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Implementation of Arduino Uno-Based Temperature Control for Drying Tamarind (*Garcinia xanthochymus)*

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Abstract

Garcinia xanthochymus) is one of the spices that is often used for cooking and health ingredients. The post-harvest treatment of tamarind peel is by drying it. Tamarind drying can be done using a drying tool or sunlight. Generally using the sun is still not optimal because there is no temperature control during drying. In this study drying was carried out using a modified Arduino-based oven so that the initial temperature could be determined and the drying temperature could also be controlled. This is the first time this research has been conducted. The method in this research is the experimental method with drying using an arduino uno-based oven with a set point temperature of 60 ^{0}C and drying using sunlight with 0.9 kg of material for 1 time drying with 3 repetitions. This study aims to control the drying temperature in the Arduino Uno-based oven and also found the drying method carried out on the quality of the tamarind produced. The best quality of tamarind is drying using a tool, seen from several observations such as hardness, mold growth, drying time and drying rate. However, in drying using the sun, the value of vitamin C and pH has a higher value than using a tool, the initial water content in drying using a tool is 83,289% with a final moisture content of 9.672% and the initial moisture content for drying using sunlight is 83,744% with a moisture content of 83,744%. final water of 10.796%.

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1. Introduction

Indonesia is a country whose natural resources are rich in spices, both for cooking and for health. One of the most commonly used spices for cooking is tamarind (*Garcinia xanthochymus*). Tamarind has many benefits with a very sour taste and contains vitamin C. Tamarind fruit also contains organic acids in the form of hydroxycitric acid, citric acid and oxalic acid (Mardiyah, 2017).

People are more familiar with tamarind in dry or processed form. The harvest and postharvest stages of tamarind fruit are marked by the fruit that has fallen from the stem then the fruit is sliced and dried until the skin of the sour tamarind is blackish and ready to be stored (Darwis & Ballitro, 2009). Drying process to extend the shelf life of tamarind (Hakim, 2017). Drying is usually done by using sunlight and using tools. One example of people in West Sumatra, especially Agam Regency and Pasaman Regency, tamarind is dried in the traditional way using sunlight. Drying in this way takes a long time, which is ± 7 days, this drying is dependent on the weather at the time the drying takes place. so that if the weather is unpredictable it will take longer and also this drying requires a large area to dry tamarind. As a result, dried tamarind still has a high water content, so it will have an impact on the quality of tamarind produced and also the selling price obtained. Drying using a tool is usually done to help speed up the drying process, but drying tamarind using a tool generally does not have a temperature control. One of method to overcome this is by using an oven that uses temperature control based on Arduino Uno (Hakim, 2017). This oven is equipped with a heater that can dry the product. In this drying process the set point temperature can be controlled automatically. Temperature control plays an important role in the drying process of tamarind, drying is influenced by temperature and temperature will affect humidity. Temperature and humidity will be read using the DHT22, the DHT22 sensor is used because it has a wider measurement range with a longer measurement distance than the DHT11 sensor and has a fan so that the air produced will flow heat from the heat element (heater) to the oven as drying room. The fan will automatically stay on, and the heating element will be instructed by the microcontroller to stop if the temperature has exceeded the set point temperature (60 ^{0}C) and will turn on again when it is less than the set point temperature (60 ^{0}C). The temperature used for drying agricultural products is 60 ^{0}C (Zaky et al., 2017). The purpose of this research is to evaluate the temperature control in the drying process and evaluate the quality of tamarind produced using either an Arduino Uno-based drying oven or using sunlight

2. Materials and methods

2.1 Place and time of research.

The research was conducted from November to December 2020 at the Food and Agricultural Product Processing Engineering Laboratory, Agricultural and Biosystem Engineering Study Program, Andalas University, Indonesia.

2.2 Materials and tools.

The tool used in this research is an oven Hock with a length of 34.5 cm, width 30 cm and a height of 38.5 cm which has been modified using Arduino Uno, The use of arduino uno with DHT22 is commonly used. The DHT22 will be connected to the Arduino via the pins provided on the Arduino, so that the Arduino's work is regulated by the microcontroller through the pins that are connected. 16 x 2 LCD, heater (ROSSTON, 100 Watt), fan (Hanaya DC Brushless Fan Model FAN41DC), DHT22 sensor, USB cable, power cord, alcohol thermometer, stopwatch, erlenmeyer, measuring flask, digital scale, cup, oven, desiccator, cup clamp, laptop and other stationery. The materials used in this study were tamarind (Garcinia xanthochymus), buffer solution, filter paper, 1% starch, 0.01 N iodine, aquades, cotton.

2.3 Research methods.

This research using a modified oven with Arduino Uno is the first time that has been done. The research method used is an experimental method consisting of the assembly stage of the tool, the working principle of the tool, and observation.

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2.4 Tool Assembly.

The tool used is an oven with a length (34.5 cm), width (30 cm) and height (38.5 cm) which is modified using Arduino Uno Figure 1 so that it produces heat from a heater that uses an electric source.

Figure 1. Arduino Uno

Figure 3. Heater

Figure 4. Fan

The size of the rack in the oven used is 27 cm x 27 cm. This type 2 rack oven is equipped with a temperature and humidity sensor (DHT22) (Figure 2), a heater (Figure 3), and a fan (Figure 4), whose function is to circulate heat to the drying chamber so that it can dry kandis acid.

Alcohol thermometer is inserted into the oven with the principle of Wet Ball (BB) and Dry Ball (BK) as a comparison for temperature and humidity data that is read on the LCD during the drying process. Figure 5 is a drying oven used.

Information:
1 = DHT22 . Sensor
1 = Left side heater
2 = Right side fan
3 = Input button
4 = Power cord
5 = USB Cable
6 = LCD

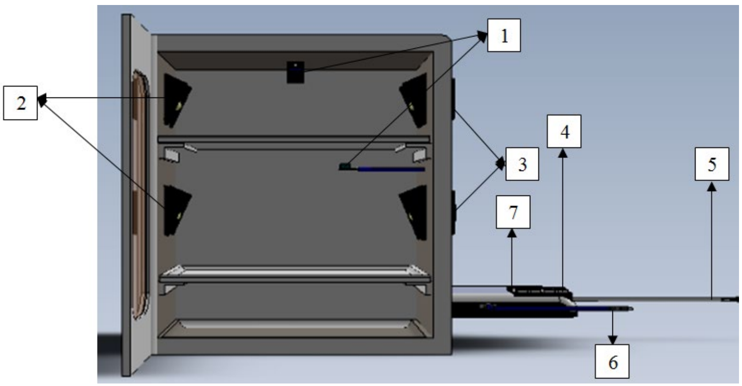

Figure 5. Arduino Uno Based Drying Oven

2.5 Tool Working Principle.

The principle of the tool used is an electric power drying oven that has been modified and controlled using Arduino Uno. The control system used in this tool is a closed loop control system which means that the output affects the input, when the drying temperature exceeds the specified set point temperature, the heater will turn off and come back on if the drying temperature is below the set point temperature. The USB cable is connected to a computer programmed for drying using the arduino uno application. The input button is used to set the set point temperature to be used for drying. Drying uses only 2 shelves the top and bottom. The heat generated through the heater as much as 4 pieces are on the right side (2 pieces) and left (2 pieces) at the top and bottom, so the heat generated will be spread by the fan until the set temperature set point (60 ^{0}C) (Hakim, 2017) has been reached, temperature and humidity will be read by the DHT22 sensor on shelve 1 and shelve 2, if the set temperature has reached the maximum limit (> 60 ^{0}C), the heater will turn off, the fan automatically lowers the temperature in the drying chamber so that when the temperature reaches < 60 ^{0}C, heater will return to life to reach the set point temperature. The drying process using this drying oven will obtain temperature and humidity data on the LCD during the drying process. Arduino uno-based oven working principle flowchart can be seen in Figure 6.

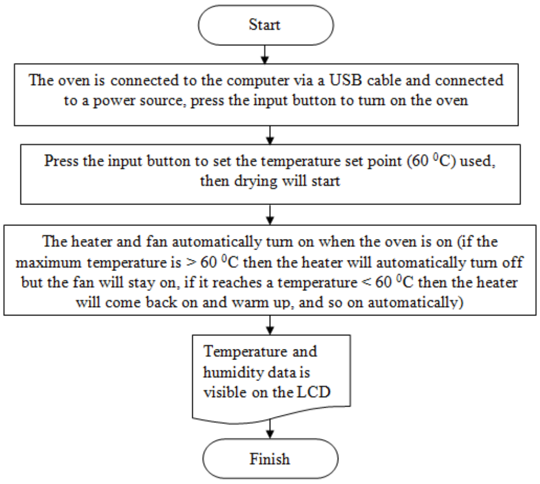

Figure 6. Arduino Uno-Based Oven Working Principle Flowchart

2.6 Observation

2.6.1 Moisture Content.

Measurement of the initial moisture content using the oven method. The initial moisture content was measured using tamarind samples, the material was put in an oven at a temperature of 100 - 105 ^{0}C until the dried material weighed constant or fixed. Measurement of moisture content during drying using an Arduino Uno based drying oven by taking 3 samples on each shelf by measuring changes in weight in the first 1 hour every 15 minutes, then every 30 minutes thereafter. Moisture content in agricultural products is usually measured by wet weight (wet). The formula for calculating the moisture content of wet weight (Taib et al., 1988) using Equation (1).

$$MC = \frac{B-C}{B-A} \times 100\ \% \qquad (1)$$

Where: MC = Moisture Content (%), A = cup weight (g), B = Weight of material before drying + cup (g), C = Weight of material after drying + cup (g).

2.6.2 The temperature and humidity

The temperature and humidity in the drying oven will automatically be read by the sensor used, namely DHT22. This drying will display temperature and humidity data every 15 minutes. Temperature and humidity errors are seen when measuring temperature using an alcohol thermometer with the principle of reading Wet Ball (WB) and Dry Ball (DK) so that the data on the LCD is compared with what is read on the alcohol thermometer. Equations (2), (3) and (4) are used to calculate the error, standard deviation and relative uncertainty (Satya et al., 2020) that is:

$$\text{Error} = |\ \text{Test Value} - \text{Standard Value}\ | \qquad (2)$$

$$\text{Standard Deviation} = \sqrt{\frac{\sum [\bar{X} - Xi]^2}{n-1}} \qquad (3)$$

$$KR = \frac{\text{Test Value} - \text{Standard Value}}{\text{Standard Value}} \times 100\ \% \qquad (4)$$

Where:

Test Value = Value read on the Arduino Uno based LCD Oven,

Standard Value = Value on a measuring instrument (alcohol thermometer),

SD = Standard deviation

Xi = Middle value

$\bar{X}$= Average value read

n = Total data

KR = relative uncertainty.

The evaluation of the temperature control carried out can be seen on the control chart by seeing whether the drying temperature is still within the limits of UCL and LCL. UCL (Upper Control Limit) and LCL (Lower Control Limit) are the upper and lower limits on the values contained in the control system

2.6.3 Content of Vitamin C.

The measurement method used is the titration method. The titration method is carried out by weighing 10 grams of the material to be mashed. The fine material was put into a 250 ml volumetric flask with the addition of distilled water until it was full to the limit of 250 ml. The solution was stirred until mixed and then filtered using filter paper, take 25 ml of the filtered solution and put it into a 125 ml Erlenmeyer. The final step is adding 1 ml of 1% starch indicator to the solution and titrating with 0.01 N iodine until it turns blue in 10 seconds. (Sudarmadji et al., 1997). Equation (5) to calculate the content of vitamin C:

$$\text{Content Of Vitamin C} = \frac{V \times P \times 0{,}88 \times 100}{\text{g sample}} \qquad (5)$$

Where: 0.88 = Constant, V = Titration Volume (End – Beginning), g sample = Number of samples (g), P = Number of dilutions.

2.6.4 Growing Mold.

The visual characteristics of agricultural commodities that have begun to grow mold are white and yellow spots on the upper surface and gradually turn dark brown to black. This calculation is obtained by looking at each piece of tamarind peel overgrown with mold at the end of drying and divided by the total dried tamarind peel. For the percentage of tamarind that has been overgrown with mold using Equation (6).

$$PTJ = \frac{\text{Number of tamarind chips overgrown with mold}}{\text{Total of tamarind chips}} \qquad (6)$$

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2.6.5 Tool Performance Test

2.6.5.1 Drying time will be observed both using a tool with a set point temperature of 60 ^{0}C and drying in sunlight, the process of decreasing water content is in line with the drying temperature used. (Putri et al., 2015) with the final stage when the water content has reached 12%.

2.6.5.2 Drying rate is the weight of water that is evaporated on a material per unit time (hours). The drying rate is calculated using Equations (7) and (8) (Suharjo, 2007).

$$We = Iw - Fw \quad (7)$$

$$\dot{W} = \frac{We}{t} \quad (8)$$

Where: Iw = Initial weight (kg), Fw = Final weight (kg), We = Weight of evaporated water (kg), t= Drying time (hours), W = Drying rate (kg/hour).

3. Results and discussion

This is the first time this research has been conducted. The method in this research is the experimental method with drying using an arduino uno-based oven with a set point temperature of 60 ^{0}C with 0.9 kg of material for 1 time drying with 3 repetition and drying using sunlight with 0.9 kg of material for 1 time drying with 3 repetitions.

Figure 6. Tamarind Drying Process with Arduino Uno Based Oven

3.1 Initial Moisture Content.

The average value of the initial moisture content of the tamarind peel in each drying method has a value that is not much different. The average initial moisture content of tamarind peel drying using a tool or using the sun can be seen in Figure 7.

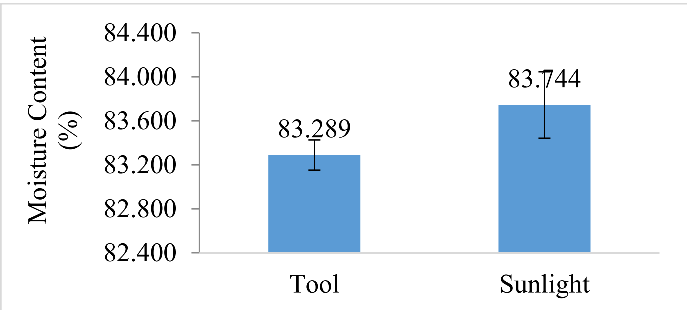

Figure 7. Graph of Initial Moisture Content

Based on the graph, it can be seen that the initial moisture content value of tamarind peel on drying using a tool is obtained an average of 83,289%, for drying using the sun the obtained levels of the initial water content is 83,744%, this is in accordance with previous research with the initial water content of

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tamarind in the range of 83% (Nuraini, 2016). From the statistical results of the T test, it can be seen that the moisture content of drying suing the tool and the sun is not different, it can be seen with a significant value is below 0.05.

Based on the table above, it can be seen that the initial moisture content parameter of tamarind peel has a significant value of 0.076 on drying using tools and 0.104 on drying using the sun, a significant value higher than 0.05 so that H0 is accepted and H1 is rejected, meaning that there is no significant difference in levels. the initial moisture content of the tamarind peel on the drying method used.

Table 1. T-Test Table of Initial Moisture Content

Observation	Treatment	Average	Standard Deviation	Sig.	T
Initial Moisture Content	Tool	83,289	0,137	0,076	-2,379
	Sunlight	83,743	0,301	0,104	-2,379

3.2 Final Moisture Content.

The value of moisture content after drying obtained is not much different between the drying methods used. The value of the final moisture content of the tamarind peel is a maximum of 12% (Nuraini, 2016). The final moisture content of tamarind peel can be seen in Figure 8.

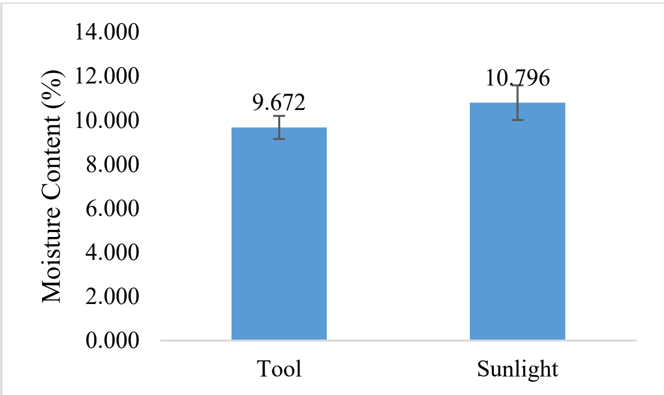

Figure 8. Graph of Moisture Content at the End of Drying using Tools and Sunlight

The average final moisture content in drying using a tool is 9.672%, and for drying using the sun is 10.796%. The final moisture content value for drying using the sun is higher than the final moisture content for drying using a tool. in the drying process using a tool there is a temperature control so that the final moisture content achieved in drying using a smaller tool. During the drying process, there will be a decrease in the water content, both drying using tools and drying using the sun.

Based on the T test, it can be seen that the moisture content after drying has a significant value on drying using a 0.109 tool and 0.119 on drying using the sun, which is higher than 0.05 (significant), it can be concluded that H0 is accepted so that H1 is rejected. This means that there is no significant difference between the drying method on the final moisture content of the resulting tamarind peel. Drying was stopped when the moisture content value had reached 12%, this caused no difference in the final moisture content value of the tamarind peel.

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Table 2. T-Test Table of Final Moisture Content

Observation	Treatment	Average	Standard Deviation	Sig.	T
Final Moisture Content	Tool	9,672	0,524	0,109	-2,057
	Sunlight	10,796	0,788	0,119	-2,057

3.3 Temperature and humidity.

The process of measuring temperature and humidity is carried out from the beginning of drying to the end of drying. Temperature and humidity are obtained from the LCD which is read by the DHT 22 sensor. The temperature control graph can be seen in Figure 9.

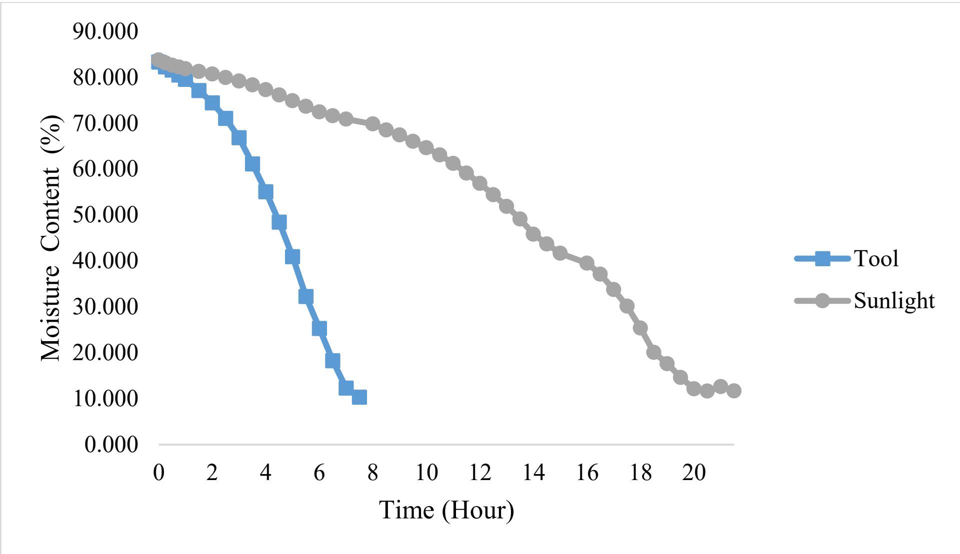

Figure 9. Graph of Decrease in Mositure Content of Drying Tools and the Sun

The image shows the drying temperature line which is on the average line not crossing the UCL (Upper Control Limit) and LCL (Lower Control Limit) lines), what is meant by the UCL and LCL lines are as the upper and lower limits on the values contained in the control system, in other words the drying temperature values obtained are not found outside the control limits. The average value of the drying temperature using the tool is 59.9 ^{0}C, this is close to the set point temperature used, which is 60 ^{0}C, so the graph above can explain the drying temperature obtained during the drying process is still in the upper and lower limits of control, Based on the data and graphs produced, it can be said that the tool used can control the drying temperature, but it is not optimal because there is still a drying temperature that exceeds the set point temperature during the drying process.

Based on Figure 10, the average error value obtained at the drying temperature using the tool is 4.8 0C. The graph also shows the error value that occurs during the drying process, by looking at the difference between the set point value and the drying temperature value that is read on the LCD of the tool. The lower the error value obtained, the better the tool used, and vice versa. The temperature control has been running well, the tool can control the drying temperature to return to the set point temperature, but it is still not optimal because there are still some drying temperatures that exceed the set point temperature during drying.

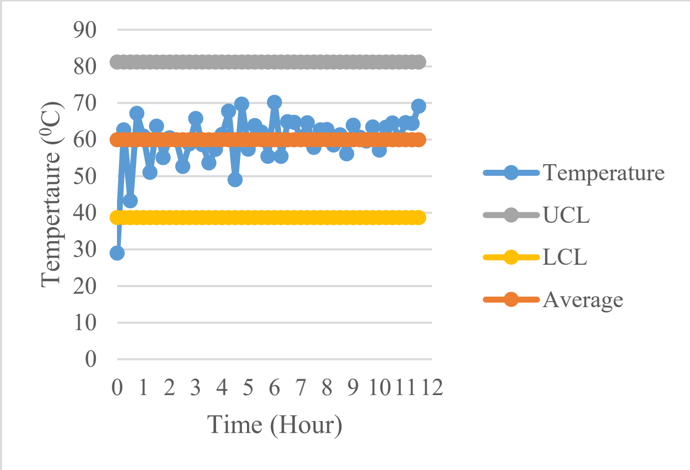

Figure 10. Drying Temperature Control Chart

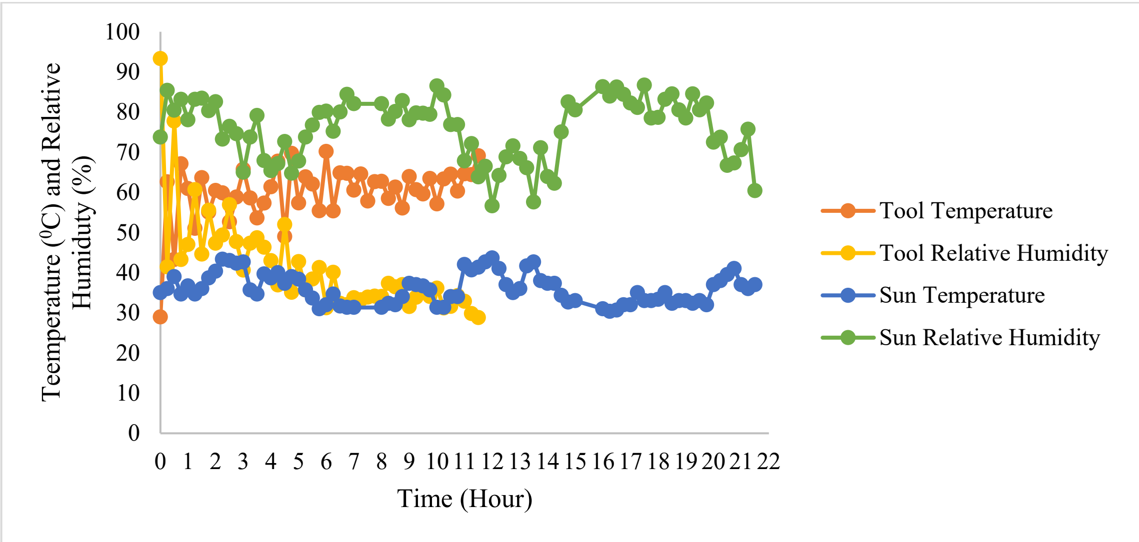

Figure 11. Graph of Temperature and RH Drying using Tools and the Sun

Based on Figure 11, the graph provides information about the temperature and relative humidity obtained when drying using tools and using the sun, the temperature produced when drying using tools is higher than drying using the sun. The temperature control has been running well, the tool can control the drying temperature to return to the set point temperature, but it is still not optimal because there are still some drying temperatures that exceed the set point temperature during drying. The average drying temperature using the sun is 36 ^{0}C, but the average drying temperature using the tool is 59.9 ^{0}C. This difference makes drying using tools faster than drying using the sun. The relative humidity obtained in drying using a tool is lower than drying using sunlight, due to the heat provided by the heater in the drying room, heater and fan will keep the drying room in a hot condition with the working principle of temperature control during the drying process. The relative humidity of drying using a tool is 41.4%, while the drying using the sun is 75.8%.

Table 3. T-Test Table Drying Temperature

Observation	Treatment	Average	Standard Deviation	Sig.	T
Temperature	Tool-Sun	23,202	7,930	0,000	20,058

Based on Table 3, it can be seen that the significant value generated for the drying temperature between drying using tools and drying using the sun is 0.000 so it is lower than 0.05 which means that the drying temperature is significantly different between drying using tools and drying using the sun. Statistical tests were also carried out on the relative humidity obtained during drying, which can be seen in Table 4.

Based on Table 4, it can be seen that the significant value produced for the relative humidity between drying using tools and drying using the sun is 0.000 which means it is small from 0.05 which means that there is a significant difference in relative humidity between drying using tools and drying using the sun.

Table 4. Drying RH T Test Table

Observation	Treatment	Average	Standard Deviation	Sig.	T
RH	Tool-Sun	-34,421	13,392	0,000	-17,620

3.4 Content of Vitamin C.

The content of vitamin C in drying using a tool and the sun can be seen in Figure 12.

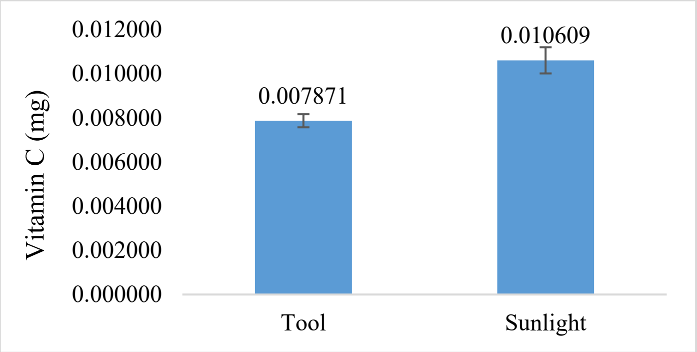

Figure 12. Vitamin C Content Drying Using Tools and The Sunlight

In the picture it can be seen that the vitamin C content in drying using a tool is obtained an average of 0.007871 mg/g of material, while for drying using the sun is 0.010609 mg/g of material, it can be seen that the resulting value has a difference between vitamin C drying using a tool and drying using the sun, vitamin C in drying using a tool is less than drying using the sun. The content of vitamin C contained in the material is influenced by several factors, such as heating, storage and also the drying medium itself. An increase in heating temperature will have an impact on decreasing ascorbic acid, this will affect the vitamin C content in the material (Karadeniz et al., 2005), so it can be concluded that vitamin C is very dependent on the drying temperature given to the material.

3.5 Mold Growing.

Mold growth parameters are very important to see the final results of dried tamarind skin from drying carried out, namely drying using an Arduino Uno-based oven and drying using sunlight. The graph of the percentage growth of dried tamarind mold is shown in Figure 13.

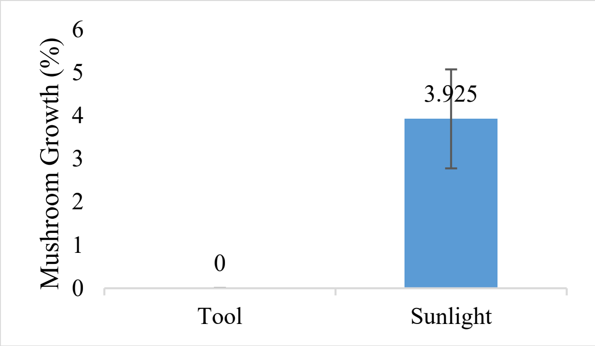

Figure 13. Graph of Growing Mold Drying using Tools and the Sun

The percentage value of mold growth on drying using a tool is 0%. Drying using the sun usually undergoes a faster mold growth process. This is because drying on the tool requires a relatively fast time and drying does not depend on the weather so that the drying process does not trigger the occurrence of mold. Drying using the sun obtained an average mold growth of 3.925%. Drying using the sun takes 3 days so that the final result for the dried tamarind skin is overgrown with mold. Factors that can affect the growth of fungi in agricultural products include water content in these products, ambient temperature in agricultural products and storage time. Drying using the sun is very susceptible to mold growth on the dried product, because the drying takes longer and when the turn of the day for drying the product is already affected by the ambient humidity. The picture of mold growing in tamarind drying using oven and sunlight can be seen in Figure 14 and Figure 15

Figure 14. Arduino Uno-Based Oven Tamarind Drying

Figure 15. Sunlight Tamarind Drying

3.6 Drying Time.

The drying time of the tamarind peel from the drying method obtained different values. Drying time depends on the amount of material to be dried and the drying temperature itself.

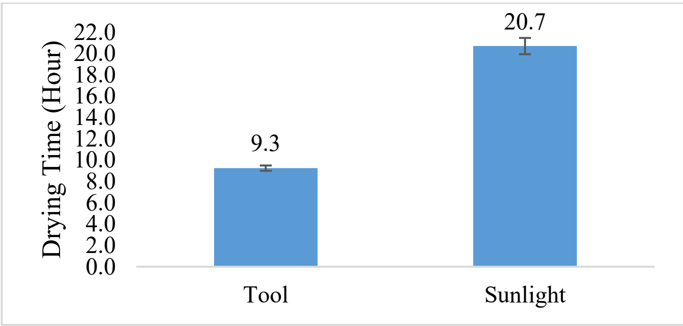

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Figure 16. Graph of Drying Time using Tools and the Sun

Figure 16 is a graph of the drying time of the two methods carried out. The picture shows the difference in drying time between drying using a tool and drying using the sun. The drying time for drying using a tool is 9.3 hours, while drying using the sun is obtained an average of 20.7 hours. Drying using a tool only takes 1 day, for drying using the sun it takes 3 days. Drying using the sun depends on the weather at the time of drying. During the drying process using the sun there are no obstacles such as rain so that drying can be faster. Drying time depends on the drying temperature, drying will be faster if the drying temperature used is high (Yulni et al., 2017).

3.7 Drying Rate.

The decrease in the water content of the material during the drying process per unit time is called the rate of water evaporation (Yadollahinia et al., 2008). Drying rate is the amount of water vapor lost per unit time. The graph of the drying rate using the tool and the sun can be seen in Figure 17.

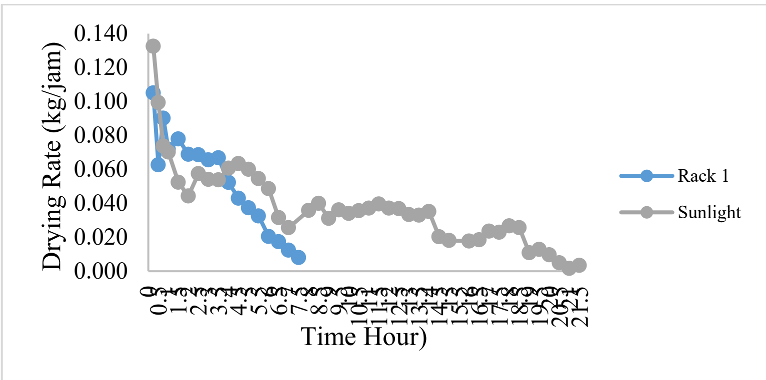

Figure 17. Drying Rate Graph

The graph of the drying rate obtained fluctuates, this condition is caused by several factors such as temperature, humidity and also air flow in the drying room. (Rozana et al., 2016). The graph of the drying rate shows changes that are not constant, because at the beginning of drying there is no free water on the surface of the material (Syah et al., 2020). Two main factors that affect the drying process are the drying air factor and the material itself. The drying air factor includes drying temperature and air humidity. The higher the temperature difference when drying, the more evaporation occurs so that the drying process can be faster. Humidity also depends on the temperature at the time of drying, high humidity causes the drying process to be slower. Factors of the dried material include the initial moisture content contained in the material and the size of the material. The decrease in water content will cause the drying rate to decrease, and vice versa, because with increasing time the water contained in the material will decrease, this causes the drying rate to decrease. (Hayati et al., 2012). The graphic information on the drying rate using sunlight shows the drying rate value which is relatively the same, as shown in the graph above.

4. Conclusion

Temperature control on drying using the tool goes well, the drying temperature can be controlled according to the set point temperature used, 60 ^{0}C. The best drying method is drying using a tool, judging by the quality of dried tamarind produced. The difference is seen in the parameters of final moisture content (9,672 %), drying time (9,3 hour), drying rate (0,041 kg/hour) and mold growth (0 %).

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