JURNAL ONLINE
PERTANIAN TROPIK

Analysis of Thermal Energy in the Drying Process of Taro Tubers (*Colocasia esculenta (L.)*) using a Rack-Type Dryer

Nurul Aen, Rahmat Sabani , Ida Ayu Widhiantari*

Study Program of Agricultural Engineering, Faculty of Food and Agroindustrial Technology, University of Mataram, Indonesia
*Corresponding Author: ida.ayuwidhiantari@unram.ac.id

ARTICLE INFO

Article history:
Received : 15 July 2024
Revised : 10 Oktober 2024
Accepted : 27 November 2024
Available online
https://talenta.usu.ac.id/jpt

E-ISSN: 2356-4725
P-ISSN: 2655-7576

How to cite:
Aen, N. (2020). Analysis of Thermal Energy in the Drying Process of Taro Tubers (Colocasia esculenta (L.)) using a Rack-Type Dryer. Jurna Online Pertanian Tropik (1), 26-40.

ABSTRACT

Repok Pidendang Hamlet is one of the hamlets in the Pemepek Village area, Pringgarata District, Central Lombok Regency which has a superior agricultural commodity, one of which is the taro plant. An important problem faced by the people of Repok Pindendang Hamlet is the abundant taro harvest but still lacks in processing, causing taro to spoil quickly. Therefore, it is necessary to process taro that can increase the shelf life and quality of taro. This study aims to analyze the energy balance in the drying process of taro tubers (Colocasia esculenta (L.)) in a rack-type dryer. The method used is an experimental method using an energy equilibrium approach. The material used is taro tubers with a thickness of I mm which will be dried with temperature variations of 40-45°C, 50-55°C and 60-65°C until the moisture content is constant. The results show the amount of heat energy in, useful heat energy, outgoing heat energy, lost heat energy, and the highest number of enthalpy were obtained at 60-65°C temperature treatment, which were 1719.72 kJ, 869.59 kJ, 823.98 kJ, 1693.57 kJ, and 304.82 kJ/kg, respectively. The total efficiency of the drying system during drying using rack-type dryers was obtained at a temperature of 60-65°C of 50.56% and the lowest efficiency was found at a temperature of 50-55°C of 24.26%.

Keyword: Heat energy, Rack type drying, Taro

ABSTRAK

Dusun Repok Pidendang adalah salah satu dusun di wilayah Desa Pemepek, kecamatan Pringgarata, Kabupaten Lombok Tengah yang memiliki komoditas pertanian unggulan salah satunya yaitu tanaman talas. Masalah penting yang dihadapi masyarakat Dusun Repok Pindendang yaitu hasil panen talas yang melimpah akan tetapi masih kurang dalam pengolahan sehingga menyebabkan talas cepat rusak. Oleh karena itu perlu adanya pengolahan talas yang dapat meningkatkan umur simpan dan kualitas dari talas. Penelitian ini bertujuan untuk menganalisis kesetimbangan energi pada proses pengeringan umbi talas (*Colocasia esculenta (L.*)) pada alat pengering tipe rak. Metode yang digunakan adalah metode eksperimental dengan menggunakan pendekatan kesetimbangan energi. Bahan yang digunakan yaitu umbi talas dengan ketebalan I mm yang akan dikeringkan dengan variasi suhu 40-45°C, 50-55°C dan 60-65°C hingga kadar air konstan. Hasil penelitian menunjukkan jumlah energi panas masuk, energi panas berguna, energi panas keluar, energi panas hilang, dan jumlah entalpi tertinggi diperoleh pada perlakuan suhu 60-65°C yaitu berturut-turut sebesar 1719,72 kJ, 869,59 kJ, 823,98 kJ, 1693,57 kJ, dan 304,82 kJ/kg. Besarnya efisiensi total sistem pengering selama pengeringan menggunakan alat pengering tipe rak diperoleh efisiensi tertinggi pada suhu 60-65°C sebesar 50,56 % dan efisiensi paling rendah terdapat pada suhu 50-55°C sebesar 24,26 %.

Keyword: Energi panas, Pengeringan tipe rak, Talas

http://doi.org/10.32734/jpt.v11i2.17286

1. Introduction

Food ingredients such as tuber products and other horticultural products have a distinctive property, which is that they continue to undergo changes after harvesting. Taro tubers that have been harvested still contain a lot of water content, which is 70-85% and the taro itself contains oxalic acid which can cause itching if it is directly exposed to the skin, so it is necessary to carry out proper handling after harvesting (Arsini et al., 2023).

The drying process requires a large amount of energy to evaporate the water. This is a major challenge for the drying industry to achieve energy efficiency while maintaining product quality. Thermodynamic analysis, which consists of energy and allergy analysis, is an important analysis used to evaluate and investigate the availability of energy in the system, the energy required from the energy produced, and detect energy loss. So, it is necessary to conduct an energy analysis for each machine and equipment used to find out how much energy is needed, energy is given, and energy is wasted during the drying process (Suherman & Trisnaningtyas, 2016).

Taro tubers that have been harvested are easily damaged because they contain 63-85% water. Harvested taro cannot last long without the processing process. One of the solutions taken to overcome this problem is to process taro tubers to increase shelf life. The drying process in taro tubers is one of the cursial stages, because it determines the quality and durability of taro tubers. Drying is carried out using a rack-type dryer. Drying using a rack-type dryer has more advantages because the drying temperature can be adjusted, so that drying is faster and more even. Heat will be absorbed by taro tubers during the drying process, this can affect the dryness of taro tubers. (Adila et al., 2023), stated that drying using a rack type drying machine is able to optimize the drying process of agricultural products. Therefore, a study was conducted on "Heat Energy Analysis in the Drying Process of Taro Tubers (*Colocasia esculenta (L.*)) Using a Rack Type Dryer".

1.1. Research Purposes
The purpose of this study is to analyze the energy balance in the drying process of taro tubers (*Colocasia esculenta (L.*)) in a rack-type dryer.

2. Research Methods

2.1. Tools and materials
The tools used in this study include: rotary rack type hybrid dryer, digital thermometer/K-type thermocouple, camera, stopwatch, anemometer, digital scale, knife, ruler, tray, taro slicer, wet ball thermometer and dry ball. The material used in this study is taro tubers (*Colocasia esculenta (L.)*) with a harvest age of 8-12 months and a coconut shell biomass.

2.2. Method
This research was conducted using an experimental method using an energy equilibrium approach. Testing is carried out using a rack-type dryer. The number of shelves on the dryer is 8 racks, consisting of 4 shelves on the left side of the dryer, and 4 shelves on the right side of the dryer. The material used is taro tubers with a thickness of 1 mm which will be dried with temperature variations of 40-45°C, 50-55°C and 60-65°C until the moisture content is constant.

2.3. Research Parameters
The parameters used in this research are as follows:

Relative Humidity (RH)
The RH measurement is carried out by comparing the temperature of the wet bulb and the temperature of the dry ball, to determine the temperature of the wet ball, namely by using a thermometer wrapped in a wet cloth and placed in the drying room. Meanwhile, to determine the temperature of the dry ball, use a thermometer that is allowed to dry. The RH value was calculated using a psychrometric application and compared to a psychometric table.

Moisture Content (%)
In this study, the measurement of moisture content is carried out based on the decrease in the mass of the material, so it can be formulated with equation (1) as follows (Kurniawan et al., 2020).

$$KA = \frac{(M1-M2)}{M1} \times 100\% \quad (1)$$

Information:
M1 = Initial mass of material (grams)
M2 = Final mass of material (grams)

Energy Balance

a. Rate of Energy Entering the Drying Room, EIN (kJ)

The rate of energy entering the drying chamber, (EIN) is the amount of heat energy entering a system per unit of time through the inlet (biomass). The rate of energy entering the drying chamber can be calculated using the following equation (2) (Hariri & others, 2021):

E IN =mx Cp x TIN...(2)

Information:
E IN = Rate of energy entering the drying chamber (kJ)
m = Rate of airflow into the dryer chamber, (kg)
Cp = specific heat of the air, (1,007 kJ/kg°C)
TIN = Temperature of the air entering the drying chamber, (°C)

b. Useful Energy Rate, EUSE (kJ)

E B1 = mw x LH ....(3)

Information:
E B1 = Useful energy to evaporate water, (kJ)
Mw = Mass of evaporated product, (kg)
LH = Latent heat of water evaporation, (2800 kJ/kg)

Drying Energy Efficiency (%)

Drying energy efficiency is the ratio between useful heat energy and heat energy entering the drying room. The energy efficiency of drying can be calculated by the following equation (4)

$$\eta = \frac{EUSE}{EIN} x\ 100\% \quad (4)$$

Information:
the = Drying energy efficiency (%)
E IN = Inlet heat energy (kJ)
E USE = Useful heat energy (kJ)

3. Results and Discussion

3.1. Relative Humidity (RH)

Based on the results of the study, a graph of the relationship between the relative humidity of the drying room and the length of drying time can be seen in the following Figures 1 to 3:

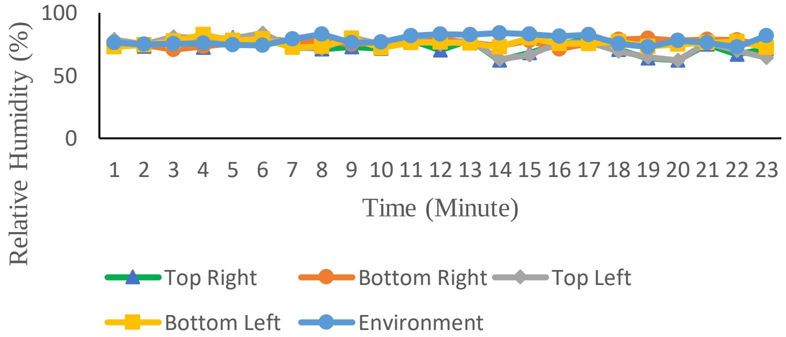

Figure 1. Relative Humidity (RH) during Drying Taro Bulbs at 40-45°C

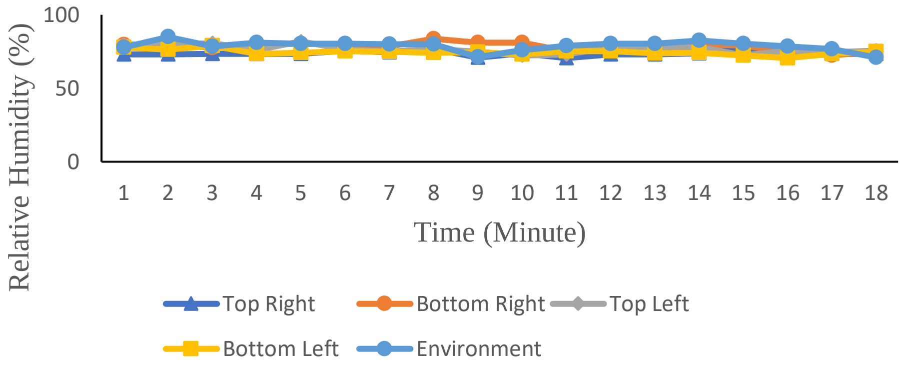

Figure 2. Relative Humidity (RH) during Drying Taro Bulbs at 50-55°C

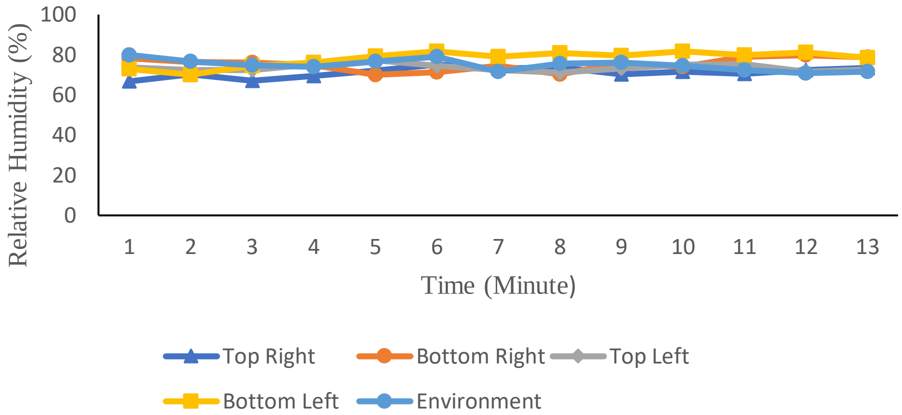

Figure 3. Relative Humidity (RH) during Drying Taro Tubers at 60-65°C

Relative Humidity (RH) is greatly affected by the temperature in the drying process. Based on the figure of graphs 1-3 above, it shows that there is an increase and decrease in the RH value in the drying room during the drying process. This is because the temperature in the drying room also rises and falls during the drying process, which is caused by temperature control, which is difficult to control. At a temperature of 40°C-45°C, the average RH values of the drying room on the upper right, lower right, upper left, lower left, and environmental RH were obtained of 72.61%, 76.07%, 73.81%, 75.80%, and 78.23%, respectively. At a temperature of 50°C-55°C, the average RH values of the drying room on the upper right, lower right, upper left, lower left, and environmental RH were 73.56%, 78.25%, 76.44%, 74.58%, and 78.83%, respectively. At a temperature of 60°C-65°C, the average RH values of the drying room on the upper right, lower right, upper left, lower left, and environmental RH were 71.19%, 75.28%, 73.58%, 78.12%, and 74.90%, respectively. Based on the analysis of the data, it is known that temperature has a very strong relationship with RH changes, the higher the drying temperature, the lower the relative humidity. This is in accordance with the (Islami et al., 2017) which states that the higher the temperature used to dry the material, the lower the RH value. So that the time needed to dry the material is getting shorter. The higher the temperature of the dryer room, the higher the decrease in moisture content. This is because the higher the temperature of the dryer, the greater the heat energy carried by the air so that the greater the amount of liquid mass evaporated from the surface of the evaporated material (Purwanti et al., 2017)

3.2. Temperature (°C)

The energy consumption of this rack-type dryer comes from coconut shell biomass. Based on the temperature observation during the drying process, the ambient temperature, drying room temperature, biomass furnace temperature, inlet temperature and outlet temperature in each treatment can be seen in Figure 4 to 9 below.

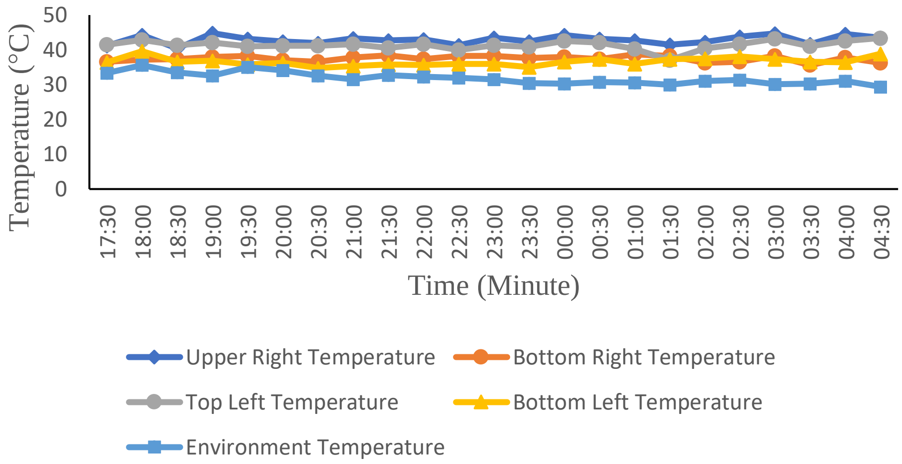

Figure 4. Drying Room Temperature and Environment during Drying Taro Tubers, Temperature 40-45°C

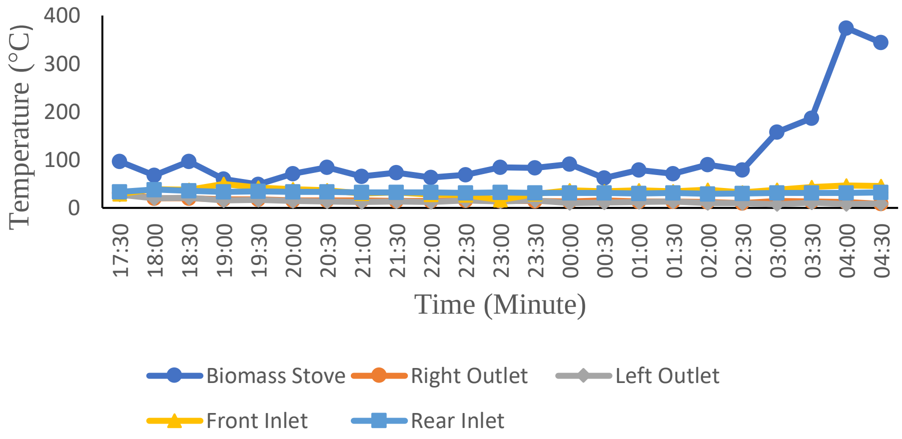

Figure 5. Biomass Furnace Temperature, Inlet and Outlet during Taro Bulb Drying, Temperature 40-45°C

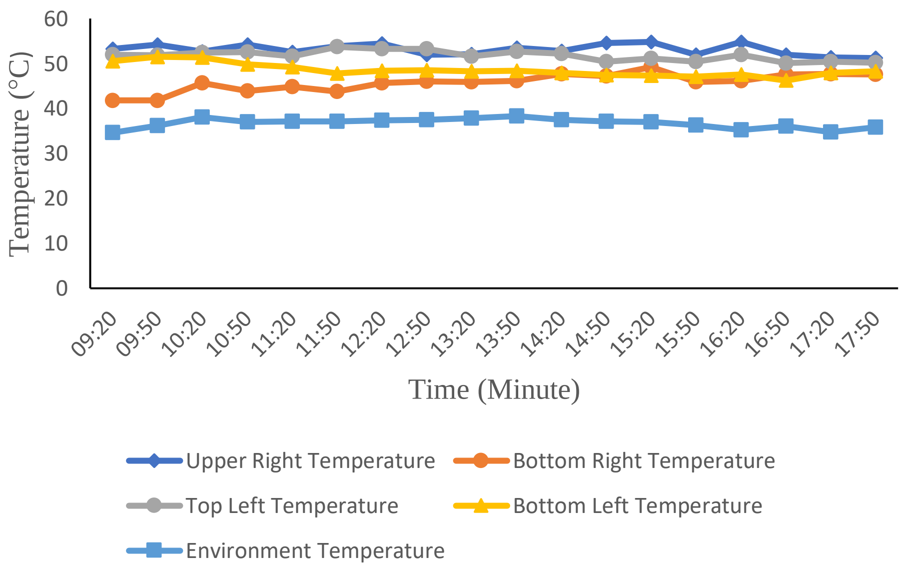

Figure 6. Drying Room Temperature and Environment during Drying Taro Bulbs, Temperature 50-55°C

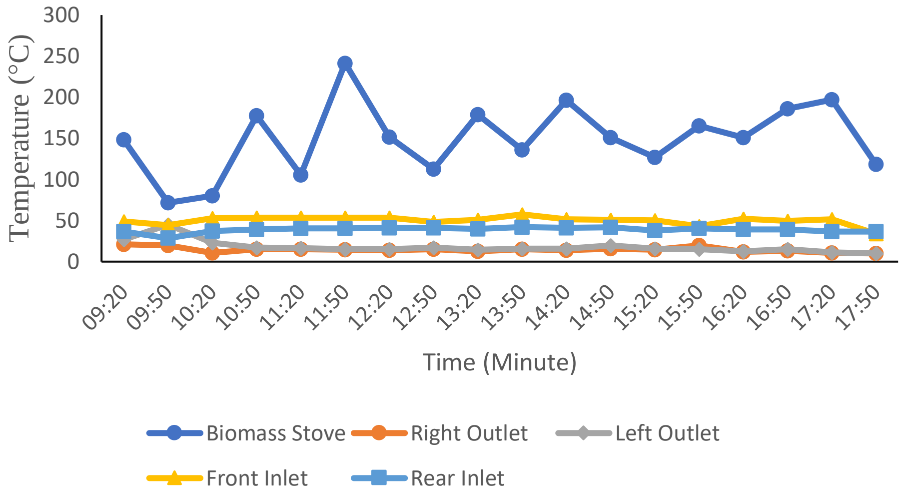

Figure 7. Biomass Furnace Temperature, Inlet and Outlet during Taro Bulb Drying, Temperature 50-55°C

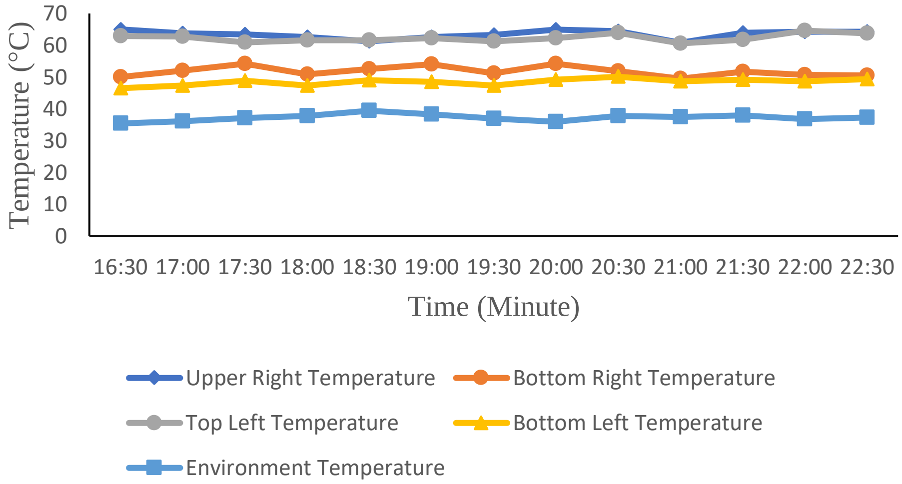

Figure 8. Drying Room Temperature and Environment during Taro Bulb Drying, Temperature 60-65°C

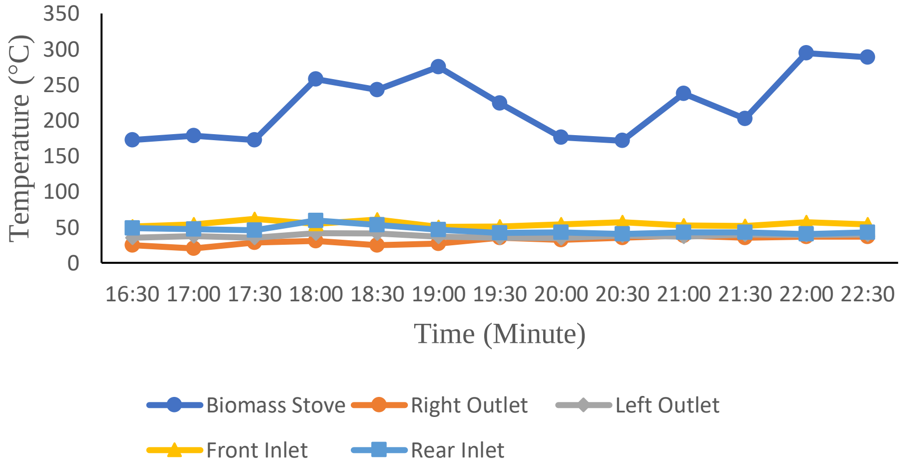

Figure 9. Biomass Furnace Temperature, Inlet and Outlet during Taro Bulb Drying, Temperature 50-55°C

Based on the temperature graph in Figure 7-9 above, it can be seen that the hot temperature in the drying room can accelerate the decrease in the moisture content of the material. The higher the temperature of the drying room, the greater the energy to dry the material, while the lower the temperature of the drying room, the less energy is needed to dry the material (Tobing et al., 2019). Based on the temperature graph, the temperature distribution range during the drying process was obtained, namely at the temperature treatment of 40-45°C, on the upper right shelf the temperature distribution range was obtained to 40.4 – 44.8°C, on the lower right shelf the temperature distribution range was obtained 36.3 – 38.7°C, on the upper left shelf the temperature distribution range was obtained 37.06 – 43.4°C, on the lower left shelf the temperature distribution range was obtained 34.8 – 39.6°C, for the ambient temperature the range is 29.4 – 35.01°C, in the biomass furnace the temperature range is obtained 48.9 – 374.3°C, in the front inlet the temperature range is 16.3 – 49.7°C, in the rear inlet the temperature range is 29.4 – 38.3°C, on the right outlet the temperature range is 8.4 – 31.2°C, and in the left outlet the temperature range is 7.3 – 27.4°C.

In the drying treatment with a temperature of 50-55°C, the temperature distribution range in the upper right drying room was obtained around 51.2 – 54.8°C, in the lower right drying room the temperature range was obtained 41.8 – 49.2°C, in the upper left drying room the temperature range was obtained 50.1 – 53.7°C, in the lower left drying room the temperature range was obtained 47.1 – 51.5°C. The ambient temperature was obtained in the range of 34.6 – 38.3°C. In the biomass furnace, the temperature range is 71.6 – 241.5°C, in the front inlet the temperature range is 33.9 – 57.5°C, in the rear inlet the temperature range is 28.5 – 42.1°C, in the right outlet the temperature range is 10 – 21.1°C, and in the left outlet the temperature range is 10 – 44.9°C.

In the drying treatment with a temperature of 60-65°C, the temperature distribution range in the drying room of the upper right shelf was obtained which was 60.9 – 65°C, in the lower right drying room the temperature range was obtained 49.5-54.2°C, in the upper left drying room the temperature range was obtained 60.6-64.6°C, in the lower left drying room the temperature range was obtained 46.5-50.1°C, and for the ambient temperature 35.4-39.4°C was obtained. In the biomass furnace, the temperature range is 171.3 – 294.3°C, in the front inlet the temperature range is 50.5 – 61.7°C, in the rear inlet the temperature range is 40.3 – 59.5°C, in the right outlet the temperature range is 20.2 – 38.2°C, and in the left outlet the temperature range is 34.7 – 41.6°C. (Aisah et al., 2021) stated, the higher the air temperature in a drying and the greater the heat energy carried by the air, the amount of liquid mass evaporated from the surface of the material will be more.

3.3. Moisture Content (%)
The moisture content of the material is one of the factors that affect the drying process. The decrease in the moisture content of the material is very closely related to the decrease in the mass of the material, this is due to the evaporative water content of the dried material can be seen from the decrease in the mass of the material.

Based on the results of the study, a graph of changes in moisture content over time during drying is obtained in the following Figure 10:

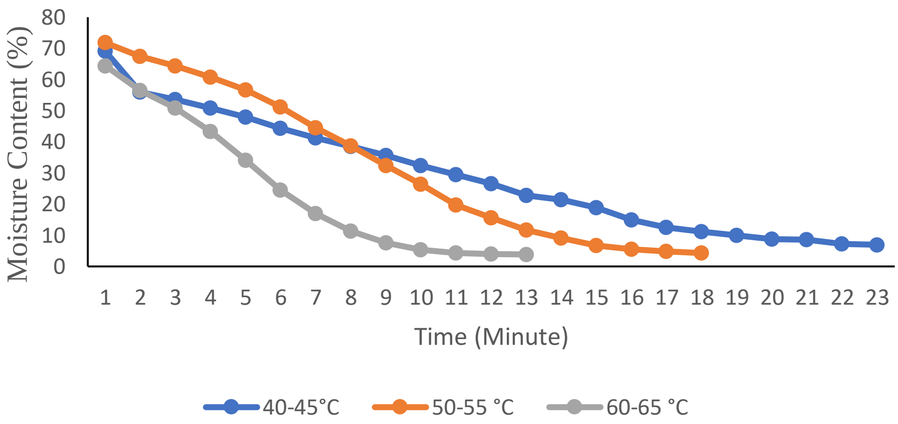

Figure 10. Change in Moisture Content of Materials to Time during Drying

Based on Figure 10, it can be seen that during the drying process, the moisture content continues to decrease. The higher the drying temperature, the faster the rate of decrease in moisture content in the material will decrease. In Figure 10, it can be seen that the variation in drying temperature affects the process of decreasing the moisture content. In the drying treatment with a temperature of 40-45°C, the initial moisture content was 69.03% and the final moisture content was 6.95% with a drying time of 12.5 hours. In the drying treatment with a temperature of 50-55°C, the initial moisture content was 71.78% and the final moisture content was 4.27% with a drying time of 8.5 hours. In the drying treatment with a temperature of 60-65°C, the initial moisture content was 64.39% and the final moisture content was 3.84% with a drying time of 7 hours. In the drying process, the moisture content of the material initially decreases very quickly and the longer the drying decreases the moisture content of the material will be slower, this is because the hot air contained in the drying chamber can cause the temperature in the baking pan and the material to rise, the increase in temperature in the material causes an increase in water vapor pressure so that there is a mass transfer from the material to the dryer air in the form of steam.

3.4. Energy Balance

The drying system has a thermal energy balance. Thermal energy equilibrium is an energy equilibrium that is always changing with time (Maulana et al., 2019)

The energy entering the dryer will be used to heat the air of the drying room, heat the temperature of the material, heat the temperature of the water of the material and evaporate the water of the material. Useful energy is the energy used to heat the material in the drying room. The energy that comes out is the energy that is lost through the walls of the drying room and *exhaust fan* (*outlet*). The energy lost is the energy that comes out of the dryer and the energy stored in the dryer. Lost energy can also occur when opening the door of the drying room.

Table 1. Results of calculation of incoming energy

Temperature °C	Total Energy Intake (kJ)
40-45	928,32
50-55	1270,65
60-65	1719,72

At a temperature of 40-45°C, the energy consumption of biomass is 928.32 kJ. At a temperature of 50-55°C, the use of biomass energy is 1270.65 kJ. At a temperature of 60-65°C, the use of biomass energy is 1719.72 kJ. In Table 1, it can be seen that the largest inlet energy is found at a temperature of 60-65°C, which is 1719.72 kJ and the lowest inlet energy is found at a temperature of 40-45°C, which is 928.32 kJ. According to (Ardiyanto et al., 2021), this happens because the higher the temperature of the object, the hotter the object.

Table 2. Results of useful energy calculation

°C	Q Useful heating appliance (kJ)	Q useful heating space (kJ)	Q Useful for evaporating water on materials (kJ)	Total Q useful (kJ)
40-45	143,76	100,47	1,064	245,29
50-55	190,17	116,98	1,176	308,32
60-65	629,65	238,91	1,036	869,59

Useful energy is the energy used to heat the material in the drying room. From Table 2, the most useful value for heating the appliance is 629.65 kJ, for heating the highest chamber is 238.91 kJ, for evaporating water on the material has the highest value of 1.176 kJ. The lowest useful value for heating the appliance is 143.76 kJ, for heating the lowest room is 100.47 kJ. The highest total useful energy is found at 60-65 °C at 869.59 kJ, and the lowest total energy is found at 40-45 °C at 245.29 kJ. Useful energy is the energy used during the drying process both in heating materials, drying tools, and drying rooms. In Table 2, it can be seen that the useful energy is less than the rate of incoming energy because the higher the temperature in the drying room, the amount of water that evaporates in the product increases along with the longer the drying time, so that the energy needed to evaporate the water from the product is less.

Table 3. Results of calculation of exit and loss of energy

°C	Energy out (kJ)	Energy lost (kJ)
40-45	578,99	824,28
50-55	694,85	1003,17
60-65	823,98	1693,57

In the drying process, the average energy output and energy loss are quite high. The factors that cause heat loss are also present when the instrument is opened to take samples, so it is assumed that there is an incalculable heat loss located in the process of taking data with the instrument opened. In the Umami study (2021) stated that the factor that causes heat loss in the tool is when the tool is opened to take a sample when weighing the sample, so it is assumed that the incalculable heat loss lies in the time of opening the tool in the data collection process.

Table 4. Drying mass equilibrium data at 40-45 temperatures°C

°C	Initial Mass of Material (grams)	Initial Water Content (%)	Final Mass of Material (grams)	Final Water Content (%)	Reduced Mass of Materials (grams)	Evaporated Water Content (%)
40-45	60	69,03	18,71	6,95	41,29	52,08
	60		20,01		39,99	
	60		19,42		40,58	
	60		19,74		40,26	
	60		19,74		40,26	
	60		24,69		35,04	
	60		20,33		39,67	
	60		17,13		42,87	
Sum	480		159,77		319,76	

Table 5. Data on drying mass equilibrium at 50-55°C

°C	Initial Mass of Material (grams)	Initial Water Content (%)	Final Mass of Material (grams)	Final Water Content (%)	Reduced Mass of Materials (grams)	Evaporated Water Content (%)
50-55	60	71,78	17,97	4,27	42,03	67,51
	60		16,13		43,87	
	60		17,86		42,14	
	60		16,28		43,72	
	60		22,83		37,17	
	60		15,66		44,34	
	60		18,30		41,7	
	60		16,48		43,52	
Sum	480		141,51		338,49	

Table 6. Drying mass equilibrium data at 60-65°C

°C	Initial Mass of Material (grams)	Initial Water Content (%)	Final Mass of Material (grams)	Final Water Content (%)	Reduced Mass of Materials (grams)	Evaporated Water Content (%)
60-65	60	64,39	21,71	3,84	38,29	60,55
	60		20,44		39,56	
	60		21,57		38,43	
	60		21,81		38,19	
	60		28,1		31,9	
	60		21,25		38,75	
	60		21,83		38,17	
	60		21,05		38,95	
Sum	480		177,76		302,24	

In drying taro tubers using a rack-type dryer, the calculation results were obtained using the general equation of mass equilibrium, namely: Input Mass – Output mass = *Mass accumulation.* The data in Table 4 explains that at a temperature of 40-45°C the mass of material evaporated was 319.76 grams with the weight of evaporated water being 52.08%. The data in Table 5 explains that at a temperature of 50-55°C, the mass of material evaporated was 338.49 grams with the weight of evaporated water being 67.51%. The data in Table 6 explains that at a temperature of 60-65°C, the mass of material evaporated was 302.24 grams with the weight of evaporated water being 60.55%. From the three comparisons of drying temperatures used in drying taro tubers, it can be seen that at the highest temperature, namely 60-65°C, the lowest amount of evaporated water was obtained, namely 60.55%. This shows that the lower the accumulated mass, the lower the water content in the dried material so that the water mass of the resulting material is lower than the water mass of the evaporated material. (Manfaati et al., 2019) states that the equilibrium water content for each material is different which is not only influenced by the type of material, but also depends on the relative humidity of the drying air. Equilibrium data are usually given as the relationship between the relative humidity of the air and the liquid contained in the solid material (mass of liquid per mass of dry solid). The humidity of the drying air is of course also influenced by the temperature of the drying room.

Entalpi

Enthalpy is the amount of heat (energy) in the air per unit mass. Enthalpy is the total amount of energy present in the air, both from the air and the water vapor contained in it.

Table 7. Enthalpy data on drying

°C	Enthalpy (kJ/Kg)
40-45	130,796
50-55	214,645
60-65	304,82

In drying taro tubers using a rack-type dryer, the results of the enthalpy calculation at a temperature of 40-45°C were obtained at a temperature of 130.796 kJ/kg, at a temperature of 50-55°C an enthalpy value of 214.645 kJ/Kg, and at a temperature of 60-65°C an enthalpy value of 304.82 kJ/kg was obtained. According to (Putra & Finahari, 2011), the change in enthalpy tends to increase if the temperature increases.

3.5. Energy Efficiency

Drying efficiency can be defined as a comparison between the energy released to heat the material and the energy from the dryer (Suhelmi et al., 2022). The energy input used is in the form of heat energy from biomass. Meanwhile, the output is in the form of energy used to raise the temperature of the material and evaporate the water in the material. The higher the efficiency, the less energy will be wasted from the tool (Zamharir et al., 2016).

Table 8. Comparison of drying efficiency

°C	Energy Inlet (kJ)	Q Useful heating appliance (kJ)	Q Useful heating space (kJ)	Q Useful for evaporating water on materials (kJ)	Efficiency (%)
40-45	928,32	143,76	100,47	1,064	26,42
50-55	1270,65	190,17	116,98	1,176	24,26
60-65	1719,72	629,65	238,91	1,036	50,56

Based on Table 8, the total efficiency of the drying system during drying at a temperature of 40-45°C was obtained with an efficiency of 26.42%, at a temperature of 50-55°C an efficiency of 24.26%, and at a temperature of 60-65°C an efficiency of 50.56%. The amount of drying efficiency varies due to the heat source of different drying temperatures that result in the evaporation of water in the material will also be different, when the water evaporates, the moisture of the product decreases.

4. Conclusions and Suggestions

4.1. Conclusion

Based on the research that has been carried out, several conclusions can be drawn, including:

1. The amount of inlet heat energy, useful heat energy, outgoing heat energy, lost heat energy, and the highest number of enthalpy were obtained at 60-65°C temperature treatment, which were 1719.72 kJ, 869.59 kJ, 823.98 kJ, 1693.57 kJ, and 304.82 kJ/kg, respectively.
2. The total efficiency of the drying system during drying using rack-type dryers was obtained at a temperature of 60-65°C of 50.56% and the lowest efficiency was found at a temperature of 50-55°C of 24.26%.

4.2. Suggestion

Based on the research that has been carried out, it can be suggested for further research to better control the temperature in the drying room. It is hoped that the tool can be modified to make it easier to collect data, one of which is the collection of airflow speed data. It is expected that the tool can be modified to the heat dissipation system on *exhaust fan*. In the next study, an accurate monitoring system and a combination of energy sources were used for drying.

References

Adila, H., Damion, D., & others. (2023).). *Indonesia Journal of Science and Technology Research*, *2*(2), 249–256.

Aisah, A., Harini, N., & Damat, D. (2021). The effect of drying time and temperature using a cabinet dryer in the manufacture of MOCAF (modified cassava flour) with yeast tape fermentation. *Food Technology and Halal Science Journal*, *4*(2), 172–191. https://doi.org/10.22219/fths.v4i2.16595

Ardiyanto, A., Ariman, A., & Supriyadi, E. (2021). The Arduino-based temperature measuring device uses an infrared sensor and an alarm that detects body temperature above normal. *Sinusoida*, *23*(1), 11–21. https://doi.org/10.37277/s.v23i1.1016

Arsini, A., Handayani, B. R., & Amaro, M. (2023).Hariri, H., & others. (2021). Design of a 30 kg clove dryer based on Arduino. *Technobiz: Scientific Journal of the Master of Mechanical Engineering Study Program*, *11*(2), 122–128. https://doi.org/10.35814/teknobiz.v11i2.2465

Islami, A., Murad, M., & Priyati, A. (2017). Drying Characteristics of Slots (Alium Ascalonicum. l) Using ERK (Greenhouse) dryers. *Scientific Journal of Agricultural and Biosystems Engineering*, *5*(1), 330–338. 10.29303/jrpb.v5i1.42

Kurniawan, H., Septiyana, K. R., Adnand, M., Adriansyah, I., & Nurkayanti, H. (2020). Characteristics of Drying Ant Sugar Using a Rack-type Cylinder Dryer. *Huan of Agricultural Engineering*, *13*(2), 1–13. https://doi.org/10.17969/rtp.v13i2.17284

Benefit, R., Baskoro, H., & Rifai, M. M. (2019). The effect of time and temperature on the process of drying shallots using a tray dryer. *Fluids*, *12*(2), 43–49. https://doi.org/10.35313/fluida.v12i2.1596

Maulana, Y., Gaos, Y. S., & Wiradinata, I. (2019). ANALYSIS OF THE THERMAL BALANCE OF THE COOLING SYSTEM OF THE ORC (ORGANIC RANKINE CYCLE) POWER PLANT ENGINE WITH A CAPACITY OF 500 kW. *AME (Applications of Mechanics and Energy): Scientific Journal of*

Mechanical Engineering, *5*(1), 24–37. https://doi.org/10.32832/ame.v5i1.2354
Purwanti, M., Jamaluddin, J., & Kadirman, K. (2017). Water Evaporation and Shrinkage of Cassava Slices During the Drying Process Using a Cabinet Dryer Machine. *Journal of Agricultural Technology Education*, *3*(1), 127–136.
Putra, T. D., & Finahari, N. (2011). Effect of Temperature Change of Cooling Media on Direct Evaporative Cooler. *PROTON*, *3*(1). 10.31328/jp.v3i1.216
Suhelmi, M. F., Anjani, R. D., & Fauji, N. (2022). Calculation of Drying Efficiency in Flat Bed Dryer Type Grain Drying Machine in CV. XYZ. *Journal of Mechanical Engineering*, *17*(1), 15–20. http://dx.doi.org/10.32497/jrm.v17i1.2848
Suherman, S., & Trisnaningtyas, R. (2016). Energy and allergy analysis in tapioca flour drying using a vibrating fluidization bed continuous dryer. *Reactor*, *16*(1), 24–31. ORDER: https://doi.org/10.14710/reaktor.16.1.24-31
Tobing, I. F., Mustaqimah, M., & Agustina, R. (2019). Modification of tray dryer type dryer with the addition of insulator. *Scientific Journal of Agricultural Students*, *4*(4), 422–431. https://doi.org/10.17969/jimfp.v4i4.12685
Zamharir, Z., Sukmawaty, S., & Priyati, A. (2016). Analysis of Heat Energy Utilizationin Onion (Allium ascalonicum, L.) using Greenhouse Effect Drying Equipment (ERK): Analysis of Heat Energy Utilizationin Onion (Allium ascalonicum, L.) DryingusingGreenHouses Gasses (GHG) Drye. *Scientific Journal of Agricultural Engineering and Biosystems*, *4*(2), 264–274.