Innovative Development of a Dual-Mode Herbal Foot Spa Prototype with Temperature Regulation and Time Control

Saksri Kaensom[1], Parichart Kaensom[1], Natthawat Woranetsuttikul[1],
Thanyapob Sirimaskasem[1], Kedsara Palachai[2] and Promphak Boonraksa[3]

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Abstract

This research aims to design and develop an herbal foot spa machine using local resources for the Khao Na Tat Community Enterprise Group, Village No. 12. The focus is on developing a temperature and operating time control system, as well as evaluating the performance of the developed prototype. The developed foot spa machine has two operating modes: Mode 1 operates at a temperature range of 36–38 degrees Celsius for 15 minutes, and Mode 2 allows setting a target temperature of 37 degrees Celsius for 15 minutes. The prototype's basin is designed for optimal use, with a base measuring 21 cm wide, 29 cm. long, and 20 cm. high, and a top measuring 31 cm. wide and 40 cm. long, with 6 mm. hot diameter and cold-water pipe connections for water circulation. Temperature control testing showed that Mode 1 achieved a maximum average temperature of 37.85 degrees Celsius and a minimum average temperature of 36.00 degrees Celsius, while Mode 2 achieved a maximum average temperature of 37.19 degrees Celsius and a minimum average temperature of 37.00 degrees Celsius. The results demonstrate that the developed foot spa machine maintains stable temperature control as designed and has the potential for practical application at the community level.

Keywords: Herbal foot spa machine, Temperature control system, Engineering prototype

[1]Faculty of Industrial Technology, Phranakhon Rajabhat University, 9 Changwattana Road, Bang Khen, Bangkok, Thailand, 10220.

[2]Department of Electrical Engineering, Faculty of Engineering, Bangkokthonburi University, Bangkok, Thailand, 10170.

[3]Department of Mechatronics Engineering, Faculty of Engineering and Architecture, Rajamangala University of Technology Suvarnabhumi, Nonthaburi, Thailand, 11000.

***Corresponding author email:** promphak.b@rmutsb.ac.th

Introduction

Ban Khao Na Tat, Village No. 12, located in Lam Narai Subdistrict, Chai Badan District, Lopburi Province, is a community rich in locally available medicinal herbs such as turmeric, Jaeng leaves, butterfly pea, lemongrass, aloe vera, Phyllanthus emblica, Plai, and other traditional Thai herbs (Kaensom et al., 2020, Kaensom et al., 2024, Faculty of Pharmacy, Ubon Ratchathani University, 2024, Kaensom et al., 2025). These herbal resources have been utilized by the Ban Khao Na Tat Community Enterprise Group to generate local income through traditional health-related practices (Praekha, 2014). One such practice is herbal foot spa treatment, which applies local wisdom by soaking feet in warm water infused with medicinal herbs (Thatsanara-phan et al., n.d., Nuthim et al., 2022, Sukchai, 2025).

Traditional herbal foot spa practices generally rely on manual preparation methods, including mixing hot and cold water in a basin to achieve the desired soaking temperature. Although this approach is widely used, it presents several engi-neering limitations, such as the inability to maintain a stable water temperature, lack of precise time control, inconsistent water levels, and potential electrical safety risks when heating elements are used near water. Previous studies have reported recommended temperature ranges for foot soaking between 36–40 °C and soaking durations of 10–30 minutes; however, most existing methods do not provide automated temperature regulation or standardized operating conditions (Primus Thai, 2019, Vejthani International Hospital, n.d., Susetyo et al., 2024).

To address these limitations, this research focuses on the design and development of an herbal foot spa system with an automated temperature and time control mechanism suitable for community-level applications. The proposed system integrates a temperature sensing unit with a microcontroller-based control system to regulate heat transfer from a boiler to the foot spa basin. A controlled water circulation mechanism is employed to release excess water and maintain a stable temperature within the basin. The system is designed to operate in two modes: Mode 1 maintains a temperature range of 36–38 °C with a fixed operating time of 15 minutes, while Mode 2 allows users to set the temperature between 36–40 °C and the soaking duration from 10–30 minutes (Siriprasert & Konghin, 2022,Yuthavornwit, 2023, Maxim Integrated, n.d., Physical Balance Solution, 2023, Omkar et al., 2024).

In addition to performance considerations, electrical safety is a critical design requirement. The developed system incorporates electrical isolation between the power supply and the water containing components, reducing the risk of electrical hazards during operation. The proposed herbal foot spa machine therefore represents an engineering-based solution that combines local herbal resources with automated control technology, providing a safe, stable, and standardized foot spa system for practical use by the Ban Khao Na Tat Community Enterprise Group.

Objectives

1. To design and develop an herbal foot spa system using locally available medicinal herbs for promoting health within the Ban Khao Na Tat Community Enterprise Group, Village No. 12, Lam Narai Subdistrict, Chai Badan District, Lopburi Province.

2. To evaluate the performance of the developed herbal foot spa system in terms of temperature control, time regulation, and operational effectiveness for community-level applications.

Conceptual Framework

This research focuses on developing a foot spa device using local herbs to promote health for the community enterprise group in Ban Khao Na Tat, Village No. 12, Lam Narai Subdistrict, Chai Badan District, Lopburi Province. The device has two modes: Mode 1 operates at 36-38 degrees Celsius for a 15-minute foot soak, and Mode 2 allows for temperature settings from 36-40 degrees Celsius and a soaking time of 10-30 minutes. Safety is ensured through the separation of the electrical and water systems for the foot spa process.

Research methodology

The development of an herbal foot spa machine using locally available medicinal herbs for promoting health in the Ban Khao Na Tat Community Enterprise Group, Village No. 12, employed an experimental research approach. The objectives were to develop an herbal foot spa machine using local medicinal herbs for promoting health in the Ban Khao Na Tat Community Enterprise Group, Village No. 12, and to test the performance of the developed herbal foot spa machine.

A. Development of a herbal foot spa machine

1. Structural design of the foot spa machine

The base of the foot spa basin is made of plastic, with a width of 21 cm, a length of 29 cm, and a height of 20 cm. The upper part of the basin has a width of 31 cm and a length of 40 cm. The top cover is made of plastic and includes openings for connecting a hot water inlet pipe and discharging cold water from the basin to the outside, with a pipe diameter of 6 mm, as shown in Figure 1.

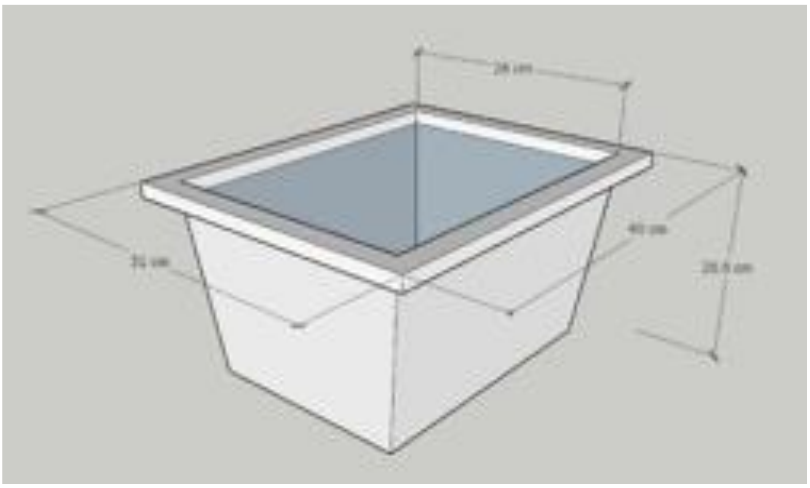

Figure 1: Designing the base structure of a foot spa basin

In addition, the top cover includes openings for connecting a hot water inlet pipe and discharging cold water from the basin to the outside, with a pipe diameter of 6 mm. It also Includes an opening for installing a temperature sensor on the upper side, as well as an opening for foot insertion with a width of 27 cm, as shown in Figure 2.

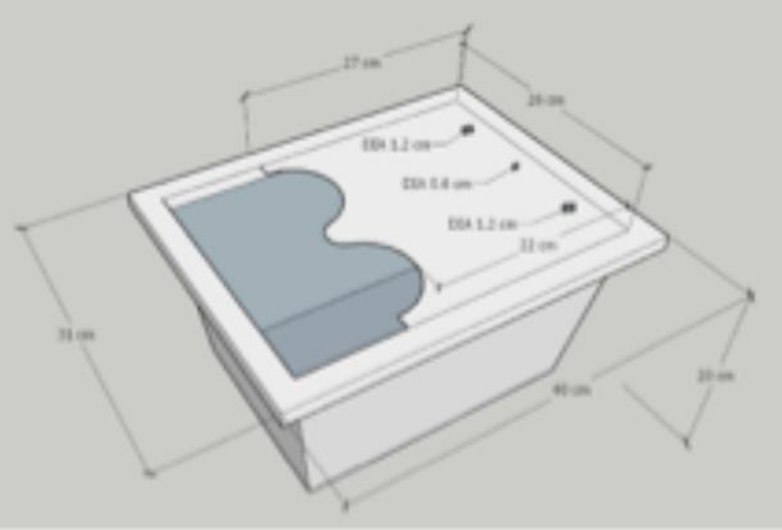

Figure 2: The structural design of the upper foot spa basin.

2. Structural design of the heating unit and foot spa system

The boiler used for water storage has a diameter of 22 cm and a height of 22 cm, with an additional height of 10 cm allocated for installing the heating coil, resulting in a total height of 32 cm. The upper part of the boiler includes an opening for pipe installation to transfer hot water from the boiler to the foot spa basin for controlling the water temperature inside the basin. A 6 mm heat-resistant pipe is connected to the first high-temperature water pump to draw heated water from the boiler and transfer thermal energy to the basin for temperature control. In addition, a 6 mm heat-resistant pipe is connected to the second high-temperature water pump to draw cold water out of the basin in order to regulate the water temperature inside the basin, Structural design of the foot spa machine, as shown in Figure 3, And Figure 4 shows Installation of the temperature control system inside the foot spa basin. The design and construction of the control circuit for the foot spa machine were carried out, as shown in Figure 5.

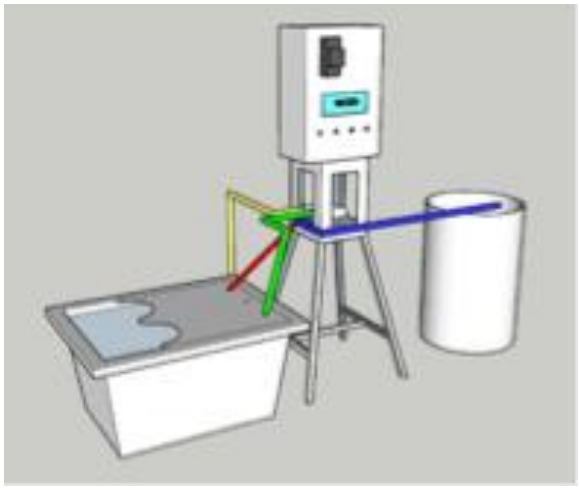

Figure 3: Structural Design of the Heating Unit and Foot Spa Machine

Figure 4: Installation of the temperature control system inside the foot spa basin

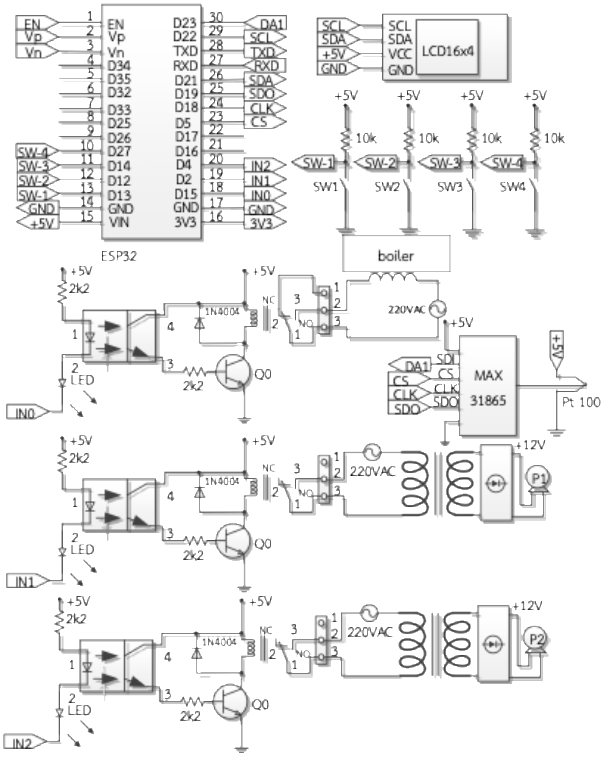

Figure 5: Installation of the temperature control system inside the foot spa basin

Figure 5 illustrates the control circuit of the foot spa system, which includes an input section using switches for selecting the operating mode. Two operating modes can be selected via switch SW1, and the system operation is initiated using switch SW4. Mode 1 operates automatically with temperature control in the range of 36–38 °C for 15 minutes. Mode 2 is a user-defined mode that allows the temperature to be set between 36–40 °C and the operating time between 10–30 minutes. Temperature measurement is performed using a PT100 sensor, and the measured data are pro-

cessed by an ESP32 microcontroller and displayed on a four-line LCD. The control system interfaces with optocouplers and relays to control the heating coil in the boiler, as well as the hot water pump and cold-water discharge from the foot spa basin in an automatic manner. An external control switch is provided to enhance operational safety.

B. Performance testing of the developed herbal foot spa machine

Testing Procedure

- Inspect the physical structure of the foot spa system to ensure that all mechanical components, pipes, pumps, and sensors are correctly installed according to the design specifications.
- Fill the boiler and the foot spa basin with water to the specified operating level before starting the test.
- Power on the control circuit and initialize the temperature control system.
- Set the desired water temperature using the control interface.
- Activate high-temperature water pump 1 to circulate hot water from the boiler to the foot spa basin.
- Activate high-temperature water pump 2 to circulate cooler water from the basin back to the boiler for temperature regulation.
- Monitor the water temperature inside the basin using the installed temperature sensor.
- Record the temperature response over time to evaluate the system's ability to reach and maintain the set temperature.
- Observe the stability of the temperature control during continuous operation.
- Turn off the system and allow it to cool down after completing the test.
- Inspect the system for any leakage, abnormal noise, or malfunction after testing.

Results and discussion

To evaluate the performance and accuracy of the temperature control system of the developed foot spa machine, which was designed to support the use of local herbal resources for health pro-motion in the Ban Khao Na Tat Community Enter-prise Group, Village No. 12, the testing focused on the operation of the temperature control system within the foot spa basin under different operating conditions. The evaluation considered the response of the heating element, the water boiler, and the hot–cold water pumping system, as well as the operating status displayed on the user interface. The detailed testing procedures are presented in the following subsections, namely Subsection A and Subsection B.

A. Results of the Design and Development of the Foot Spa Machine Control System

The foot spa machine control system was de-signed using an ESP32 microcontroller as the main processing unit, in conjunction with a PT100 temperature sensor and a MAX31865 signal conditioning circuit to convert temperature signals into digital data. The control system consists of a heating element, relays, a PC817 optocoupler, water pumps, and an LCD display.

The operating principle of the control system begins with measuring the temperature inside the foot spa basin using the PT100 sensor. The tem-perature data are then transmitted to the micro-controller for processing, which subsequently con-trols the relays to operate the water boiler and the hot–cold water pumps. When the temperature inside the basin falls below 36 ℃, the system activates the heating element and

water pumps. Conversely, when the temperature exceeds 37 ℃, the system automatically stops operation.

The operating status of the system is displayed on the LCD screen, showing the message “ON” during operation and “OFF” when the system is inactive, as illustrated in Figures. 6-7. These results demontrate that the system can continuously maintain the water temperature within an appropriate range for foot spa applications.

Figure 6: LCD Display of the foot spa machine operation when the temperature exceeds 36 ℃

Figure 7: LED Display of the foot spa machine operation when the temperature exceeds 37 ℃

B. Performance Test Results of the Developed Foot Spa Machine

The performance testing of the foot spa machine was conducted by evaluating the temperature control of the water inside the foot spa basin under two operating modes: Mode 1 and Mode 2. Each mode was tested ten times, with a duration of 15 minutes per test.

1. Test Results in Mode 1

The test results in Mode 1 indicated that the system was able to control the water temperature in the foot spa basin within the range of 36.00–37.99 ℃. The average maximum temperature was 37.85 ℃, while the average minimum temperature was 36.00 ℃, as presented in Table 1.

Table 1 Results of the temperature control performance evaluation of the foot spa machine in Mode 1

Time (min)	Temperature control of the foot spa machine										
	1	2	3	4	5	6	7	8	9	10	Average
0	36.00	36.00	36.00	36.00	36.00	36.00	36.00	36.00	36.00	36.00	36.00
1	37.63	37.83	37.87	37.94	37.94	37.63	37.83	37.87	37.97	37.99	37.85
2	37.19	37.46	37.53	37.66	37.66	37.36	37.46	37.70	37.53	37.58	37.51
3	36.24	37.16	37.21	37.46	37.39	36.88	37.12	37.60	37.16	37.27	37.15
4	37.87	36.85	36.96	37.05	36.95	36.41	36.88	37.36	36.85	36.85	37.00
5	37.50	36.48	36.68	36.75	36.34	37.50	36.61	36.99	36.41	36.44	36.77
6	36.85	37.99	36.27	36.33	37.77	37.33	37.7	36.85	37.48	37.46	37.20
7	37.66	37.53	37.94	37.83	37.53	36.85	37.33	36.68	37.94	37.19	37.45
8	37.83	37.21	37.66	37.46	37.16	37.66	37.02	36.34	37.77	37.02	37.31
9	37.33	36.99	37.36	37.12	36.78	37.12	36.75	36.21	37.60	36.88	37.01
10	37.05	36.53	37.05	36.99	36.34	36.88	36.34	37.94	37.36	36.66	36.91
11	36.88	36.22	36.88	36.68	37.87	36.44	36.78	37.87	36.95	36.54	36.91
12	36.51	37.7	36.51	36.21	37.58	37.49	37.97	37.73	36.44	36.41	37.06
13	38.00	37.53	36.07	37.83	37.36	37.02	37.66	37.36	37.19	36.27	37.23
14	37.87	37.26	37.87	37.46	36.99	36.88	37.39	37.02	37.50	37.39	37.36
15	37.12	36.99	37.22	37.16	36.54	36.51	37.12	36.78	37.09	37.22	36.98

From the temperature–time relationship graphs (Figure 8), it can be observed that the system successfully maintained the temperature within a suitable range for foot spa treatment throughout the 15-minute operating period. These results demonstrate the stability of the temperature control system in automatic mode.

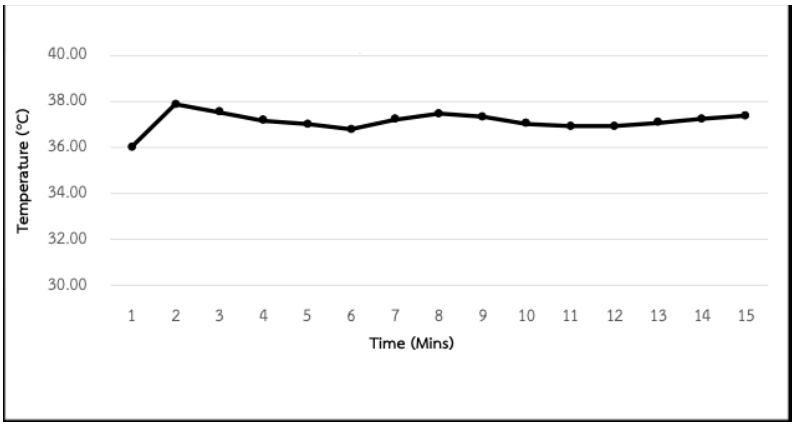

Figure 8: The temperature-time relationship graphs in Mode 1 (average).

2. Test Results in Mode 2

The test results in Mode 2, with the target temperature set to 37 °C, showed low temperature fluctuation in the foot spa basin. The maximum temperature was 37.36 °C, and the minimum temperature was 37.00 °C. The average maximum temperature was 37.19 °C, while the average minimum temperature was 37.00 °C, as shown in Table 2.

The temperature–time relationship graphs (Figure 9. illustrate that the system was able to maintain the water temperature close to the specified setpoint throughout the 15-minute operating period. This confirms the effectiveness of the temperature control system in the user-defined operating mode. 2.

Table 2 Results of the temperature control performance evaluation of the foot spa machine in Mode 2

Time	Temperature control of the foot spa machine										
(min)	1	2	3	4	5	6	7	8	9	10	Average
0	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00
1	37.02	37.19	37.16	37.05	37.12	37.16	37.09	37.16	37.19	37.22	37.14
2	37.22	37.05	37.19	37.19	37.05	37.05	37.29	37.02	37.05	37.16	37.13
3	37.36	37.26	37.05	37.09	37.22	37.19	37.19	37.22	37.19	37.09	37.19
4	37.12	37.09	37.12	37.29	37.12	37.12	37.05	37.12	37.09	37.02	37.11
5	37.02	37.02	37.19	37.16	37.29	37.02	37.22	37.05	37.12	37.19	37.13
6	37.22	37.16	37.29	37.09	37.16	37.22	37.12	37.19	37.19	37.12	37.18
7	37.19	37.22	37.12	37.29	37.09	37.12	37.02	37.09	37.05	37.02	37.12
8	37.22	37.12	37.33	37.12	37.22	37.02	37.22	37.02	37.19	37.22	37.17
9	37.05	37.29	37.09	37.02	37.16	37.22	37.16	37.22	37.12	37.16	37.15
10	37.00	37.36	37.16	37.22	37.05	37.09	37.05	37.12	37.02	37.05	37.11
11	37.12	37.22	37.02	37.09	37.26	37.22	37.19	37.05	37.22	37.19	37.16
12	37.26	37.16	37.09	37.29	37.19	37.12	37.09	37.22	37.12	37.19	37.17
13	37.12	37.26	37.29	37.19	37.05	37.00	37.26	37.12	37.05	37.09	37.14
14	37.22	37.33	37.22	37.05	37.22	37.22	37.19	37.02	37.22	37.02	37.17
15	37.02	37.02	37.05	37.19	37.09	37.09	37.05	37.19	37.16	37.19	37.11

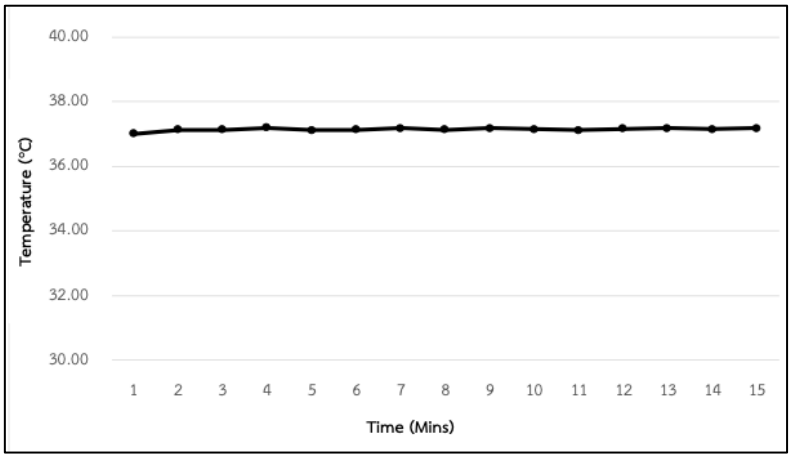

Figure 9: The temperature-time relationship graphs in Mode 2 (average).

Conclusion

This research presented the design, development, and performance evaluation of a foot spa machine using local herbal resources to promote health within the Ban Khao Na Tat Community Enterprise Group, Village No. 12. The developed system integrates a temperature control unit based on an ESP32 microcontroller, a PT100 temperature sensor, and a MAX31865 signal conditioning circuit to ensure accurate and stable temperature regulation during operation.

The foot spa machine was designed to operate in two modes. Mode 1 functions as an automatic mode, maintaining the water temperature within the range of 36–38 °C for a fixed duration of 15 minutes. Mode 2 allows users to manually set the temperature between 36–40 °C and adjust the soaking time from 10–30 minutes. The system employs a heating element, water boiler, hot and cold-water pumps, relays, and optocouplers to control heat exchange efficiently while ensuring electrical safety by separating the electrical system from the water.

Performance testing results demonstrated that the system could effectively control and maintain the water temperature within the specified ranges for both operating modes. In Mode 1, the water temperature remained stable within the appro-priate range for foot spa treatment throughout the 15-minute operation period, indicating reliable automatic temperature control. In Mode 2, the temperature showed minimal fluctuation around the set value, reflecting the accuracy and respon-siveness of the user-defined control mode.

Overall, the results confirm that the developed foot spa machine operates with stable temperature control, appropriate safety mechanisms, and flexible operating modes. The system is suitable for supporting the use of local herbal resources in community-based health promotion and can be applied as a practical engineering solution for small-scale community enterprises.

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