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ORIGINAL RESEARCH

EVALUATION OF DEHYDRATION PERFORMANCE OF BELITUNG TARO (XANTHOSOMA SAGITTIFOLIUM) USING TRAY DRYER

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Abstract

Belitung Taro (Xanthosoma sagittifolium) is a plant that can be processed into various food products. The high-water content of taro and the lack of a precise drying system made this material easy to rot. This study aims to evaluate the dehydration performance of tray dryers to reduce the water content of Belitung Taro. The independent variables used were air velocity (3-6 m/s), taro thickness (1-4 mm), and drying time (30-120 min). The results showed that the optimum drying time of taro is 30 min. The dryer airflow of 5 m/s significantly reduces the water content. The thickness of the slices positively affects the drying rate. The lowest water content was obtained in drying with a thickness of 1 mm. The ANOVA results show the effect of thickness, time, and flow rate variations on the drying rate. Three types of mathematical modeling are used to estimate moisture content: Newton, Page, and Modified Page. The Modified Page equation was preferred to detect the moisture content of the taro. From this study, the optimum condition of the tray dryer can be the best solution to dehydrate Belitung Taro effectively and efficiently.

KEYWORDS:

ANOVA, Belitung Taro, Dehydration, Tray Dryery, Xanthosoma Sagittifolium

1 | INTRODUCTION

Belitung Taro (Xanthosoma sagittifolium) is one of the potential resources in Indonesia that can be utilized to strengthen food security [1, 2]. The high carbohydrate content in taro positions it as a staple food source for rice substitution [2, 3]. Taro has high economic value because all parts of the taro plant (tubers, midribs, and taro leaves) have a monetary value when it is managed properly [4, 5]. Compared to other tubers, the annual production of taro is higher than sweet potato but lower than cassava [6, 7]. Currently, taro processing mostly uses fresh tubers used as various processed products. Due to the high water content in Belitung

Taro and the absence of a precise drying mechanism, this substance is susceptible to decomposition. The most critical processing is drying [8, 9].

Drying is one of the oldest unit operations and most widely used methods of food preservation [10] Drying was carried out on taro to lower the water content and stop all activities of organisms that can cause spoilage [11, 12]. Belitung Taro contains 63.1% water with 34.2% carbohydrates [13–15]. Carbohydrates in taro tubers are mostly starch components, while other components are pentose, crude fiber, dextrin, sucrose, and reducing sugars [15, 16]. Drying using sunlight can cause a loss of nutrients from dried foodstuffs because the temperature cannot be regulated [17]. Setting the temperature and drying time significantly affect the quality of the material to be dried. Generally, it is known that the higher the drying temperature, the longer the drying time, which can cause changes in food ingredients [18].

The critical process in the processing of taro is when drying taro. Taro drying can be done using several methods: sunlight, oven drying, vacuum dryer, tunnel dryer, and rotary dryer. But some of these methods have many disadvantages, such as a long process, high temperatures, and high Energy required [8, 19]. Rotary dryers are not recommended for small to mid-scale drying because they can cause reduction due to erosion or damage, inconsistent dry product characteristics, low energy efficiency, and complex equipment maintenance [20]. A tray dryer is a multilevel dryer using hot air in a closed space. This dryer technology is suitable for drying taro and other materials that are easily sensitive to heat and easy to mold.

A tray dryer is a drying machine widely known to have advantages, namely being able to condition the drying air uniformity, easy to use, and cost affordable investment [21]. Tray dryers are included in the convection drying system using hot air flow to dry the product. Commonly, the tray dryer is set to a high drying rate. The airflow in the drying chamber optimizes the evaporation of water from the material to increase the drying rate. The shelf in the tray dryer has holes that function to circulate hot air from the plenum chamber. The heat would pass through the pile of materials causing the water content of the materials to decrease. However, in the drying process, the continuous mass loss of products usually occurs due to simultaneous heat and mass transfer. Therefore, controlling drying taro under different conditions is an essential subject to be investigated.

From these backgrounds, in this work, a tray dryer performance was evaluated and optimized to dehydrate the moisture content of Belitung Taro by varying airflow, thickness, and drying time. Moreover, the drying rate of taro was estimated by several mathematical modeling.

2 | PREVIOUS RESEARCHES

In previous research, drying on taro is traditionally carried out directly in the sun [22]. Drying using sunlight is less effective because it depends on weather, temperature, and humidity [23]. Drying using the oven, another conventional method can lead to losing nutrients from the dried ingredients [24]. Alternatively, a tray dryer is more optimal than the conventional method because it can maintain the quality of products, control the temperatures, and accelerate the drying rates [25]. Optimizing the operating conditions of taro drying with a tray dryer can be performed by studying the drying kinetics through a mathematical model of the thin layer [26].

Several kinetic studies and mathematical models of drying foodstuffs with various methods have been carried out, such as chili drying conducted by Bekir et al. [27] using 12 models. However, the most optimal model is only the two-term model. Lestari and Samsuar [28] examined three mathematical models of chili drying. It was found that Page's model was the most suitable for predicting the humidity ratio. The latest research by Irfan and Lestari [29] used 15 mathematical models to optimize chili drying. The most accurate model to describe the drying characteristics of red chili in each treatment was the Modified Midilli-Kucuk Model.

Several studies that have been carried out show that the drying of the same material has different accurate mathematical models for each method. By using the same concept, optimization of taro drying can be done by studying the kinetics and mathematical models of drying. Although there have been many studies on taro drying, from the literature studies, no publication reports the drying of Belitung Taro using a tray dryer with moisture content prediction using mathematical modeling. Therefore, this paper aims to study the dehydration performance and determine the most suitable drying mathematical model for Belitung Taro through variations in dimensions of thickness, soaking time, and airflow.

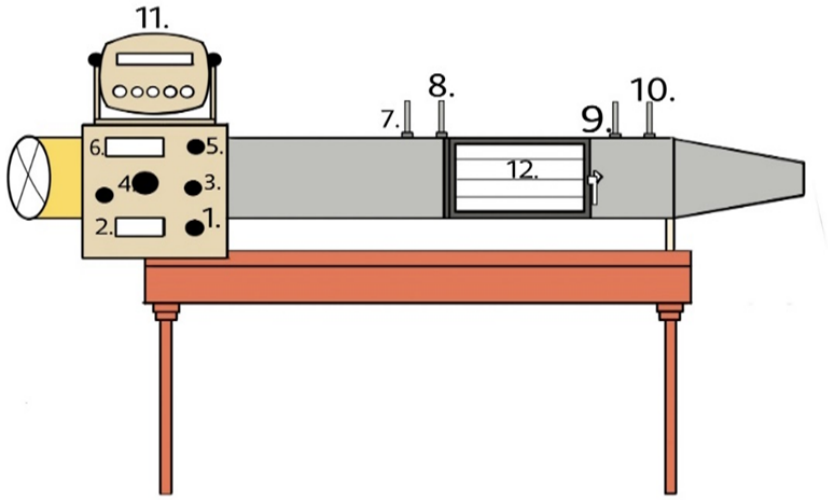

FIGURE 1 The schematic diagram of tray dryer.

3 | MATERIAL AND METHOD

3.1 | Material

Belitung Taro was collected from Tanjung Market, Jember, Indonesia.

3.2 | Instrumentations

The tray dryer used in this work is shown in Figure 1; the heater power button (1), temperature control (2), fan power button (3), fan speed control button (4), temperature button (T1-T4) (5), temperature display (T1-T4) (6), dry bulb temperature sensor before tray (7), wet bulb temperature sensor before tray (8), dry bulb temperature sensor after tray (9), wet bulb temperature sensor after tray (10), balance (11), and material tray. The tray dryer used has a capacity of 42 m3/min, type SF-25H with a frequency of 50 Hz, a power of 190W, a voltage of 220-240V, a size of 250 mm, and a speed of 2800 r/min, HoldPeak HP-866B anemometer. In addition to the tray dryer, the supporting tools for this research are the GSF G-4405 analytical balance, stainless steel knife, oven, sieve, and blender.

3.3 | Procedure

The taro drying process begins with peeling, washing, and slicing the Belitung Taro. The taro was cut circularly with an average surface area of 20 cm2. In this study, the observed variables were airflow velocity of 3 - 6 m/s, slice thickness of 1 - 4 mm, and drying time of 30 - 120 min. The initial time drying was 30 min as the waiting time to reach the 50 °C set point temperature. The sliced taro weighed about 50 g and was then placed on the tray dryer shelves for drying. Temperature data of T1 - T4 were recorded during drying. All experiments were conducted in triplicate.

3.4 | Drying Rate Data Processing

The sample weight data obtained during drying was calculated using Eq. 1 [30]

$$mass\ loss = mass\ before\ drying - mass\ after\ drying \tag{1}$$

Meanwhile, the drying rate is calculated using Eq. 2

$$drying\ rate = \frac{mass\ loss}{time\ interva3} \tag{2}$$

Mathematical modeling and Analysis of Variance (ANOVA) Eq. 2 was used to calculate the moisture content.

TABLE 1 Mathematical models to predict the moisture content of Belitung Taro.

Models	Equation	References
Newton	$MC = \exp(-kt)$	Attkan et al.[30]
Page	$MC = \exp(-kt^n)$	Martinazzo et al.[31]
Modified Page	$MC = \exp(kt)^n$	Carteri Coradi et al.[32]

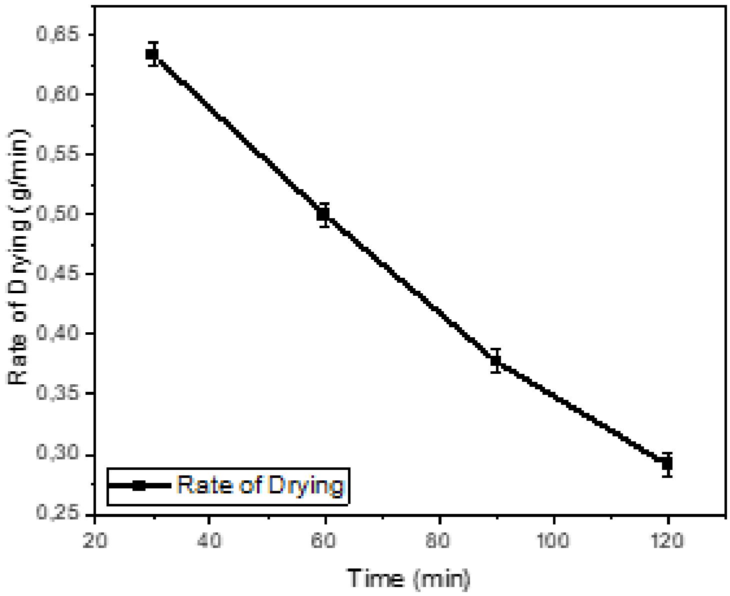

FIGURE 2 The effect of time on drying rate.

$$moisture\ content = \frac{w - d}{d} \tag{3}$$

Where w is the wet mass and d is the mass after drying. Some reported mathematical models are presented in Table 1.

Where k is the rate constant (min-1), t is the drying time (min), and n is the dimensionless coefficient. In this experiment, statistical methods were used to analyze variance (ANOVA) to determine the significant effect of the observed variables. The software used for ANOVA analysis is IBM SPSS Statistics 20[33–36]

4 | RESULTS AND DISCUSSION

4.1 | Effect of Time on Drying Rate

The drying rate on the tray dryer was affected by several factors. Drying time is an important variable that affects the quality of the drying results because it is proportional to the increase in temperature. The longer the time used, the drying temperature also increases, and the increasing temperature would affect the drying product. If the drying temperature is too hot, the material is easily damaged, while if it is too low, the drying results are not good[23]

Fig 2 describes the relationship between taro drying rate and time. The drying process of taro using a temperature of 50 °C, a thickness of 1 mm, an airflow rate of 5 m/s using a tray dryer with time variables of 30, 60, 90, and 120 min obtained drying rates of 0.63, 0.50, 0.42, and 0.29 g/min. Based on these data, the optimum time for taro drying is 30 min because it showed the highest drying rate. The high drying rate based on statistical data decreased significantly with the length of drying time, and

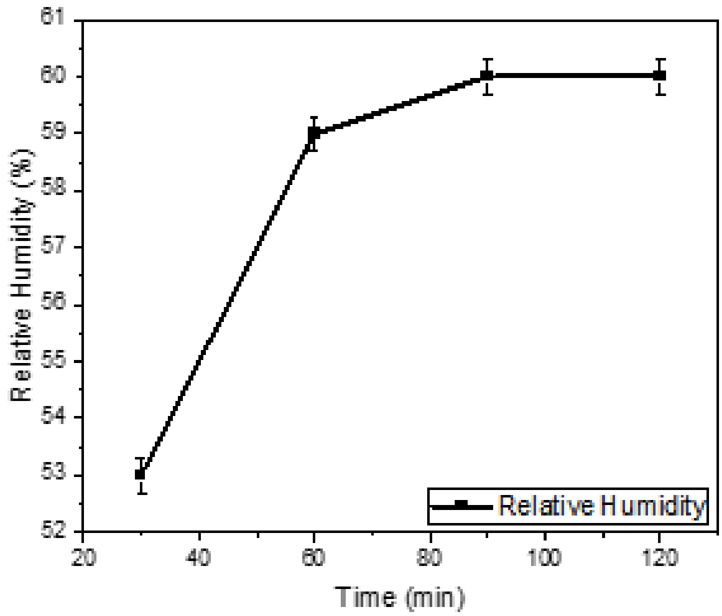

FIGURE 3 The effect of time on relative humidity.

the decrease occurred after 90 min. The dry material was exposed to dew due to re-contact with air, causing an increase in mass after drying, as shown in Fig 3 .

This study found the same trend as the work conducted by Sudomo and Hani [37]. The investigation was carried out using time variables of 5, 6, and 7 h with a thickness of 1 mm, showing the highest drying rate of 5.10 g/min at five h to a temperature of 50 ℃. In contrast, the lowest drying rate is 2.00 g/min at seven hours to 70 ℃. The experimental results show conformity with the literature, which states that a considerable decrease in drying rate at the beginning of drying is due to the high-water content of taro which makes it easy to evaporate. Inversely proportional to the end of drying, namely, the water content in the material is getting less, which causes the water content to be challenging to evaporate so that the drying rate is slower [38]. Based on the results of the ANOVA, it was obtained that different times can reduce the drying rate significantly.

4.2 | Effect of Air Velocity on Drying Rate

Fig. 4 shows the relationship between air velocity and the drying rate of Belitung Taro. Based on the figure, the drying rate would increase along with the addition of air velocity. At air velocities of 3, 4, and 5 m/s, the drying rates were 0.63, 0.67, and 0.70 g/min, respectively. The effect of air velocity on the drying rate was related to the heat transfer process. Along with the increase in air velocity, the temperature occupying the drying room increases to speed up the time needed in the drying process [39] On the other hand, Alit and Bawa Susana [40] reported on drying shelled corn using a heat exchanger that the higher the air velocity, the better the heat transfer in the heat exchanger pipe.

The drying rate in this study tends to increase for each variation of air velocity. At an air velocity of 3, 4, 5, and 6 m/s, drying rates of 0.63, 0.67, and 0.70 g/min are obtained, respectively. The highest drying rate was obtained at an airflow of 5 m/s. In addition, the drying rate of 0.67 g/min decreased when an airflow of 6 m/s was used. The decrease in drying rate may be due to the more significant the air velocity, the shorter the contact time between the air and the sample, so the evaporation process of the water content in the sample does not take place ideally. In other words, if the airflow rate is too large at the same temperature, the contact between hot air and wet materials would be faster, so the amount of water evaporated cannot be maximized.

Fig. 4 exhibits that the most effective evaporation process is at an airflow of 5 m/s with a humidity difference of initial and final 27.19%. The percentage of initial humidity is 55.15%, and the percentage of absolute air humidity is 82.34%. The results obtained from this experiment are comparable to the research conducted by [39] in drying stink lily (Amorphophallus muelleri) for 120 min using a tray dryer at an air velocity of 4 m/s. The most significant mass decrease occurred, so the drying process

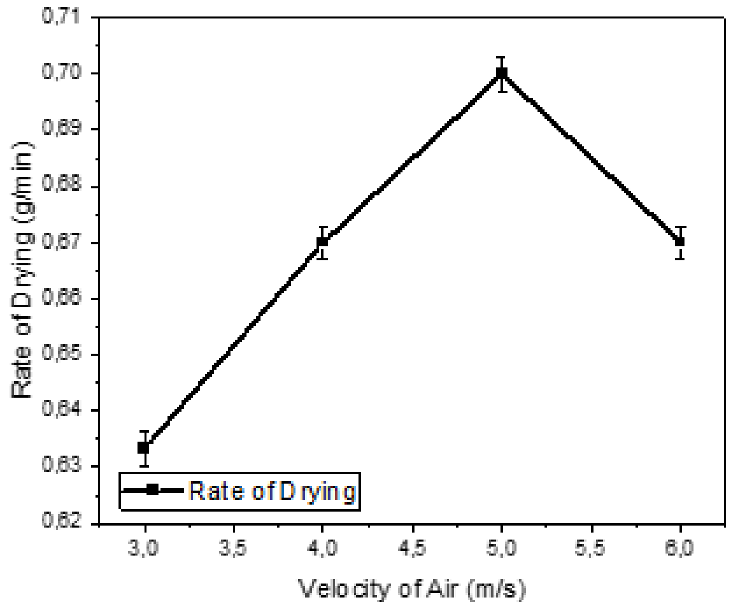

FIGURE 4 The effect of air velocity on drying rate.

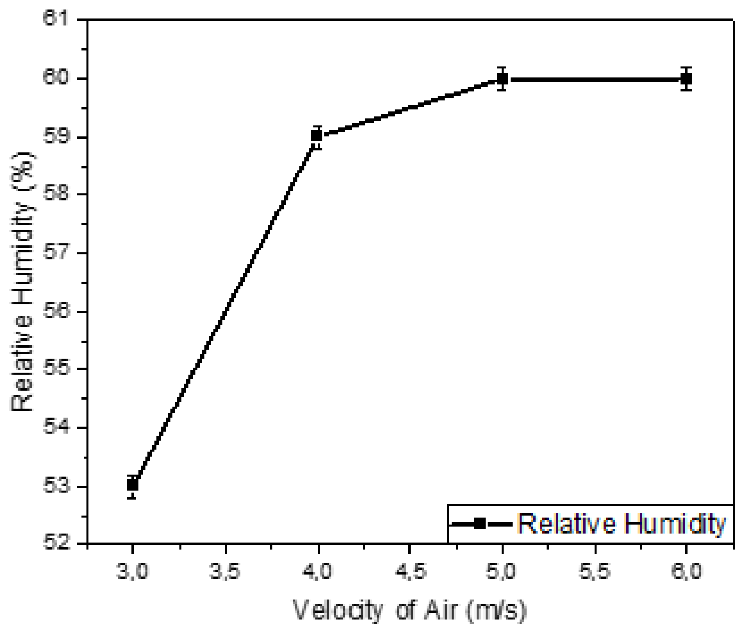

FIGURE 5 The effect of air velocity on relative humidity.

lasted shorter than at air velocities of 2 m/s and 6 m/s. This phenomenon occurred because the air velocity of 4 m/s has the highest temperature, accelerating the evaporation process of the water content of the material. In experiments that have been carried out on the drying rate of Belitung Taro, it can be concluded that the optimal air velocity is at 5 m/s. These results differ from the research conducted by Maulana and Kurniawan[39] and could be made possible due to differences in the sample type and the drying time length. Based on the results of the ANOVA, different airflow can significantly reduce the drying rate.

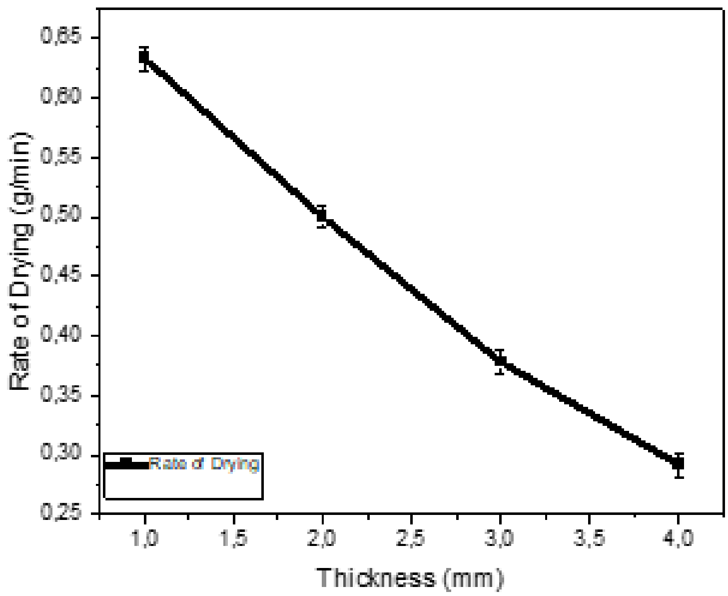

FIGURE 6 The effect of thickness on drying rate.

4.3 | Effect of Thickness on Drying Rate

Fig. 6 shows the relationship between taro drying rate and thickness. It can be seen that the drying rate at 1 mm thickness is the highest. This phenomenon is possible because the thinner the thickness of the taro, the more significant the reduction in mass, causing the drying process to take time to be faster. This study is comparable to research conducted by Fikarauza et al.[41], which showed that the drying process for potatoes at a thickness of 2 mm took 2 hours and 30 min, while the drying process for potatoes at a thickness of 6 mm was much longer, namely for 4 hours 15 min.

The results showed that the drying rate tends to decrease as the thickness of the taro increases. This phenomenon is because the water vapor moves further to close the water outflow and is held in the pores so that it does not dry out quickly. The drying rate at high air velocity variation and thinner material thickness is faster than at low air velocity variation and large material thickness. This fact is because the high air velocity causes the free water content in the material to be pushed out, and nothing is entangled in the material. Suppose lower air velocity makes it difficult for the water content in the material to come out due to the water's lack of encouragement and tendency. It becomes challenging to get out. The thickness of the material also affects the drying rate. If the material is thick, it is difficult for water to come out of it because water is free to collide with the components of other materials. The greater the airflow used, the higher the drying rate, and vice versa, and the greater the thickness of the material, the lower the drying rate, and vice versa, the use of desiccated and the role of radiation intensity is higher.

The drying rate would decrease as the moisture content decreases during drying. The amount of bound water would decrease. The change from constant to decreasing drying rates for different materials would occur at different moisture contents[42]. Based on the graph, the thickness variation significantly affects the drying rate. Based on the results of the ANOVA obtained, it can be concluded that different thicknesses can reduce the drying rate significantly[33]. This result is supported by research[43]. Fig. 7 shows the significant drying rate and the most negligible moisture content obtained at the thickness of cassava with a thickness of 1 cm, which is 5.42%. The optimal drying conditions in Belitung Taro are at a thickness of 1 mm with the most considerable drying rate of 0.63. In addition, the relative humidity tends to increase along with the thickness of the taro being tested. Due to the increasing thickness, heat absorption would take longer, so drying would take longer.

4.4 | Mathematical Model

The thin layer drying model is obtained by finding the value of the constant k and from the non-linear regression form. The constants were determined using the solver of Ms. Excel, and the solver automatically searches for constant values from non-linear regression equations. Table 2 shows the results of the analysis of the constant values of each model, and figure 8 shows

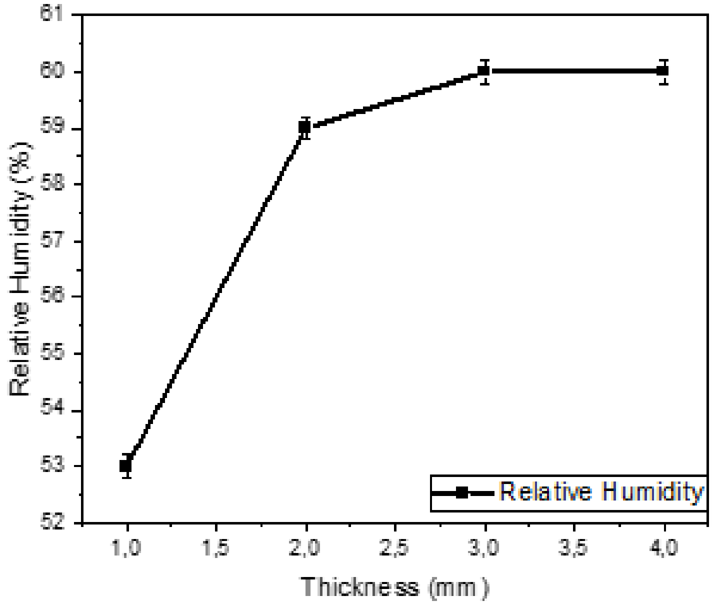

FIGURE 7 The effect of thickness on relative humidity.

TABLE 2 Mathematical modeling of Belitung Taro drying.

Newton			Page			Modified Page		
k	**n**	**R2**	**k**	**n**	**R2**	**k**	**n**	**R2**
0.3		0.8373	0.12	1.2	0.83729	0.23	1.009	0.83786

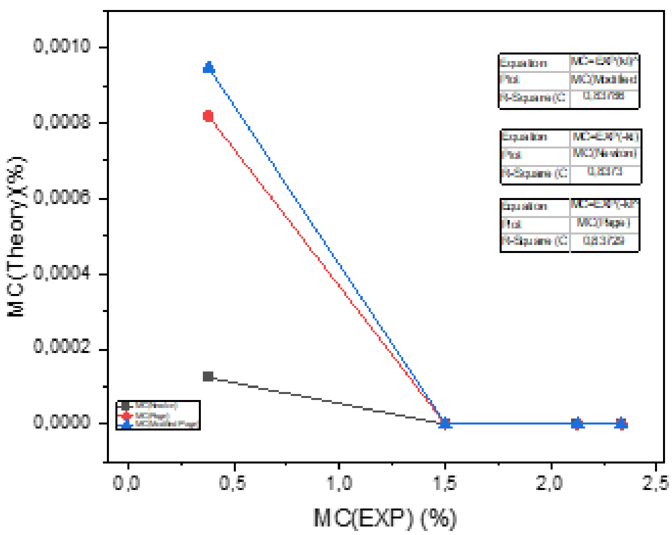

FIGURE 8 The mathematical modeling of Belitung taro drying.

the value of R2 in each model equation. The R2 value of the Modified Page model shows the most significant value compared to the equations of the Newton and Page models. This fact shows that the Modified Page model is the best model to present Belitung Taro drying theoretically. The results of the thin-layer modeling are similar to those of Carteri Coradi et al.[32].

5 | CONCLUSION

Based on the research results, the drying rate of Belitung Taro is influenced by time, airflow velocity, and slice thickness. The drying rate decreases with increasing time because the water content in the material decreases, and the thickness of the material drying rate decreases as the thickness of the taro increases. Meanwhile, the drying rate is optimal for air velocity when the difference between the initial and final air humidity is highest. The Modified Page model is the most accurate in predicting the drying characteristics of Belitung Taro based on the resulting constant value. The Modified Page model produces a predicted moisture content value relationship that matches the experimental moisture content.

CREDIT

Maktum Muharja and Rizki Fitria Darmayanti: Conceptualization, Methodology, Supervision, Resources. **Achri Isnan Khamil:** Writing, Formal Analysis, Data Curation. **Andika Prastika:** Writing, Visualization. **Muhammad Rizalluddin:** Investigation, Writing Draft Preparation. **Siska Nuri Fadilah:** Writing, Validation, Project Administration. **Difka Augustina Diana Sari:** Review and Editing.

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