Agricultural and Biological Engineering

https://ph04.tci-thaijo.org/index.php/abe/index

Published by the Faculty of Engineering, Khon Kaen University, Thailand

# Dehumidifying cassava leaf and trunk by rotary dryer for processed animal feed

Yodsawadee Arthan*, Emwarin Sangwiset, Kittipong Laloon and Chaiyan Junsiri

Department of Agricultural Engineering, Faculty of Engineering, Khon Kaen University, Khon Kaen, 40002, Thailand

*Corresponding author.
Email address: yosawadee@kkumail.com

Received 20 March 2024
Accepted 17 April 2024

## Abstract

The purpose of this project was to study the dehumidification of cassava leaves and trunks by rotary dryer for animal feed processing. The physical properties of cassava leaves and trunks and the dehumidification of cassava leaves and trunks using sunlight were studied to compare the results of dehumidification by a rotary dryer. In the process of rotary dryer dehumidification, the control factors were a drum speed of 4 rpm, feed rate 120 kg/h and hot air temperature of 140°C, and 3 h of drying time. The study factors were three levels of hot air speed: 2.0 m/s, 2.5 m/s, and 3.0 m/s. According to a study of the physical properties of cassava leaves and trunks, the average initial humidity was 60.42%wb. Also, the size of the chopped cassava leaves and trunks by the sieve shaker in the sieve size of 4.75 mm had the highest residue, 53.12% and had an average particle size at 16.08 mm. Compared to sunlight method, the study of dehumidification of cassava leaves and trunk by rotary dryer revealed that a rotary method dryer was more effective than sunlight method. The rotary dryer's optimal setting was a hot air speed of 2.0 m/s, specific energy consumption (SEC) of 31.40 $MJ/kg_{water}$, and drying rate (DR) of 25 kg/h. The statistical analysis shows the relationship between hot air speed and drying rate. It's shows that different hot air speed to different drying rate at 95% confidence.

**Keywords:** Rotary Dryer, Cassava Leaf and Trunk, Dehumidifying

## 1. Introduction

Cassava is a type of root crop that is an economic staple in Thailand. It is a plant that requires little water, is easy to grow, and is drought-resistant, making it widely popular in many countries. Cassava ranks as the fifth most important crop in the world, following wheat, corn, rice, and potatoes. Currently, cassava represents a significant source of income for Thai farmers, particularly in the northern, northeastern, and central regions, in that order. In Thailand, there are approximately 9.5 million rai (approximately 3.8 million acres) of cultivated land, with a domestic production of about 31.6 million tons [1]. Thailand is one of the world's leading producers and exporters of cassava, with prospects for further growth in the coming years.

Cassava leaves and stems are considered agricultural by-products that are not utilized for their potential benefits. Only the roots of cassava are processed industrially, and only the healthy parts of the stems are used as cuttings for the next planting cycle. The rest of the stem has no value, leading to its disposal and destruction. Cassava leaves and stems are left in the fields at an estimated 500-1000 kilograms per rai, depending on the variety's health and age at harvest. The protein content in cassava leaves averages 23.7% [2].

Currently, the animal feed industry aims to increase income for cassava farmers by using by-products from cassava harvesting to produce animal feed. Given that the cost of producing animal feed is relatively high—for example, cattle feed costs about 11-23 baht per kilogram, the price of dried cassava leaves and stems is only 4-6 baht per kilogram. However, studies have found that cassava leaves and stems have a high level of toxicity from hydrocyanic acid, which is poisonous to animals. Therefore, it is necessary to reduce the hydrocyanic acid content to non-toxic levels. Reducing the hydrocyanic acid in cassava leaves and stems for use in animal feed can be achieved through heating and fermentation. Nonetheless, drying using sunlight and fermenting cassava leaves and stems have significant limitations, such as time, labor, and space requirements [3].

From the research study on testing a rotary drum dryer to improve the efficiency of solar energy drying for coffee cherries, this research investigated the use of a rotary drum dryer for drying coffee cherries, starting with a moisture content of 62%wb. The experimental results showed that drying with sunlight took 16 days, whereas using the rotary drum dryer took an average of 28 h. It was concluded that the efficiency of the rotary drum dryer was superior to that of using sunlight [4].

This research aimed to address the problem by studying the reduction of moisture in cassava leaves and stems using a rotary drum dryer (Rotary Dryer) for animal feed. The physical properties of cassava leaves and stems were explored, current moisture reduction methods using sunlight, and the hot air flow rate of the rotary drum dryer used in dehydrating cassava leaves and stems. This research was conducted to identify the best method for reducing the moisture in cassava leaves and stems, addressing the issue of leftover cassava leaves and stems, and adding value to these cassava by-products.

## 2. Materials and methods

### *2.1 Rotary dryer*

The rotary dryer (Figure 1) is a cylindrical drum with a length of 6 m and a diameter of 60 cm, powered by an electric motor (Mitsubishi). Cassava leaves and stems are fed into the machine through a hopper at the material inlet and exit at the other end of the moisture reduction drum, with hot air blowing in the opposite direction. The drum's rotation speed was controlled by an inverter (Jaden Inverter), and hot air is introduced into the drum by a blower driven by an electric motor (Mitsubishi). The heat was generated by an electric heater. The main components of the rotary dryer (Rotary Dryer) were as follows:

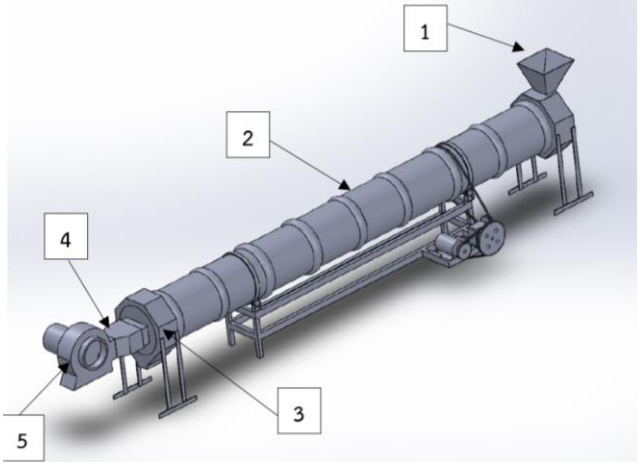

**Figure 1** Rotary Drum Dryer

1) Hopper and Material Feeding Slot: This is the material entry slot on the side of the drying drum where materials are fed into the dryer.

2) Drying Drum: The drum has a diameter of 60 cm and a length of 610 cm, with a volume of 1.7 m$^3$. It was powered by an electric motor (Mitsubishi) and a gear reduction unit with a ratio of 1:60. Speed was controlled by an inverter (Jaden Inverter, 2.2 kW). It served as the compartment for housing and conveying for drying, utilizing a helical fin. This cylindrical drum had material feeding and discharging slots on the side.

3) Hopper for Receiving Dried Materials: When the materials are conveyed out of the drying drum, they fall into a hopper positioned below to collect them.

4) Electric Heater: Serves as the source of heat energy for the air, equipped with a Thermocouple Type K 0-800°C to measure the temperature inside the drying drum used for moisture reduction.

5) Blower: Powered by an electric motor (Mitsubishi, 3 phase, 1.5 kW). The hot air produced by the electric heater is mixed with external air, with a Thermocouple Type K 0-800°C at the outlet end of the hot air.

### *2.2 Size separation equipment*

The Sieve Shaker test set utilizes standard sieves numbered 4 (4.75 mm), 8 (2.36 mm), 16 (1.18 mm), 30 (600µm), 50 (300µm), 100 (150µm), 200 (75µm), 400 (38µm), and a receiver.

### *2.3 Testing Methods*

1) Physical Properties

1.1) Moisture Content Determination: This can be done by chopping the cassava leaves and stems and placing them in a drying oven at a temperature of 105°C (standard AOAC 2000) for 24 hours. Afterward, the moisture content of the cassava leaves and stems is calculated using the moisture content equation (2).

1.2) Determination of Size of Chopped Cassava Leaves and Stems: Take the dried samples of cassava leaves and stems and measure their size using a Sieve Shaker, which has different sized openings. Arrange the sieves so that the larger ones are on top and the smaller ones below. Prepare 100 grams of dried cassava leaves and stems. Place the prepared sample on the top sieve and then place it into the Sieve Shaker, set to shake at an amplitude of 2.0 mm/g for 15 minutes. After the time has elapsed, weigh the material remaining on each sieve to determine the weight and calculate the average particle size.

2) Study of Moisture Reduction in Cassava Leaves and Stems Using Sunlight

2.1) Spread the chopped cassava leaves and stems on five aluminum trays, making sure the material layer is 1.5 cm thick.

2.2) Place the aluminum trays with chopped cassava leaves and stems on canvas to dry in the sun, ensuring the material is exposed to sunlight throughout the day, from 9:00 AM to 5:00 PM.

2.3) Weigh the trays every hour to determine the moisture content at each time point and measure the temperature and relative humidity simultaneously.

3) Prepare cassava leaves and stems.

3.1) Measure the initial moisture content of the materials. This is done by drying the samples in an oven at 105°C (standard AOAC 2000) for 24 h.

3.2) Start the rotary drum dryer with the specified parameters, turning on the blower at the hot air speeds (2.0 m/s, 2.5 m/s, and 3.0 m/s). Set the drum motor to rotate at 4 rpm using an inverter and heat the air to a temperature of 140°C. Then, feed the cassava leaves and stems at a rate of 120 kg/hr. As the leaves and stems begin to exit the drum, reintroduce them into the drum every 5 minutes through the same path.

3.3) Sample the cassava leaves and stems every 30 minutes, and determine the moisture content using the oven drying method at 105°C (standard AOAC 2000) for 24 hours. Record and store the data the following day.

3.4) Continue the process for a total of 3 hours, repeating the procedure three times and adjusting the test parameters as per the experimental design, to compare the moisture content results from each level of hot air speed.

### *2.4 Performance Evaluation Metrics for Testing*

The performance evaluation of the testing used the data collected to analyze the average particle size, moisture content of the material, specific energy consumption, drying rate, and variability analysis.

1) Average particle size

$$D = 0.0041(2)^{FM} \tag{1}$$

Where FM stands for Fineness Modulus.

2) Moisture content of the material

$$\mathrm{MC} = \frac{(\mathrm{Mw}-\mathrm{Wd})}{\mathrm{Mw}} \times 100 \tag{2}$$

Where Mc is the moisture content on a wet basis (%wb), Md is the weight of the sample after drying (g), and Mw is the weight of the sample before drying (g)

3) Specific energy consumption (SEC)

$$\mathrm{SEC} = \frac{\mathrm{P_e} \times \mathrm{t} \times 3.6}{\mathrm{W_t} - \mathrm{W_f}} \tag{3}$$

Where SEC stands for Specific Energy Consumption (MJ/$\mathrm{kg_{water}}$), Pe is the total energy input to the system (kW), T is the drying time (h), Wi is the mass of the material before drying (kg), and Wf is the mass of the material after drying (kg).

4) Drying Rate (DR): The drying rate is the amount of water evaporated from the material per unit of drying time.

$$\mathrm{DR} = \frac{\mathrm{M_i} - \mathrm{M_f}}{\mathrm{t}} \tag{4}$$

Where DR stands for Drying Rate (kg/h), Mi is the initial weight (kg), Mf is the final weight (kg), and T is the drying time (h).

5) Analysis of Variance (ANOVA)

A two-way analysis of variance is conducted using a Randomized Completely Block Design (RCBD) and post-hoc comparisons are made using the Least Significant Difference (LSD) method with a 95% confidence level.

## 3. Results and Discussion

### *3.1 Results of the Study on the Physical Properties of Cassava Leaves and Stems*

1) Moisture content:

From sampling 27 examples of cassava leaves and stems to determine the average moisture content, it was found that the chopped cassava leaves and stems had an average moisture content of 60.42%wb. The suitable moisture content for animal feed production should not exceed 14%wb to avoid issues with mold growth.

2) Particle size measurement of chopped cassava leaves and stems (Figure 2):

Physical property testing was conducted by randomly sampling 20 examples of dried, chopped cassava leaves and stems to determine material size using a Sieve Shaker (Figure 3). It was found that the highest amount of residual material, accounting for 53.12%, was on the 4.75 mm sieve. Following this, the sieves with sizes of 2.36 mm, 1.18 mm, 0.6 mm, 0.15 mm, 0.075 mm, 0.38 mm, and the pan had residual material percentages of 28.14%, 13.23%, 3.82%, 0.73%, 0.16%, 0.11%, and 0.07%, respectively. The average particle size was determined to be 16.08 mm.

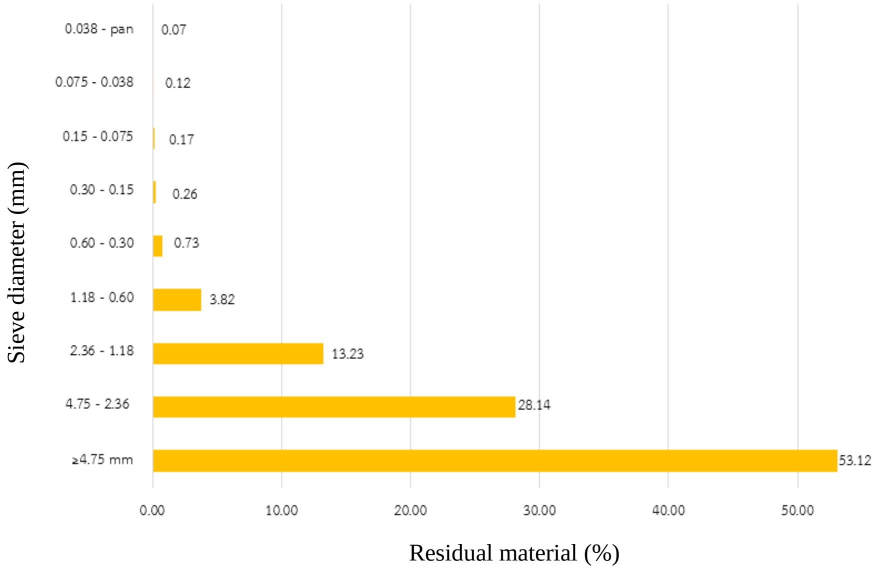

**Figure 2** The relationship between the weight of residual material and sieve size.

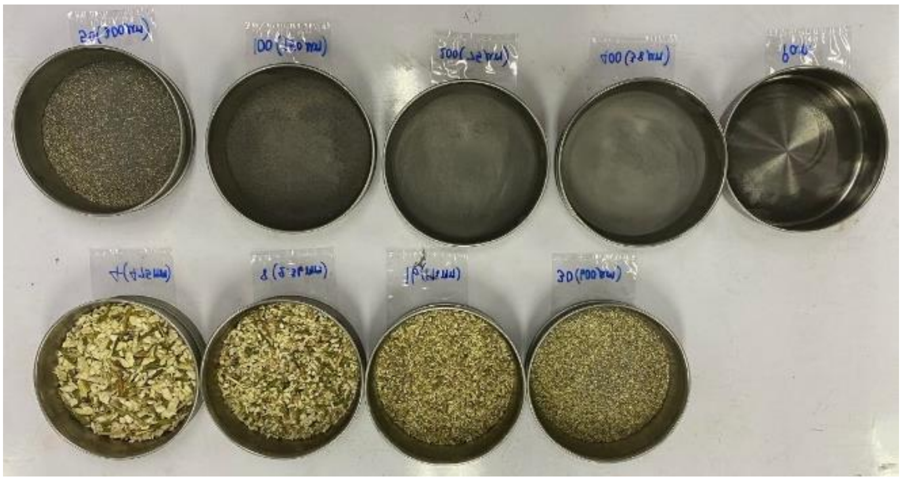

**Figure 3** Residual materials on each sieve size from the sieving process.

*3.2 Results of the Study on Moisture Reduction in Cassava Leaves and Stems Using Sunlight*

From the experiment where cassava leaves and stems were dried using sunlight to determine the average moisture content, along with recording the air temperature and relative humidity (Figure 4), the graph shows the relationship between moisture content and drying time. In the case of moisture reduction using sunlight, it was found that 8 hours of sun drying with material flipping was more effective than without flipping. For the flipping method, with a material thickness of 1.5 cm, the average air temperature was 32.67°C and the relative humidity was 60.39%. For the first instance of non-flipping, the material thickness was 1.5 cm, with an average air temperature of 32.56°C and a relative humidity of 51.7%. The second instance of non-flipping, with the same material thickness of 1.5 cm, had an average air temperature of 32.67°C and a relative humidity of 60.39%.

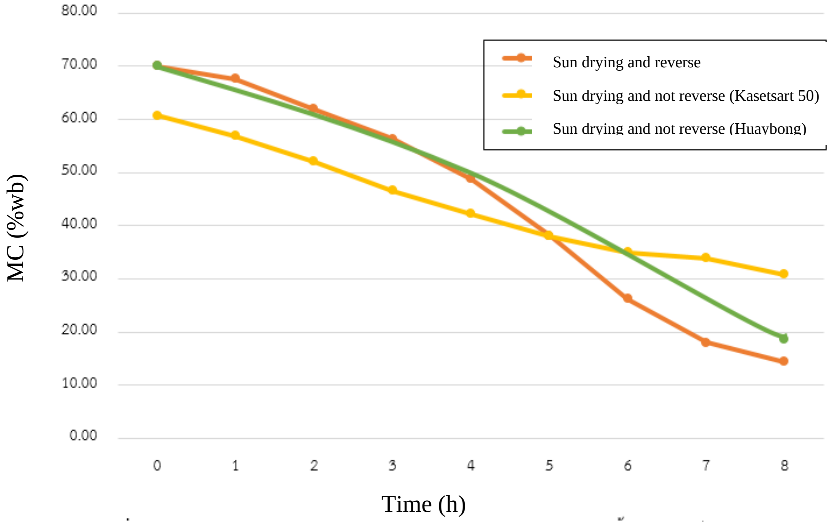

**Figure 4** Graph showing the relationship between moisture content and time for the method of moisture reduction using sunlight.

*3.3 Results of the Study on Moisture Reduction in Cassava Leaves and Stems Using a Rotary Dryer*

The graph shows the relationship between moisture content and time at a temperature of 140°C, drum rotation speed of 4 rpm, and hot air speeds of 2 m/s, 2.5 m/s, and 3 m/s. It was found that the speed of 2 m/s was the most effective in reducing moisture, reducing from an initial moisture content of 58.63%wb to a final moisture content of 7.83%wb within 3 hours (Figure 5). The suitable moisture content for storage is 14%wb, and at a hot air speed of 2 m/s, it took 2.49 hours to reduce the moisture. Results of the variance analysis among hot air speed, time, and drying rate (DR) are presented in Table 1.

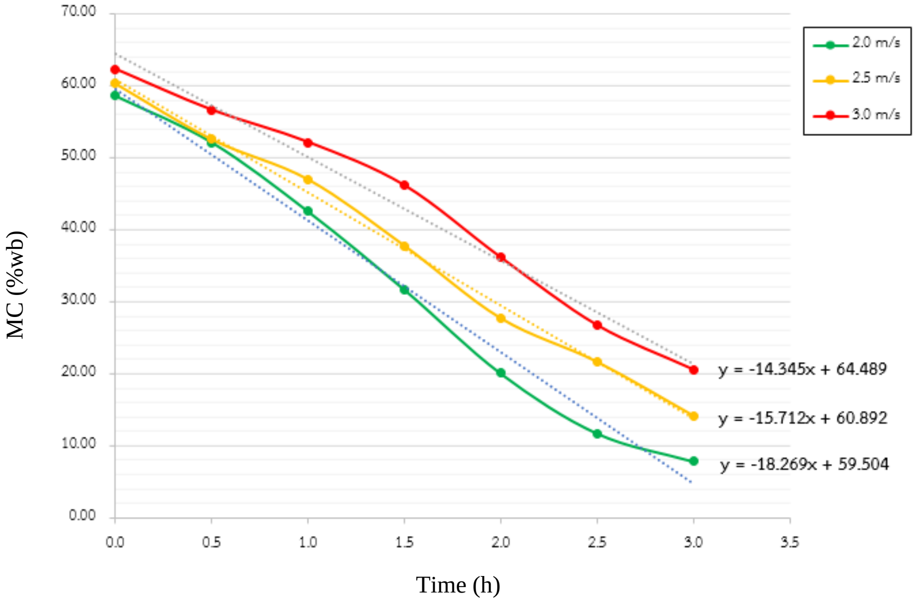

**Figure 5** Graph showing the relationship between moisture content and time at three different hot air speeds.

**Table 1** Results of the variance analysis between hot air speed, time, and drying rate (Drying Rate, DR)

| Source of Variation | Type III Sum of Squares | df | Mean Square | F | P-value |
|---|---|---|---|---|---|
| Time | 5417.74 | 6 | 902.96 | 119.60 | 5.39E-10 * |

***Note** ns : Non – Significance difference
* : Significance difference

Testing whether different levels of hot air speed affect the drying rate.
Hypothesis Set
Ho: The drying rates (DR) at all three levels of hot air speed are not significantly different.
H1: There is at least one pair where the drying rates (DR) at different hot air speeds are significantly different.

Given that F = 29.06, which is in the rejection region for Ho, it indicates that there is at least one pair where the drying rates at different hot air speeds are significantly different, or the hot air speed significantly affects the drying rate at the 0.05 level.

Results of the comparison of the differences in average values for each level of hot air speed (Table 2)

**Table 2** Comparison of Average Hot Air Speed Values

| Hot air speed | Avg |
|---|---|
| 2.0 m/s | $32.10^{c}$ |
| 2.5 m/s | $37.31^{b}$ |
| 3.0 m/s | $43.29^{a}$ |

**Note:** Average values with different letters in the column are statistically different at the 95% confidence level ($P \leq 0.05$).

Graph of drying rates and three levels of hot air speed at 14%wb moisture content: It was found that at a hot air speed of 2.0 m/s, the highest drying rate is achieved, with a value of 25 kg/h, while at a speed of 3.0 m/s, the drying rate is the lowest, at 19.15 kg/h (Figure 6).

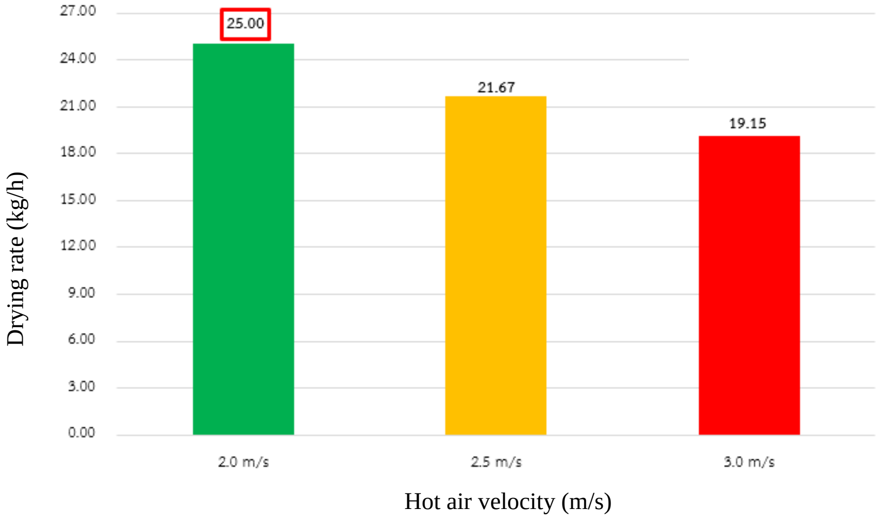

**Figure 6** Chart of drying rates and three levels of hot air speed at 14%wb

Chart of specific energy consumption values and three levels of hot air speed: It was found that at a hot air speed of 2 m/s, the specific energy consumption for drying is the lowest at 31.40 MJ/kg water, and at a speed of 3 m/s, the specific energy consumption for drying is the highest at 33.84 MJ/kg water (Figure 7).

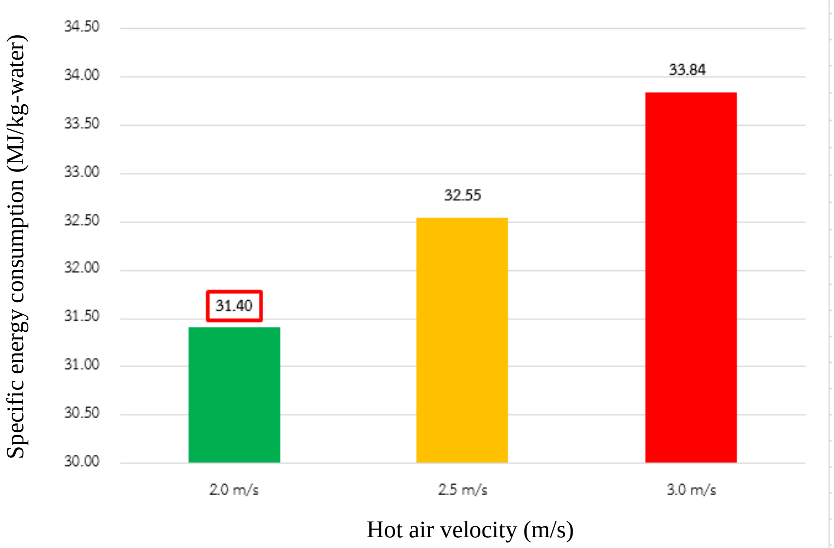

**Figure 7** Chart of specific energy consumption and three levels of hot air speed.

### *3.4 Results of Moisture Reduction Testing Using a Rotary Dryer and Sunlight*

A comparative study of moisture reduction using a rotary dryer and sunlight found that the rotary dryer is more effective than sun drying. At a hot air speed of 2 m/s, the rotary dryer reduced moisture within 3 hours to reach the desired level (Figure 8).

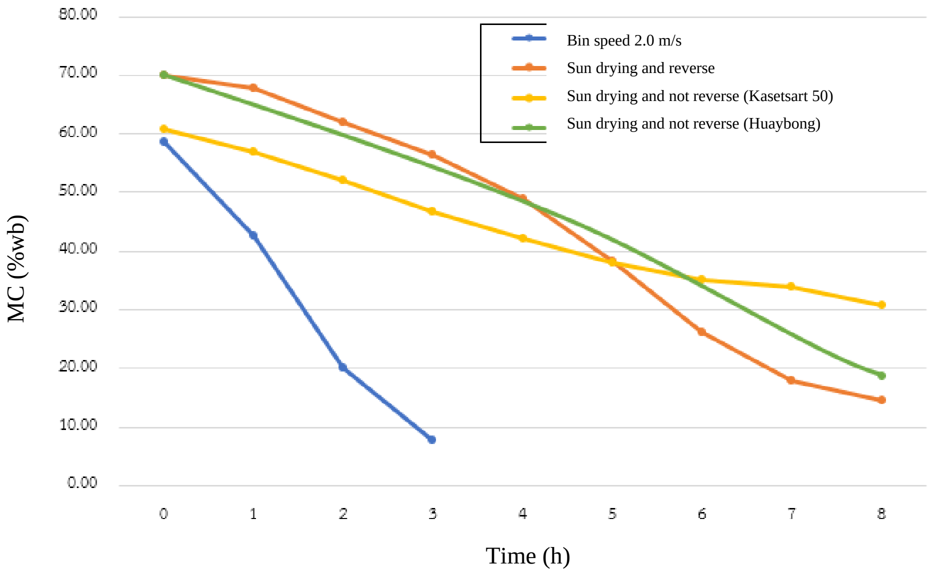

**Figure 8** Graph showing the relationship between moisture content and time for moisture reduction methods using a rotary dryer and sunlight.

## 4. Conclusions

The study on the physical properties of cassava leaves and stems found that the average moisture content was 60.4%wb. For chopped cassava leaves and stems that underwent moisture reduction, the average particle size was 16.08 mm. The material retained the most on a 4.75 mm sieve, accounting for 53.12%, followed by 2.36 mm, 1.18 mm, 0.6 mm, 0.15 mm, 0.075 mm, 0.38 mm, and pan, with residual materials accounting for 28.14%, 13.23%, 3.82%, 0.73%, 0.16%, 0.11%, and 0.07%, respectively.

The study on moisture reduction in cassava leaves and stems using a rotary dryer showed that at a hot air speed of 2.0 m/s, a temperature of 140°C, and drum rotation speed of 4 rpm, moisture could be reduced most effectively within 3 hours, achieving a specific energy consumption of 31.88 MJ/kg water and the highest drying rate of 25 kg/hr. Different hot air speeds statistically affected the drying rates.

Comparing moisture reduction using a rotary dryer to sun drying, it was found that reducing moisture to 14%wb using the rotary dryer took 2.49 hours at a hot air speed of 2.0 m/s. In contrast, reducing moisture using sunlight to reach 14%wb took up to 8 hours or more, depending on weather conditions, temperature, and relative humidity. The conclusion is that moisture reduction using a rotary dryer is more efficient than using sunlight, offering reductions in space required, duration, and labor.

## 5. Acknowledgements

I would like to thank the Department of Agricultural Engineering, Faculty of Engineering, Khon Kaen University, the Agricultural Machinery and Postharvest Technology Research Center, and the Integrated Rubber Learning Center at Khon Kaen University for their support in making this project successful.

## 6. References

[1] Office of Agricultural Economics. Agricultural product production data [Internet]. 2022 [cited 2024 Jan 15]. Available from: https://www.oae.go.th/view/1/ข้อมูลการผลิตสินค้าเกษตร/TH-TH.

[2] Worapun J, Sukanya C. Utilization of cassava by-products [Internet]. 2009 [cited 2024 Jan 15]. Available from: https://shorturl.asia/67Qrn.

[3] Nilubol T. Development of a model for utilizing cassava leaves as animal feed [Internet]. 2016 [cited 2024 Jan 15]. Available from: https://www.doa.go.th/research/attachment.php?aid=1706.

[4] Susana GB, Alit IB, Okariawan IDK. 2023. Rice husk energy rotary dryer experiment for improved solar drying thermal performance on cherry coffee. Case Studies in Thermal Engineering. 2023;41(1): https://doi.org/10.1016/j.csite.2022.102616