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Development of a Prototype System for Monitoring and Controlling Apple Cider Vinegar Fermentation Using IoT-Based Fuzzy Methods

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Abstract. *The apple cider vinegar fermentation process requires careful monitoring and control of variables such as pH, alcohol content, and amount of acetic acid. This research adopts Fuzzy Logic Control by utilizing the MQTT communication protocol, pH, alcohol and water pump sensors, as well as solenoid valves and DC motors as actuators. This Internet of Things (IoT) based solution provides real-time monitoring information on the fermentation process. The results showed that the test system succeeded in maintaining a stable pH of around 3.9-4.0 during the initial stages of fermentation, while industrial data showed greater variations. Alcohol content increased consistently in the test system, in contrast to the spike on day 7 in industry data. At the formulation stage, the pH dropped to 3.68 in the test system, while the industry maintained 3.70. At medium and slow mixing stages, the test system showed a significant decrease in pH and a consistent increase in alcohol. At the harvest stage, the pH was lower in the test system compared to industrial, with slightly higher alcohol content. Test results show that the implementation of this system can reduce the fermentation process time by up to 2 days faster compared to conventional methods. This conclusion shows that IoT-based systems are able to provide better control and monitoring than conventional systems, so they have great potential for wider adoption in the apple vinegar fermentation industry to increase production effectiveness.*
Keywords: *Apple Cider Vinegar, Fermentation, Fuzzy Logic Control, Internet of Things, MQTT.*

1. INTRODUCTION

The fermentation process of apple vinegar is a complex biochemical transformation, turning apple juice into vinegar through the activity of specialized microorganisms. In two main stages, alcohol fermentation and acetic acid fermentation, apple sugar is converted to alcohol by yeast in the first stage, and then alcohol is oxidized to acetic acid by Acetobacter aceti bacteria in the second stage(Ayesha et al., 2021). The successful fermentation of apple cider vinegar not only creates unique flavor and aroma characteristics, but also involves the natural preservative properties of acetic acid, providing resistance to microorganism growth and extending the shelf life of the product. With the combination of these factors, apple vinegar fermentation is not just the transformation of sugar into acid, but a complex process that creates an end product with desirable characteristics in terms of flavor, aroma and nutritional content.(Djuang, 2022)

Nonetheless, the fermentation process is not free from a number of challenges and variability. Variability in environmental conditions, such as temperature fluctuations that can affect the activity of microorganisms, as well as changes in pH that play an important role in

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the activity of enzymes and microorganisms, are factors that need to be taken into account. In addition, mixing in apple vinegar fermentation is very important as it supports the growth of Acetobacter aceti bacteria and yeast as they require oxygen accessed through mixing to convert alcohol into acetic acid. Thus, mixing not only improves fermentation efficiency, but also contributes to the final quality of apple vinegar.(Ayesha et al., 2021)

The importance of monitoring and controlling in the apple vinegar fermentation process can be seen from various aspects, especially in monitoring the pH level, alcohol content, and the amount of acetic acid. Monitoring pH is crucial because it can affect the activity of enzymes and microorganisms during the fermentation process. Alcohol levels need to be monitored regularly to ensure that the alcoholic fermentation stage runs efficiently and according to the desired standard. Meanwhile, measuring the amount of acetic acid ensures the achievement of the desired flavor characteristics in the final product.

Effective control is also necessary in maintaining the quality of the fermentation process. Oxygen control is key, especially in alcohol and acetic acid fermentation, as oxygen can affect the dominant types of microorganisms and lead to undesirable results. Controlling the amount of acetic acid added is an important step to achieve an acidity level that matches the product standard. In addition, control measures through the mixing process are essential to evenly distribute microorganisms, nutrients, and energy sources in the fermentation medium.

Conventional monitoring and control systems in the apple vinegar fermentation process have limitations that can affect product quality. Inefficient manual monitoring can increase the risk of microorganism contamination that can be detrimental to product characteristics. In addition, in the context of different production sites and headquarters in different cities, communication delays and coordination difficulties can hinder the effectiveness of control during fermentation. The solution to overcome these limitations involves implementing more advanced monitoring and control systems, such as sensor automation technology, to improve the accuracy and efficiency of apple vinegar fermentation supervision.

The use of Internet of Things (IoT)-based technologies in monitoring and control systems provides the advantages of remote accessibility and efficient integration. Remote access allows management of the apple vinegar fermentation process from any location via an Internet of Things (IoT) connection, while providing quick response to changing conditions. Easy data integration enables centralized data collection from various sensors, creating an efficient unity of analysis for optimal monitoring and control. These advantages not only increase operational efficiency, but also strengthen system adaptability, creating a more integrated work environment and responsive to production growth and development.(Nabi & Kharaz, 2023)

This research aims to develop a prototype Internet of Things (IoT)-based system with a fuzzy method approach for monitoring and controlling the apple vinegar fermentation process. The main focus includes improving the efficiency and accuracy of monitoring key parameters, rapid response to changing conditions, and easy access and integration of data from various sensors. Other objectives involve technological innovation with the application of fuzzy methods to improve the accuracy of managing the variability of fermentation process complexity. It is expected that this system can improve the quality of apple vinegar products, as well as facilitate use for various users.(Bharadwaj et al., 2021)

2. METHOD

This research method utilizes sensors that can measure in real-time key parameters during the fermentation process. The system was developed to provide live data visualization to enable accurate monitoring and quick response to changes in fermentation conditions. The following are some of the components needed in this research:

1. pH sensor (PH-4502C): as a detector of changes in pH levels during the fermentation process.
2. Alcohol Sensor (MQ-3): as a detector of alcohol levels during the fermentation process.
3. Water Flow Sensor (YF-S401): to detect the quantity of acetic acid added in the formulation stage fermentation process.
4. Solenoid Valve Residue: as the ventilation output on the fermentation tube connected to the aqueous bottle.
5. Solenoid Valve Vent: as the output of the ventilation net in the stage 2 fermentation process for oxygen in and out.
6. DC Motor: as an output for mixing in the fermentation process.

Parameters are implemented as set points in the monitoring and controlling process which are factors in measuring the success of this research. This parameter becomes a guide value in achieving production standards. Based on the evaluation of research components and parameters.

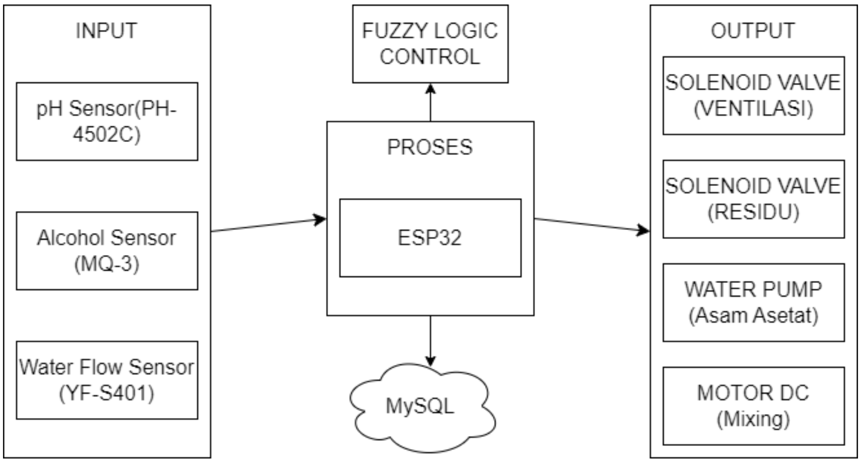

Figure 1 Block Diagram Device

Figure 1 illustrates the block diagram of the device used in this final project research, which integrates a fuzzy logic-based control system with an ESP32 microcontroller. This system consists of several main components in the input section, namely the pH Sensor (PH-4502C), Alcohol Sensor (MQ-3), and Water Flow Sensor (YF-S401). The pH sensor is used to measure the acidity or basicity of a liquid, the alcohol sensor to detect alcohol levels, and the water flow sensor to measure the volume of water entering the system. The data generated by these sensors is sent to the ESP32 microcontroller, which then processes it using a fuzzy logic-based control method. The ESP32, with a built-in Wi-Fi module, allows real-time transmission of data to a MySQL database system for storage and further analysis. Once the data is processed, control commands are sent to actuators consisting of solenoid valves for ventilation and residue, water pumps for acetic acid, and DC motors for the mixing process. The results of this monitoring and control are displayed via a web interface, allowing real-time data access and remote parameter control. Thus, the system offers a comprehensive and flexible solution for fuzzy logic-based process monitoring and control, supported by connectivity that facilitates data integration and accessibility.

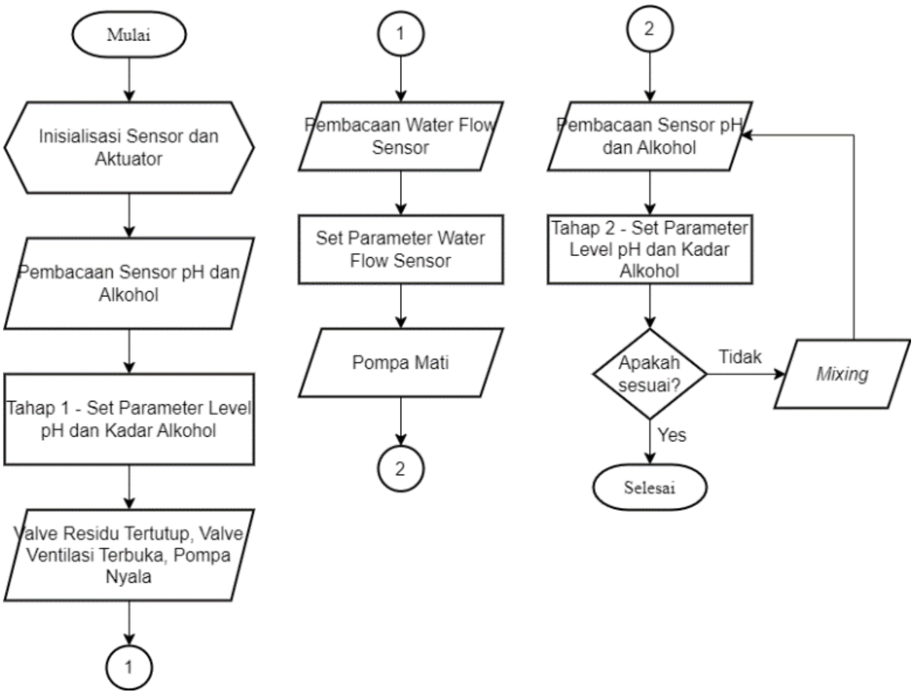

Figure 2 Flowchart System

Figure 2 is a flowchart of the tool that has been designed for this research. The workflow of the tool starts with the initialization of sensors and actuators which will then take readings on the apple vinegar fermentation sample by the pH sensor and alcohol sensor. In this first stage is the alcohol fermentation stage, where the pH and alcohol levels are measured until they reach the set point. After the set point has been reached, the residue hose valve will be closed because the alcohol fermentation process has been completed, the ventilation valve will open because it will enter the second stage, and the tube valve will open because acetic acid will be added. After adding acetic acid, it will enter the second stage, namely reading the water flow to measure the amount of acetic acid added. Next, enter the acetic acid fermentation stage, which starts from reading the pH sensor and alcohol sensor.

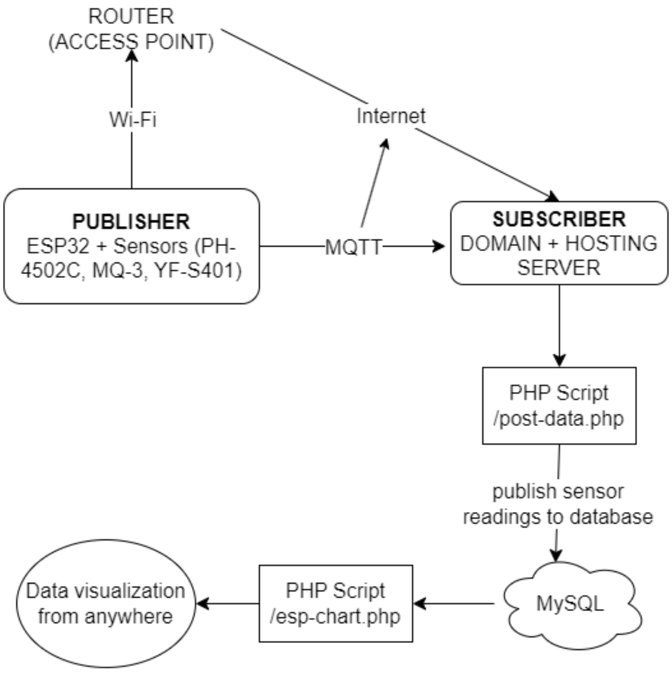

Figure 3 Block Diagram System

Figure 3 shows the workflow of the Internet of Things (IoT)-based monitoring and control system for apple vinegar fermentation process. The system starts with an ESP32 module equipped with a pH sensor (PH-4502C), alcohol gas sensor (MQ-3), and flow sensor (YF-S401), which functions as a Publisher to collect data from these sensors. The data is sent via a Wi-Fi network connected to a router or access point, then forwarded to the server via the MQTT protocol. The server, which acts as a Subscriber with a domain and hosting, receives the data from the Publisher and processes it using the PHP script `post-data.php`, which publishes the data into a MySQL database. This database stores all sensor data for further access and analysis. The PHP script `esp-chart.php` is used to access and visualize data from the database, allowing monitoring of fermentation conditions from anywhere via the internet. The system leverages IoT technology, sensors, and a web-based server to manage and analyze apple vinegar fermentation data in real-time and efficiently.

Table 1 Input and Output Fuzzy Logic Control

Input	pH Level Alcohol Content
Output	Valve Vent Valve Residue DC Motor

Identify the input and output variables of the control system. Input variables relate to the input parameters to be set, while output variables relate to the expected results. The fuzzy control process of apple vinegar fermentation involves eight different conditions to optimize the production yield. The first stage is the alcohol fermentation stage, where the pH is at a high level, the alcohol content is low, the acetic acid quantity is high, the vent is closed, the residue is open, the pump is off, and the motor is off. Next, the acetic acid addition stage has medium pH, medium alcohol content, high acid level, open ventilation, closed residue, pump on, and motor off.

Then, the mixing stage has medium pH, medium alcohol content, low acetic acid quantity, open ventilation, closed residue, pump off, and motor on. In the acetic acid fermentation stage, the conditions are low pH, high pH, high alcohol content, low acetic acid quantity, open ventilation, open residue, pump off, and motor off. Fuzzy Logic Control Input and Output can be seen in table 1.

Table 2 Input and Output Value Analysis

pH Level		
Low	Medium	High
2,9	3,7	4

Alcohol Content		
Low	Medium	High
0	0.9	2.7

Valve Vent		Valve Residue	
Open	Close	Open	Close

DC Motor		
Medium	Slow	Off
20	10	0

Divide the domain (range of values) of each input and output variable into several fuzzy sets with appropriate membership functions. Analysis of input and output values can be seen in table 2.

Table 3 Fuzzy Rule Base Analysis

RULE	INPUT		OUTPUT		
	pH	Alcohol	Vent	Residue	Motor

R1	Low	Low	Open	Close	Slow
R2	Low	Medium	Open	Close	Slow
R3	Low	High	Open	Open	Off
R4	Medium	Low	Open	Close	Medium
R5	Medium	Medium	Open	Close	Off
R6	Medium	High	Open	Close	Medium
R7	High	Low	Close	Open	Off
R8	High	Medium	Close	Open	Off
R9	High	High	Close	Open	Off

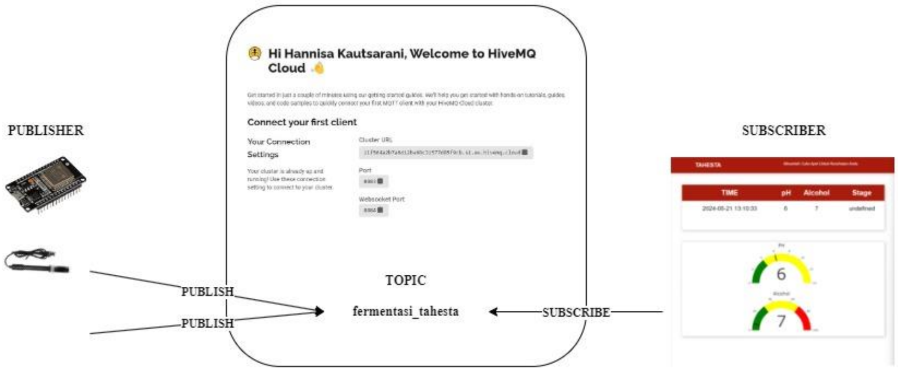

Figure 4 Schematic Diagram of MQTT Implementation

In the implementation of this system, the “publisher” is tasked with delivering data to the broker using the predetermined “topic” and “message”. The ESP32 device used in this system is equipped with three sensors that produce three sets of data that can be sent alternately. With the three “topics” that have been “fermented_tahesta” previously, the “publisher” function will initiate the data publication process three times according to the corresponding topics. Specifically, the topic related to the pH sensor will contain information about the pH level, the topic related to the MQ-3 sensor will carry information about the alcohol level, and the topic for the ultrasonic sensor will contain data about the acetic acid level. The role of “subscriber” is held by a website that acts as a subscriber (“subscribe”) to the topics that have been previously published by the “publisher”. With this approach, the system managed to devise an effective mechanism, known as the “publish-subscribe” mechanism, to manage and deliver data from the ESP32 device to the subscriber through the broker. In Figure 4 is the Schematic Diagram of the MQTT Implementation

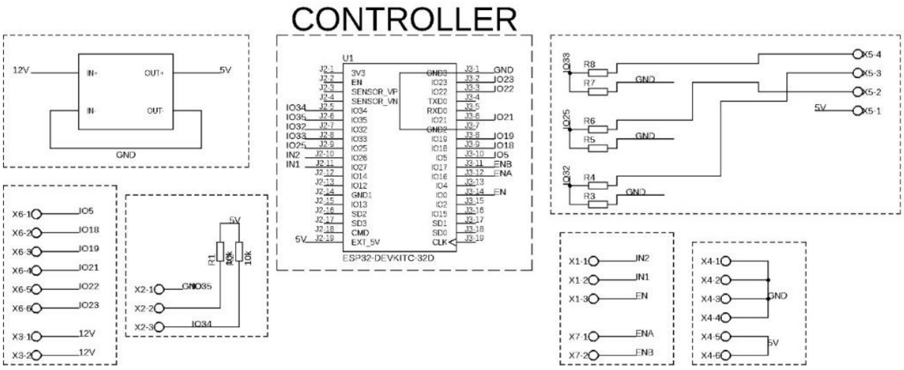

Figure 5 Electrical Circuit System

Figure 5 is the electrical circuit design that will be used for this final project research which connects all electrical components to form an electrical flow path.

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3. RESULTS AND DISCUSSION

Results

Table 4 Fuzzy Membership Function Initialization

Membership Function	Condition	Value
Variable Input		
Membership Function pH	Low	[0 2.9 3.3]
	Medium	[3.2 3.7 3.95]
	High	[3.85 4 14]
Membership Function Alkohol	Low	[-1 0 0.55]
	Medium	[0.25 0.9 1.95]
	High	[1.65 2.6 4]
Variable Output		
Membership Function Vent	Open	1
	Close	0
Membership Function Residue	Open	1
	Close	0
Membership Function Mixing	Off	0
	Slow	10

	Medium	20

The purpose of creating a Membership Function is to provide an appropriate mathematical representation of a fuzzy set in a fuzzy logic system. Table 4 is the result of creating and initializing the fuzzy membership value.

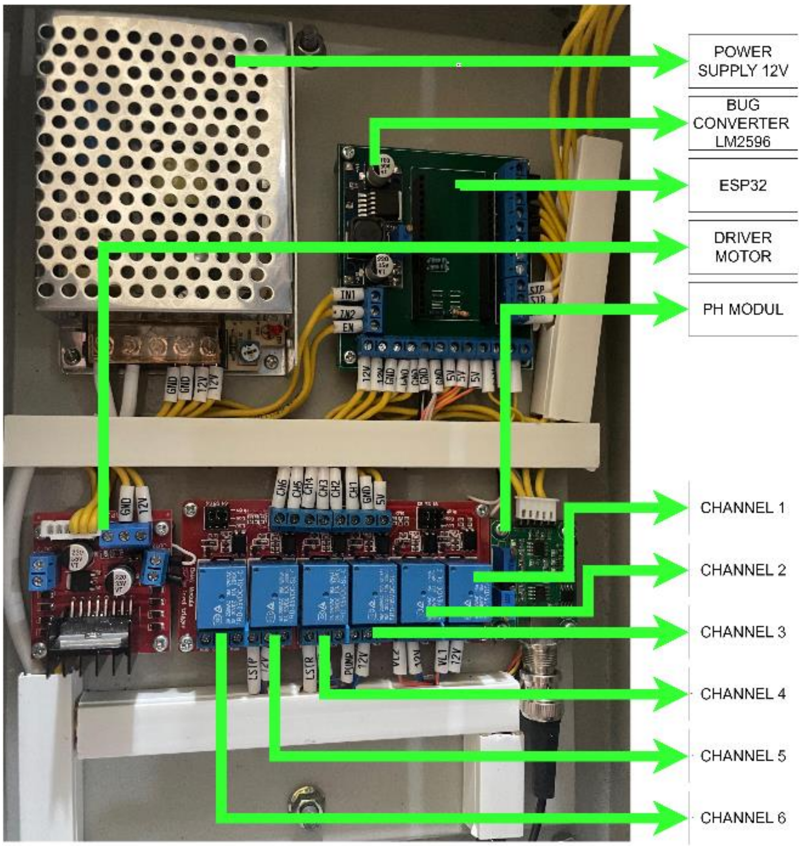

Figure 6 Electrical Panel Wiring

In the results of the electrical design design, a panel is made using PCB components, ESP32, power supply, pH sensor, MQ-3 sensor, water flow¸ solenoid valve, water pump, DC motor, motor driver, buck converter, and 6 channel relaty. For the results of electrical panel wiring can be seen in Figure 6.

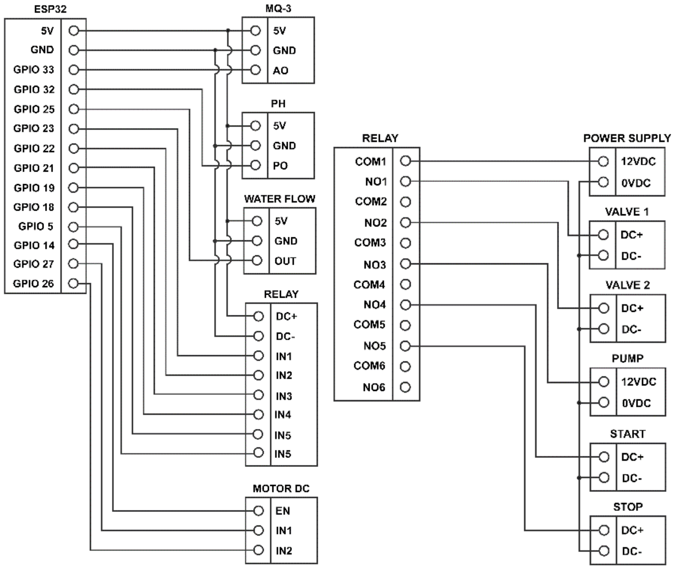

Figure 7 Electrical Panel Wiring Diagram

Figure 7 is a wiring diagram of the electrical panel pin configuration. Where the 5V pin of the MQ-3 sensor, pH sensor, water flow, and DC+ relay pin are connected to the 5V pin of the ESP32. The GND pin of the MQ-3 sensor, pH sensor, water flow, and DC- relay pin are connected to the ESP32 GND pin. The AO pin of the MQ-3 sensor is connected to the GPIO33 pin, the PO pin of the pH sensor is connected to the GPIO32 pin, the OUT pin of the water flow is connected to the GPIO25 pin. IN1, IN2, IN3, IN4, and IN5 relay pins are connected to GPIO22, GPIO21, GPIO19, GPIO18, and GPIO5 pins. For the DC motor configuration, the EN pin is connected to the GPIO14 pin, the IN1 pin is connected to the GPIO27 pin, and the IN2 pin is connected to the GPIO26 pin.

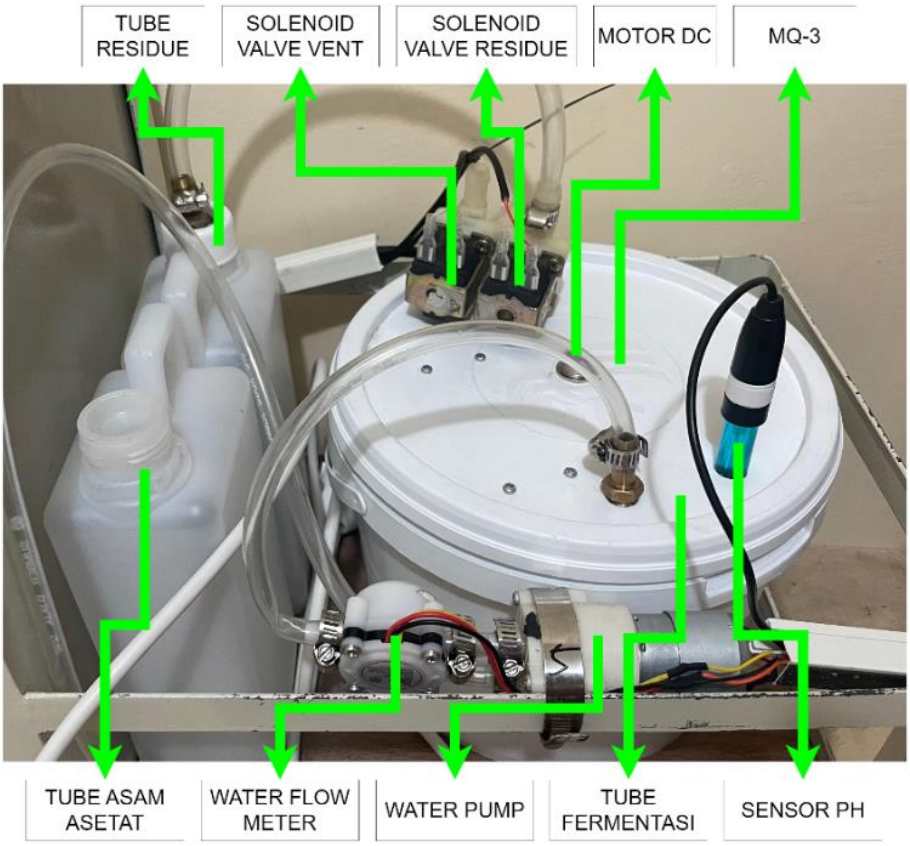

Figure 8 Mechanical Design Results

In this research, the components used can be seen in Figure (4.25). The pH Sensor (PH-4502C) is used to detect changes in pH levels that occur during the fermentation process, while the Alcohol Sensor (MQ-3) serves to detect the level of alcohol formed. The Water Flow Sensor (YF-S401) serves as a detection device to measure the quantity of acetic acid added at the fermentation formulation stage. Furthermore, the Residue Solenoid Valve serves as the ventilation output on the fermentation tube connected to the aqueous bottle, while the Vent Solenoid Valve serves as the ventilation output in the second stage of the fermentation process to regulate the inflow and outflow of oxygen. Finally, the DC Motor is used as an output for the mixing process at the fermentation stage.

In the testing phase, the fermentation process of apple vinegar started on June 7, 2024 and lasted for 11 days. During this stage, the sugar in the apple juice was converted into alcohol by yeast. By the end of the fermentation stage, most of the sugar had been converted into alcohol, marking the success of this initial stage. Figure 4.28 is the result of apple juice entering the control system test and Figure 4.29 is the result of system monitoring in the fermentation stage. In the first stage, yeast (Saccharomyces cerevisiae) converts the sugar contained in apple cider into alcohol (ethanol) and carbon dioxide through anaerobic fermentation (without oxygen). Thus, at this stage, the vent solenoid valve is closed to prevent oxygen entry, while the residual solenoid valve is opened to support the anaerobic process.

Figure 9 Results of Fermentation Stage System Control Testing

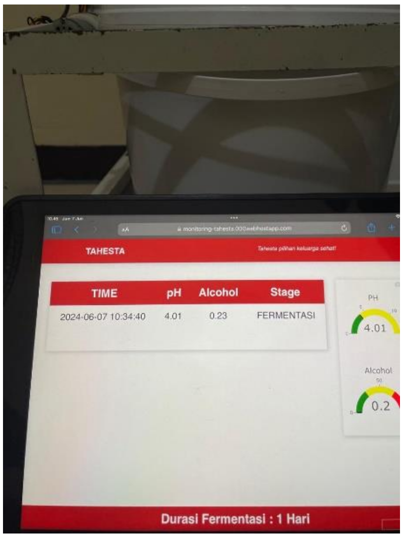

Figure 10 Results of Fermentation Stage System Monitoring Testing

On day 12 (June 18, 2024), the fermentation process entered the formulation stage. At this stage, acetic acid is added to the mixture to accelerate the conversion of alcohol into acetic acid. Figure 4.30 is the result of apple cider entering system control testing and Figure 4.31 is the result of system monitoring at the formulation stage. In the second stage, acetic acid bacteria (Acetobacter Aceti) convert alcohol into acetic acid (vinegar) through an oxidation process that requires oxygen.

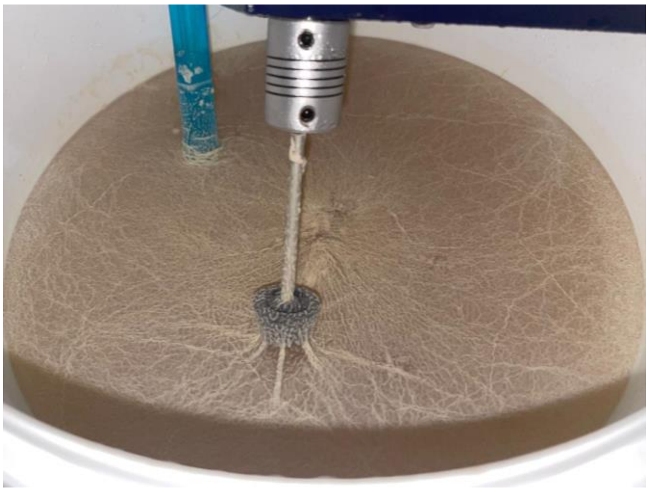

Figure 11 Results of Formulation Stage System Control Testing

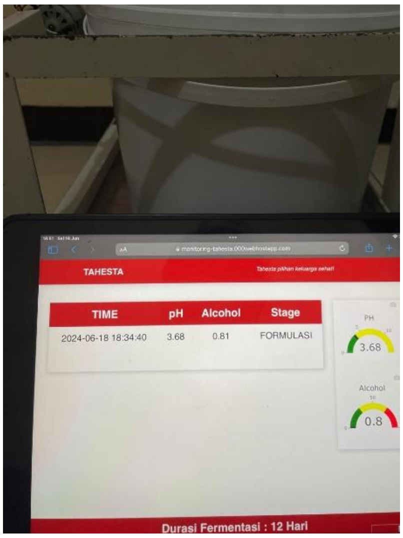

Figure 12 Results of Formulation Stage System Monitoring Testing

On day 13 (June 19, 2024), the mixing stage was carried out at medium speed. Mixing at this stage aims to ensure that the mixture between acetic acid and apple vinegar becomes homogeneous. The medium speed was chosen to ensure that the ingredients in the mixture were evenly mixed without damaging the structure of the microorganisms involved in the fermentation process. In addition, the ventilation solenoid opens to regulate the entry and exit of oxygen, which is essential to support the aerobic fermentation process by acetic acid bacteria. Figure 4.32 is the result of apple cider having entered the system control test and Figure 4.33 is the result of system monitoring at the 20 RPM mixing stage.

Figure 13 Results of Mixing 20 RPM Stage System Control Testing

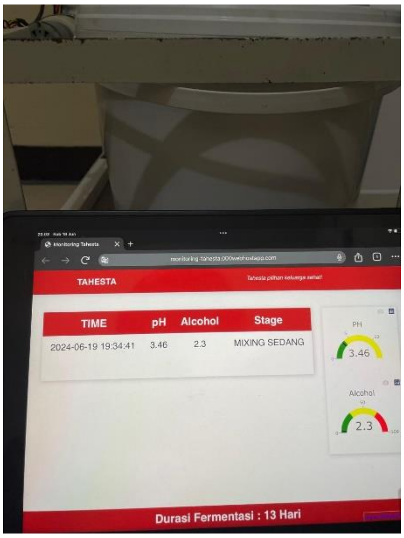

Figure 14 Results of Mixing 20 RPM Stage System Monitoring Testing

On day 17 (June 23, 2024), the slow mixing stage began. Mixing slowly is done to maintain the stability of the mixture as fermentation approaches the final stage and to avoid the formation of foam that can damage the quality of apple vinegar. Figure 4.34 is the result of apple cider entering the system control test and Figure 4.35 is the result of system monitoring at the slow mixing stage.

Figure 15 Results of Mixing 10 RPM Stage System Control Testing

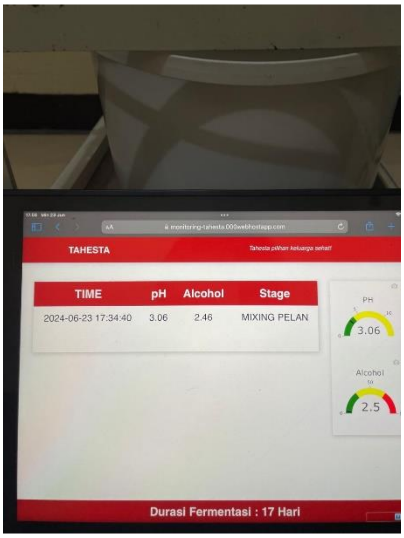

Figure 16 Results of Mixing 10 RPM Stage System Monitoring Testing

The last stage is the harvest stage which takes place on day 21 (June 27, 2024). At this stage, the fermentation of apple vinegar has been completed and the product is ready to proceed to the pasteurization process aimed at killing unwanted microorganisms and extending the shelf life of the product, ensuring that apple vinegar is safe for consumption. Figure 4.36 is the result of apple cider having entered the system control test and Figure 4.37 is the result of system monitoring at the harvest stage.

Figure 17 Results of Mixing Harvest Stage System Control Testing

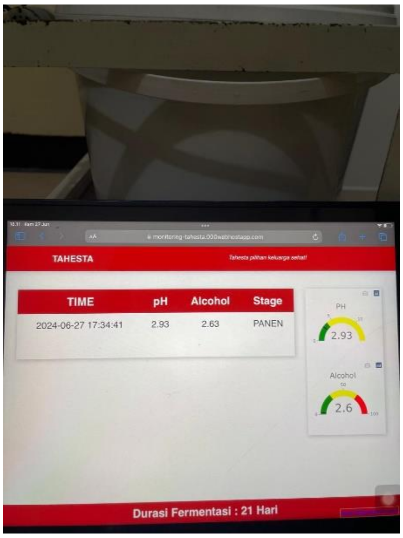

Figure 18 Results of Harvest Stage System Monitoring Testing

A recapitulation of the results of fermentation data collected at each stage, starting from the fermentation stage to harvesting, can be seen in Table 4.12 recapitulation of results, data was taken at intervals of every 6 hours for 21 days, resulting in a total of 87 data.

Table 5 Recapitulation of Fermentation Process Results

Waktu	Level pH	Kadar Alkohol	Tahap
10.30	3.97	0.12	Fermentasi
16.30	3.95	0.01	Fermentasi
22.30	4.00	0.26	Fermentasi
04.30	3.96	0.22	Fermentasi
10.30	4.00	0.23	Fermentasi
16.30	4.00	0.13	Fermentasi

22.30	4.00	0.17	Fermentasi
04.30	3.99	0.36	Fermentasi
10.30	3.99	0.37	Fermentasi
16.30	3.99	0.28	Fermentasi
22.30	4.00	0.17	Fermentasi
04.30	3.94	0.35	Fermentasi
10.30	3.93	0.33	Fermentasi
16.30	3.92	0.34	Fermentasi
22.30	3.91	0.34	Fermentasi
04.30	3.97	0.41	Fermentasi
10.30	3.91	0.35	Fermentasi
16.30	3.93	0.39	Fermentasi
22.30	3.96	0.33	Fermentasi
04.30	3.96	0.53	Fermentasi
10.30	3.94	0.48	Fermentasi
16.30	3.97	0.56	Fermentasi
22.30	3.93	0.47	Fermentasi
04.30	3.89	0.44	Fermentasi
10.30	3.92	0.52	Fermentasi
16.30	3.90	0.46	Fermentasi
22.30	3.93	0.56	Fermentasi
04.30	3.93	0.79	Fermentasi
10.30	3.90	0.74	Fermentasi
16.30	3.93	0.73	Fermentasi
22.30	3.93	0.70	Fermentasi
04.30	3.90	0.82	Fermentasi
10.30	3.93	0.80	Fermentasi
16.30	3.89	0.83	Fermentasi
22.30	3.91	0.82	Fermentasi
04.30	3.90	0.86	Fermentasi
10.30	3.93	0.85	Fermentasi
16.30	3.89	0.81	Fermentasi
22.30	3.91	0.79	Fermentasi

04.30	3.88	0.89	Fermentasi
10.30	3.86	0.88	Fermentasi
16.30	3.81	0.87	Fermentasi
22.30	3.75	0.86	Fermentasi
00.30	3.67	0.86	Fermentasi
02.30	3.68	0.87	Formulasi
04.30	3.76	0.88	Mixing 20 RPM
10.30	3.66	0.91	Mixing 20 RPM
16.30	3.50	0.89	Mixing 20 RPM
22.30	3.55	1.97	Mixing 20 RPM
04.30	3.48	2.23	Mixing 20 RPM
10.30	3.25	2.07	Mixing 20 RPM
16.30	3.28	2.32	Mixing 20 RPM
22.30	3.26	2.31	Mixing 20 RPM
04.30	3.46	2.17	Mixing 20 RPM
10.30	3.49	2.04	Mixing 20 RPM
16.30	3.26	2.37	Mixing 20 RPM
22.30	3.44	2.31	Mixing 20 RPM
04.30	3.41	2.08	Mixing 20 RPM
10.30	3.21	2.36	Mixing 20 RPM
16.30	3.40	2.37	Mixing 20 RPM
22.30	3.36	2.38	Mixing 20 RPM
04.30	3.09	2.27	Mixing 20 RPM
10.30	3.05	2.19	Mixing 20 RPM
16.30	3.06	2.21	Mixing 20 RPM
22.30	3.01	2.26	Mixing 20 RPM
04.30	3.09	2.27	Mixing 10 RPM
10.30	3.05	2.19	Mixing 10 RPM
16.30	3.06	2.21	Mixing 10 RPM
22.30	3.01	2.26	Mixing 10 RPM
04.30	3.12	2.42	Mixing 10 RPM
10.30	3.13	2.32	Mixing 10 RPM
16.30	3.00	2.48	Mixing 10 RPM

22.30	3.12	2.51	Mixing 10 RPM
04.30	3.15	2.36	Mixing 10 RPM
10.30	3.08	2.30	Mixing 10 RPM
16.30	3.21	2.37	Mixing 10 RPM
22.30	3.12	2.40	Mixing 10 RPM
04.30	2.98	2.47	Mixing 10 RPM
10.30	3.01	2.42	Mixing 10 RPM
16.30	3.01	2.52	Mixing 10 RPM
22.30	3.08	2.39	Mixing 10 RPM
04.30	2.99	2.58	Mixing 10 RPM
10.30	2.99	2.48	Mixing 10 RPM
16.30	2.99	2.51	Mixing 10 RPM
22.30	2.99	2.39	Mixing 10 RPM
04.30	2.94	2.50	Mixing 10 RPM
07.30	2.93	2.63	Panen

Discussion

In the fermentation stage, it can be seen that on the first day, the system test results showed pH 4.01 and 0.23% alcohol, while the industry data showed pH 4.00 and 0% alcohol. Until the eleventh day, the data trend showed that the pH of the system test results tended to be lower than the industry data, while the alcohol content of the system test results was generally higher. On the ninth day, the system test data showed pH 3.82 and alcohol 0.86%, while the industry data showed pH 3.70 and alcohol 0.80%.

At the formulation stage, the system test data on day 12 showed pH 3.68 and alcohol 0.81%, while the industry data on day 13 showed pH 3.70 and alcohol 0.90%. At the medium mixing stage, the system test data on day 13 showed pH 3.46 and alcohol 2.30%, while the industry data on day 14 showed pH 3.50 and alcohol 2.20%. At the slow mixing stage, system test data on day 17 shows pH 3.06 and alcohol 2.46%, while industry data on day 18 shows pH 3.00 and alcohol 2.40%. At harvest stage, the system test data on day 21 showed pH 2.93 and alcohol 2.63%, while the industry data on day 23 showed pH 2.90 and alcohol 2.60%.

4. CONCLUSION

The implementation of the fuzzy method in the apple cider vinegar fermentation process control system was successfully integrated. The fuzzy method is used to regulate input variables such as pH and alcohol, with outputs in the form of solenoid valve control and mixing motor. The fuzzy system is able to make precise decisions based on uncertain input variables, thus supporting an optimal and consistent fermentation process.

The prototype of the apple cider vinegar fermentation process monitoring and control system based on the fuzzy method and IoT demonstrated high efficiency. This system allows for a reduction in fermentation time by 2 days faster compared to conventional methods. Additionally, efficiency is also seen in the ease of remote monitoring, where users can monitor and control the fermentation process from different locations, reducing the need for direct intervention.

The apple cider vinegar fermentation process monitoring and control system based on the MQTT protocol was successfully used in real-time. The MQTT protocol allows for fast and reliable data transmission with very low latency. This ensures that any changes in fermentation parameters such as pH and alcohol can be immediately responded to by the system, thereby maintaining the stability and quality of the apple cider vinegar fermentation.

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