Design of a Cashless Vending Machine System for the Distribution and Conservation of Traditional Herbal Medicine

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***Abstract*—Indonesia, as a center of biodiversity, plays a significant role in preserving various plant species, including approximately 28,000 plant varieties and 7,500 medicinal plant species, representing 10% of the global total. Indonesians have long relied on traditional herbal remedies derived from wild plants, with jamu being one of the most prominent products. However, the market penetration and accessibility of traditional jamu remain limited. This research proposes the implementation of a vending machine with a cashless payment system to improve accessibility and promote the preservation of traditional jamu. The vending machine provides six jamu variants and three water temperature options, utilizing a cashless payment system integrated with an ESP-32 and Arduino MEGA 2560 microcontroller. The system incorporates the Midtrans payment gateway with a dedicated website to support seamless cashless transactions. Test results show that the vending machine dispenses jamu with an average weight of 219.81 g, yielding an error margin of 1.18% from the 220 g setpoint. The average brewing time is 93.7 seconds, with water temperature aligning with user preferences. Cashless payment testing achieved a 100% success rate, demonstrating the system's effectiveness.**

Keywords— traditional jamu, vending machine, payment gateway, ESP-32, Arduino MEGA 2560

I. INTRODUCTION

Indonesia is one of the twelve global centers of biodiversity, as it lies within the vast Indomalayan biogeographic realm [1]. The country is home to around 28,000 plant varieties, including approximately 400 edible fruit types, which contribute significantly to genetic diversity for breeding programs. Additionally, Indonesia is rich in medicinal plant species, with an estimated 7,500 species—representing roughly 10% of the world's medicinal plants. Despite this, only about 940 species have been formally identified to date.

Indonesian communities have long utilized various traditional medicinal ingredients, with approximately 1,000 types in use. Of these, around 74% are sourced from wild plants growing abundantly in forests. Jamu, a traditional Indonesian herbal drink, is part of the nation's cultural heritage, commonly used for maintaining health and aiding in healing processes, and is classified as a traditional medicine [3]. However, challenges arise as growing demand for jamu is not matched by sales growth, largely due to conventional sales methods—typically through door-to-door vendors [4]. Low market penetration and limited accessibility hinder the realization of jamu's full market potential. Therefore, modernization of jamu marketing strategies is necessary to expand market reach and make products more accessible to the public.

The objective of this study is to design a vending machine with a cashless payment system to enhance accessibility and support the preservation of traditional jamu, while simultaneously preserving local culture in the digital age. The vending machine is developed as an automated system that allows users to obtain jamu beverages without direct interaction with sellers, using self-service selection and payment [5]. Fundamentally, a vending machine is an electromechanical device that automatically dispenses goods after receiving user input for payment and selection [6]. In this study, the vending machine incorporates a cashless payment system based on QRIS (Quick Response Code Indonesian Standard), a contactless payment method that consolidates various digital payment channels in Indonesia into a single standardized QR code established by Bank Indonesia [7].

The machine is designed to offer six traditional jamu variants: beras kencur, jahe merah, kunyit asam, temulawak, sinom, and kunci sirih. These six variants are selected based on herbal literature in Indonesia and are commonly consumed for health and wellness [8]. The system also provides three water temperature options—warm, room temperature, and cold—tailored to user preferences and in accordance with typical herbal beverage comfort standards [9].

From a technical perspective, the system employs the ESP-32 as an internet communication controller and the Arduino Mega 2560 as the hardware control unit. Cashless payment integration is achieved via the Midtrans payment gateway, connected to a website used for real-time transaction validation. The entire system is designed to facilitate convenient transactions and enable users to select their preferred jamu variant and water temperature automatically and efficiently.

II. MATERIALS AND METHODS

This section presents the components and methodology related to the block diagram of the traditional jamu vending machine system, including the hardware design, software design, mechanical design, and formulation of powdered jamu composition.

A. Vending Machine Block Diagram

The following is the block diagram of the traditional herbal drink vending machine system that will be implemented in this research [10][11].

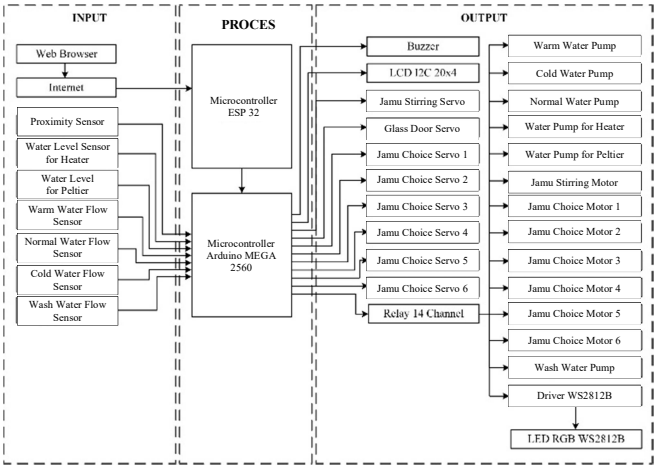

Figure 1. Vending Machine Block Diagram

As shown in Figure 1, the Arduino Mega 2560 microcontroller functions as the main controller of the entire system and is integrated with the ESP32, which involves a web server as the user interface to facilitate input and display the menu on the vending machine. In the input block, there are water flow sensors that monitor the flow rate of hot water, cold water, and regular water, which are dispensed into the herbal drink glass. In the output section, there are actuators such as a buzzer that provides notifications when the vending machine door is opened—either for inserting a cup or for retrieving the cup that has been filled with herbal drink. A 20x4 LCD serves as an informative visual interface, offering detailed insights into the herbal drink selection and preparation process for the user. The relay module controls the granule powder feeder motors corresponding to the buyer's selected herbal drink, ranging from the first to the sixth menu option. Thus, the integration of all these components not only creates an efficient traditional herbal drink vending machine, but also delivers ready-to-consume herbal drinks to the user.

B. *Hardware Design*

a) Water Flow Sensor Circuit Diagram

The following figure shows the circuit diagram between the Arduino MEGA 2560 microcontroller and the water flow sensor.

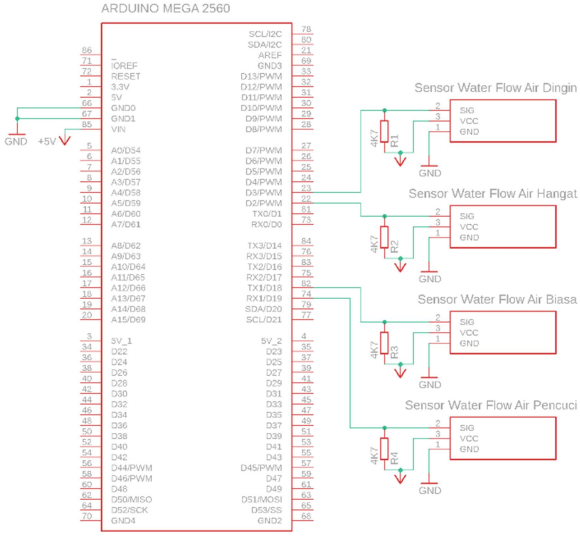

Figure 2. Water Flow Circuit Diagram

The water flow sensor in the vending machine plays a vital role in measuring the water output discharged by the water pump. The water flow sensors are connected to pins D2, D3, D18, and D19 on the Arduino MEGA 2560 microcontroller, as shown in Figure 2.

b) Servo Motor Circuit Diagram for Herbal Powder Valve Actuation

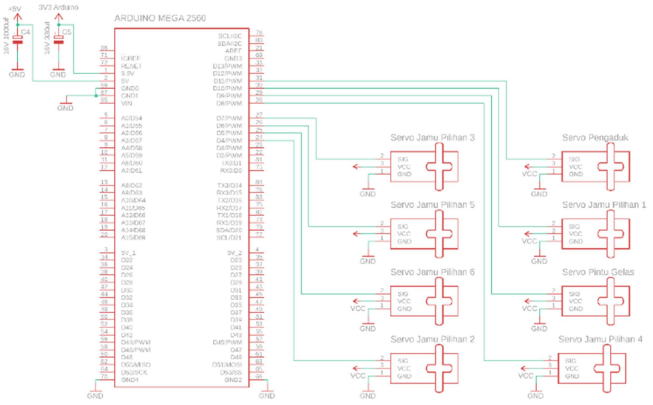

Figure 5. Servo Motor Circuit Diagram

The servo components used in the traditional herbal medicine vending machine function as controllers to open and close the powdered herbal medicine valves. The connections to the Arduino Mega 2560 are as follows: servo for herbal menu 1 is connected to pin D10, menu 2 to pin D4, menu 3 to pin D7, menu 4 to pin D8, menu 5 to pin D6, and menu 6 to pin D5, as shown in Figure 5.

c) Water Pump Circuit Diagram

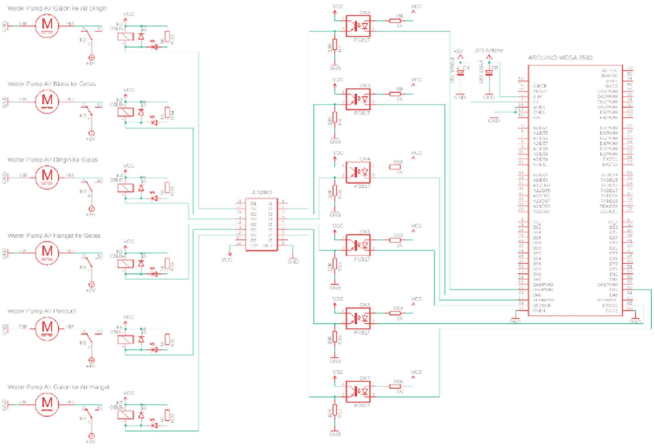

Figure 6. Water Pump Circuit Diagram

Figure 6 above illustrates the circuit diagram between the Arduino MEGA 2560 microcontroller and the water pumps. The water pumps in the traditional herbal medicine vending machine function to deliver hot, cold, and regular water into the herbal drink cup. The connection configuration is as follows: the hot water pump is connected to pin D52, the cold water pump to pin D50, and the regular water pump to pin D48.

C. *Software Design*

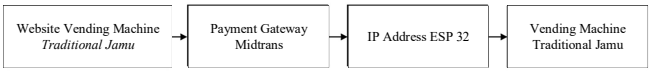

Figure 7. Software Design Block Diagram

In the software design of this study, users access a website dedicated to displaying various herbal medicine menus and prices on the traditional herbal medicine vending machine. After the user makes a selection, the system automatically generates a cashless payment bill in the form of a QR code. This bill uses Midtrans as the payment gateway service provider. In this case, Midtrans acts as the distributor of the QRIS code created by PTEN (PT Penyelesaian Transaksi Elektronik Nasional). Once the payment is successfully processed through Midtrans, the system receives feedback and automatically redirects the user to the ESP32 web server, where the selected menu is sent as a signal to the Arduino MEGA 2560 to process and serve the herbal medicine according to the order.

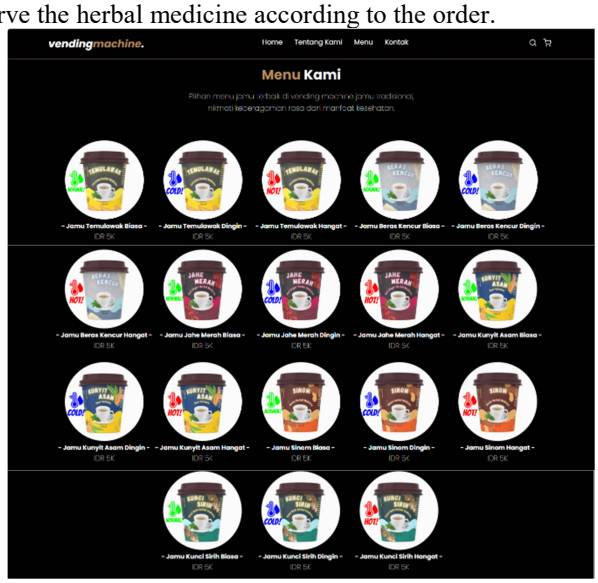

Figure 8. Herbal Medicine Menu Design on the Vending Machine Website

D. *Mechanical Design*

The following is the mechanical design of the traditional herbal medicine vending machine as shown in Figure 9, Figure 10, and Figure 11.

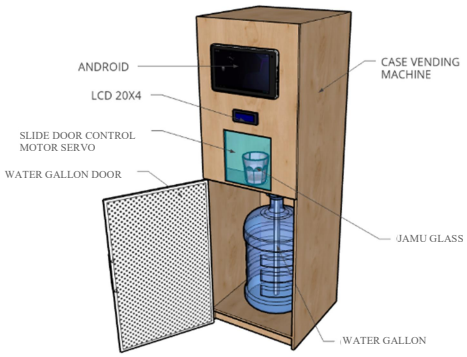

Figure 9. Front View of the Vending Machine Design

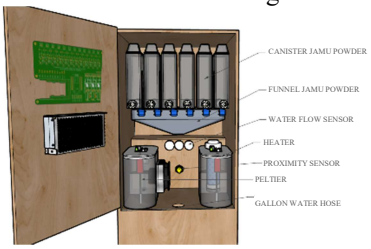

Figure 10. Rear View of Component Design

Next, Figure 11 provides information about the dimensions or size of the traditional herbal medicine vending machine.

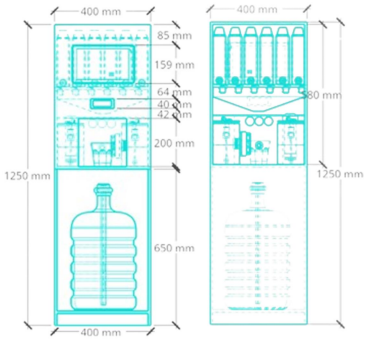

Figure 11. Vending Machine Design Dimensions

E. *Herbal Powder Composition*

The brewing process of herbal medicine in the traditional herbal medicine vending machine is performed automatically, starting with mixing the herbal powder with the selected water in a ready-to-serve glass [12]. To achieve an optimal brewing level, the composition of herbal powder in each glass is regulated according to the measurements listed in Table 1 below [13][14][15].

TABLE I. GELAS POWDER COMPOSITION IN EACH GLASS

No.	Herbal Medicine Type	Composition	Reference
1	Temulawak	5 grams	Decree of the Minister of Health of the Republic of Indonesia No. HK.01.07/MENKES/187/2017
2	Beras Kencur	5 grams	Decree of the Minister of Health of the Republic of Indonesia No. HK.01.07/MENKES/187/2017
3	Jahe Merah	6 grams	Decree of the Minister of Health of the Republic of Indonesia No. HK.01.07/MENKES/187/2017
4	Kunyit Asam	5 grams	Decree of the Minister of Health of the Republic of Indonesia No. HK.01.07/MENKES/187/2017
5	Sinom	4 grams	Dr. Nies Endang Mangunkusumo, 2021
6	Kunci Sirih	5 grams	Regulation of the Minister of Health of the Republic of Indonesia No. 6 of 2016

III. RESULTS AND DISCUSSION

This section presents the results of the device implementation, calibration, and testing of both hardware and software in the traditional herbal medicine vending machine.

A. *Device Design Results*

Figure 12. Traditional Herbal Medicine Vending Machine

After a comprehensive device design process, the result is a traditional herbal medicine vending machine. The following is an image of the vending machine design shown in Figure 12.

B. Calibration Testing of the YF-S401 Water Flow Sensor

YF-S401 water flow sensor is used to measure the volume of water dispensed during the brewing process of herbal medicine in the traditional herbal medicine vending machine. In this test, the YF-S401 sensor detects the flow of water into the glass, including warm water, cold water, regular water, and the water flow to the herbal medicine mixer. The purpose of this test is to evaluate the accuracy and effectiveness of the sensor in detecting water flow according to the predetermined setpoints. The testing was conducted 50 times. The YF-S401 sensor test includes three types of water flow: warm water, regular water, and cold water.

Figure 13. *Water Flow Sensor YF-S401 for Vending Machine*

TABLE II. FLOW SENSOR CALIBRATION TEST RESULTS

No.	Setpoint Value	Test Result	Difference	Error (%)	Time
1	170 ml	168 ml	2 ml	1,18 %	12159 ms
2	170 ml	170 ml	0 ml	0,00 %	12448 ms
3	170 ml	170 ml	0 ml	0,00 %	12647 ms
4	170 ml	170 ml	0 ml	0,00 %	12691 ms
5	170 ml	170 ml	0 ml	0,00 %	12741 ms
6	170 ml	171 ml	1 ml	0,59 %	12497 ms
7	170 ml	169 ml	1 ml	0,59 %	12350 ms
8	170 ml	169 ml	1 ml	0,59 %	12449 ms
9	170 ml	169 ml	1 ml	0,59 %	12396 ms
10	170 ml	169 ml	1 ml	0,59 %	12587 ms
11	170 ml	169 ml	1 ml	0,59 %	12590 ms
12	170 ml	170 ml	0 ml	0,00 %	12545 ms
13	170 ml	170 ml	0 ml	0,00 %	12545 ms
14	170 ml	170 ml	0 ml	0,00 %	12967 ms
15	170 ml	170 ml	0 ml	0,00 %	12753 ms
16	170 ml	167 ml	3 ml	1,76 %	12680 ms
17	170 ml	169 ml	1 ml	0,59 %	12636 ms
18	170 ml	169 ml	1 ml	0,59 %	12584 ms
19	170 ml	169 ml	1 ml	0,59 %	12593 ms
20	170 ml	169 ml	1 ml	0,59 %	12673 ms
21	170 ml	170 ml	0 ml	0,00 %	12646 ms
22	170 ml	170 ml	0 ml	0,00 %	12735 ms
23	170 ml	169 ml	1 ml	0,59 %	12594 ms
24	170 ml	169 ml	1 ml	0,59 %	12836 ms
25	170 ml	168 ml	2 ml	1,18 %	12847 ms
26	170 ml	169 ml	1 ml	0,59 %	12689 ms
27	170 ml	169 ml	1 ml	0,59 %	12734 ms
28	170 ml	170 ml	0 ml	0,00 %	12765 ms
29	170 ml	170 ml	0 ml	0,00 %	12893 ms
30	170 ml	170 ml	0 ml	0,00 %	12654 ms
31	170 ml	170 ml	0 ml	0,00 %	12914 ms
32	170 ml	170 ml	0 ml	0,00 %	12837 ms
33	170 ml	169 ml	1 ml	0,59 %	12573 ms
34	170 ml	170 ml	0 ml	0,00 %	12643 ms
35	170 ml	169 ml	1 ml	0,59 %	12773 ms
36	170 ml	170 ml	0 ml	0,00 %	12683 ms
37	170 ml	170 ml	0 ml	0,00 %	12434 ms
38	170 ml	170 ml	0 ml	0,00 %	12650 ms
39	170 ml	170 ml	0 ml	0,00 %	12918 ms
40	170 ml	170 ml	0 ml	0,00 %	12801 ms
41	170 ml	170 ml	0 ml	0,00 %	12921 ms
42	170 ml	169 ml	1 ml	0,59 %	12593 ms
43	170 ml	170 ml	0 ml	0,00 %	12386 ms
44	170 ml	170 ml	0 ml	0,00 %	12843 ms
45	170 ml	169 ml	1 ml	0,59 %	12924 ms
46	170 ml	169 ml	1 ml	0,59 %	13032 ms
47	170 ml	170 ml	0 ml	0,00 %	13014 ms
48	170 ml	170 ml	0 ml	0,00 %	13210 ms
49	170 ml	170 ml	0 ml	0,00 %	12763 ms
50	170 ml	170 ml	0 ml	0,00 %	12947 ms
Average		169,52 ml	0,52 ml	0,31 %	12695,66 ms

The table above shows the error percentage of the water flow sensor measurement, which is 0.31%. The slight error is due to residual flow from the water pump after it is turned off. This indicates that the water flow sensor has a high level of accuracy in measuring the water flow rate used in the vending machine system

C. Calibration Testing of the Servo Motor Driving the Herbal Powder Valve

In this test, the servo motor acting as a valve cover actuator moves to adjust the valve position of the herbal powder container according to a predetermined angle. The valve cover test using the servo motor was conducted 50 times. This test involved measuring the angle produced by the servo motor movement based on a setpoint of 90°, as well as recording the time required by the servo motor to open the herbal powder valve cover.

Figure 14. Testing of the Herbal Powder Valve in the Vending Machine

TABLE III. SERVO MOTOR CALIBRATION TEST RESULTS

No	Setpoint Angle	Protractor Angle	Difference	Error (%)	Movement Time
1	90°	83°	7°	7,78	78 ms
2	90°	83°	7°	7,78	79 ms

No	Setpoint Angle	Protractor Angle	Difference	Error (%)	Movement Time
3	90°	83°	7°	7,78	77 ms
4	90°	83°	7°	7,78	78 ms
5	90°	83°	7°	7,78	80 ms
6	90°	88°	2°	2,22	78 ms
7	90°	88°	2°	2,22	79 ms
8	90°	89°	1°	1,11	78 ms
9	90°	88°	2°	2,22	79 ms
10	90°	87°	3°	3,33	80 ms
11	90°	87°	3°	3,33	78 ms
12	90°	88°	2°	2,22	79 ms
13	90°	88°	2°	2,22	77 ms
14	90°	88°	2°	2,22	79 ms
15	90°	87°	3°	3,33	79 ms
16	90°	88°	2°	2,22	78 ms
17	90°	87°	3°	3,33	78 ms
18	90°	88°	2°	2,22	81 ms
19	90°	87°	3°	3,33	78 ms
20	90°	87°	3°	3,33	77 ms
21	90°	88°	2°	2,22	79 ms
22	90°	88°	2°	2,22	79 ms
23	90°	88°	2°	2,22	80 ms
24	90°	88°	2°	2,22	78 ms
25	90°	87°	3°	3,33	78 ms
26	90°	88°	2°	2,22	79 ms
27	90°	87°	3°	3,33	80 ms
28	90°	87°	3°	3,33	78 ms
29	90°	86°	4°	4,44	79 ms
30	90°	88°	2°	2,22	78 ms
31	90°	88°	2°	2,22	78 ms
32	90°	83°	7°	7,78	77 ms
33	90°	83°	7°	7,78	81 ms
34	90°	83°	7°	7,78	80 ms
35	90°	83°	7°	7,78	78 ms
36	90°	84°	6°	6,67	79 ms
37	90°	83°	7°	7,78	78 ms
38	90°	83°	7°	7,78	79 ms
39	90°	82°	8°	8,89	79 ms
40	90°	83°	7°	7,78	77 ms
41	90°	83°	7°	7,78	81 ms
42	90°	83°	7°	7,78	79 ms
43	90°	83°	7°	7,78	80 ms
44	90°	82°	8°	8,89	78 ms
45	90°	82°	8°	8,89	80 ms
46	90°	83°	7°	7,78	78 ms
47	90°	83°	7°	7,78	78 ms
48	90°	83°	7°	7,78	81 ms
49	90°	83°	7°	7,78	79 ms
50	90°	85°	5°	5,56	78 ms
Average		85,4°	4,60°	5,11	78,72 ms

From Table III above, it can be seen that the error percentage of the herbal powder valve angle on the servo motor compared to the actual valve angle measured using a conventional protractor is 5.11%, meaning the servo angle accuracy rate is 94.88%. This indicates that the servo motor performs precisely in controlling the herbal powder valve angle, with a deviation level suitable for non-critical mechanical applications such as vending machines.

D. Overall System Testing

In the overall testing, the data collected include measurements of the brewed herbal medicine weight, the time required during the brewing process, and the temperature of the brewed herbal medicine. The purpose of this testing is to determine the quality of the brewed herbal drink from the traditional herbal medicine vending machine based on weight, brewing duration, and resulting temperature.

TABLE IV. OVERALL SYSTEM TEST RESULTS

Jamu Choice	Water Choice	Setpoint Weight (g)	Actual Weigh t (g)	Diff (g)	Error (%)	Time (ms)	Temp (°C)
Temu lawak	Normal	220	215	5	2,27	96531	34,3
		220	217	3	1,36	94157	34,3
		220	216	4	1,82	93730	34,9
	Cold	220	225	5	2,27	95514	21,1
		220	220	0	0,00	92951	21,6
		220	220	0	0,00	93313	21,3
	Warm	220	226	6	2,73	91516	61,3
		220	224	4	1,82	94923	58,8
		220	219	1	0,45	91407	58,6
Beras Kencur	Normal	220	218	2	0,91	91698	34,6
		220	221	1	0,45	94479	34,7
		220	223	3	1,36	92491	35,2
	Cold	220	217	3	1,36	93346	21,8
		220	219	1	0,45	95848	20,9
		220	218	2	0,91	92074	21,5
	Warm	220	222	2	0,91	92154	61,1
		220	222	2	0,91	93250	61,5
		220	221	1	0,45	95275	60,3
Jahe Merah	Normal	220	220	0	0,00	91917	34,1
		220	217	3	1,36	95335	34,9
		220	215	5	2,27	95878	34,8
	Cold	220	219	1	0,45	94947	21,9
		220	219	1	0,45	93881	21,9
		220	220	0	0,00	94351	20,9
	Warm	220	223	3	1,36	91853	61,3
		220	225	5	2,27	94533	62,3
		220	225	5	2,27	94024	62,3
Kunyit Asam	Normal	220	221	1	0,45	94805	34,6
		220	219	1	0,45	95316	34,9
		220	215	5	2,27	91939	34,8
	Cold	220	215	5	2,27	91494	20,3
		220	217	3	1,36	96390	21,8
		220	218	2	0,91	93883	21,6
	Warm	220	222	2	0,91	93301	60,4
		220	222	2	0,91	91773	59,5
		220	223	3	1,36	93909	60,2
Sinom	Normal	220	220	0	0,00	94464	34,8
		220	222	2	0,91	94422	34,9
		220	221	1	0,45	92062	34,9
	Cold	220	213	7	3,18	94687	21,6
		220	225	5	2,27	95808	21,9
		220	219	1	0,45	96018	21,7
	Warm	220	223	3	1,36	92409	62,5
		220	215	5	2,27	93147	60,5
		220	215	5	2,27	96476	59,8
Kunci Sirih	Normal	220	222	2	0,91	92301	34,7
		220	219	1	0,45	92527	34,6
		220	222	2	0,91	93564	34,6
	Cold	220	222	2	0,91	93525	20,4
		220	215	5	2,27	92648	21,1
		220	222	2	0,91	91614	21,3
	Warm	220	219	1	0,45	93950	61,5
		220	217	3	1,36	92896	60,1
		220	221	1	0,45	92838	61,5
Average			219,81	2,59	1,18	93695,2	

From Table IV above, it can be seen that the average weight of the brewed herbal medicine is 219.81 grams, with a set point of 220 grams. This result indicates a small error percentage of 1.18%, demonstrating that the control system of the developed vending machine operates accurately. Furthermore, the average brewing time is 93.7 seconds, indicating that the machine operates efficiently and consistently in completing one serving cycle of the herbal drink.

The following presents the test results of cashless payment transactions during the comprehensive testing of the traditional herbal medicine vending machine.

TABLE V. CASHLESS PAYMENT TEST RESULTS

No	Order ID	Product Name	Price	Jamu ID	Transaction Status
1	1389753847	Kunci Sirih	12.000	6	*settlement*
2	45867015	Kunci Sirih	12.000	6	*settlement*
3	1753312488	Kunci Sirih	12.000	6	*settlement*
4	315550264	Kunci Sirih	12.000	6	*settlement*
5	1594147197	Kunci Sirih	12.000	6	*settlement*
6	472844856	Kunci Sirih	12.000	6	*settlement*
7	182128009	Kunci Sirih	12.000	6	*settlement*
8	2095650820	Kunci Sirih	12.000	6	*settlement*
9	1524997245	Kunci Sirih	12.000	6	*settlement*
10	1717740087	Sinom	12.000	5	*settlement*
11	195506745	Sinom	12.000	5	*settlement*
12	2011393044	Sinom	12.000	5	*settlement*
13	1603999329	Sinom	12.000	5	*settlement*
14	545372813	Sinom	12.000	5	*settlement*
15	465421636	Sinom	12.000	5	*settlement*
16	356628220	Sinom	12.000	5	*settlement*
17	885945869	Sinom	12.000	5	*settlement*
18	1514787672	Sinom	12.000	5	*settlement*
19	553796800	Kunyit Asam	12.000	4	*settlement*
20	1437005731	Kunyit Asam	12.000	4	*settlement*

From Table V above, it can be seen that the entire cashless payment process—from menu selection to payment confirmation on the payment gateway dashboard—was completed successfully without any issues. The settlement condition in the data refers to the transaction completion process, where funds from the buyer were successfully transferred to the seller through the Midtrans payment gateway, indicating that the transaction was successful with a 100% success rate.

IV. CONCLUSION

Based on the testing results described above, the following conclusions can be drawn regarding the design of a cashless vending machine system for the distribution and preservation of traditional herbal medicine:

1. This research has successfully designed a vending machine system with a cashless payment method.
2. The testing of the YF-S401 water flow sensor showed an average error rate of 0.31% and an accuracy of 99.69%. These results indicate that the water flow sensor has a high level of accuracy in measuring the water flow rate used in the vending machine system.
3. The testing of the servo motor for the herbal powder valve showed an average angle of 85.4° with a servo motor angle error of 5.11% and an angle accuracy of 94.89%. These results indicate that the servo motor performs precisely in controlling the valve angle for the herbal powder in the vending machine.
4. The overall system testing of the vending machine produced consistent results, with the average brewed traditional herbal medicine weight being 219.81 g, and an error rate of 1.18% from the 220 g setpoint. The average brewing time was 93,695.22 ms or 1 minute and 33 seconds, with the resulting water temperature meeting the required category. The system successfully met the defined parameters with a high success rate.
5. The cashless payment testing on the traditional herbal medicine vending machine using the Midtrans payment gateway was 100% successful, with 50 transactions completed without issues.

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