

# Design and Build a Mini Aquaponic *Smart System* for Subtropical Plants Based on *the Internet of Things (IOT)*.

Sagita Rochman  
Electrical Engineering  
University of PGRI Adi Buana  
Surabaya, Indonesia  
sagitaRochman@unipasby.ac.id

Muhammad Arief Hidayat  
Electrical Engineering  
University of PGRI Adi Buana  
Surabaya, Indonesia  
ardyarief9@gmail.com

*As a country with a tropical climate, Indonesia stands out as a land rich in various types of animals and plants. The diversity of climates and environments provides fertile habitats, enabling the survival of various species that adorn Indonesia's natural beauty. To fulfill the desires of subtropical plant lovers whose hobby is agriculture, researchers have the idea of creating a research automatic planting system that can be used to grow subtropical plants in urban areas. The ESP32 acts as a monitoring device that produces vital information regarding environmental conditions, such as soil moisture, water acidity levels, and feed supplies in a system. Through this monitoring, research can collect relevant data to analyze conditions and optimize these factors. The data obtained will be processed and analyzed through daily development comparisons. The existence of intelligent systems, such as monitoring water pH and humidity, providing fish food, and regulating the water content in ponds and hydroponic growing media, can make it easier for those who want to develop farming and fish farming hobbies in urban areas where land is limited and busy with activity.*

**Keywords**—ESP32, PH Sensor, Humidity, Aquaponics, Hydroponics, Fish.

## I. INTRODUCTION (HEADING 1)

As a country with a tropical climate, Indonesia stands out as a land rich in various types of animals and plants. The diversity of climates and environments provides fertile habitats, enabling the survival of various species that adorn Indonesia's natural beauty. Strawberries are one of the important fruit commodities in the world, especially for countries with subtropical climates. Strawberries are subtropical plants that can adapt well to tropical highlands with temperatures of 17-20°C and accompanied by rainfall of 600-700 mm/year. Strawberries also require good air humidity for growth, which ranges from 80-90% and the length of sunlight needed is around 8-10 hours every day [6]. In Indonesia, generally the lives of people who live in urban areas cannot be separated from the lack of land for agriculture due to the large number of buildings that have been erected, so that urban residents who have a hobby in agriculture are ultimately limited by the conditions of the urban environment. To fulfill the desires of subtropical plant lovers whose hobby is agriculture, researchers have the idea of creating a research automatic planting system that can be used to grow subtropical plants in urban areas. In this case, there are several techniques for planting plants in urban areas, namely hydroponic and aquaponic methods.

. In the aquaponics system, water quality in fish cultivation is one of the main requirements for the success of the cultivation process. The basic principle that is beneficial for aquaculture is that leftover fish feed and waste, which have the potential to worsen water quality, will be used as fertilizer for aquatic plants. Therefore, an automatic control system is needed that can meet the needs of aquaponics, such as a feed and water pH monitoring system for fish ponds and a watering system for subtropical plants. The death point for fish is generally 4 at an acidic pH and 11 at an alkaline pH, whereas most freshwater fish will live well in a slightly acidic to neutral pH range at a pH value of 6.8 – 7.8. Meanwhile, for reproduction, a good acidity level is "pH 6.4 –7.0 [9]. It is hoped that the application of aquaponic technology can provide more benefits to partners and have a wider impact on the community and the surrounding environment. Liquid waste that is circulated into an aquaponic system can become a planting medium that is rich in nutrients for plants as well as a means of irrigation [10].

Automatic aquaponic control systems that have been implemented include IoT-based aquaponic systems and fuzzy interference [5] Where aquaponics has a control system to control the frequency of feeding, water changes and monitoring. To monitor pH levels, nutrient concentration (TDS), and water temperature for the main nutrients originating from fish ponds, which are leftover fish food and waste, Arduino Uno and NodeMCU ESP8266 are used as microcontrollers connected to the internet to send data from sensors to the application. Blynk Android, as well as as a plant and fish care control [8]. The aim of an Internet of Things (IoT)-based monitoring system that regulates activities in aquaponic cultivation systems is to make it easier for farmers to carry out maintenance tasks, including providing food to fish, checking and regulating water quality, and monitoring temperature and humidity. This system utilizes an Android application known as Blynk, which connects via the internet with the NodeMCU. NodeMCU acts as a brain that processes input from various sensors, such as pH, turbidity and DHT11 sensors, and produces output in the form of commands for relays and data that is sent back to the Blynk application [4].

From several previous studies, researchers have the idea of building an aquaponic system that can be used for subtropical plants and types of ornamental freshwater fish with the title "Design of a Mini Aquaponic Smart System for Subtropical Plants Based on the Internet of Things (IOT).

II. METHODS

In the method section, the design product being developed will be explained in detail, namely the Smart Aquaponics System Design. The explanation will include the variables and definitions used in this research, as well as the data collection procedures and data analysis methods used. This will help gain a comprehensive understanding of how these smart aquaponic system designs are developed and tested, as well as how the data obtained from this research will be analyzed to produce relevant and informative results.

A. Product Design

In this research, a glass aquarium measuring 30 cm x 50 cm x 30 cm was used as a container. Hydroponic media is placed above the aquarium with dimensions of 30 cm x 50 cm x 15 cm. The planting medium uses rockwool which is placed in a 2.5" diameter pipe.



Fig. 1. Glass Aquariums and Hydroponic Media.

This approach creates an efficient spatial system for hydroponic research, utilizing carefully measured dimensions, namely 30 cm long, 50 cm wide and 30 cm high for aquariums, and 30 cm long, 50 cm wide and 15 cm high for media. hydroponics. This structure is designed to support plant growth effectively and in a controlled manner.

B. Smart aquaponics system design

The following are some of the circuits used in smart aquaponics systems:

1. PH sensor input circuit

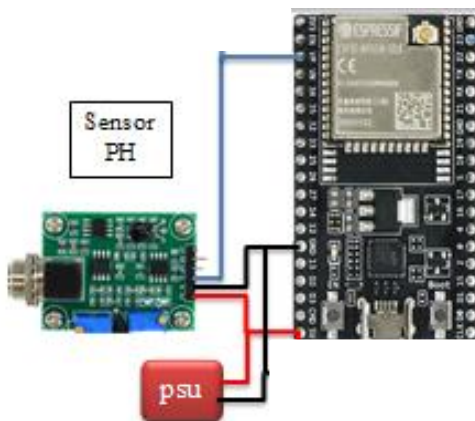


Fig. 2 PH Sensor Circuit.

For the PH sensor module, pin v+ is connected to (+5VDC) on the ESP32 pin, pin G is connected to (G) on the ESP32 pin, and pin P0 is connected to pin (35) on the ESP32.

2. Relay module output circuit

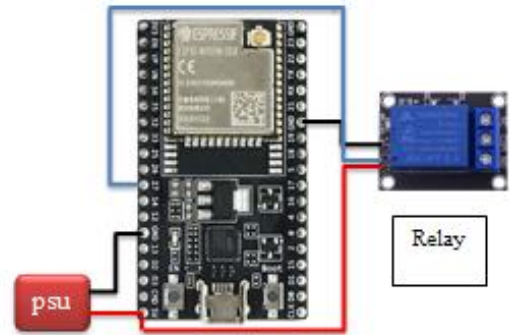
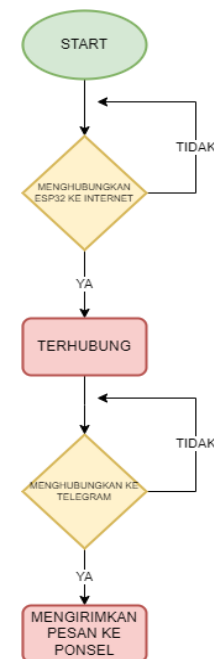


Fig. 3. Relay Module Circuit.

For the relay module, the VCC pin is connected to (+5VDC) on the ESP32, while the GND pin is connected to (G) on the ESP32. Then, pin IN1 is connected to (25), pin IN2 to (33), pin IN3 to (26), and pin IN4 to (32). In specific functions, pin 25 acts as an output for the feeding motor, pin 33 controls the automatic plant sprayer pump, pin 26 is used to manually control the plant sprayer pump, and pin 32 functions to open the valve tap.

3. Configure the smart aquaponics device with your cell phone.

When the device is turned on, the device's initial command is to synchronize with the phone, ensuring that all features and systems run as the user commands. When successfully connected to a cellphone via Telegram, the user will receive a notification that the device has been successfully connected.



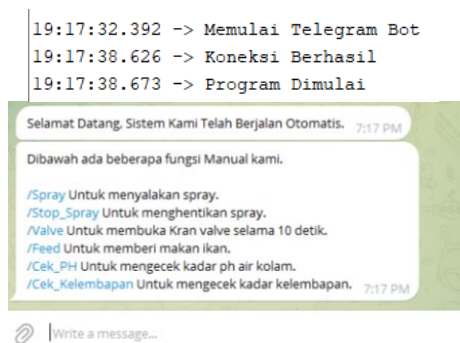


Fig. 4. Flowchart of Device Configuration and Display When Connected.

C. Variables and Definitions

A combination of a humidity sensor and a soil watering pump, then a PH sensor and tap valve are used as independent variables, then what is used as a dependent variable is the condition of the soil and the PH of the pool water.

D. Data Collection and Data Analysis Methods

The data collected in this research involves reading results from ESP32 I/O monitoring. The I/O includes readings of moisture levels, water pH levels, and feed availability. The ESP32 acts as a monitoring device that produces vital information regarding environmental conditions, such as soil moisture, water acidity levels, and feed supplies in a system. Through this monitoring, research can collect relevant data to analyze conditions and optimize these factors, supporting a deeper understanding of the growing environment and care of plants or animals. The data obtained will be processed and analyzed through daily development comparisons. This process aims to gain in-depth insight into the evolution of data and changes that occur over time in the context of this research.

III. RESULTS AND DISCUSSION

A. Data Presentation

1. Humidity Sensor Test Data

This sensor consists of two probes which are used to flow current through the soil, then read its resistance to produce a humidity level value (Anggara Tri Bayu et al., 2018). In testing the humidity sensor, several values are obtained from the sensor readings and then converted into percentages as follows:

```

Nilai kelembapan: 4095  Persentase Kelembapan: 0%
Level Air Kolam Normal
PH Air: 4.00
Tegangan: 3.30
Nilai kelembapan: 1674  Persentase Kelembapan: 59%
Level Air Kolam Normal
PH Air: 8.00
Tegangan: 2.37
Nilai kelembapan: 816  Persentase Kelembapan: 80%
Level Air Kolam Normal
PH Air: 7.82
Tegangan: 2.41
    
```

Fig. 5 Results of reading humidity values via the Arduino serial monitor.

Based on the sensor reading value, it is in the range 0 to 4095, which reflects the sensor reading results. The ADC value on the soil moisture sensor when connected to the NodeMCU ESP32 microcontroller gets an ADC value from 0 - 4095 because the analog input pin of the NodeMCU ESP32 uses 12bit resolution (Al Faqih et al., 2023). The higher the ADC value of the sensor reading, the drier the planting media. To convert the ADC value of the humidity sensor into a percentage, use the following formula:

```
int moisturePercentage = (100-((soilMoistureValue*100)/4095.00));
```

Fig. 6 Coding to convert ADC humidity values into percentages.

Where, the result of the sensor value reading is multiplied by 100 percent then divided by the maximum ADC value of 4095 then reduced by 100. Then the results displayed by the ESP32 will be a percentage of the sensor reading value.

Table 1. Humidity Sensor Test.

No	Sensor Reading	Percentage	Information
1	816	80%	Wet
2	1199	70%	Wet
3	1674	59%	Wet
4	4095	0%	Dry

2. PH Sensor Test Data

The installed sensor will be calibrated using PH Buffer Powder which is mixed into a glass filled with water, then the several PH Buffers used will show different voltage results. The following is the voltage data from the calibration using the PH Buffer:



```

Nilai kelembapan: 4095  Persentase Kelembapan: 0%
Level Air Kolam Normal
PH Air: 4.00
Tegangan: 3.30
    
```

Fig. 7 PH Sensor Testing with PH Buffer 4.



```

Nilai kelembapan: 4095  Persentase Kelembapan: 0%
Level Air Kolam Normal
PH Air: 6.93
Tegangan: 2.62
    
```

Fig. 8 PH Sensor Testing with PH Buffer 6.86.

After the pH sensor is dipped into the pH Buffer solution, the voltage value reading is displayed via the Serial Monitor contained in the Arduino software. Next, the results are entered into table form as follows:

Table 2PH Sensor Voltage Test.

No	PH Buffers	Voltage (VDC)
1	4	3.3
2	6.86	2.62

The calibration data will be used as a reference for pH sensors which have a voltage range between 0 and 4.99 Vdc. In the process of determining pH values that vary from 1 to 14, calculations are required involving the sensor voltage, which will then be interpreted within the specified pH range.

To determine the pH value of a solution in a drink, it can be calculated using the following formula:

$$V = \frac{\text{AnalogRead}}{2^n} * V_{cc}$$

$$PH = 3.5 * V$$

Analogread refers to the input value that comes from the signal condition at the electrode or the Analog-to-Digital Converter (ADC) value. The microcontroller has a bit resolution of 10 bits, which is equivalent to 1024. The reference voltage (Vcc) used is 5 volts, while the value of 3.5 reflects the constant coefficient of the manufacturer's calibration for the pH sensor [3]. Since ESP 32 is 12 Bit the resolution is 4095. To test the sensitivity of the sensor, researchers used litmus paper as a comparison. Litmus paper is a medium used to detect the PH level of water through changes in the color of the paper. There are two types of litmus paper, namely red litmus and blue litmus. The presence of H+ ions in solution can turn blue litmus paper red (blue litmus turns red and red litmus remains red). The presence of OH ions

in the solution can turn red litmus paper blue (red litmus changes color to blue and blue litmus remains blue) [7].



Fig. 9 PH Testing Using Litmus Paper.

The left side shows litmus paper dipped in a glass filled with water with a PH Buffer of 4, while the right side shows the color change of litmus paper dipped in a glass filled with water with a PH Buffer of 6.86.

Table 3PH Sensor Test .

No	PH Buffers	PH Sensor	Litmus Paper
1	4	4.00	4
2	6.86	6.93	7

The data shows that the comparison of the values shown by the PH sensor and Litmus Paper is close to each other because the changes shown by the litmus paper are not far from the PH sensor reading data.

## B. Data analysis

### 1. Humidity Test

Based on the humidity sensor test data, the humidity sensor test data was then analyzed over a period from day 1 to day 4. Data collection was carried out at 04.00, 10.00, 16.00, and 22.00 to pay attention to the effect of room temperature and humidity at those times. As follows:

Table 4 Periodic Humidity Sensor Testing.

NO	Day Measurement	Time	Humidity	Temperature Room	Pool Temperature	Ket
1	Day 1	04:00	73%	25°C	22°C	Wet
		10:00	70%	33°C	31°C	
		16:00	71%	31°C	30°C	
		22:00	72%	29°C	27°C	
2	Day 2	04:00	73%	27°C	22°C	Wet
		10:00	70%	34°C	31°C	
		16:00	71%	30°C	30°C	
		22:00	72%	28°C	27°C	
3	Day 3	04:00	73%	26°C	22°C	Wet
		10:00	70%	34°C	31°C	
		16:00	71%	31°C	30°C	
		22:00	72%	28°C	27°C	
4	Day 4	04:00	73%	28°C	22°C	Wet
		10:00	70%	33°C	31°C	
		16:00	71%	32°C	30°C	
		22:00	72%	29°C	27°C	

The results of humidity monitoring via the LCD display show changes in humidity levels that are not too far between these times. Additionally, it was found that moisture levels remained within acceptable limits for strawberry plants. These findings show that moisture stability supports plant growth, making a positive contribution to a supportive and conducive environment for strawberry plants at certain times.

## 2. Water PH Test

Based on the humidity sensor test data, the PH sensor test data was then analyzed for periods from day 1 to day 4. Data collection was carried out at 04.00, 10.00, 16.00, and 22.00 to pay attention to changes in water content experienced during the period. The following are the results of observations:

Table 5 Periodic PH Test.

No	Measurement Day	Time	PH level	Number of Fish	Has been fed/has not been fed
1	Day 1	04:00	7.5	6	Not given food yet
		10:00	7.2	6	It's been fed
		16:00	7.5	6	Not given food yet
		22:00	7.4	6	Not given food yet
2	Day 2	04:00	7.6	6	Not given food yet
		10:00	7.3	6	It's been fed
		16:00	7.4	6	Not given food yet
		22:00	7.4	6	Not given food yet
3	Day 3	04:00	7.6	6	Not given food yet
		10:00	7.3	6	It's been fed
		16:00	7.5	6	Not given food yet
		22:00	7.4	6	Not given food yet
4	Day 4	04:00	7.8	6	Not given food yet
		10:00	7.4	6	It's been fed
		16:00	7.6	6	Not given food yet
		22:00	7.6	6	Not given food yet

Data is taken flexibly by monitoring pH levels, comparing the number of fish, and observing feeding. Collecting this data is essential because feeding and the number of fish have the potential to influence the acidity level in the pond water. This approach provides a holistic understanding of the factors that influence pond environmental conditions, especially in fish management. Therefore, the results of pH measurements are able to provide complete and relevant information regarding the impact of feeding activities and the presence of fish on water conditions. This approach is important for increasing understanding and efficiency in aquaculture environmental management.

## C. Discussion

The research into the development of a Mini Smart Aquaponic System Design for Subtropical Plants Based on the Internet of Things (IoT) presents an innovative solution for urban agriculture enthusiasts. By integrating IoT technology into aquaponic systems, the study aims to provide urban dwellers with a convenient and efficient means of cultivating subtropical plants even in limited spaces. The results obtained from testing the tool offer valuable insights into its functionality and potential implications for urban farming. Advantages of IoT Integration The incorporation of IoT technology into the Mini Smart Aquaponic System brings several benefits. Firstly, it enables remote monitoring and control of essential parameters such as water quality,

temperature, and nutrient levels. This feature allows users to conveniently manage their aquaponic system from anywhere via a smartphone or computer, enhancing accessibility and ease of use. Moreover, IoT integration facilitates real-time data collection and analysis, enabling users to make informed decisions and optimize plant growth conditions for maximum yield.

Efficiency and Sustainability The data obtained from testing the Mini Smart Aquaponic System demonstrate its effectiveness in promoting resource efficiency and sustainability. By leveraging IoT sensors to monitor environmental variables and automate system operations, the tool minimizes water and nutrient waste while maintaining optimal growing conditions. This not only conserves resources but also reduces the environmental footprint of urban agriculture, making it a viable solution for eco-conscious individuals seeking sustainable food production methods. Accessibility and Scalability One of the key advantages of the Mini Smart Aquaponic System is its accessibility and scalability. The compact design and IoT-enabled features make it suitable for urban environments where space is limited. Additionally, the modular nature of the system allows for easy expansion and customization to accommodate varying plant types and user preferences. This scalability ensures that individuals with diverse needs and preferences can benefit from the technology, further democratizing access to urban farming opportunities.

Future Implications and Considerations The successful development and testing of the Mini Smart Aquaponic System pave the way for broader adoption and integration of IoT technology in urban agriculture. As the global population continues to urbanize, the demand for sustainable food production solutions will rise, making innovations like this increasingly relevant. However, future research and development efforts should focus on addressing potential challenges such as cost-effectiveness, user interface design, and compatibility with existing infrastructure to ensure widespread adoption and long-term viability. In conclusion, the Mini Smart Aquaponic System represents a promising advancement in urban agriculture, offering a scalable, efficient, and sustainable solution for cultivating subtropical plants in urban settings. By harnessing the power of IoT technology, this innovative tool empowers individuals to engage in farming practices and contribute to food security and environmental sustainability in their communities.

## IV. CONCLUSION

Based on data obtained from research on smart mini aquaponic systems for subtropical plants based on the Internet of Things (IoT), the results show that the smart system in the

device is able to support the development and growth of pond habitats and subtropical plants. The existence of intelligent systems, such as monitoring water pH and humidity, providing fish food, and regulating the water content in ponds and hydroponic growing media, can make it easier for those who want to develop farming and fish farming hobbies in urban areas where land is limited and busy with activity.

Furthermore, research can focus on optimizing aquaponic systems by exploring various types of plants and fish that can obtain maximum results. The use of sensor technology and automated controls can also be deepened to ensure efficient maintenance. Additionally, research can consider the economic and social aspects of aquaponic systems, such as the potential for improving local economies and community sustainability. Finally, research can explore the potential for integration with emerging technologies such as the Internet of Things (IoT) to monitor and manage systems more effectively. By considering these aspects, research in the field of aquaponics can make a significant contribution to the development of sustainable and innovative agricultural systems.

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#### REFERENCES

- [1] Al Faqih, W. ', Komang Somawirata, I., & Ashari, MI (2023). IoT-Based Grape Planting Media Monitoring System for Generative and Vegetative Phases. <http://eprints.itn.ac.id/id/eprint/13182>
- [2] Anggara Tri Bayu, Rohmah Mimin Fatchiyatur, & Sugianto. (2018). Agricultural Soil Moisture Measuring and Automatic Watering Systems Based on the Internet of Things (IoT). Agricultural Soil Moisture Measuring and Automatic Watering Systems Based on the Internet of Things, 1–8. <http://repository.unim.ac.id/id/eprint/241>.
- [3] Azwardi, Yusuf, DM, & Miftakul Amin, M. (2018). Tool for detecting acidity levels of fruit juice, soft drink and liquid milk using a pH sensor based on the Arduino UNO ATMEGA328 microcontroller. Journal of Engineering, 12(2), 1–11. <https://doi.org/10.5281/zenodo.3865138>.
- [4] Danih, D., & Sugiyatno, S. (2021). Internet of Things (IoT) Based Monitoring System for Controlling Water Quality and Fish Feed in Aquaponic Cultivation Systems. Journal of Students' Research in Computers
- [5] Rozie, F., Syarif, I., Al Rasyid, MUH, & Satriyanto, E. (2021). Aquaponic System for Catfish Farming and Hydroponic Water Spinach Plants Based on IoT and Fuzzy Inference System. Journal of Information Technology and Computer Science, 8(1), 157. <https://doi.org/10.25126/jtiik.0814025>.
- [6] Ramadhan, AF (2018). The Effect of Shading on Growth and Yield in Three Varieties of Strawberry Plants (*Fragaria chiloensis* L.). [Brawijaya University]. <http://repository.ub.ac.id/id/eprint/10947>
- [7] Riyayanti, E. (2021). Determining the properties of acid , base and salt solutions using ornamental plant leaf extract indicators. ACADEMIA: Journal of Academic Research Innovation, 1(2), 176–182. <https://doi.org/10.51878/academia.v1i2.672>
- [8] Saifuridin, AR (2021). Smart Aquaponics System Based on Arduino and IoT. [http://eprints.ums.ac.id/id/eprint/93273%0Ahttp://eprints.ums.ac.id/93273/7/NASKAH\\_PUBLICATION.pdf](http://eprints.ums.ac.id/id/eprint/93273%0Ahttp://eprints.ums.ac.id/93273/7/NASKAH_PUBLICATION.pdf) (20 18 ) The IEEE website. [On line]. Available: <http://www.ieee.org/>
- [9] Tamam, MT, & Aji, DN (2022). Design and Manufacture of Systems for Regulating pH and Water Temperature in Fish Ponds. RESISTOR (Computer Electrical Power Telecommunication Control Electronics), 5(1), 81. <https://doi.org/10.24853/resistor.5.1.81-84>
- [10] Utami, NR, Margareta R, YUA, Partaya, & Sriyadi. (2021). IBM Application of Aquaponic Technology to support urban agriculture in the Green Village housing complex, Kel. Ngijo, District. Gunungpati, Semarang City. BERDAYA Indonesian Journal of Community Empowerment, 1(1), 15–21. <https://doi.org/10.15294/berdaya.v1i1.42561>