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# Thin Layer Drying Kinetics of Dried Mango Acid at Different Drying Temperature in A Food Dehydrator

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**ABSTRACT**

Dried mango acid has been known for a long time as a traditional food product made from unripe mangoes. This product is dried to treat damaged mangoes due to an abundant harvest. One of the drying methods that can be used for this product is a food dehydrator, but information regarding the kinetics of drying manganese acid for drying is still lacking. This study aimed to analyze the effect of drying temperature using a food dehydrator on the drying kinetics characteristics of dried mango acid. Young mango slices were dried at three temperature levels of 40ºC, 50ºC and 60ºC until the moisture content reached equilibrium. Weight, moisture content, drying rate, moisture ratio, and effective moisture diffusivity were analyzed. The results of the moisture ratio analysis were applied and evaluated in several mathematical models of thin layer drying and the curve fitting process was carried out through the application of nonlinear regression analysis. The results showed that the most suitable mathematical model to describe the drying characteristics of a thin layer of mango acid using a food dehydrator is the Page model. The value of effective moisture diffusivity drying mango acid at a temperature of 40ºC was 1.826 x $10^{-10}$ $m^2$/s, a temperature of 50ºC was 3.651 x $10^{-10}$ $m^2$/s and a temperature of 60ºC was 4.564 x $10^{-10}$ $m^2$/ s. The results of this research can be used as information to optimize the mango acid drying process.



## INTRODUCTION

Mango (*Mangifera indica*, L) is one of the leading horticultural commodities in Indonesia. According to BPS Direktorat Jenderal Hortikultura (2019), in 2015, the amount of mango production in South Sulawesi was 117,205 tons and continued to increase in 2019 to 129,432 tons. One of the mango production centers in eastern Indonesia is South Sulawesi. This province has a large area of mango production with a high level of productivity. Utilization of mango fruit for consumption in the form of fresh fruit is still a priority, although other products made from mango fruit are also being developed, such as jam, canned syrup, candied mango, and including dried mango acid.

Mango acid is sliced dried mango fruit which is used as a food additive in typical South Sulawesi dishes. This dried mango fruit can also be mixed with tamarind as a food additive in making chutney. In Indian cuisine, dried half ripe mangoes are also used as an additional

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ingredient in cooking pumpkin soup or curry (Kaushik et al., 2014). In addition, mango acid is also a traditional ingredient in Bugis culture as a medicine for stomach aches. In principle, mango acid is made from young mangoes, which are then sliced thin and dried in the sun to dry. These dried mango slices are then brewed with hot water and allowed to cool so that they can be consumed to relieve stomach pain (M. Kumar et al., 2021).

Postharvest handling of mangoes needs to be done to maintain the quality and quantity of the fruit after the harvesting process so that the fruit can be stored for a longer time. Mango fruit is a seasonal fruit with a large number of harvests in one season. The supply of fruit which is more than the demand results in mangoes being stored for a long time and rotting, which results in a decrease in the commercial value of the fruit (Alam, 2018; Hor et al., 2020). One of the postharvest handling that affects the quality of food products is drying. The drying process carried out on mango acid aims to reduce the water content in the ingredients so that the remaining water cannot be used as a living medium for destructive microbes and to extend the shelf life of the ingredients with nutritional quality that can be maintained (Jamaluddin et al., 2022; Murali et al., 2019).

In principle, each food ingredient has a unique drying behavior according to the type of material being dried. The drying kinetics of a material are influenced by related drying parameters and can be explained through a mathematical equation in the form of a drying model (Rauf, 2021). Research related to the kinetics of drying food by hot air-drying method and controlled conditions has been widely carried out. Treatment of different drying methods for a particular material interprets the different forms of mathematical model equations for drying thin layers (Fithriani et al., 2016; Jamaluddin et al., 2022).

Drying of mango acid is generally done in the traditional way by drying directly in the sun using tarpaulins, cement floors or other containers. In the process, the product can easily get mixed with dirt and dust, requires a lot of energy, takes a long time and is in an uncontrolled environment (Sharma & Kumar, 2022). In addition to drying in direct sunlight, several studies related to drying perishable foods have used as the most widely used (Tan et al., 2022). Hunaefi et al. (2021) explained that the use of a tray dryer as one of the drying methods studied can extend the shelf life of dried mango slices. One of the dryers that can be used for drying mango acid is a food dehydrator. Jena et al. (2022) explained that drying using a food dehydrator aims to preserve food and products such as vegetables and fruit to remove the water content contained in food. A food dehydrator consists of trays, heating components, air vents, and a fan that circulates the heat throughout the device. The food is spread out over trays and placed inside of the dehydrator. The heating element serves as the catalyst that raises the temperature within the machine, and the fan serves as the air circulation tool that helps remove the moisture. Together, these two components work together to achieve the desired effect.

Research on food dehydrators for drying various food products has been done before. Food dehydrators have been used to dry onions (Sarjono, 2022), mushrooms (Kragh et al., 2022), edamame (Yudiastuti et al., 2021), chrysanthemum flowers (Yulianti et al., 2020), and stevia leaves (Chandra & Witono, 2018). Research on food dehydrators was also carried out to improve the efficiency, functionality and performance of this equipment. Studies have examined various aspects, such as heat distribution, airflow patterns, and drying kinetics, to optimize the drying process and improve the quality of dry food products (Jebitta et al., 2020; Madhankumar et al., 2021; Mokhtar et al., 2023; Tripathi et al., 2018). Previous studies have shown that a food dehydrator can produce a high-quality dry food product. Food dehydrator can also be used to produce good mango acid products. Various information about the mango acid drying process is needed to optimize the process. However, information regarding the drying of mango acid with a food dehydrator is still lacking. Therefore, this study aims to analyze the drying kinetics of mango acid thin films using a food dehydrator at various drying temperatures. It is hoped that the results of this study can become a specific reference in the drying process and have an impact on the good quality of dried mango acid.

## MATERIALS AND METHODS

### Sampel preparation

Fresh mangoes (*Mangifera indica*), with a young fruit maturity level, are harvested at the age of 65 days after flowering (Abu et al., 2020). Samples were washed with water to remove adhering dirt. Then the samples were peeled and sliced with a thickness of 3 mm, with length of 100 mm and width of 5 mm. Samples were put into a food dehydrator containing 10 trays with an initial average sample weight of 150 g per tray.

**Drying Process**

Fresh mango slices were dried using a thin layer drying method using a food dehydrator model type FDH-10 Wirastar with a size of 46 cm x 40 cm x 44 cm containing 10 trays with a size of 39 cm x 28 cm (Figure 1). Drying was carried out at three temperature levels, namely 40ºC, 50ºC and 60ºC with 3 repetitions. The fruit is dried using a food dehydrator until the moisture content is equilibrium. Sample weight data was collected every 20 minutes during drying by measuring the weight of the dried material using the KERN ABT 320-4M analytical balance with an accuracy of 0.001 g. Then the weight of the material is calculated by Equation 1 (Jamaluddin et al., 2022).

$$Weight\ loss(\%) = \frac{initial\ weight - final\ weight}{initial\ weight} x\ 100\% \quad (1)$$

Gambar 1. *Food Dehydrator*

The dried fruit was then put into the oven at 105ºC to determine the final moisture content of the sample. Measurement of water content was carried out using 2 methods, namely the oven method (AOAC, 2000) and the method of measuring dry basis moisture content (Jha et al., 2021) with the following Equation 2:

$$MC_{d.b.} = \frac{Wa}{Wd} \text{ x } 100\% = \frac{Wt\text{-}Wd}{Wt\text{-}Wa} \text{ x } 100\% \quad (2)$$

where:

$MC_{db.}$ = Dry basis moisture content ($\%_{db}$)
$W_a$ = Weight of water in material (g)
$W_d$ = Absolute dry weight of material (g)
$W_t$ = total weight (g) = $W_a + W_k$

**Drying Kinetics and Thin Layer Drying Models**

The results of measuring the moisture content on a dry basis form the basis for measuring the drying rate of the material. Drying rate means the amount of water evaporated during drying at a certain time. Calculation of the drying rate is done by Equation 3 (Jamaluddin et al., 2022):

$$DR = \frac{dw}{dt} = \frac{w_t - w_{t+1}}{t_2 - t_1} \quad (3)$$

where:

DR = Drying rate ($\%_{d.b.}$ /hour)
$d_w$ = the weight of water that evaporates
$d_t$ = the change in time during drying
$w_t$ = the weight of the material at time (t, hour).

The ratio of water content in drying mango slices is calculated based on changes in dry base moisture content in a certain time unit. Measurement of the ratio of water content using Equation 4 (Jamaluddin et al., 2022):

$$MR = \frac{M_t - M_e}{M_o - M_e} \quad (4)$$

Where

MR = Moisture ratio
$M_t$ = Moisture content at time t (time during drying, hours),
$M_o$ = Initial moisture content of the material,
$M_e$ = Moisture content obtained after the weight of the material is constant.

Table 1. Mathematical model of thin layer drying used to describe the drying kinetics of *mango acid*

| No. | Model | Equation | Reference |
|---|---|---|---|
| **1.** | Newton | Mr = exp (-kt) | (Lewis, 1921) |
| **2.** | Henderson and Pabis | Mr = a exp (-kt) | (Henderson & Pabis, 1961) |
| **3.** | Page | Mr = exp (-kt$^n$ ) | (Page, 1949) |
| **4.** | Logarithmic | Mr = a exp (-kt) + c | (Hii et al., 2009) |
| **5.** | Modified Page | Mr = exp [-(kt)$^n$] | (Uribe et al., 2017) |

a, c, k, n, drying constant; MR, moisture ratio; t, drying time (h)

The drying behavior is interpreted through the thin film drying model which is obtained based on the identification of drying kinetics by finding the constant values a, c, k and n of each model tested. This value is the result of the modeling used to produce MR values through nonlinear regression analysis. The mathematical model equation used is shown in Table 1.

The flow rate of water from inside the material that diffuses during drying is identified through the calculation of Effective moisture diffusivity ($D_{eff}$). $D_{eff}$ calculation by connecting ln MR value and time on a graph. Based on the slope value of the graph, the effective moisture diffusivity value is calculated using Equation 5:

$$slope = -D_{eff}\left(\frac{\pi^2}{4l^2}\right) \qquad (5)$$

Where:

$D_{eff}$ = effective moisture diffusivity ($m^2/s$)

L = thickness of the material (m).

The selection of the best thin film drying mathematical model is carried out by analyzing the suitability level based on the coefficient of determination ($R^2$), chi square ($X^2$), Root Mean Error (RMSE), Sum Square Error (SSE) and Modeling Efficiency (EF). The calculation of these variables is shown in Equations 6 – 10 (Omolola et al., 2019; Suherman & Susanto, 2019).

$$R^2 = \frac{\sum_{i=1}^{N}(MR_i - MR_{pre.i}).\sum_{i=1}^{N}(MR_i - MR_{pre.i})}{\sqrt{\left[\sum_{i=1}^{N}(MR_{exp.i} - MR_{pre.i})^2\right].\left[\sum_{i=1}^{N}(MR_{exp.i} - MR_{pre.i})^2\right]}} \qquad (6)$$

$$X^2 = \frac{\sum_{i=1}^{N}(MR_{exp.i} - MR_{pre.i})^2}{N-Z} \qquad (7)$$

$$\mathrm{RMSE} = \sqrt{\frac{\sum_{i=1}^{N}(MR_{exp.i} - MR_{pre.i})^2}{N}} \qquad (8)$$

$$\mathrm{SSE} = \frac{\sum_{i=1}^{N}(MR_{exp.i} - MR_{pre.i})^2}{N} \qquad (9)$$

$$\mathrm{EF} = \frac{\sum_{i=1}^{N}(MR_{exp.i} - MR_{\mathrm{exp}\,mean.i})^2 \quad \sum_{i=1}^{N}(MR_{pre.i} - MR_{exp.i})^2}{\sum_{i=1}^{N}(MR_{exp.i} - MR_{\mathrm{exp}\,mean.i})^2} \qquad (10)$$

## RESULTS AND DISCUSSION

### Drying Kinetics

The drying pattern of mango acid at 50°C and 60°C showed the same behavior of decreasing water content (Figure 2). The water content of the samples decreased significantly in the first 2 hours and then slowed down until the water content reached equilibrium. While the temperature of 40°C shows a different pattern. Even though the decrease in water content seems significant, the decrease will be slower until it reaches the equilibrium water content. This is related to the application of a temperature of 40°C which is lower than other drying temperature levels. The low drying temperature has an impact on the amount of time needed to remove water from the material until it reaches the equilibrium moisture content. Conversely, the higher the drying temperature, the faster the drying process and the decrease in the water content of the mango acid will be more visible (Jamaluddin et al., 2022; Pongpichaiudom & Songsermpong, 2018; Taheri-Garavand & Meda, 2018). The use of high temperatures tends to accelerate the drying process of the material towards the equilibrium moisture content. The higher the temperature of the dryer, the faster the drying time required, the greater the temperature difference between the heater and the food, the faster the evaporation of water from the food will be (Zhang et al., 2020). According to

Jamaluddin et al. (2022), the impact of high temperatures triggers a faster heat transfer process so that the time needed to remove the moisture content of the material is shorter. When the water content approaches the equilibrium water content, the decrease in water content is slower because the mass of water on the surface of the material is getting thinner so that a diffusion process occurs (Wang et al., 2011).

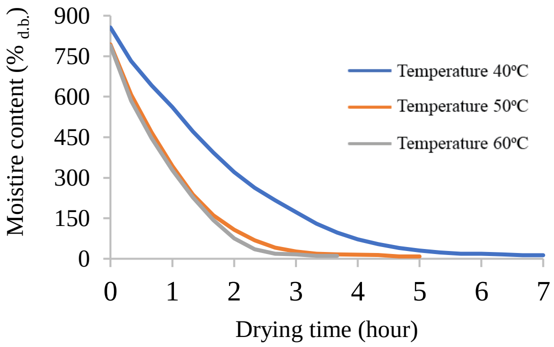


Figure 2. Changes in water content in drying of mango acid using a food dehydrator at different temperatures

## Drying Rate

The results of the analysis show that the highest drying rate occurs in the first 1 hour of the drying process and then the drying rate slowly decreases until the moisture content reaches equilibrium (Figure 3). The highest drying rate occurs at the beginning of drying because the free water content in the material is high so that water easily comes out to the surface and undergoes evaporation. Furthermore, the drying rate decreased rapidly. This is in accordance with (Jha et al., 2021) which states that as the drying process progresses, the drying rate decreases because the process of transferring water from the material to the surface continues to occur. The tendency of the material to experience a greater decrease in water content is affected by a large drying temperature.

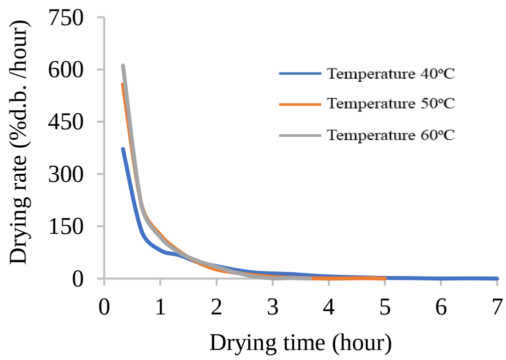


Figure 3. Drying rate of mango acid using a food dehydrator at different temperatures

The higher the drying temperature, the faster the drying rate, and the shorter the drying time. Changes in drying rate during the final drying period tend to decrease. This is because most of the free water in the material has evaporated and the rest is bound water which is difficult to diffuse to the surface. The fan on the food dehydrator also increases the effectiveness of drying so that the drying rate is higher. Jamaluddin et al. (2022) states that the critical water content is the lowest water content when the rate of free water from inside the material to the surface is equal to the rate of maximum water vapor extraction from the material. This illustrates the unique characteristics of mango acid drying which is characterized by a falling rate drying process. The high or low drying rate of a food that is dried will be different from other types of food.

The condition of the drying chamber is one of the factors that affect the drying rate. This also causes differences in the drying behavior of a food that is dried. Differences in temperature and water vapor pressure also have an effect during the drying process, especially on the moisture ratio. During the drying process, the MR value decreased (Figure 4). There was a decrease in MR in line with the decrease in water content. This is because changes in MR values are calculated with reference to water content.

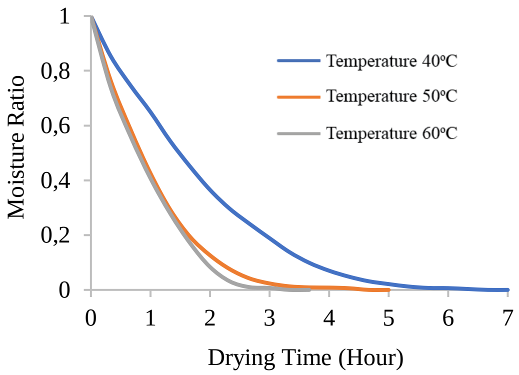


Figure 4. Changes in moisture ratio in drying mango acid using a food dehydrator at different temperatures

MR values at 50°C and 60°C decreased faster than the drying temperature of 40°C. The hot condition of the drying chamber will have an impact on increasing the amount of water that comes out of the material and undergoes evaporation. This is in accordance with (Kasara et al., 2021) which states that the impact of high temperatures triggers faster heat and mass transfer processes, so that the time needed to remove the moisture content of the material is shorter. The MR pattern from the results of this analysis is then used to analyze and determine the mathematical equation model for thin layer drying that is suitable for describing the drying kinetics of mango acid.

The results of evaluating the trendline on each model graph, in the form of constant values, $R^2$, $X^2$, RMSE, SSE and EF in each model, are shown in Table 2. Evaluation of the thin layer drying model showed that the Page model was the most suitable model to describe the kinetics of drying mango acid using a food dehydrator dryer. The Page model has the highest $R^2$ values for temperatures of 40°C, 50°C and 60°C, namely 0.9978, 0.9990 and 0.9957 respectively. In addition, the Page model has smaller RMSE and $X^2$ values compared to the other models. Page's model has produced suitable simulations to explain various drying of

Table 2. Value of contanta , $R^2$, $X^2$, RMSE, SSE and EF froem each drying model on temperature of 40°C, 50°C and 60°C

| Temperature | Model | Contanta | | | | $R^2$ | $X^2$ | RMSE | SSE | EF |
|---|---|---|---|---|---|---|---|---|---|---|
| | | k | a | n | c | | | | | |
| 40°C | Newton | 0.5400 | | | | 0.9930 | 0.0015 | 0.0375 | 0.0310 | 0.9848 |
| | Henderson Pabis | 1.0541 | 0.5667 | | | 0.8804 | 0.0675 | 0.2477 | 1.3498 | 0.3392 |
| | Page | 0.4355 | | 1.2563 | | **0.9978** | **0.0003** | **0.0154** | **0.0052** | **0.9975** |
| | Logarithmic | 0.5667 | 1.0541 | | 0.0000 | 0.9905 | 0.0013 | 0.0338 | 0.0251 | 0.9877 |
| | Modified Page | 0.7350 | | 0.7350 | | 0.9929 | 0.0015 | 0.0375 | 0.0375 | 0.9848 |
| 50°C | Newton | 0.9000 | | | | 0.9961 | 0.0007 | 0.0254 | 0.0142 | 0.9902 |
| | Henderson Pabis | 0.9765 | 1.0360 | | | 0.995 | 0.0005 | 0.0215 | 0.0102 | 0.9930 |
| | Page | 0.8904 | | 1.2115 | | **0.9990** | **0.0001** | **0.0083** | **0.0015** | **0.9990** |
| | Logarithmic | 0.9765 | 1.0360 | | 0.0000 | 0.9945 | 0.0005 | 0.0215 | 0.0102 | 0.9930 |
| | Modified Page | 0.7285 | | 0.7285 | | 0.9777 | 0.0189 | 0.1310 | 0.3773 | 0.7416 |
| 60°C | Newton | 1.0000 | | | | 0.9921 | 0.0009 | 0.0295 | 0.0191 | 0.9846 |
| | Henderson Pabis | 1.0532 | 1.0349 | | | 0.9894 | 0.0009 | 0.0278 | 0.0170 | 0.9862 |
| | Page | 0.9672 | | 1.2468 | | **0.9957** | **0.0008** | **0.0166** | **0.0060** | **0.9951** |
| | Logarithmic | 1.0532 | 1.0349 | | 0.0000 | 0.9894 | 0.0009 | 0.0278 | 0.0170 | 0.9862 |
| | Modified Page | 0.9672 | | 1.2468 | | 0.9780 | 0.0020 | 0.0422 | 0.0392 | 0.9683 |

agricultural products and is also easier to use than other equations (Yadollahinia et al., 2008).

To further strengthen the results obtained, the predicted MR values from Page's model were analyzed with experimental MR values in a linear relationship at three drying temperature levels (Figures 5, 6 and 7). The results of this analysis show a very strong relationship between the two variables. From this information, it can be concluded that Page's model can predict well the kinetics of drying mango acid with a food dehydrator at various drying temperatures.

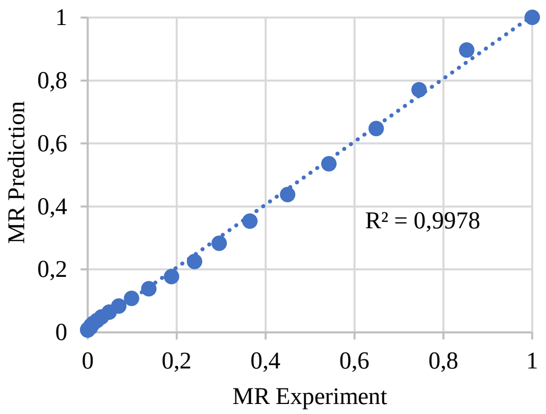


Figure 5. Relationship between Experiment MR and Predicted MR from the mango acid drying process with the Page model at 40°C

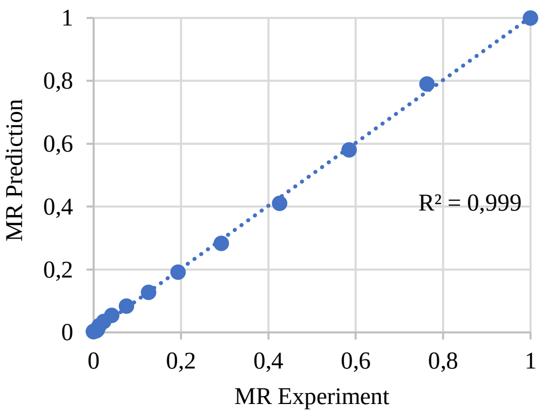


Figure 6. Relationship between Experiment MR and Predicted MR from the mango acid drying process with the Page model at 50°C

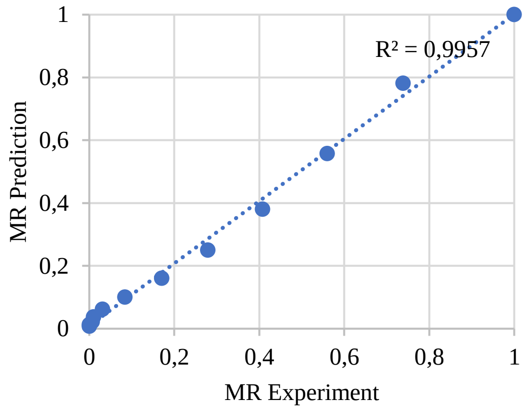


Figure 7. Relationship between Experiment MR and Predicted MR from the mango acid drying process with the Page model at 60°C

Based on the results of the ln MR plot with time and slope values from the results of the linearity curve, the effective moisture diffusivity value at 60°C is 4.564 x $10^{-10}$ $m^2/s$, at 50°C it is 3.651 x $10^{-10}$ $m^2/s$ and at 40°C it is 1.826 x $10^{-10}$ $m^2/s$ (Figures 8, 9 and 10). The value of effective moisture diffusivity increases with increasing drying temperature. This is in accordance with Jamaluddin et al. (2022) which states that the effective diffusivity will increase with increasing temperature. Evaporation is higher at a higher temperature, therefore, the effective diffusivity will be higher as well, as well as the greater the water that will be evaporated. Evaporation is also affected by drying time. A high evaporation rate in a product occurs at the beginning of the drying process (Y. Kumar et al., 2015).

One of the reasons for the increase in the effective diffusivity value is the thickness parameter used in the calculation of the effective diffusivity. The smaller the thickness of the dried material, the higher the evaporation. The ability to diffuse water from within the material will increase with increasing temperature, however, the tendency to influence other factors can also affect the diffusivity of a material such as surface area, thickness, air velocity, RH, drying time and other factors (Rauf, 2021).

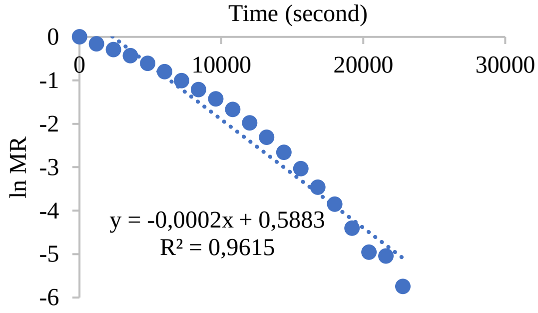


Figure 8. Relationship between ln MR and mango acid drying time with a food dehydrator at 40°C

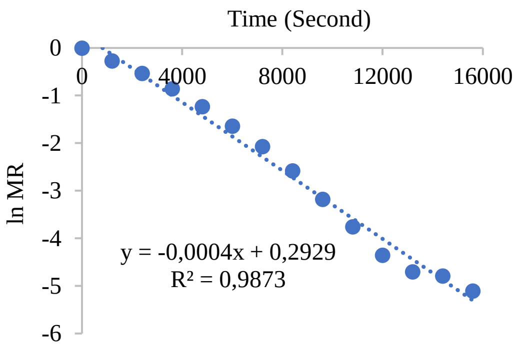


Figure 9. Relationship between ln MR and mango acid drying time with a food dehydrator at 50°C

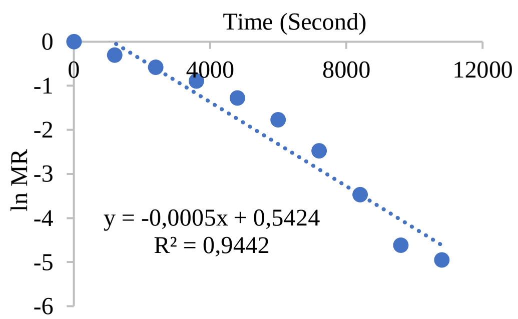


Figure 10. Relationship between ln MR and mango acid drying time with a food dehydrator at 60°C

## CONCLUSION

The drying kinetics pattern of mango tamarind is included in the falling rate drying pattern. The most appropriate mathematical model to describe the drying characteristics of mango acid thin films using a food dehydrator at 40°C, 50°C and 60°C is the Page model. The Page model has the highest $R^2$ values for temperatures of 40°C, 50°C and 60°C, namely 0.9978, 0.9990 and 0.9957 respectively. The highest effective moisture diffusivity value of drying mango acid was at 60°C and the lowest at 40°C. For further research, the variable difference in the thickness of sliced mangoes and the variable quality characteristics of dried mango tamarind can be studied. This study provides important information and contributes to the handling of mango acid on a large scale in the industry.

## REFERENCES

Abu, M., Olympio, N. S., & Ofei Darko, J. (2020). Appropriate harvest maturity for mango (Mangifera indica L.) fruit using age control and fruit growth and development attributes. *Horticulture International Journal*, *4*(5). https://doi.org/10.15406/hij.2020.04.00185

Alam, M. M. (2018). Mango supply chain and value chain analysis from farm to market. *International Journal of Supply Chain Management*, *7*(4).

AOAC. (2000). *Official Methods of Analysis of AOAC International* (17th ed.). AOAC International.

BPS Direktorat Jenderal Hortikultura. (2019). *Produksi Mangga di Indonesia Tahun 2014-2019*.

Chandra, A., & Witono, J. R. B. (2018). Pengaruh Berbagai Proses Dehidrasi Pada Pengeringan Daun Stevia Rebaudiana. *Jurusan Teknik Kimia*, *April*.

Fithriani, D., Assadad, L., & Siregar, Z. A. (2016). Characteristics and mathematical model of drying curve of Eucheuma cottonii Seaweed. *Jurnal Pascapanen Dan Bioteknologi Kelautan Dan Perikanan*, *11*(2), 159–170. https://doi.org/10.15578/jpbkp.v11i2.290

Henderson, S. M., & Pabis, S. (1961). Grain drying theory I: Temperature effect on drying coefficient. *Journal of Agricultural Engineering Research*, *6*, 169–174.

Hii, C. L., Law, C. L., & Cloke, M. (2009). Modeling using a new thin layer drying model and product quality of cocoa. *Journal of Food Engineering*, *90*(2). https://doi.org/10.1016/j.jfoodeng.2008.06.022

Hor, S., Léchaudel, M., Mith, H., & Bugaud, C. (2020). Fruit density: A reliable indicator of sensory quality for mango. *Scientia Horticulturae*, *272*. https://doi.org/10.1016/j.scienta.2020.109548

Hunaefi, D., Rahmawati, R., Saputra, D., Maulani, R. R., & Muhandri, T. (2021). Optimizing the tray dryer temperature and time of white corn flour culture. *Food Research*, *5*(5). https://doi.org/10.26656/fr.2017.5(5).718

Jamaluddin, Yahya, M., Rauf, R. F., & Rivai, A. A. (2022). Drying kinetics and quality characteristics of Eucheuma cottonii seaweed in various drying methods. *Journal of Food Processing and Preservation*, *46*(2). https://doi.org/10.1111/jfpp.16258

Jebitta, S. R., Allwin, S. J., Banu, A. H., Rifqa, R. F., & Swetha, R. (2020). Design and fabrication of portable food dehydrator. *International Journal of Food Science and Nutrition*, *5*(4).

Jena, B. N., Saily, A. S., Nanda, S. P., Madhusmita, Prof. M., & Swain, Dr. S. (2022). Development of Dehydrator for Domestic Use of Fruits. *International Journal for Research in Applied Science and*

*Engineering Technology*, *10*(5). https://doi.org/10.22214/ijraset.2022.42885

Jha, P., Meghwal, M., & Prabhakar, P. K. (2021). Microwave drying of banana blossoms (Musa acuminata): Mathematical modeling and drying energetics. *Journal of Food Processing and Preservation*, *45*(9), 1–14. https://doi.org/10.1111/jfpp.15717

Kasara, A., Babar, O. A., Tarafdar, A., Senthilkumar, T., Sirohi, R., & Arora, V. K. (2021). Thin-layer drying of sadabahar (Catharanthus roseus) leaves using different drying techniques and fate of bioactive compounds. *Journal of Food Processing and Preservation*, *45*(2), e15140. https://doi.org/10.1111/jfpp.15140

Kaushik, N., Kaur, B. P., Rao, P. S., & Mishra, H. N. (2014). Effect of high pressure processing on color, biochemical and microbiological characteristics of mango pulp (Mangifera indica cv. Amrapali). *Innovative Food Science and Emerging Technologies*, *22*. https://doi.org/10.1016/j.ifset.2013.12.011

Kragh, M. L., Obari, L., Caindec, A. M., Jensen, H. A., & Truelstrup Hansen, L. (2022). Survival of Listeria monocytogenes, Bacillus cereus and Salmonella Typhimurium on sliced mushrooms during drying in a household food dehydrator. *Food Control*, *134*. https://doi.org/10.1016/j.foodcont.2021.108715

Kumar, M., Saurabh, V., Tomar, M., Hasan, M., Changan, S., Sasi, M., Maheshwari, C., Prajapati, U., Singh, S., Prajapat, R. K., Dhumal, S., Punia, S., Amarowicz, R., & Mekhemar, M. (2021). Mango (Mangifera indica l.) leaves: Nutritional composition, phytochemical profile, and health-promoting bioactivities. In *Antioxidants* (Vol. 10, Issue 2). https://doi.org/10.3390/antiox10020299

Kumar, Y., Tiwari, S., & Belorkar, S. A. (2015). Drying: an excellent method for food preservation. *International Journal of Engineering Studies and Technical Approach*, *01*(8), 1–17.

Lewis, W. K. (1921). The rate of drying of solid materials. *Industrial and Engineering Chemistry*, *13*(5), 427–432. https://doi.org/10.1021/ie50137a021

Madhankumar, S., Muthukkhumaran, K. S. R., Navaneeth, R. A., Padmanabhan, M., & Shriram, K. M. (2021). Design and Modelling of Automated Hot Oven Food Dehydrator. *2021 7th International Conference on Advanced Computing and Communication Systems, ICACCS 2021*. https://doi.org/10.1109/ICACCS51430.2021.9441881

Mokhtar, M. H., Termizi, M. H. A., Yudin, A. S. M., & Alias, A. (2023). Performance of Food Dehydrator Using Different Type of Distributor Base Plate. *Lecture Notes in Electrical Engineering*, *882*. https://doi.org/10.1007/978-981-19-1577-2_12

Murali, S., Sathish Kumar, K., Alfiya, P. V., Delfiya, D. S. A., & Samuel, M. P. (2019). Drying Kinetics and Quality Characteristics of Indian Mackerel (Rastrelliger kanagurta) in Solar–Electrical Hybrid Dryer. *Journal of Aquatic Food Product Technology*, *28*(5), 541–554. https://doi.org/10.1080/10498850.2019.1604597

Omolola, A. O., Kapila, P. F., & Silungwe, H. M. (2019). Mathematical modeling of drying characteristics of Jew's mallow (Corchorus olitorius) leaves. *Information Processing in Agriculture*, *6*(1), 109–115. https://doi.org/10.1016/j.inpa.2018.08.003

Page, G. E. (1949). *Factors influencing the maximum rate of air drying shelled corn in thin-layers*. Purdue University, West Lafayette.

Pongpichaiudom, A., & Songsermpong, S. (2018). Characterization of frying, microwave-drying, infrared-drying, and hot-air drying on protein-enriched, instant noodle microstructure, and qualities. *Journal of Food Processing and Preservation*, *42*(3), 1–10. https://doi.org/10.1111/jfpp.13560

Rauf, R. F. (2021). Pemodelan Kinetika Pengeringan Rumput Laut Eucheuma cottonii Menggunakan Pengering Surya Efek Rumah Kaca. *Jurnal Pendidikan Teknologi Pertanian*, *7*(1). https://doi.org/10.26858/jptp.v7i1.19312

Sarjono, A. P. (2022). Drying Onion Slices using a Food Dehydrator. *Eduvest - Journal of Universal Studies*, *2*(7). https://doi.org/10.36418/edv.v2i7.502

Sharma, H. K., & Kumar, N. (2022). *Agro-Processing and Food Engineering*. Springer.

Suherman, S., & Susanto, E. E. (2019). Mathematical modelling of paddy drying using fluidized bed dryer. *IOP Conference Series: Materials Science and Engineering*, *543*(1). https://doi.org/10.1088/1757-899X/543/1/012010

Taheri-Garavand, A., & Meda, V. (2018). Drying kinetics and modeling of savory leaves under different drying conditions. *International Food Research Journal*, *25*(4), 1357–1364.

Tan, S., Miao, Y., Zhou, C., Luo, Y., Lin, Z., Xie, R., & Li, W. (2022). Effects of Hot Air Drying on Drying Kinetics and Anthocyanin Degradation of Blood-Flesh Peach. *Foods*, *11*(11). https://doi.org/10.3390/foods11111596

Tripathi, A., Sinha, A. K., Powar, S. B., & Patane, P. (2018). Design, analysis and studies on performance of the solar food dehydrator. *Proceedings of 3rdNational Conference on Recent Trends in Mechanical Engineering (NCRTME - 2018), November*.

Uribe, E., Vega-Gálvez, A., Vásquez, V., Lemus-Mondaca, R., Callejas, L., & Pastén, A. (2017). Hot-air drying characteristics and energetic requirement of the edible brown seaweed Durvillaea antarctica. *Journal of Food Processing and Preservation*, *41*(6), 1–10. https://doi.org/10.1111/jfpp.13313

Wang, Y., Zhang, M., & Mujumdar, A. S. (2011). Convective drying kinetics and physical properties of silver carp (Hypophthalmichthys molitrix) fillets. *Journal of Aquatic Food Product Technology*, *20*(4), 361–378. https://doi.org/10.1080/10498850.2011.575536

Yudiastuti, S. O. N., Wijaya, R., & Handayani, A. M. (2021). Analisis Nilai Tambah Peningkatan Kualitas Edamame Siap Saji dengan Teknik Pengeringan Food Dehydrator Berputar. *Jurnal Indonesia Sosial Teknologi*, *2*(3), 443–454. https://doi.org/10.36418/jist.v2i3.112

Yulianti, D., Sunyoto, M., & Wulandari, E. (2020). Aktivitas antioksidan daun pegagan (Centella asiatica l.urban) dan bunga krisan (Crhysanthemum sp) pada tiga variasi suhu pengeringan. *Pasundan Food Technology Journal*, *6*(3), 142–147. https://doi.org/10.23969/pftj.v6i3.1215

Zhang, J., Liu, Y., Sun, Z., Bai, X., & Chen, Y. (2020). Drying characteristics and optimization of ultrasound-strengthened cold air drying combined with sequential far-infrared radiation drying on potato. *Journal of Food Processing and Preservation*, *44*(9), 1–15. https://doi.org/10.1111/jfpp.14632