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FUZZY LOGIC-BASED TEMPERATURE CONTROL IN AN OVEN FOR EFFICIENT MORINGA LEAF DRYING.

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Article Info

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Abstract

Moringa trees (Moringa oleifera) are extensively cultivated as living fences, bordering fields or rice paddies, and serve as valuable greenery. The various parts of the Moringa plant, including the stem bark, seeds, and leaves, possess medicinal properties and are employed in traditional remedies. To harness their therapeutic potential, these plant parts are subjected to drying and processing methods such as sunlight drying, oven drying, grinding, withering, and enzymatic oxidation. However, conventional sunlight drying suffers from extended drying times and dependence on solar radiation, prompting researchers to explore oven drying as a viable alternative due to its superior temperature stability [1].

In the context of Moringa leaf drying, several temperature-time combinations have been investigated, namely 50 °C, 60 °C, and 70 °C for 100 minutes, 160 minutes, and 180 minutes, respectively. It has been found that the optimal temperature for the formation of flavonoids, which impart potent antioxidant properties, is 60 °C with a drying time of 160 minutes. This highlights the significance of temperature control during drying processes, as different herbs exhibit varying thermal sensitivities and drying requirements [2]. Herbs containing heat-sensitive or volatile active compounds should be dried at the lowest feasible temperature, such as 30°C-45°C, or by utilizing vacuum drying techniques.

The advent of modern technologies and the automation of electronic devices have revolutionized drying procedures, facilitating improved efficiency and precision. Notably, the integration of Arduino Uno microcontrollers into dryers has enabled automated temperature regulation, streamlining the drying process and optimizing product quality [3].

This review explores the diverse applications of Moringa trees, emphasizing their roles as living fences, greenery providers, and sources of medicinal substances. The discussion encompasses the

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significance of Moringa leaves as a herbal remedy and the importance of temperature control during the drying process to preserve their therapeutic compounds effectively. Furthermore, the review delves into the recent advancements in dryer technology, featuring the incorporation of Arduino Uno microcontrollers for efficient temperature regulation. The comprehensive understanding of these aspects contributes to the sustainable utilization of Moringa trees and the development of innovative drying techniques for herbal products.

1. Introduction

Moringa trees are widely planted as living fences, along fields or rice fields, and serve as greening plants. In addition, Moringa leaves are also known as efficacious medicinal plants by utilizing all parts of the Moringa plant, starting from the bark of the stem, seeds, and leaves to the roots and undergoing processing processes such as drying, grinding, withering, and enzymatic oxidation. Drying using sunlight has the disadvantage that it is relatively longer and depends on the heat of the sun's rays, while drying using an oven has advantages, including a more stable temperature [1].

The temperature used in the drying process of Moringa leaves is 50 ° C, 60 ° C, and 70 ° C with a time of 100 minutes, 160 minutes and 180 minutes, and the best temperature in the formation of flavonoids that can form optimal antioxidants is with a temperature of 60 ° C and a drying time of 160 minutes. The drying temperature depends on the type of herbs and how they are dried [2].

Herbs containing active compounds that cannot withstand heat or are volatile should be dried at the lowest possible temperature, such as 30°C-45°C, or by vacuum drying. The development of modern technologies and the automation of electronic devices today make work easier. For example, the temperature regulation system in the dryer is designed to be more automatic. The dryer is equipped with an Arduino Uno microcontroller for motor temperature control [3].

2. Literature Review

2.1. Moringa leaves

Moringa leaves are rich in nutrients and have functional properties because this plant has properties and benefits for human health. Both the content of nutrients and various active substances contained in this plant can be used for the benefit of living things and the environment [4]. Therefore Moringa got the nickname as "miracle tree. Moringa leaves as a good source of natural antioxidants because of the content of various types of antioxidant compounds in moringa 4 leaves such as ascorbic acid, flavonoids, phenolics, and carotenoids [5]. The benefits of Moringa leaves include anti-inflammatory, hepatitis, facilitating urination, and anti-allergy, besides moringa leaves (Moringa oleifera) are widely used and believed to be a medicine for infections, anti-bacterial, urinary tract infections, external wounds, anti-hypersensitive, antianemic, diabetes, colitis, diarrhea, dysentery, and rheumatism. One of the most prominent of the Moringa plant content is antioxidants, especially in the part of the leaves that contain the highest antioxidants [6].

2.2. Drying

Drying characteristics are strongly influenced by the moisture content of the material, which determines the appearance, texture and taste. The drying process can be done by drying, using a machine and also combined between the two. According to Efendi (2009), drying can also be interpreted as the process of separating or removing water from a material.[7] Drying has been widely carried out in the processing of agricultural products and foodstuffs using solar energy, heating, aerating, steam pressure difference, and freeze-drying. Pato and Yusmarini (2004), stated that the factors that affect the drying speed of a food item are the area of the surface and the heating temperature the higher the temperature used the faster the material 10 becomes dry. With the reduction

of water in foodstuffs the content of compounds such as proteins, carbohydrates, fats, and minerals will increase but vitamins and dyes decrease.[8]

2.3. Arduino Mega 2560

Arduino is a microcontroller board originally created by a smart project company. The creator of Arduino is Massimo Banzi, where this board is an open source hardware in which there is a main component, namely a microcontroller IC with the AVR type from the Atmel company. On the Arduino Mega 2560, the Atmega 2560 microcontroller IC is used. The Arduino Mega 2560 has 54 digital input/output pins, of which 15 pins can be used as PWM output, 16 pins used as analog output, and 4 pins as UART(hardware serial port), 16Mhz crystal oscillator, USB connection, power jack, ICSP header, and reset button [9]

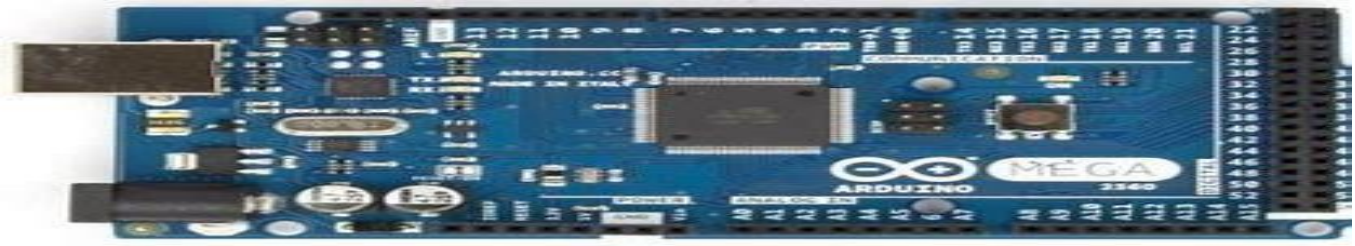

Fig 1. Arduino Mega

2.4. Arduino IDE

Arduino Arduino integrated development environment (IDE) is a software that serves to create programs and upload them from a computer to Arduino physical board.[10] the program started using arduino ide software to illustrate its design. arduino ide makes it easy for users to write and upload code to the Arduino Uno and microcontroller boards [11] 1. Program editor : a window that functions to write and edit programs.

2. Compiler : functions to check whether there are error's or not in the program code that has been made.
3. Uploader : functions to upload (upload) the program results made to the Arduino board.

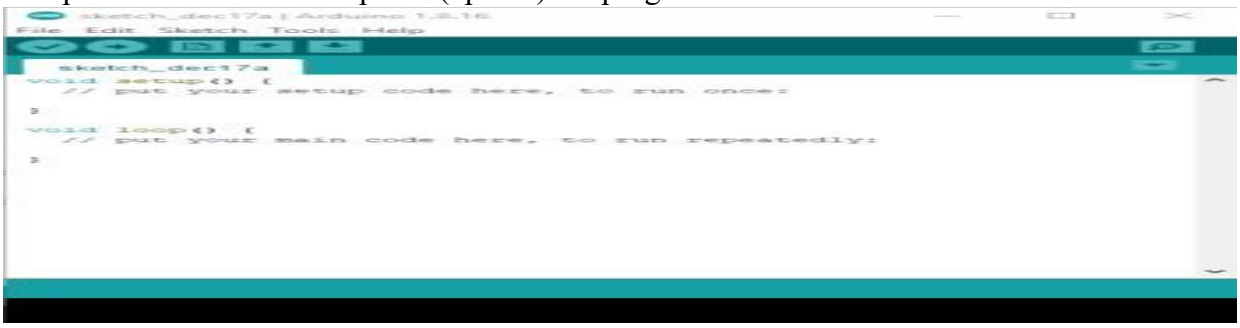

Fig 2. Display of the Arduino IDE Software

2.5. Tubular Heater

The heating element is a device that converts electrical energy into thermal energy through the Joule Heating process. The working principle of the heat element is that the electric current flowing on the element encounters its resistance, thereby generating heat in the element. The heating element of the base form is coated by pipes or sheets of metal plate for the purpose of being an adjustment to the use of such heating elements. Commonly used metal materials are: mild stell, stainless stell, copper [12].

Fig 3. Tubular Heater

2.6. Load Cell

Load cell sensor is a sensor designed to detect the pressure or weight of a load, the load cell sensor is generally used as the main component in the digital weighing system and can be applied to the weighbridge that functions to weigh the weight of the raw material transport truck, measurements made by the Load Cell using the pressure principle [13].

Fig 4. Load Cell **2.7.**

Solid State Relay (SSR)

Solid State Relay or often abbreviated as SSR is an electromechanical switch that has semi-conductor properties. This one component is usually widely applied in industries as a controlling device. Solid State Relay (SSR) is the latest type of non-contact electronic switch that has advanced performance and foreign technology and equipment. Slightly different from the function of relays in general, the way Solid State Relay 29 works is simple [14].

Fig 5. Solid State Relay (SSR)

2.8. Thermocouple Type K

Thermocouple is one of the most popular types of temperature sensors and is often used in various circuits or electrical equipment and electronics related to temperature (Temperature). Some of the advantages of thermocouples that make it popular are its fast response to temperature changes and also its wide operational temperature range, which ranges from -200°C to 2000°C [15].

Fig 6. Thermocouple Type K

2.9. LCD (Liquid Crystal Display)

LCD (Liquid Cristal Display) is an important component because the LCD can display commands that must be executed. The LCD screen uses two polarizing weight sheets and a liquid crystal between the two sheets. The use of LCD is widely used in designing a system using a microcontroller [16]. The 16x2 LCD has 16 pin numbers, where each pin has a symbol and also its functions. This 16x2 LCD operates on a +5V power supply, but can also operate a +3V depower supply. This 16x2 LCD has two important parts, namely the backlight which is useful when used at night and the contrast which serves to sharpen the display. Here is a picture of a 16x2 LCD [17].

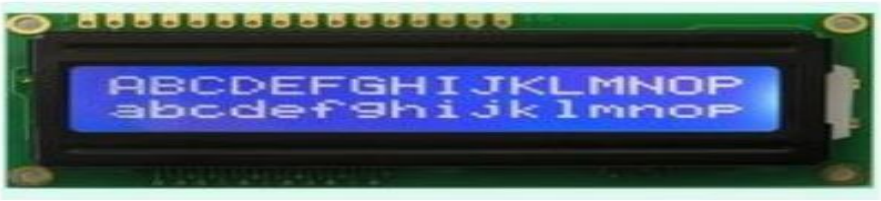

Fig 7. LCD I2C size 16x2

2.10. Fan 220V

Fan AC 220 V Fan is to adjust the heat volume of the air so that the room does not experience hot temperatures and can circulate air normally. In general, fans are used for air conditioners, air fresheners, vents (exhaust fans), or dryers (generally using heat-generating components). There are two types of fans based on the direction of the wind produced, namely centrifugal fans (wind flowing in the direction of the fan shaft) and axial fans) [18].

Fig 8. Fan 220V

2.11. Keypad

Keypad which has many keys with many functions, a function that is usually to send data to the processor. Keypads are usually found and found on mobile phones, calculators, landlines, and many others. On a phone, usually the keypad if pressed once will send data in the form of numbers, then when pressing repeatedly to send data in the form of letters [19].

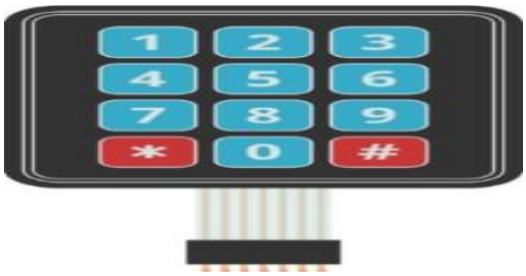

Fig 9. Keypad

3. Method

Research methodology is certain steps, procedures, techniques in presenting a number of activities carried out in order to be well conceptualized and more structured. In order to complete the design of the oven system as a Moringa leaf dryer, then the author has an investigation based on the method that runs in the planned stages [20].

3.1. Moringa Leaf Dryer Oven Working System

Then the author has an investigation based on the method that goes in the planned stages. The following is the form of the flow chart that has been created shown in figure below:

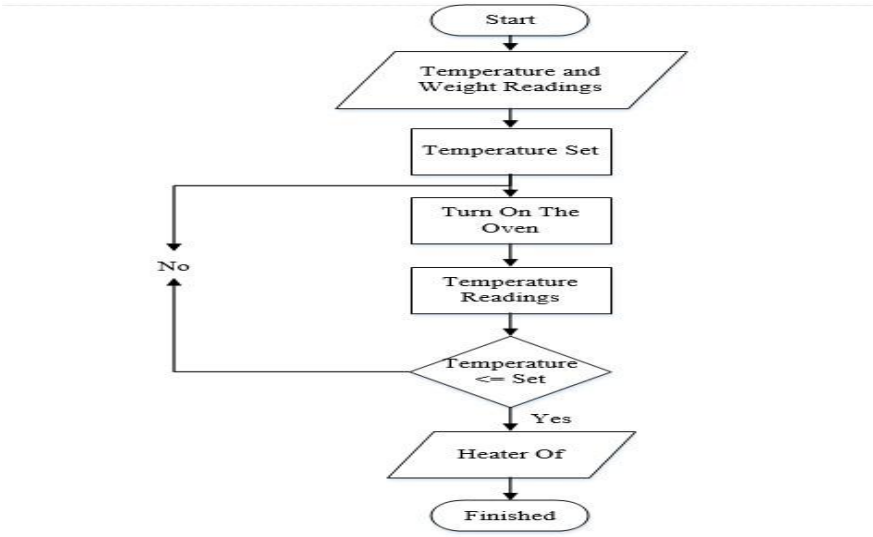

Fig 10. Tool Working Diagram

The flow chart above uses a tool starting from the temperature set on the keypad. At this stage, several sensors were used as devices in this study. after the temperature that has been set has appeared on the LCD, the research process has been completed and the data can be taken.

3.2. Testing Tools on Drying Ovens

The tests carried out in this study include several tests, namely component testing divided into several parts overall testing. Testing the overall performance of moringa leaf dryer ovens runs the entire system both input, process, and output. Moringa leaf dryer oven performance testing is carried out to determine the performance of the tool. This test tends to pay more attention to the output results displayed on the I2C LCD.

3.3. Input membership function Fuzzy Logic

In this fuzzy design, it has 2 inputs, namely temperature and weight sensors, In this fuzzy design, it has 2 inputs, namely temperature and weight sensors, each variable on the input has 3 variables. variable on temperature, Cold (D) Warm (H) Hot (P). and for variable Weight is also divided into # variable, Light (R), Weight (B), Very Heavy (SB).

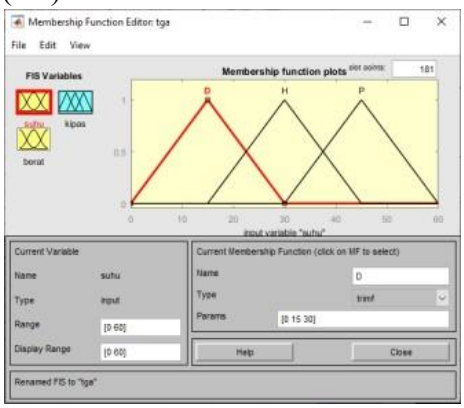

Fig 11. Variabel Weight

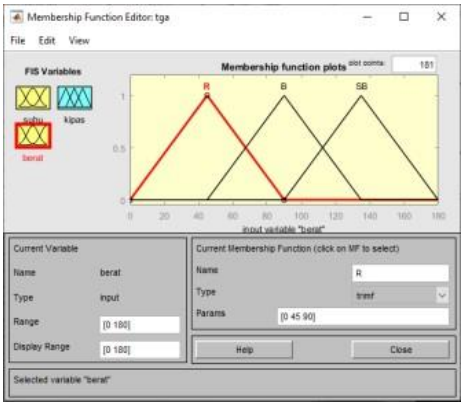

Fig 12. Variabel Temperature

3.4. Output Membership Function

On the output membership function, the output is expected to be pwm issued by fan in oven used for hot decomposer in the oven. To set pwm on the fan there are 3 variables output membership i.e. Dead (M), Slow (P), Fast (C), The amount of the pwm depends on the magnitude of the angle issued by Arduino Mega.

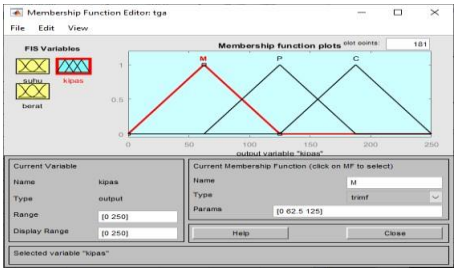

Fig 13.

Variabel Output **3.5. Designing a Rule Base**

fuzzy Rule Base in the form of statements - logical statementsFuzzy. Fuzzy Rule Base in the form of an IF-Then statement which states a statement of conditions. Rule Base Preparation This greatly affects the decision-making process which is done by the plant. Based on the fuzzy rule base in this design process, fuzzy rules are made using the Centre of Gravity (COG) method. This method is based on knowledge of the behavior of the system.

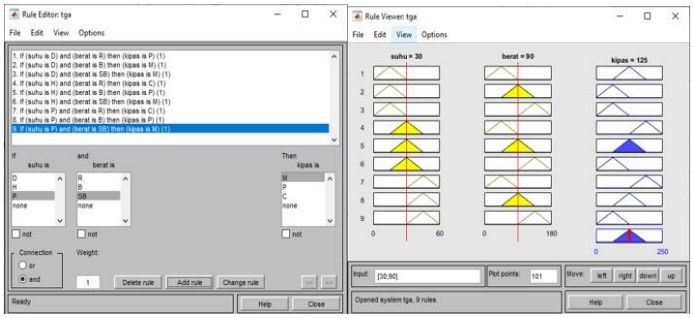

Fig 14.

Rule Base

If (Temperature is D) and (Weight is R) then (Fan is P) (1)
If (Temperature is D) and (Weight is B) then (Fan is M) (1)
If (Temperature is D) and (Weight is SB) then (Fan is M) (1)
If (Temperature is H) and (Weight is R) then (Fan is C) (1)
If (Temperature is H) and (Weight is B) then (Fan is P) (1)
If (Temperature is H) and (Weight is SB) then (Fan is M) (1) If (Temperature is P) and (Weight is R) then (Fan is C) (1)
If (Temperature is P) and (Weight is B) then (Fan is P) (1)
If (Temperature is P) and (Weight is SB) then (Fan is M) (1)

4. Result And Discussion

The test is carried out by providing input to the circuit input and observing the output output of the tested circuit. After the test result data is obtained, the data is discussed to be used as a reference in drawing conclusions. Then it can be known that the system can work and know the connection of the created tool as well as find out if there are any weaknesses. Furthermore, it can be concluded whether the tool that has been created can run the system correctly and in accordance with the at want.

4.1. Moringa Dryer Design Results

Based on the results of this final project research, a moringa dryer was produced with temperature control using the fuzzy logic method. The shape of the results of making the tool can be seen in Figure 15 where the tool length is 72 cm, 80 cm high, and 69 cm wide. Above the drying oven there is a control box.

Fig 15. Moringa Dryer Design Result

Moringa leaf drying oven is made of aluminum plate covered with wood with the specifications described. There is an opening on the side of the oven to allow air to circulate from the drying chamber and to blow air through the duct using a 220V AC fan. Moringa leaf dryer is equipped with an upper control box which contains a microcontroller circuit. Inside the control box there is a 16x2 LCD which is used to provide information as shown in the Figure below. The LCD displays information such as temperature monitoring, weight and fan Pwm. Next to the LCD there is a keypad that can be used to set the type of control used and the desired temperature set point.

4.2. Drying Moringa Leaves 180 Grams with a temperature of 60°C

This drying is done to find out how muchdecrease in the percentage of mass in dried Moringa leavesusing fuzzy control with a temperature of 60°C likethe result of such drying.

Table 1. Moringa drying test a set point temperature of 60°C

Time (m)	Temperature (°C)	Weight (g)	Difference	Error (%)
0	26°C	180g	1	0,02%
5	41°C	177g	1	0,02%
10	56°C	176g	1	0,02%
15	55°C	175g	1	0,02%
20	55°C	174g	1	0,02%
25	57°C	172g	0	0,00%
30	57°C	171g	2	0,04%
35	58°C	168g	1	0,02%
40	58°C	165g	0	0,00%
45	58°C	160g	1	0,02%
50	59°C	157g	1	0,02%
55	59°C	154g	1	0,02%
60	59°C	148g	0	0,00%
75	59°C	138g	1	0,02%
90	60°C	127g	1	0,02%
105	60°C	115g	0	0,00%
120	60°C	102g	0	0,00%
			Rata-Rata Eror =	0,01%

From the results of testing the moringa dryer with a temperature set at 60°C, the average percentage error value that is read is 0.1%, so that the value read by the sensor can work optimally.

4.3. Drying Moringa Leaves 180 Grams with a temperature of 50°C

This drying is done to find out how much percent decrease in the percentage of time in dried Moringa leavesusing fuuzzy control with a temperature of 50°C like the result of such drying.

Table 2. Moringa drying test a set point temperature of 50°C

Time (m)	Temperature (°C)	Weight (g)	Difference	Error (%)
0	26°C	180g	1	0,02%
5	40°C	176g	1	0,02%
10	49°C	172g	1	0,02%
15	50°C	170g	1	0,02%
20	49°C	169g	1	0,02%
25	49°C	167g	0	0,00%
30	49°C	163g	2	0,04%
35	49°C	158g	1	0,02%
40	50°C	155g	0	0,00%
45	48°C	151g	1	0,02%
50	48°C	147g	1	0,02%
55	49°C	144g	1	0,02%
60	49°C	139g	0	0,00%
75	49°C	137g	1	0,02%
90	50°C	134g	1	0,02%
105	50°C	131g	0	0,00%
120	50°C	129g	0	0,00%
			Rata-Rata Eror =	0,01%

From the results of testing the moringa dryer with a temperature set at 50°C, the average percentage error value that is read is 0.1%, so that the value read by the sensor can work optimally.

5. Conclusion

Based on the results and discussion of the Moringa leaf drying oven system that has been made, it can be concluded that:

1. The desired weight loss during the grinding process is 50% of the initial weight of Moringa leaves, which is 180 grams at a temperature of 60 ° C and 50 ° C with a time of 2 hours and 4 hours.
2. Percentage of mass reduction of 10% without control with a temperature of 70°C without temperature control within 10 minutes with an initial weight of 180 grams to 134 grams. And if the temperature is too hot and exceeds the specified temperature, it will damage the properties of the Moringa leaf material.

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