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Temperature Control for Seaweed Dryer Based on PID

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Abstract – *Seaweed is a commodity that has great potential in terms of establishing small or medium scale community businesses which are usually referred to as SMEs. The first thing you need to know about cultivating seaweed is the drying process, which aims to reduce the water content of the seaweed. When drying seaweed, people still use the traditional method, namely drying it in the sun, which takes 2 to 3 days. During the rainy season, farmers have to take 3 to 5 days for good results. Apart from that, the work is still manual or traditional, namely drying seaweed which takes quite a long time. If the weather when harvesting seaweed is rainy season, it will cause losses to seaweed farmers. As an alternative, a PID-based seaweed temperature and humidity control device has been developed using a light bulb heater as a substitute for sunlight for the process of drying the seaweed. The DS18B20 sensor is used to measure temperature, which is then displayed on the LCD. The Arduino Uno microcontroller is used to control the seaweed drying tool. This seaweed dryer can speed up drying by utilizing the Arduino system to reduce humidity so that drying time is faster. The results obtained with this simple seaweed dryer can speed up the drying process to 1.5 to a maximum of 2 days and the quality of the dried seaweed is better because it is protected from surrounding dust and dirt. The result of this research is a seaweed dryer that can help farmers dry the results of their seaweed cultivation in any weather conditions with the hope of better results.*

Keywords – *seaweed drying; PID control; Arduino Uno; humidity control; temperature sensor.*

I. Introduction

SEAWEED is a highly lucrative commodity within the marine and fisheries industry. Additionally, it serves as a significant export product and a crucial element of the fisheries revival effort, contributing significantly to the well-being of the community [1]. Seaweed cultivation is currently being heavily encouraged in Indonesia as a fishery product. Seaweed shows great promise as a leading export commodity in the marine and fisheries industry. Seaweed has significant potential as a leading export commodity in the marine and fisheries industry, with a wide range of applications including food, feed, medicine, and cosmetics [2, 3]. The development of seaweed agro-industry, particularly in the production of processed foods, can significantly increase its value [4]. The successful cultivation of seaweed, such as Gracilaria, has led to a significant increase in export values [5]. Seaweed aquaculture, which accounts for a significant portion of global aquaculture production, can contribute to environmental sustainability and economic stability [6]. However, the industry faces challenges in the production of bioactives and the need for standardization and quality control [7]. The concept of a seaweed biorefinery presents a sustainable approach to the use of marine resources [8]. Therefore, while seaweed shows great promise as an export commodity, its sustainable management and development are crucial for its long-term success [9].

Seaweed, a valuable agricultural commodity, has great potential for development in the marine and fisheries industry [2,4,10]. It is a rich source of phytochemicals such as agar and algin, which are used in various industries [11]. Seaweed cultivation can be a source of income for coastal communities [4], and its high value-added processed food products can increase farmers' income [4]. Seaweed is also a promising source of feed and fertilizer for agriculture [12]. The development of a seaweed biorefinery could further exploit its commercial potential [13]. Typically, seaweed must undergo a dehydration procedure prior to being processed. Historically, farmers have employed the method of sun-drying seaweed by exposing it directly to sunshine. This method has disadvantages, particularly during the rainy season, when the process of drying is impeded. Normally, the process of sun-drying requires a duration

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of 1-2 days. However, in the event of overcast weather conditions, this duration may extend to 3-5 days.

A primary drawback of sun-drying is the potential exposure of seaweed to freshwater, which may result from unexpected rainfall or excessive atmospheric moisture levels. Exposure to freshwater can induce a color transformation in Gracilaria seaweed, turning it from black to white, which may signify a decline in quality [14]. However, the specific mechanisms and implications of this transformation are not fully understood. Other factors such as nitrogen species, seawater flow rate, and pH can also significantly impact the growth and biochemical composition of Gracilaria [15, 16]. Additionally, changes in salinity, darkness, and algal nutrient status can influence the floridoside and starch content, $\alpha-$galactosidase activity, and agar yield of Gracilaria [17]. UV-B radiation can inhibit the accumulation of pigments and phycocolloid in Gracilaria [18], while changes in nitrogen and phosphorus concentrations can affect its growth and physiological features [19]. The depth at which Gracilaria is grown can also impact its growth, pigments, UV-absorbing compounds, and agar yield [20]. Lastly, elevated CO2 levels can affect the growth, photosynthetic performance, and biochemical components of Gracilaria [21].

In addition, the presence of airborne dust in the drying area leads to a higher level of contamination in the seaweed. The permissible threshold for contamination typically does not exceed 2%. Practical considerations seldom motivate the sorting of seaweed for quality grading. Instead, farmers typically combine the dried seaweed by rolling it directly on drying racks, resulting in a decline in quality that warrants its classification as grade III. The dried seaweed, which contains 14-16% moisture, is subsequently sold to collectors or companies for additional processing [22].

In light of these challenges, it is necessary to develop a temperature controller for seaweed drying that utilizes a PID (Proportional-Integral-Derivative) system. This controller is anticipated to effectively resolve the aforementioned issues. The seaweed drier, which utilizes a PID (Proportional-Integral-Derivative) control system, is anticipated to provide dried seaweed that achieves a more uniform dryness level in terms of both moisture content and consistent black coloration, while also reducing the overall drying time. The previous research has focused on the title ”Prototype of a Portable Solar Dryer for Seaweed with Microcontroller-Based PLTS” [22]. A recent study called ”Evaluation of Seaweed (Kappaphycus Alvarezii) Quality through Sun Drying and Cabinet Dryer Techniques, and Semi-Refined Carrageenan (SRC) Yield” has been carried out. Daraeny conducted research on temperature and humidity detection for the purpose of drying seaweed. The study utilized a stove as a heat source and a load cell for automated weighing.

The objective of this project is to develop a seaweed dryer that utilizes a microcontroller and a ceramic heater, controlled by a PID system, to effectively dry seaweed.

II. Research Methods

The method used in this research is experimental. The seaweed dryer is operated by an individual who sets the desired temperature, and the device then automatically performs the drying process. Therefore, a system analysis is required to ensure that the designed device meets system requirements, which include: Hardware Design and Software Design.

i. *Hardware Design*

Several plans are presented in the system block diagram, which distinguishes between software and hardware methods.

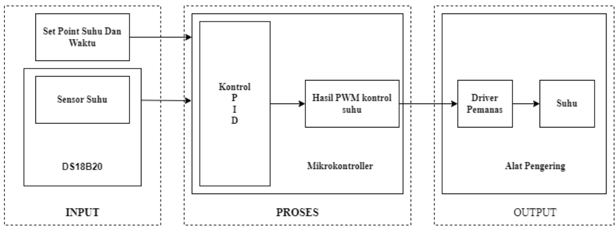

Figure 1: System Block Diagram

From the analysis in Figure 1, it is explained that the temperature sensor reads the temperature value and the input duration time enters the microcontroller, which is then processed using PID and produces a PWM output that then enters the heater driver. The heater driver is used to control the heater as a temperature controller. The fan functions to evenly distribute the temperature. If the heater output is deemed insufficient, the controller will work to reach the set point and display it on the LCD.

The planned design of the tool to be worked on serves as a reference for its future design. In this subsection, the design of the tool will be displayed and divided into two sub-subsections.

Below is the overall schematic of the seaweed drying system, as shown in Figure 2. The schematic includes Arduino Uno, DS18B20 Sensor, Buzzer, 4x4 LCD, and crucially, the AC light dimmer component, which functions as a PWM regulator. Component details are provided in Table 2.

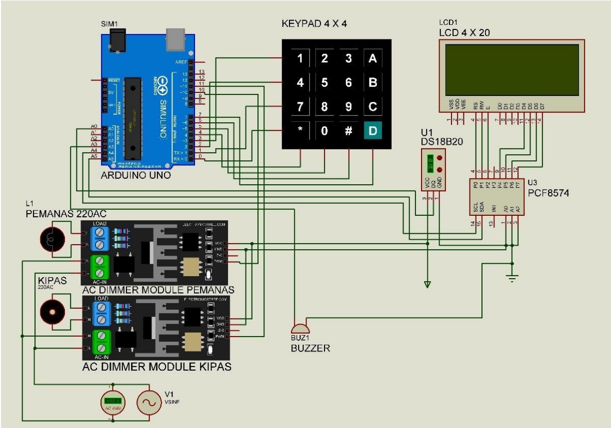

Figure 2: Overall Schematic

The Input Voltage indicates the range of AC voltage that the dimmer can accept, 110-240V AC. The AC light dimmer can be controlled by a PWM (Pulse Width Modulation) signal or other control methods. The required components include Arduino Uno, an AC Dimmer Module to control AC power, a Keypad to input values and set temperature, a DS18B20 Sensor to measure the heater temperature, a 4x4 LCD to display the temperature, and a Buzzer to serve as an indicator. The steps involved are as follows: designing the circuit schematic carefully and connecting it according to the specific equipment requirements, writing Arduino code that uses PID control to regulate the temperature, programming the Arduino to read data from the temperature sensor, and calibrating and testing the sensor and program thoroughly to ensure the PID settings function correctly and safely.

Figure 3 depicts the PID temperature control system block. Achieving a steady state means the system has reached a condition where the controlled variable (such as temperature) remains constant at the setpoint without significant changes. This occurs when the error (the difference between the setpoint and the measured value) approaches or reaches zero.

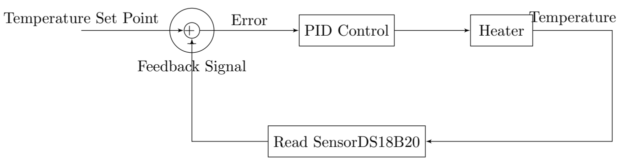

Figure 3: PID Block Diagram

When the actual temperature (PV) is not equal to the setpoint (SP), the error (e) becomes non-zero. The PID control processes the error to generate an appropriate control signal for the heater. The heater receives the control signal from the PID and generates heat energy according to the control signal. The heating process experiences temperature changes based on the power provided by the heater. The temperature sensor continuously measures the actual temperature, and the cycle repeats. The PID control continuously processes the error to regulate the heater power so that the temperature reaches the setpoint. The error, integral of the error, and derivative of the error together help the PID control respond dynamically to temperature changes and maintain the system at the desired temperature. This process continues automatically to keep the temperature at the set level.

The output devices used here include an LCD, fan, and ceramic heater controlled by Arduino Uno. Thus, the tool to be created will function as desired.

A flowchart is a diagram that describes the workflow of a program. In a broader context, it can also be used to describe the process of a system. It is often used in medical, chemical, engineering, or any field requiring complex visualization. Using a flowchart concept can simplify researchers in conveying the system concept to be created. The initial stage is the start, followed by entering the set point by pressing the keypad, and the system will work. Once the system reaches the set point, it will stop, and the buzzer will sound/completion.

Figure 4 shows the design of a seaweed dryer with a length of 100 cm and a width of 50 cm, made of 0.4 mm stainless steel. It has two layers: the inner layer functions as the drying place for seaweed, and the outer layer serves as a cover. Between the outer and inner layers, there is glass wool as a heat insulator to prevent the outer layer of the seaweed dryer from becoming hot.

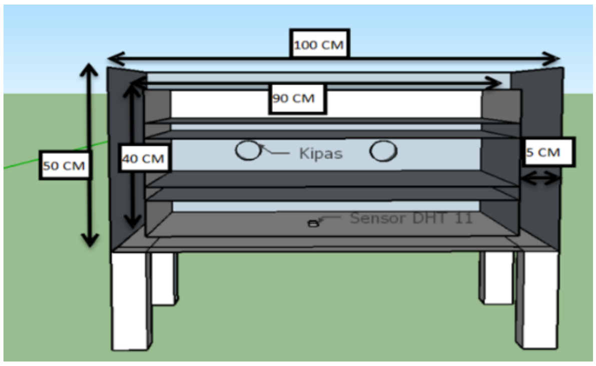

Figure 4: Seaweed Dryer Design

Figure 5 shows the design of a control box made of acrylic with dimensions of 20 cm length, 15 cm width, and 5 cm height. The control box contains several components such as Arduino Uno for the microcontroller, AC light dimmer to control PWM so that the system operates according to the predetermined value, 20x4 LCD to display temperature data sent from the DHT11 sensor, 4x4 keypad to input the set point, and other supporting components like power supply and power button.

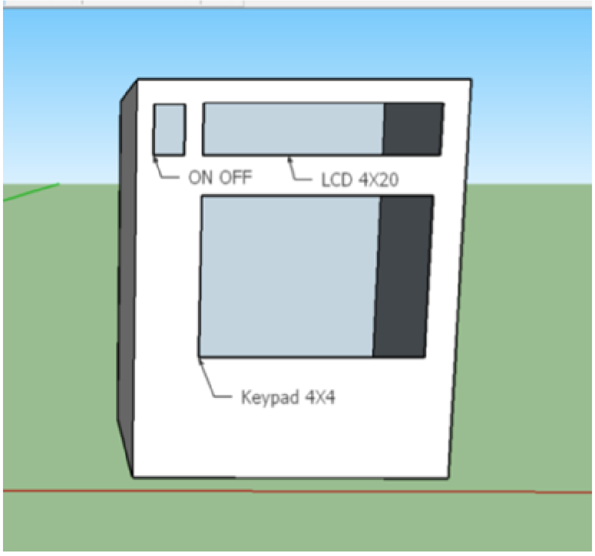

Figure 5: System Control Box Design

The hardware design in this research involves the implementation of a previously designed system, consisting of the creation of a prototype room to test the system and the placement of components used in the research.

Figure 6: Seaweed Dryer Box

The prototype of the drying room is $100cm \times 50cm$, as shown in Figure 6. Inside, a heater is placed to provide temperature changes in the room, along with a DHT11 sensor and a fan connected to an AC light dimmer driver to receive input signals from the microcontroller, regulating speed according to the temperature data detected by the sensor. The temperature sensor is placed inside, and the fan is located at the back of the drying box to remove moisture. The microcontroller and the AC light dimmer driver are placed outside the room to be sensed.

In Figure 7, there is an image of the system box containing components such as the power supply, keypad, AC light dimmer, 20×4 LCD, and supporting components such as jumper cables and power buttons.

III. Results and Discussion

Figure 7: System Control Box

i. DS18B20 Sensor Testing Results

The program used is Arduino IDE to test the DS18B20 reading values.

Figure 8: DS18B20 Sensor Reading

In Figure 8, the DS18B20 sensor reading is displayed on a 4×20 LCD. This data is compared with the readings from a Digital Thermometer to determine the accuracy of the sensor data. Accurate temperature readings are crucial because excessive temperature can cause uneven heating of the seaweed. Uneven heating results in one side of the seaweed drying first while the other side remains moist, making the drying process less optimal.

Table 1 shows temperature data collected from the dryer without seaweed. For the first trial, I set the temperature to 40°C, which took about 10 minutes to reach. The DS18B20 sensor read 37°C, while the digital thermometer read 38°C. Comparing the DS18B20 sensor and digital thermometer readings helps assess

Table 1: Temperature Data Without Seaweed

No	Temperature	Thermometer	DS18B20	Time
1	40°C	38°C	37°C	10 minutes
2	45°C	43°C	42°C	16 minutes
3	50°C	48°C	47°C	21 minutes
4	55°C	53°C	52°C	27 minutes
5	60°C	59°C	58°C	35 minutes

the accuracy of the sensor against the reference thermometer.

The purpose of this testing is to reduce the moisture content in seaweed and set a target temperature where the ceramic heater will heat the system until the input setpoint temperature is reached and stop heating when the temperature exceeds the setpoint. The tools and materials needed for this testing are a ceramic heater, which provides the necessary heat to dry the seaweed; an AC fan, which helps in distributing the heat evenly within the drying chamber; a DS18B20 sensor, which measures the temperature to ensure accurate control; and a buzzer, which serves as an indicator for the completion of the drying process. The ceramic heater is used to heat the room, which is monitored by the DS18B20 sensor and displayed on the LCD. The 220 VAC fan is used to evenly distribute the temperature inside the drying box, and the buzzer serves as a completion indicator.

ii. Tuning Experiment

In this heating control, I use a PID controller with parameters Kp = 2, Ki = 5, and Kd = 1 to stabilize the output to the setpoint. The tuning graph can be seen in Figure 9. Achieving steady state does not always mean the system response will reach the setpoint without overshoot or oscillation. Optimal tuning will vary depending on the unique characteristics of the controlled system. Therefore, careful experimentation and parameter tuning are required to achieve the desired balance.

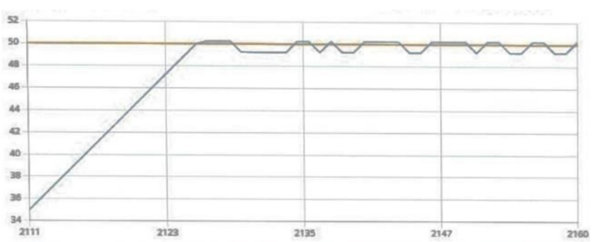

Figure 9: Tuning Graph Kp = 2, Ki = 5, Kd = 1

Here is a general explanation: Kp (Proportional) determines the extent of the heater's response to the difference between the desired and actual temperature, with a higher Kp value indicating a more responsive heater. Ki (Integral) determines the extent of the integral response to the accumulated temperature error over time, where a higher Ki value helps address static offset and maintain a stable temperature. Kd (Derivative) determines the extent of the derivative response to the rate of temperature change, with a higher Kd value helping to prevent overshooting or excessive oscillation, thus optimizing the system's response to temperature fluctuations. The PID controller for the heater is used to maintain the temperature at the setpoint by responding quickly and efficiently to temperature changes. Each parameter value (Kp, Ki, and Kd) should be adjusted according to the characteristics of the heater and the overall control system.

In the first experiment, shown in Figure 10, with tuning values Kp = 4, Ki = 4, Kd = 2, the graph oscillates and does not reach steady state.

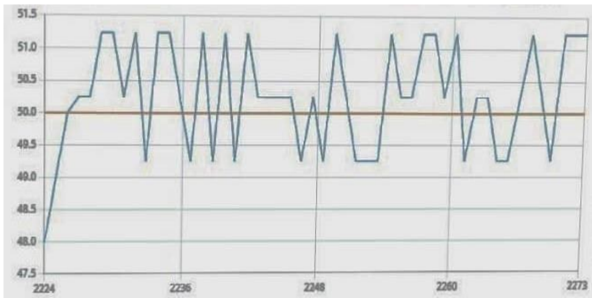

Figure 10: Tuning Graph Kp = 4, Ki = 4, Kd = 2

In the second tuning experiment shown in Figure 11, using tuning values Kp = 2, Ki = 4, Kd = 2, there is high overshoot. This indicates that the PID control can cause the system's response to exceed the setpoint before stabilizing. The graph also shows oscillation, indicating that steady state is not achieved.

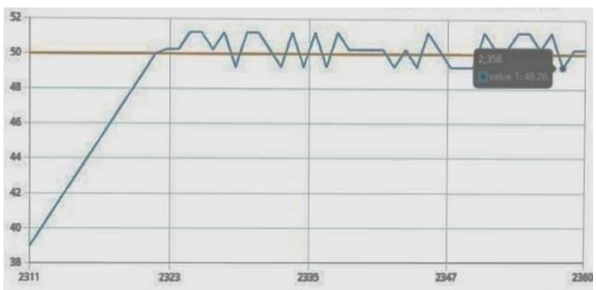

Figure 11: Tuning Graph Kp = 2, Ki = 4, Kd = 2

In the next experiment shown in Figure 12, using tuning values Kp = 4, Ki = 4, Kd = 1, the desired heating graph reaches the setpoint at 50°C, then drops back to 48°C.

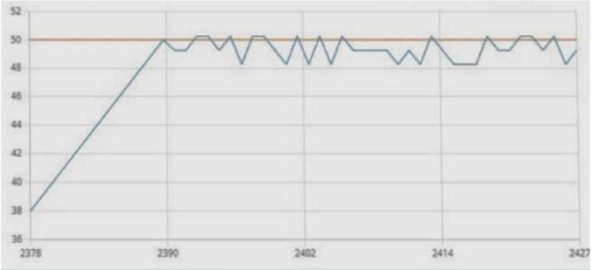

Figure 12: Tuning Graph Kp = 4, Ki = 4, Kd = 1

iii. Initial Moisture Content Data Collection

The initial moisture content was measured using a Digital Moisture Meter AR991 by inserting it into the seaweed stack or placing it on two sharp metal probes at the top of the sensor. Before drying in the oven, the

Figure 13: Seaweed Moisture Content 48.4%

moisture content was 48.4%, as shown in Figure 13, with a brown color.

Figure 14 shows a moisture content of 43.1% with a darker brown color. The color difference between high and low moisture content is visible. The moisture content will be processed for drying with the dryer, and the final value will be 31.0%.

iv. Seaweed Data Collection at 40°C

Data collection at 40°C is performed to monitor the change in moisture content during the drying process. The dryer can remove 1.075% moisture per hour, as shown in Table 2. Data collection can include specific times to record changes in seaweed and measure moisture content.

Here is an example of data collection during the drying process at 40°C:

Figure 14: Seaweed Moisture Content 43.7%

Table 2: Hourly Moisture Check at 40°C

No	Time	Initial Moist.	Final Moist.	Loss Moist.
1	1 hour	49.4%	48.5%	0.9%
2	2 hours	48.5%	47.6%	0.9%
3	3 hours	47.6%	46.4%	1.2%
4	4 hours	46.4%	45.1%	1.3%
Average				4.3% / 4 = 1.075%

Table 3: Seaweed Data at 40°C

No	Drying	Initial Moist.	Final	Time
1	40°C	48.4%	23.1%	25 hours 20 minutes
2	40°C	45.3%	22.9%	22 hours 15 minutes
3	40°C	43.7%	20.6%	23 hours 60 minutes
4	40°C	42.1%	21.6%	20 hours 12 minutes
5	40°C	39.1%	21.2%	17 hours 7 minutes

1. Calculate Moisture Reduction Initial Moisture - Final Moisture = 48.4% - 23.1% = 25.3%
2. Estimate Drying Time

$$\begin{aligned}\text{Drying Time} &= \frac{\text{Moisture to be Reduced}}{\text{Drying Rate per Hour}}\\ &= \frac{27\%}{1.54}\\ &= 18 \text{ hours } 4 \text{ minutes}\end{aligned}$$

Figure 15: Seaweed Moisture Content 31.0%

v. *Seaweed Data Collection at 50°C*

The estimated drying time can be calculated by considering the desired moisture reduction and drying rate. The dryer can remove 1.45% moisture per hour at 50°C, as shown in Table 4. Here is the calculation from Table 4 in the first experiment:

Table 4: Hourly Moisture Check at 50°C

No	Time	Initial Moist.	Final Moist.	Moist. Loss
1	1 hour	49.6%	48.3%	1.3%
2	2 hours	48.3%	46.9%	1.4%
3	3 hours	46.9%	45.4%	1.5%
4	4 hours	45.4%	43.8%	1.6%
Average				5.8% / 4 = 1.45%

1. Calculate Moisture Reduction

$$\text{Initial Moisture} - \text{Final Moisture} = 49.4\% - 22.4\% \\ = 27\%$$

2. Estimate Drying Time

$$\text{Drying Time} = \frac{\text{Moisture Reduction}}{\text{Drying Rate per Hour}} \\ = \frac{27\%}{1.45\%/\text{hour}} \\ = 18 \text{ hours } 4 \text{ minutes}$$

vi. *Seaweed Data Collection at 60°C*

In this drying process at 60°C, the highest temperature among the experiments, the drying rate is quite fast, reducing moisture by 2.025% per hour, as shown in Table 5. Here is the calculation from Table 5 in the first experiment:

Table 5: Moisture Content Over Time

No	Time	Initial Moist.	Final Moist.	Moist. Loss
1	1 hour	47.2%	45.1%	2.1%
2	2 hours	45.1%	43.2%	1.9%
3	3 hours	43.2%	41.2%	2.0%
4	4 hours	41.2%	39.1%	2.1%
Average				8.1% / 4 = 2.025%

1. Calculate Moisture Reduction

$$\text{Initial Moist.} - \text{Final Moist.} = 47.2\% - 27.8\% \\ = 19.4\%$$

2. Estimate Drying Time

$$\text{Drying Time} = \frac{\text{Moisture Reduction}}{\text{Drying Rate per Hour}} \\ = \frac{19.4\%}{2\%/\text{hour}} \\ = 9 \text{ hours } 8 \text{ minutes}$$

Table 6: Seaweed Data at 60°C

No	Drying Temp.	Initial	Final	Time
1	60°C	47.2%	27.8%	9 hours 8 minutes
2	60°C	46.2%	28.7%	8 hours
3	60°C	44.9%	28.2%	8 hours 1 minute
4	60°C	44.0%	25.1%	9 hours 1 minute
5	60°C	33.2%	22.2%	5 hours 12 minutes

IV. Conclusion

The seaweed dryer is useful as an alternative drying tool, allowing farmers to continue drying seaweed even during the rainy season. However, the drawback of this dryer is its limited capacity of approximately 2 kg. Continue to seek innovations in drying techniques or process improvements to enhance efficiency and product quality. Choose environmentally friendly methods and consider efficient energy use.

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