Hydroponic Nutrition Water Quality Identification System on Cayenne Pepper Using Fuzzy Method Based on IoT

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Abstract: This study aims for an Internet of Things system for determining the nutritional water quality of hydroponic cayenne pepper plants based on fuzzy logic. Variable values were obtained from the readings of three sensors, water temperature, TDS, and pH. Hydroponic cayenne pepper plants can grow optimally at a water temperature from 18 to 28 °C, with a pH of 5 - 7. Nutrient levels in cayenne pepper will increase according to the age of the chili. The IoT system can provide corrections to any variables outside the specified range by giving commands from Arduino to the actuator. The actuators that run the water pump turn on and off, the addition of nutrients and water levels, and the process of neutralizing the pH with KOH and HCl compounds. The results of testing the IoT system send data to the website successfully, and then it is processed using fuzzy logic. This study found that the average accuracy of the three sensors was 93.61%.

1 INTRODUCTION

Hydroponics is a plant cultivation technique that utilizes water-containing nutrients as a growing medium and no longer needs to use soil media. Water is mixed with fertilizer to meet the nutrients required by plants (Swastika et al., 2017). The level of nutrients dissolved in water or the concentration of the mixture is expressed by TDS (Total Dissolved Solid). The TDS value is an essential indicator in hydroponic cultivation systems. Plants have normal levels to absorb nutrients for plant growth (Rahmadhani et al., 2020). If the TDS value is too high or too low, it will interfere with the absorption of nutrients in plants. The effect of a TDS value that is too high is that the plant leaves will turn yellow or burn due to excess nutrients. The degree of acidity (pH) and water temperature also affect the growth rate of hydroponic plants. Temperatures that are too high can cause plants to wither. So it needs good regulation of nutrient levels, pH, and temperature in hydroponic water.

Cayenne pepper is a leading commodity in Indonesia. Cayenne pepper is commonly used to add a spicy taste and natural red coloring to food. Based on data from the Central Statistics Agency and the Directorate General of Horticulture, the productivity of cayenne pepper increased by 13.07% from 2017 to 2018, with a productivity of 7.78 tons/ha. Farmers are increasingly carrying out the cultivation of cayenne pepper with a hydroponic system. The advantage of growing cayenne pepper using hydroponics is that it does not require a large area of land and can be done on a household scale.

Problems that arise and are still experienced by many farmers are regulating and monitoring levels of TDS values, pH, and hydroponic water temperatures continuously. If nutrient water is not monitored regularly and carefully, it can disrupt plant growth (Aprillia & Myori, 2020). Improper nutrient water regulation will affect the growth rate of cayenne pepper plants. When monitoring nutrient water conditions, Hydroponic farmers mostly do it manually using a TDS meter to measure TDS value

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and temperature; and a pH meter to measure the pH value of nutrient water.

This study was preceded by using the linear regression method to design a nutrient monitoring information system for hydroponic plants (Wibowo et al., 2022). In applying hydroponics, nutrition is a need that must always be met for plant development, where each plant requires different nutrients. The Nutrient Film Technique (NFT) is a technique that is often used in hydroponic cultivation. Because in this method, the circulation of nutrients in the water will constantly flow through the plant at any time. So plant growth is faster because plants get oxygen and nutrients all the time. The NFT technique is said to be an energy-intensive technique because the water pump will run continuously and still use human power. Previously some studies designed the design of the same system (Setyo Wibowo et al., 2022). This study aims to design a nutrient monitoring information system for hydroponic water spinach plants with an NFT system to increase the productivity of hydroponic farmers by automatically regulating nutrition and monitoring nutrients in hydroponic plants using the Linear Regression method. This Linear Regression method can determine the nutritional valve opening the next day so that the system can monitor nutrition.

Previously, the internet of things had also been carried out on oyster mushroom cultivation (Agustianto et al., 2021). In this study, the fuzzy logic method was applied to monitor oyster mushroom cultivation. The research then proceeds to the adaptive application of temperature and humidity using a fuzzy neural network algorithm (Hartadi et al., 2022). The use of modern technology can be a solution to the above problems. One solution is to use an Arduino microcontroller and several sensors such as TDS, pH, and temperature sensors as readings for hydroponic nutrient water conditions. Real-time monitoring through the website can also help farmers to know firsthand the necessity of nutrient water. Then Farmers can access the website via a smartphone or laptop. The microcontroller that can be integrated by Arduino and used to send nutrient water condition data to the website is the MCU node. The MCU node sends data using the internet network. Then the decision determination from the input is processed using the Sugeno fuzzy logic method—this study's purpose using it because of the suitability of the problems described above. Sugeno's fuzzy logic has a rule in the form of IF-THEN to determine the desired result in using nutrient water conditions for hydroponic cayenne pepper. This research aims to monitor the quality of hydroponic water in real-time and to produce a tool in the form of an IoT-based hydroponic system. The decision results from fuzzy logic calculations of water temperature are used for: Automating on/off the water pump; Automating the administration of nutrient concentrations; And automating the administration of compounds to neutralize the pH of the water.

2 LITERATURE REVIEW

2.1 Hydroponics

According to Sardare in (Dudwadkar et al., 2020) hydroponics is the process of cultivating plants that do not use soil media but water. Hydroponic plants can be grown on a household scale as a hobby or a large scale for commercial purposes. Cultivating this plant does not require a large area of land. It can also be done in the yard, on the house's terrace, or in a greenhouse. Some hydroponic experts suggest several advantages of the hydroponic system compared to conventional farming, including more efficient land use, plants growing without using soil, no risk for continuous planting throughout the year, higher and cleaner production quantity and quality, and fewer human resource requirements. , the use of fertilizers and water is more efficient, pest and disease control is more manageable, and the selling price of crop products is higher than non-hydroponic products.

2.2 Hydroponic Nutrient Water

Hydroponic nutrient water is a mixture of water with soluble inorganic minerals used as a nutrient provider by plants. Plants need 16 nutrients/nutrients for growth from air, water, and fertilizer. These elements are carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), potassium (K), sulfur (S), calcium (Ca), iron (Fe), magnesium (Mg), boron (B), manganese (Mn), copper (Cu), zinc (Zn), molybdenum (Mo) and chlorine (Cl) (Agricultural Research and Development Agency, 2019). Two crucial factors in a nutrient solution formula are the composition of the solution and the concentration of the solution. These two factors greatly determine crop production. Each type of plant requires a balance of the amount and composition of the nutrient solution and different concentration levels (Swastika et al., 2017).

Every liquid has TDS (Total Dissolved Solid), acidity (pH), and temperature. Total Dissolved Solid (TDS) shows the number of solids dissolved in nutrients as measured from the TDS meter. Liquid objects also have a degree of acidity written pH (power of hydrogen). pH is used to express a solution's acidity or alkalinity level. The pH of the nutrient water is kept in the range of 5 to 7 to get good results and tends to be acidic (Swastika et al., 2017). Indicators of good nutrient water can also be seen in the temperature of the water. The ideal temperature for good nutrient water for plants is 18 – 28°C. Temperatures too high will make the plants wither quickly (Firdausyah et al., 2022).

2.3 Cayenne Pepper

Chili is a plant classified as a member of the genus Capsicum. Chili is a food ingredient that is needed by the community. Chili is commonly used as a cooking ingredient and as a healthy plant. Chili also contains nutrients that are indispensable for human health (Afrilia, 2017). The cultivation of chili plants in Indonesia is very diverse. Not only planted on extensive land but also a narrow land, such as in the yard of the house planted in pots and polybags or planted in a hydroponic system. Cayenne pepper can be grown hydroponically using the Dutch bucket system. Here are the parameters/average temperature, nutrient levels, and pH in the growth of hydroponic chili plants.

Table 1: Parameters of Hydroponic Chili Plant Cultivation Needs.

Parameters	Normal level
Temperature	18 – 28oC
Nutrition	500 – 2500 ppm
pH	5 - 7

2.4 Fuzzy Logic

Fuzzy logic was first introduced by a researcher at the University of California, Barkley, in the field of computer science named Prof. Lutfi A. Zadeh in 1965 (Adiguna, 2017). The difference between digital logic and fuzzy logic is the degree of membership which has a value of zero to one, while digital logic only has a value of 0 or 1 which means "yes" or "no". Fuzzy logic can explain an uncertainty phenomenon in a mathematical model (Hariyadi, n.d.). Fuzzy divides the degree of membership and truth on the interval [0,1], which is something that can be partially true and partially false at the same time. Fuzzy logic translates a quantity described using language (linguistics). For example, the magnitude of the TDS value in ppm is expressed as very low, low, normal, high, and very high. The advantages of fuzzy logic are its ability to model very complex nonlinear functions, easy-to-understand logic concepts, and flexible use.

2.5 Internet of Things

Internet of Things is a modern and latest technology that allows every electronic device to be controlled, communicate, and exchange information between other devices through the internet network (Ciptadi & Hardyanto, 2018). Every device connected to the internet can exchange data and information. IoT can also virtualize anything tangible onto the internet. Another advantage of IoT is that it can monitor a device that works remotely by connecting it to the internet and then using other devices such as smartphones. Not only can it be used to watch, but IoT also acts as a medium for remote control of working devices. The function of IoT is to facilitate human work, increase work efficiency, and increase work productivity.

2.6 Website

A website is an application stored on a server computer that is accessed via the internet. According to Yeni Susilowati, a website has several pages with interrelated topics between one page and another. Websites are generally built using HTML and CSS programming languages to beautify the appearance of a page (Reizandi, 2019). The contents of the website pages vary and can contain text or text, images, videos, animations, or a combination of one another. Data from the website is stored in a structured database. Someone who wants to access a web page must type the URL in a browser.

3 DESIGN METHODOLOGY

3.1 Fuzzy Membership Function

This study uses a fuzzy logic method to determine the nutritional water quality of hydroponic chili plants, whose value is obtained from the readings of three sensors. The variables of this study were water temperature, nutrient content (ppm), and acidity (pH). Water temperature has a fuzzy set: cold, average, and hot. Nutrient levels have a group: low, sufficient, and high. The degree of acidity or pH has a fuzzy set: acidic, neutral, and essential. The collection of each variable described above is presented as a graphic diagram of the group of fuzzy membership functions.

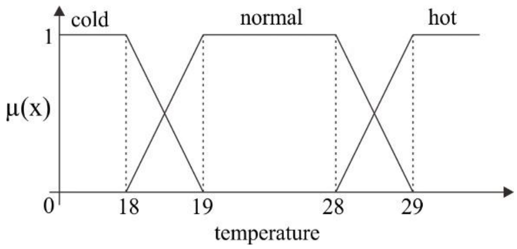

Figure 1: Water Temperature Chart.

If the temperature is too hot or more than 29 °C, the nutrient water pump from the reservoir will work to cool the water in the pot. The best average water temperature as nutrient water is in the range of 18 – 29 °C. However, if the temperature is too cold or below 18 °C, the system does not perform a command, and the nutrient water heating process does not occur in the reservoir.

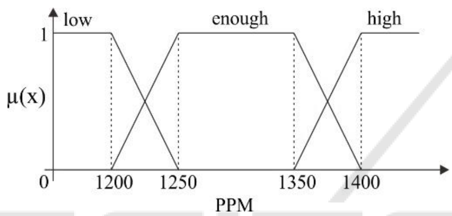

Figure 2: Water Ppm Chart.

The water ppm graph is obtained from the data regarding the relationship between water ppm and the addition of ab mix nutrient water or the addition of water. The picture above shows that the ppm level was entirely from 1200 to 1400. The ppm is adjusted according to the age of the chili plant. If the ppm is too high or more than specified, the water pump will work to lower the nutrient levels. However, if the ppm is too low or below the set, the system will add a mix of nutrients to the nutrient water bath.

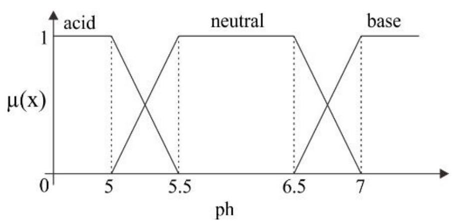

Figure 3: Water pH Chart.

The pH graph of the water is obtained from the data on the relationship between the pH of the water and the neutralization of the acidity of the nutrient water. The neutral pH of the nutrient water is in the range of 5 – 7. The system will add alkaline compounds to neutralize the nutrient water if the pH is too acidic. However, the system will add a sour mixture if the pH is too alkaline or above 7.

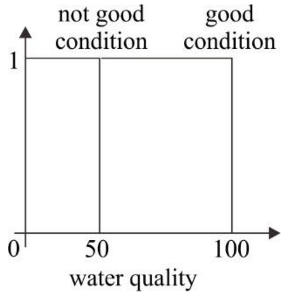

Figure 4: Water Quality Output Chart.

Water quality is declared less good if it is in values 0-50. From this value, various actions are taken according to predetermined rules. Nutrient water conditions are announced well if the fuzzy calculation results show a value range of more than 50 to 100. Based on interviews with experts, the author's observations showed that there are two kinds of nutritional water quality for hydroponic chili plants, namely water quality with good conditions and water quality with poor conditions. Good water conditions are temperatures in the normal range and ppm in an acceptable range. While an acid or alkaline state can tolerate it, the IoT system still gives orders to the actuator to neutralize it.

3.2 Determination of Nutritional Water Quality

Table 2: Determination of Nutritional Water Quality Conditions.

Rule	Temp	Ppm	Ph	Quality
[R1]	Cold	Low	Acid	Not Good
[R2]	Cold	Low	Netral	Not Good
[R3]	Cold	Low	Alkali	Not Good
[R4]	Cold	Fair	Acid	Not Good
[R5]	Cold	Fair	Netral	Not Good
[R6]	Cold	Fair	Alkali	Not Good
[R7]	Cold	High	Acid	Not Good
[R8]	Cold	High	Netral	Not Good
[R9]	Cold	High	Alkali	Not Good
[R10]	Normal	Low	Acid	Not Good
[R11]	Normal	Low	Netral	Not Good
[R12]	Normal	Low	Alkali	Not Good
[R13]	Normal	Fair	Acid	Good
[R14]	Normal	Fair	Netral	Good
[R15]	Normal	Fair	Alkali	Good
[R16]	Normal	High	Acid	Not Good
[R17]	Normal	High	Netral	Not Good
[R18]	Normal	High	Alkali	Not Good
[R19]	Hot	Low	Acid	Not Good

Table 2: Determination of Nutritional Water Quality Conditions.(cont.)

Rule	Temp	Ppm	Ph	Quality
[R20]	Hot	Low	Netral	Not Good
[R21]	Hot	Low	Alkali	Not Good
[R22]	Hot	Fair	Acid	Not Good
[R23]	Hot	Fair	Netral	Not Good
[R24]	Hot	Fair	Alkali	Not Good
[R25]	Hot	High	Acid	Not Good
[R26]	Hot	High	Netral	Not Good
[R27]	Hot	High	Alkali	Not Good

3.3 Actuator Motion Determination

On Arduino, each variable's fuzzy logic calculation process is carried out without relating to other variables. The calculation is done to determine the motion of the actuator so that the quality of nutrient water is always in good condition. The following is a table for deciding actuator motion in an IoT system.

Table 3: Actuator Motion Determination.

		Temperature		
		Cold	Normal	Hot
PPM & PH	Low & Acid	Add nutrition, add KOH	Add nutrition, add KOH	Add nutrition, add KOH, turn on the nutrition water pump
	Low & Netral	Add nutrition	Add nutrition	Add nutrition, turn on the nutrition water pump
	Low & Alkali	Add nutrition, Add HCl	Add nutrition, Add HCl	Add nutrition, Add HCl, turn on the nutrition water pump
	Fair & Acid	Add KOH	Add KOH	Add KOH, turn on the nutrition water pump
	Fair & Netral	No action	No action	Turn on the nutrition water pump
	Fair & Alkali	Add HCl	Add HCl	Add HCl, turn on the nutrition water pump
	High & Acid	Add water, add KOH	Add water, add KOH	Add water, add KOH, turn on the nutrition water pump
	High & Netral	Add water	Add water	Add air, turn on the nutrition water pump
	High & Alkali	Add water, Add HCl	Add water, Add HCl	Add water, add HCl, turn on the nutrition water pump

3.4 Plant Nutrient Needs

The nutritional needs of hydroponic plants are directly proportional to the age of the plant. The older the chili plant, the more dietary needs are. The following is a table of the nutritional needs of hydroponic cayenne pepper plants. The following is a table of the dietary needs of hydroponic cayenne pepper plants, along with the age of the plant.

Table 4: Hydroponic Chili Nutrition Needs.

Plant Age (HST)	**Nutritional needs (ppm)**
8 – 14 HST	500 – 700
15 – 21 HST	700 – 1000
22 – 28 HST	1000 – 1200
29 – 35 HST	1200 – 1400
36 – 42 HST	1200 – 1400
43 – 49 HST	1400 – 1600
50 – 56 HST	1600 – 1800
57 – 63 HST	1800 – 2000
64 – and so on	2000 – 2200

3.5 Research Stages

The following is a flow chart of the system's work, illustrated in the image below. The diagram explains the input flow in the form of sensor readings, part of the process, namely calculations with fuzzy logic, and output commands to the actuator and sending sensor reading values to the website.

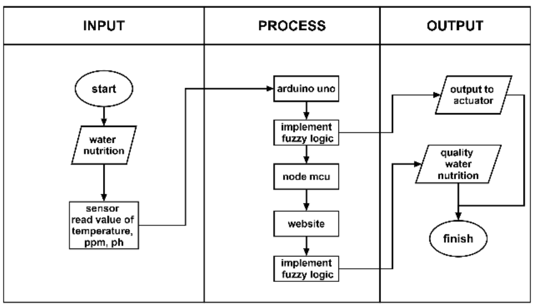

Figure 5: How the System Works.

The system's first part is the reading of temperature sensor values, TDS, and pH on hydroponic nutrients. The units for each data are: TDS has units of ppm (parts per million); PH has units of pH (Power of Hydrogen); The author takes units of degrees Celsius (°C) for temperature data.

The three sensors are immersed in the nutrient water in the sensor reading container. The sensor placement should be protected from direct sunlight so that the sensor usage time becomes longer. The sensor readings are received by Arduino and then processed using fuzzy logic.

The calculation process is carried out starting from the fuzzification process. Fuzzification is converting actual values into a fuzzy form using a membership function. The three sensor values are searched for the membership function value or its Miu(). Then the inference process is carried out; namely, the application of the IF THEN ELSE rule based on the knowledge base of the expert. After that, defuzzification changes back from the fuzzy value to a firm value that will be used as a determinant of the actuator's work. Temperature data is also sent to the MCU Node, which is then sent to the website.

The output of the Fuzzy calculation is in the form of nutritional water quality conditions on the website. On this website, farmers can monitor whether the quality of nutrient water is in good condition or not. Arduino also processes sensor data into fuzzy logic in response to actuators. The calculation results determine if, for example, the temperature is included in the too high category. Arduino will give an order to pump nutrient water to drain water with a lower temperature in the reservoir. Or if the TDS sensor readings find that the nutrient level is too low, the system will drain the nutrients to the pool.

3.6 IoT Devices Flowchart

The first IoT system workflow is the reading of temperature, TDS, and pH sensors in nutrient water. The results of the sensor readings are sent to Arduino, and then the calculation process is carried out with fuzzy logic. Each sensor value is calculated fuzzy to determine the actuator output to be run. Arduino will make corrections to stabilize the condition of the nutrient water so that it is always in good condition.

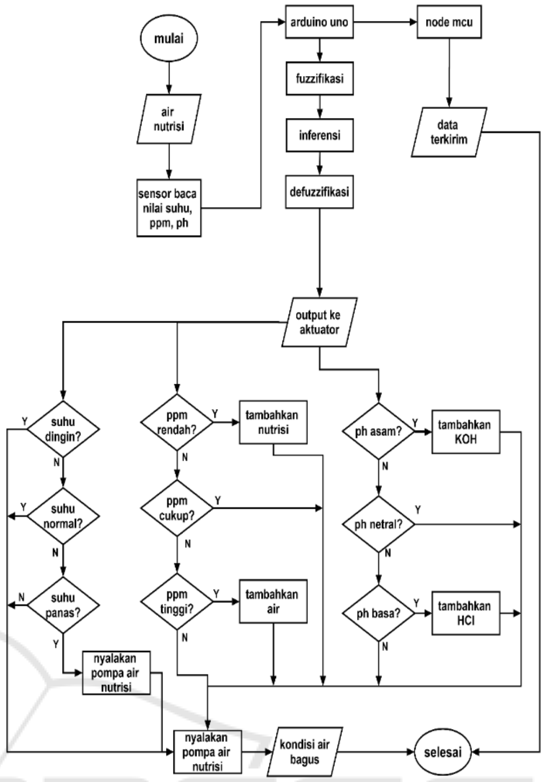

Figure 6: IoT Devices Flowchart.

3.7 Website System Flowchart

The system's workflow on the first website is admin or farmer logging in on the login page by filling in the username and password. If appropriate, it will enter the dashboard page. Admins or farmers can see the current condition of nutrient water quality and graph each sensor reading sent to the website. The admin can process (add, change, delete) the ppm data on the ppm processing data page. The fuzzy calculation page displays the results of calculations with fuzzy logic for determining nutrient water quality.

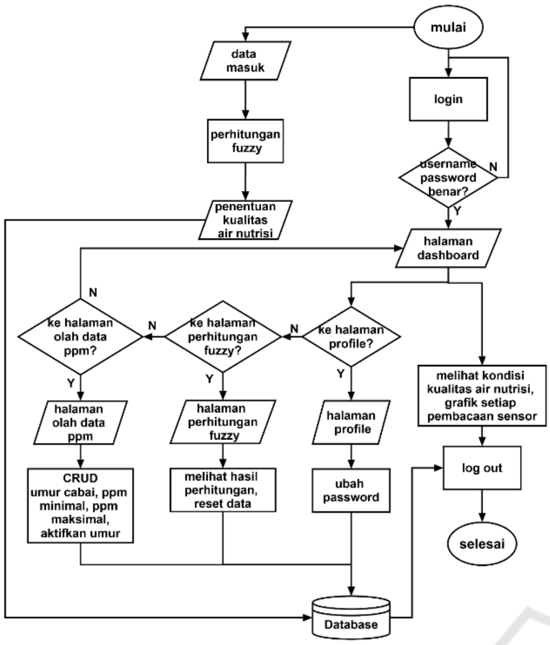

Figure 7: Website System Flowchart.

3.8 Design of Iot Devices

The design of IoT tools will be described in this section. Electronic components consist of Arduino as a microcontroller for sensor readings and a command center for the actuator.

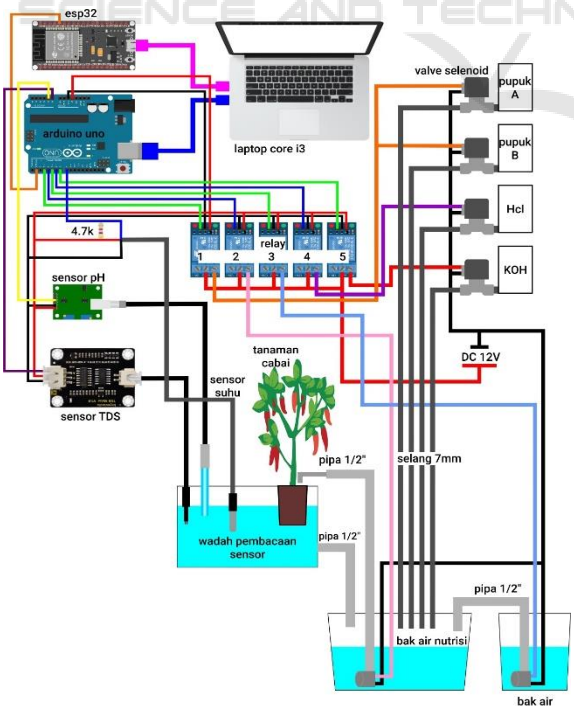

Figure 8: Desain Alat IoT.

4 RESULTS AND DISCUSSIONS

The following is a website page to monitor the quality of hydroponic nutrient water for cayenne pepper plants. There are three graphs of each sensor reading, and the results of the last sensor readings and the nutritional water quality are also displayed.

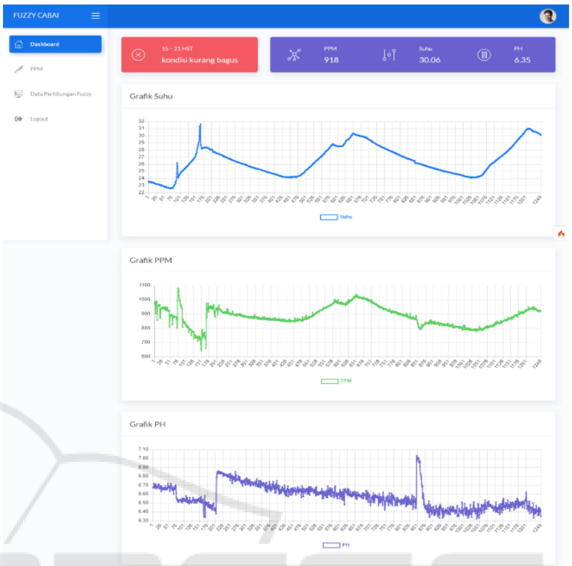

Figure 9: Dashboard Page.

This ppm data processing page is helpful for processing ppm data that is adjusted to the planting age of chili. Admins or farmers can process the data, such as adding, changing, and deleting data. This page contains the age range of chili peppers and the minimum – maximum levels of nutrients that plants need. Farmers can activate it via a button, and the fuzzy logic calculation process will automatically follow the selection of the active ppm range.

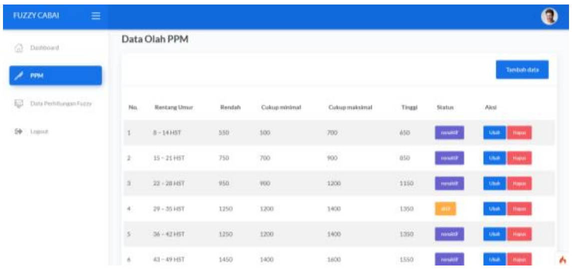

Figure 10: Ppm Processed Data Page.

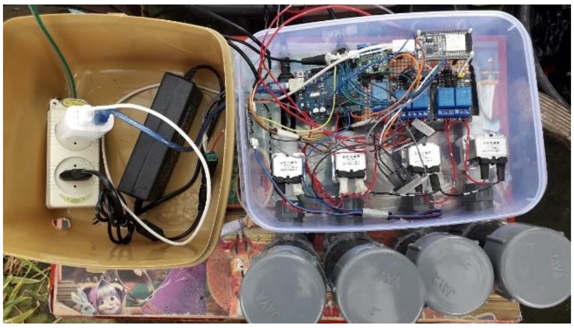

Figure 11: IoT Device System.

Figure 11 is a ready-made IoT tool. Electronic components such as Arduino, ESP32 MCU nodes, and how many relays are in the white case. Between electronic components are connected with jumper cables. The solenoid valve connected to the relay is also located in a white container, whose water flows from a line of pipes. The brown case has a 12V DC ADAPTER and a 5V DC ADAPTER 2 USB ports. The 12V DC adapter is used to supply power to two pumps and four solenoid valves. ADAPTER DC 5 V 2 USB ports control the Arduino and the ESP32 MCU node. All ADAPTERS are connected to 220V AC home power.

Table 5: Pengujian Akurasi Alat.

Var.	Man.	Sensors	Dev.	Dev. (%)	Accu. (%)
Temp	29,9	28,06	1,84	6,55	93,45
Ppm	506	497	9	1,81	98,19
PH	6	6.65	0,65	10,83	89,17
Av.			3,83	6,39	93,61

The table above results from testing the accuracy of IoT tools compared to manual measuring tools. The most significant difference between reading the sensor and reading from a manual measuring instrument is in ppm, which is 9. However, in this case, it is in the range of 500, much higher than the other variables. The temperature and pH variables are in the field of tens and units values (temperature in the range of 28 - 29, pH in the range of 6 - 7). So if it is calculated based on proportions, reading the ppm value has the smallest value of 1.81% and has the highest accuracy of 98.19%. The accuracy of reading the pH sensor on the measurement of the measuring instrument showed the lowest result, 89.17%, with a difference of 10.83%. It happens because the sensor has been used for a long time and may be damaged, or it could be from reading a manual measuring instrument that uses litmus paper, not a pH meter, to make it more accurate. At the IoT accuracy testing stage, the accuracy value is 93.61%, so the IoT tool runs quite accurately.

5 CONCLUSIONS

This research has succeeded in developing a Hydroponic Nutrition Water Quality Identification System. Determination of nutritional water quality of hydroponic using fuzzy logic method. The nutrition content was increased successfully by giving commands via Arduino to the actuator. The actuator activates and deactivates the water pump that already contains the required nutrients. The results of testing the IoT system send data to the website successfully, and then it is processed using fuzzy logic. This study found that the average accuracy of the three sensors was 93.61%. This research can be extended to the other plant case for further work. So the variable can be variated.

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