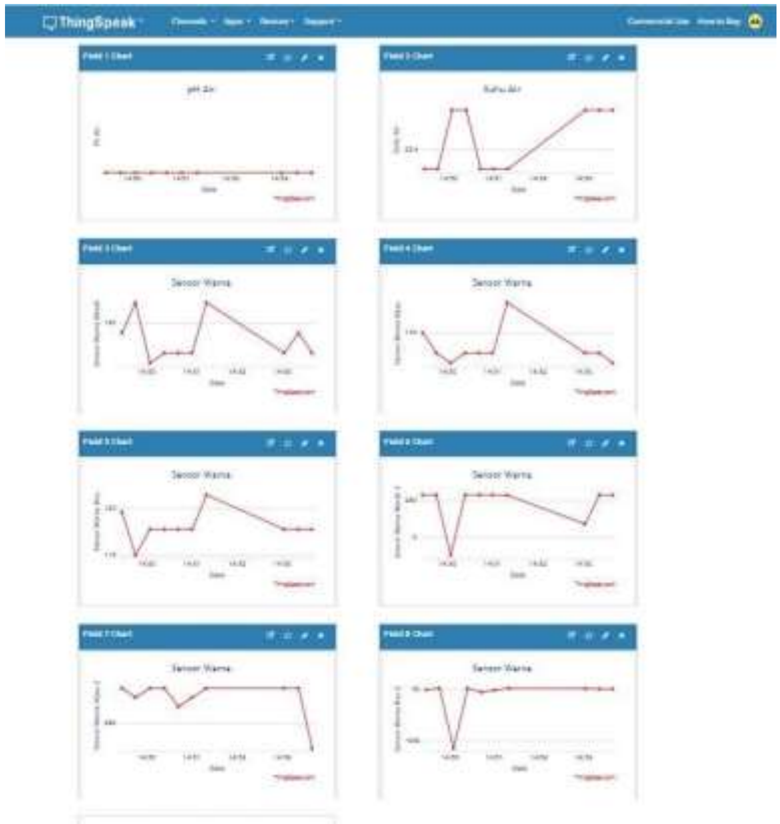

Fig 3.7 Thingspeak Sensor Overall Chart Data

The image above shows a graph on ThingSpeak that displays data from the pH sensor, water temperature, and RGB color. This graph was created to visualize changes and data trends for each parameter in a clear and structured manner. makes it easier to analyze data in real-time, so researchers can quickly identify patterns and anomalies. In the context of an aquaponic system for cultivating catfish and kale plants, monitoring pH and water temperature is very important because they affect the health and growth of fish and plants. The graph also helps in understanding the dynamics of RGB color intensity in kale leaves, which can indicate the nutritional condition and health of the plant. With this graph, researchers can make more precise and data-based decisions in managing and optimizing aquaponic environmental conditions to achieve the best results.

3.7 LCD Display Testing

Testing on the LCD circuit is carried out to find out whether the LCD can work as expected. LCD function testing is shown in the figure.

Fig 3.8 LCD Initial Display

Fig 3.9 Display of Color Sensor Testing on Kale

Fig 3.10 Temperature and pH Sensor Testing

It can be seen in figure 4.8, figure 4.9, to figure 4.10 that the LCD function displays the entire sensor value. Starting from the color, temperature and pH sensors of the aquaponic system, getting very important information in monitoring the performance process of this aquaponic system and identifying changes in temperature and pH of the aquaponic pond.

3.8 Component Tools

The series of tool components in the box as the display and function of the set of tool components is the central point for the microcontroller to carry out the compression stage and the pH sensor measurement stage. The following is a picture of a series of tool components in the box below.

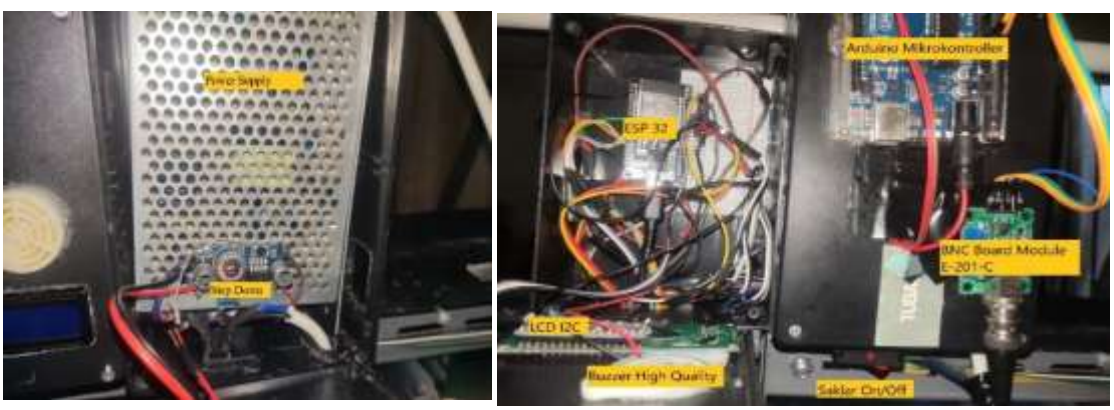

Fig 3.11 Component Tool Design

From the picture of the component tool circuit, the function and type of tool can be explained components in the table below:

No	Component Tool Type	Function
1	Power Supplies	The main function of a power supply is to convert the incoming power source (generally from an AC network or other DC source) into a voltage, current and form of power that suits the needs of the connected electronic devices.
2	Stepdown	The main function of stepdown is to reduce the voltage from higher to lower

3	ESP 32	The ESP32 is a very comprehensive chip, equipped with a processor, storage, and access to GPIO (General Purpose Input Output). The ESP32 can be used as an alternative to an Arduino, and has the ability to connect directly to a Wi-Fi network.
4	LCD I2C	LCD (Liquid Crystal Display) 16×2 is a display device that is very commonly used as an interface between a microcontroller and its user. By using this 16×2 LCD screen, users can monitor sensor conditions or program running status.
5	Buzzer High Quality	A High Quality buzzer is an electronic component that functions to produce a sound or beep. This output device converts electrical signals into sound.
6	On/Off Switch	The function of this switch is to connect or disconnect the flow of electricity from a device or electrical power source to another device or component.
7	Arduino Microcontroller	Serves as a development platform for creating various projects involving electronic control, sensor measurements, and interaction with the physical environment.
8	BNC Module Board	This module is used for signal conditioning from the pH sensor. This module can function as a replacement for the signal conditioner from DFRobot. All types of pH probes produce the same voltage for each pH value from 0-15, so this series is compatible with various types of pH probes.

3.9 How Technology Tools Work

There are 3 sensors, starting from the water temperature, detecting how many degrees of temperature are in the pool water, along with the pH sensor detecting the degree of acidity & alkalinity, and the color sensor highlights the plants in both planting media. The three sensor data is displayed on the LCD screen simultaneously sent directly via the Thingspeak cloud, the data is in the form of numbers and graphs. Then there is an automatic fish feeding system in aquaponics, using an RTC as a scheduler and a servo to activate the opening/closing system, this system feeds the fish 3 times a day, namely at preset hours, at 07:00 in the morning, 12:00 noon, and 17:00 in the afternoon, as long as the servo device is active a buzzer will sound as an indicator.

4. Conclusion

The conclusion of this research shows that the designed aquaponics system is able to provide optimal nutrition for the growth of catfish and water spinach plants. This system uses a pH sensor, TCS3200 color sensor, and DS18B20 temperature sensor, as well as an automatic feeding system that works effectively by feeding three times a day. Water temperature analysis shows that the temperature is within the ideal range for catfish health, important for creating a stable environment and supporting fish growth. Testing the RGB color sensor on kale leaves shows variations in color intensity which can indicate the nutritional status of the plant, with a deep green color indicating a plant that is healthier and getting enough nutrition. The ThingSpeak platform is used to monitor pH, temperature, and leaf color sensor data in real-time, enabling continuous monitoring and early identification of changing conditions that may affect nutrition. With this system, proper water conditions and sufficient nutrients are guaranteed to support the symbiosis between fish and plants, ensuring that both grow well in an aquaponic environment.

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