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Optimization of Temperature and Slices Thickness In Drying Turmeric Using Response Surface Methodology (RSM)

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Abstract
Dried turmeric flour quality is influenced by several factors such as drying temperature and turmeric slice thickness. Optimal conditions for temperature and slice thickness can be achieved by optimizing the process through simulation and mathematical modelling. The method that can be used for these needs is Response Surface Methodology (RSM), which is able to provide an overview of the relationship between independent variables and the observed response in order to obtain optimal information from each independent variable that affects the response. In this study, the objective responses include moisture content, curcumin content, ash content and water activity. The aim of this study is to determine the ideal conditions - including temperature and slice thickness - to maintain the quality of turmeric that has been dried. The Response Surface Methodology (RSM) was applied to process the data using the Design Expert®12 application. Following the research period, a drying temperature of 69.83 ℃ and a slice thickness of 1 mm were found to produce the optimum results, with actual value responses of 8.23% wb for the moisture content, 0.153 for the water activity (Aw), and 5.05% for the ash content.
Keywords: *design expert ®12, drying characteristics, turmeric, optimization, temperature and slices thickness, response surface methodology.*

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I. INTRODUCTION

Turmeric (*Curcuma domestica* Val.) is widely used as raw material in the manufacture of herbal medicines. The greater proportion of turmeric is produced as a raw material for cosmetics, medicine and food needs. Based on the data, it is known that the level of turmeric production in Indonesia has increased by 2.3% from 2011 to 2014 (BPS, 2014). The data indicate that the level of turmeric production has grown by 3% during the period from 2011 to 2014 (BPS, 2014).

The high harvest rate of turmeric tubers must be followed by an appropriate post-harvest process. Turmeric is highly perishable and tends to deteriorate quickly if no post-harvest process is carried out. One effective technique is the drying process, which preserves the turmeric and is useful for producing advanced products, such as turmeric powder.

Several factors influence the quality of dried turmeric flour, including the thickness of the slices and the drying temperature of the turmeric. Previous research has identified variations in slice thickness and drying temperature that yielded the finest quality turmeric flour. As per Priastuti's (2016) study, a slice thickness of 0.6 cm resulted in the most consistent turmeric flour compared to other slice thickness treatments. Basuki's (2018) research indicates that the turmeric flour's physical properties positively responded to a drying temperature of 60 ℃. Similarly, Intan et al. (2019) found that a temperature of 60 ℃ and a slice thickness of 1 cm produced better physical properties in the turmeric powder. To achieve the highest quality turmeric powder, it is necessary to use a combination of slice thickness and the optimum drying temperature

Response Surface Methodology (RSM) is a suitable method for these purposes. It offers an overview of the relationship between independent variables and observed responses. This information can then be utilized to determine which independent variables have an effect on the response. The objective of this study is to achieve optimal levels for moisture content, curcumin content, ash content and water activity.

The aim of this study is to determine the ideal combination of slice thickness and drying temperature for preserving the quality of dried turmeric, through the use of Response Surface Methodology (RSM).

II. MATERIALS AND METHODS

Tools and Materials

The tools used were stopwatch, analytical balance (Shimadzu Model, Japan), oven (Blue-m), porcelain cup, 5 kg scale digital balance (Camry Model), baking pan, Measuring Cylinder, aw-meter (PreAqua Lab), desicator. Design-Expert ®12 program. The main material used was turmeric rhizomes with a harvest age of 11-12 months and 3-4 cm in diameter obtained from farmers in Carangsari Village, Petang District, Badung Regency.

Research stage

Design optimization with RSM method

The optimal drying temperature and thickness of turmeric slices were determined using Response Surface Methodology (RSM) via Design Expert ®12 software. This experimental design aimed to obtain an ideal combination of components to achieve the optimum response (Padil et al., 2011 in Apriliani 2019).

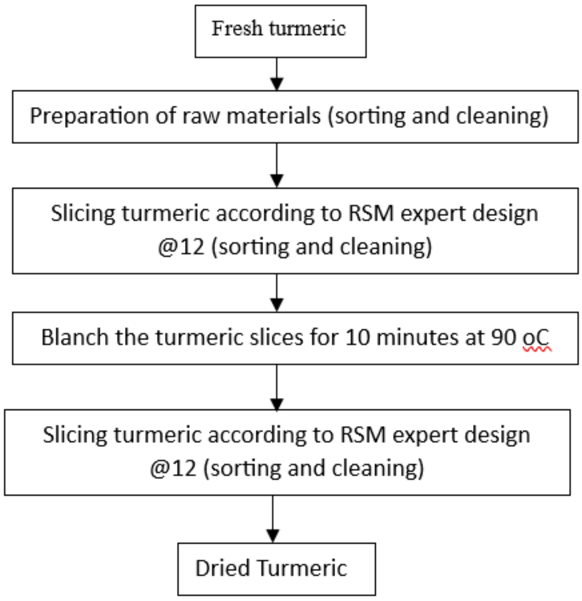

Figure 1. Flow chart of turmeric drying

Response measurement

Response measurements at this stage consist of determining moisture content, ash content, evaporation heat energy and water activity (aw) in the dried turmeric produced. Moreover, the response value is used to determine the optimum value and the mathematical model is formed.

Data Optimization

The optimization stage aims to obtain a combination of drying temperature and turmeric slice thickness that produces an optimum response according to the National Standard criteria. For this purpose, response measurement data is inputted and processed using the RSM program. The target response is determined according to SNI 01-3393-1994 (quality standard for dried turmeric). Finally, all response data is processed using the Design Expert software. The results were transformed into a response function equation model for the independent variables. A model selection analysis was performed using ANOVA test, which produced a model significance value, lack of fit value, and coefficient of determination (Pan et al., 2010). Following this, an optimal process combination was generated during the optimization stage. The preferred condition selected is the treatment combination with the highest desirability value compared to other treatments.

Model Verification

The verification stage involves testing the selected optimum drying temperature and thickness of turmeric slices. Results were verified on the treatment with the highest desirability value (Nurmiah et al., 2013), and the actual response variable was tested. The results were verified on the treatment with the highest desirability value (Nurmiah et al., 2013), and the actual response rate was shown to be within the range of response rates predicted by the model formed (Syahrul et al., 2017). The model was verified through testing and measuring of water activity, ash content, evaporation heat energy, and moisture content to generate the actual response variables. These response variables were then entered into the Design Expert®12 software. Verification results must agree within the range of 95% CI and 95% PI interval (Verschuuren, 2014).

Experimental Design

The optimization design results of drying temperature and thickness of turmeric slices using the RSMmethod are shown in Table 1.

Table 1. Experimental design table of turmeric slice thickness and drying temperature using RSM Design Expert ®12.

Sample	Drying Temperature (oC)	Thickness (mm)
1	45.9	2
2	50	1
3	50	3
4	60	2
5	60	2
6	60	3.4
7	60	2
8	60	2
9	60	0.6
10	60	2
11	70	3
12	70	1
13	74.1	2

Variables

Moisture content

Moisture content measurement can be done by either using a moisture analyzer or by using the gravimetric method (oven). To calculate the moisture content of a sample, one can employ equation (1).

$$MC\ (\%wb) = \frac{W - W1 - W2}{W} \times 100\% \quad \text{--}[1]$$

Description:
W: sample weight before drying (g)
w1: sample weight + porcelain cup after drying (g)
w2: empty porcelain cup weight (g)

Water activity (Aw)

Water activity was measured using a PreAqua Lab Water Activity Analyzer (Awmeter). The tool consists of a reading sensor, a sample holder and a disposable sample container. Prior to use, the AW meter must be conditioned in the measurement room for roughly two hours. During water activity measurement, the sample is placed into a specific tube and inserted into the tool. The progress of the measurement is displayed on the screen. Once the reading reaches a stable state, an audible signal will indicate that the process of measuring water activity has been finished (Saenab et al., 2010).

Ash content

Determination of ash content can be done using the AOAC 2005 method. Ash content is determined by equation (2):

$$\%\ ash\ content = \frac{Ash\ weight}{weight\ of\ sample} \times 100\% \quad \text{---}[2]$$

Description:
Ash weight (g) = (Weight of cup + sample after drying) - weight of empty cup
Weight of sample (g) = (Weight of cup + sample before drying) - weight of empty cup

III. RESULTS AND DISCUSSION

Model Analysis of the Relationship of Drying Temperature and Slice Thickness to Response

The dried turmeric was tested in the laboratory and obtained responses in the form of water activity, moisture content, evaporation heat energy and ash content. The response of the test results of 13 turmeric samples can be seen in Table 2 below.

Table 2. Response to treatment of drying temperature and slice thickness on turmeric drying**.**

Code Sample	Temperature Drying (℃)	Thickness Slices (mm)	Moisture Content (%bb)	Activity Water (aw)	Content Ash (%)
1	45.9	2.0	17.57	0.85	2.71
2	50.0	1.0	13.99	0.50	5.42
3	50.0	3.0	18.98	0.83	2.35
4	60.0	2.0	16.22	0.57	4.21
5	60.0	2.0	15.80	0.42	2.69
6	60.0	3.4	19.70	0.84	2.21
7	60.0	2.0	13.86	0.47	3.65
8	60.0	2.0	15.22	0.49	5.76
9	60.0	0.6	12.61	0.28	5.87
10	60.0	2.0	10.90	0.41	6.07
11	70.0	3.0	10.77	0.19	5.28
12	70.0	1.0	7.88	0.15	5.69
13	74.1	2.0	10.72	0.20	5.94

Table 2. Illustrates the variation in the responses generated by samples with different slice thicknesses and drying temperature treatments. The tabulated data demonstrates that the maximum level of moisture content amounting to 19.70% wb was found in samples with a slice thickness of 3.4 mm and drying temperature of 60 ℃. The sample with a temperature of 70°C and a slice thickness of 1mm yielded the lowest moisture content, measuring at 7.88% wb. Both results indicate that increasing the drying temperature with thinner turmeric slices causes the moisture content of the turmeric to decrease.

The moisture content present in dried turmeric affects the ash content and water activity as shown in Table 2. Among all the samples, the 3.4 mm slice thickness and 60 ℃ drying temperature treated sample having the highest moisture content, has a water activity of 0.84. On the other hand, the sample treated at 70 ℃ and 1 mm thickness, which has the lowest moisture content, has the lowest water activity of 0.15. It is established that the moisture content rises in correlation with the addition of water activity in dried turmeric.

The effect of temperature on ash content is clearly demonstrated; the highest moisture sample displayed the lowest ash content of 2.21%, whereas samples with lower moisture content of 10.72% wbbut exposed to higher temperature (74.1°C) produced a much higher ash content of 5.94%. This is a consequence of the increased heat transfer from the environment to the material at higher temperatures. Furthermore, higher ambient temperatures lead to increased heat absorption by the material (Umbas et al., 2014).

The heat energy value of vaporization decreases when the temperature used during the drying process is higher. This is due to the decrease in HFG value as the temperature used increases. The less water evaporates, the less heat energy is required for evaporation (Martiani et al., 2017). On the other hand, when water evaporates in large quantities, it will affect the moisture content response which is lower in value.

The impact of turmeric slice thickness and drying temperature on variables (water activity, moisture content, evaporation heat energy and ash content) can be modelled mathematically. The model's validity is demonstrated by ANOVA tests, including the Lack of Fit test, model significance, and predicted and adjusted R-squared coefficients, all presented in Table 3.

Table3.Mathematical model analysis of response of moisture content, water activity, ash content and evaporation heat energy

Variable	Mathematical Model	Signification (*p-value*)	*Lack of Fit*	*Adj R^2 Model*	*Pred R^2 Model*	*Adeq Precision*
Moisture content (%wb)	Linier	0.0010	0.6776	0.6999	0.5774	11.2804
Water activity (Aw)	Linier	< 0.0001	0.1360	0.8473	0.7417	16.7258
Ash content (%)	Linier	0.0099	0.9398	0.5237	0.4252	8.1028

Description: *Adj = Adjusted; Pred = Predicted; Adeq = Adequated

Drying temperature and slice thickness had a significant impact on the moisture content, water activity, and ash content variable, as shown in Table 3. The P value <0.05 and an adequate precision value (Adeq Precision >4) implies that the model is suitable to use. The resulting mathematical model for the three responses is linear. The variable for vaporization heat energy is not significant, as indicated by P>0.05 and Adeq Precision <4. However, a model can still be developed since the results of the Lack of Fit test show insignificance. A quadratic mathematical model can be formed using the evaporative heat energy variable. Lack of Fit values for all models in Table 2 are not significant. This is expected since a well-fitting model is required. Then the model analysis of each response is carried out as follows

Analysis of Moisture Content Model

The distribution of the dried turmeric moisture content response data can be seen through the residual normality plot in Figure 2.

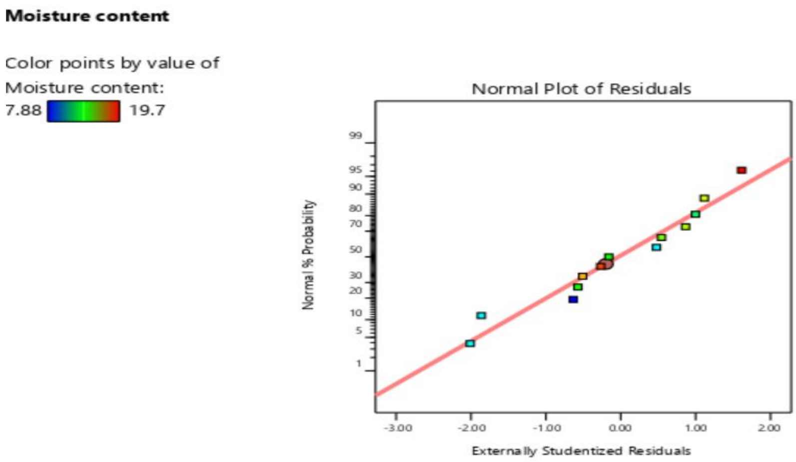

Figure 2.Normalization plot of moisture content residuals

The residual normality plot in Figure 3 shows the points of distribution of actual values with predicted values that are close to the normal line. The residual values are -3.00 to +2.00 which are spread around the normal line. This indicates that the moisture content response data spreads normally. The closer to the normal line, the actual results will be close to the predicted results shown by the model (Kumari et al., 2008).

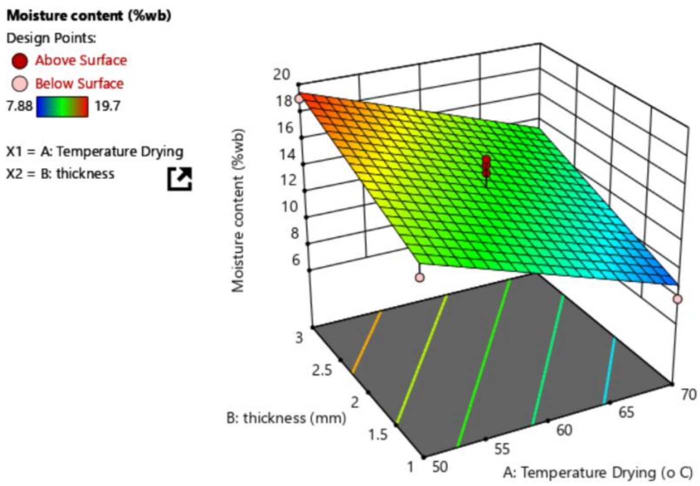

Figure 3. Three-dimensional surface graph of moisture content response

The three-dimensional response surface graph of moisture content in Figure 3 shows the response surface relationship of the combination of drying temperature and slice thickness to the moisture content of dried turmeric. The color difference indicates the value of moisture content. The blue color shows the lowest moisture content value of 7.88% wb and the red color shows the highest moisture content value of 19.70% wb.

Analysis of Variance (ANOVA) of moisture content in Table 3 shows a p value smaller than 0.05, namely 0.0010, which states that the model is significant at the 5% level. This indicates that the model gives a good description of the moisture content response. The Lack of Fit value of 0.6776 with insignificant results indicates that the fit of the model to the response produces a good picture. The resulting model has met the criteria, so it is declared reasonable agreement, namely the difference between Adj R-squared and Pred R-squared <0.2. Adj R-squared on the response of dried turmeric moisture content shows the amount of variation around the mean explained by the model of 69.99% and the model is said to predict the response with a Pred R-squared value of 57.74%. The Adeq Precision value> 4, which is 11.28, means that the model can be accepted and used for design space. The equation formed by Design Expert ®12 through the test results can be used to predict the moisture content response. The equation or RSM model to predict the response of dried turmeric moisture content with temperature and slice thickness is described by equation (3):

Moisture Content= - 0.300082A + 2.23831B + 27.69816 --[3]
Description
A = Drying temperature (℃)
B = Thickness of slices (mm)

The resulting moisture content response model is a linear model (first order) which indicates that the moisture content response produced during turmeric drying is only influenced by drying temperature and slice thickness, not their interaction. The influence exerted by the slice thickness is more dominant on the moisture content response than the influence of drying temperature. This can be seen from coefficient B which has a value of +2.24 showing a value greater than coefficient A which is -0.3.

Equation (3) illustrates that the effect of drying temperature is inversely proportional to the response of moisture content, while slice thickness is directly proportional to the response of moisture content. The response to moisture content gets smaller with increasing temperature, and slice thickness has a smaller value (Asgar and Musaddad, 2006). This is indicated by the negative sign (-) in the coefficient A which is contrary to the model constant. Positive (+) values are indicated by coefficient B and the constant in the model.

Water Activity (Aw) Model Analysis

The results of the dried turmeric water activity response are in the Aw range of 0.152 - 0.849. The distribution of the dried turmeric moisture content response data can be seen through the residual normality plot in Figure 4.

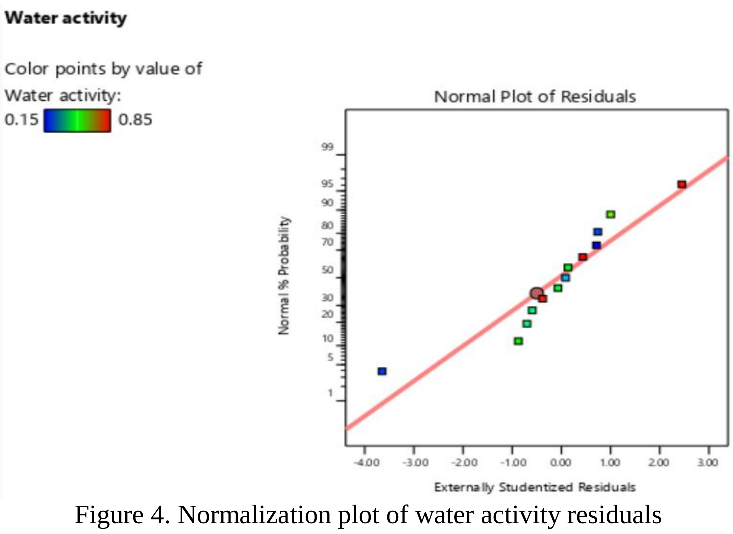

Figure 4. Normalization plot of water activity residuals

The distribution of the dried turmeric water activity response data is normal. This is shown in Figure 4, where the distribution of points representing the response data is close to the normal line. Residual values in the range of -4.00 to +3.00 are scattered around the line of normality.

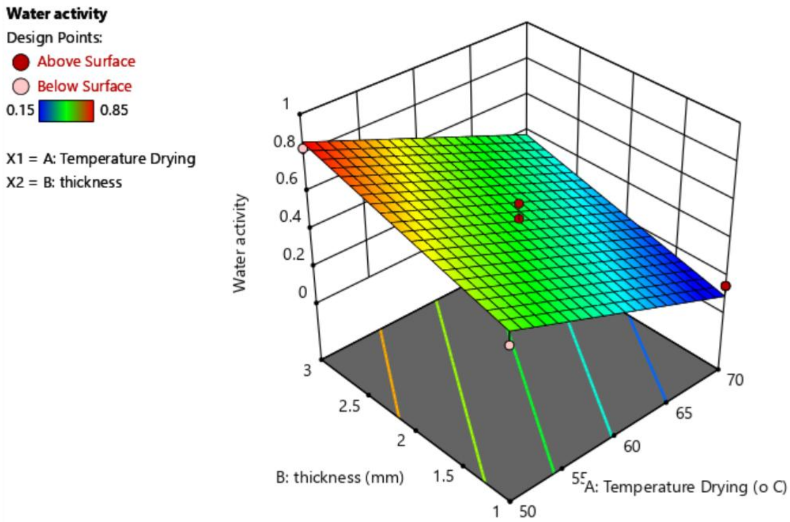

Figure 5. Three-dimensional surface graph of water activity response

An overview of the response surface of the relationship between the combination of slice thickness and drying temperature to the response of water activity in the turmeric drying process is shown in Figure 5. The color difference in the graph shows the difference in water activity response values. The blue color shows the lowest water activity value of 0.152 aw and the red color shows the highest response value is 0.849 aw. The water activity response model has a p-value smaller than 0.05 which is <0.0001. This states that the model is significant at the 5% level.

The ANOVA test results state that the model has an insignificant Lack of Fit value with a value of 0.1360. Where this value states that the model describes the fit with the response. The ability of the model to describe the actual value is 84.73% seen from the Adj R-squared value and is able to predict a response of 74.17% indicated by Pred R-squared. The model is declared reasonable agreement, because it produces a model that has met the criteria, namely the difference between Pred R-squared and Adj R-squared is less than 0.2. The Adeq Precision value of 16.725> 4 indicates that the model can be used and describes the design space. The RSM equation or model to predict the response of dried turmeric water activity with drying temperature and slice thickness is described in equation (4):

A_w= - 0.023853A + 0.143206B + 1.62092 --- [4]

Description

A = Drying temperature (℃)

B = Thickness of slices (mm)

Equation (4), it can be seen that the model used to predict the water activity of dried turmeric is a linear model. Similar to the moisture content equation, the water activity equation is influenced by slice thickness and drying temperature, while their interaction does not affect the water activity equation. Slice thickness had a more dominant influence on the moisture content response than drying temperature. This can be seen from the coefficient B with a value of +0.143 which shows a value greater than the coefficient A, which is -0.024.

Ash Content Model Analysis

The distribution of the ash content response data spreads normally. The normality of the data distribution can be seen from the clustering of data points on the normal line which can be seen in Figure 6. The ash content response data has a data distribution point that is closest to the normal line when compared to other responses. The residual value is in the range of -2.00 to +2.00 which is spread around the normal line.

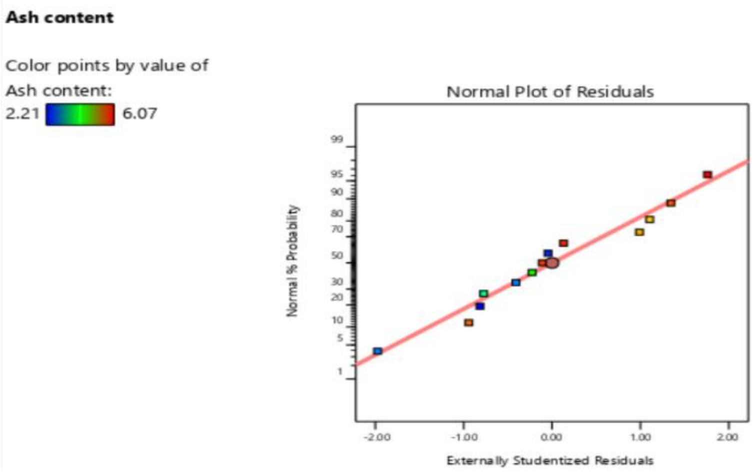

Figure 6. Residual normalization plot of ash content

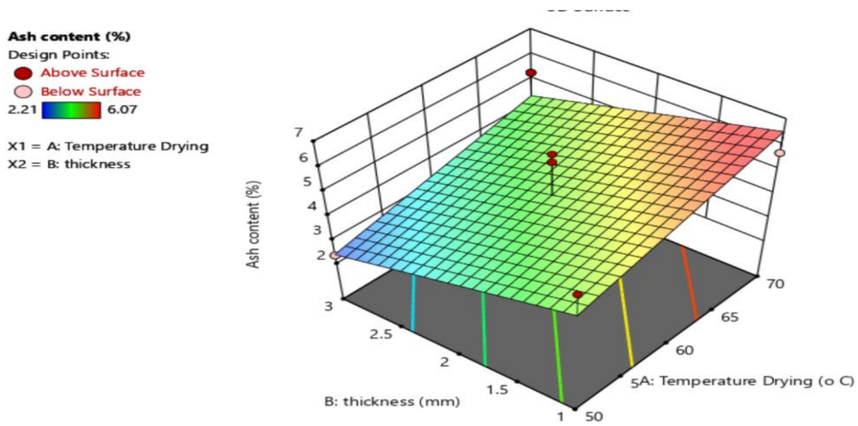

Figure 7. Three-dimensional surface graph of ash content response

Figure 7 shows the response surface of the ash content of dried turmeric. The blue color shows the lowest ash content value of 2.21% and the red color shows the highest ash content value of 6.07%.

The ANOVA analysis results show that the ash content response model has a pvalue of 0.0099 < 0.05. This value shows that the model is significant at the 5% level. The model's Lack of Fit value of 0.9398 illustrates the model's fit with the response. The model is described as fit because the model has an insignificant value of lack of fit, which is expected in forming a model. The ability of the model to provide an overview of the actual value (Adj R-squared) is 52.37%. The model also has the ability to predict the response (Pred R-squared) of 42.52%. The model meets reasonable agreement, where the difference between Adj R-squared and Pred R-squared <0.2. Adeq Precision value> 4 is 8.103 which indicates that the model is adequate for use in design space. The RSM equation or model to predict the response of dried turmeric water activity with drying temperature and slice thickness is described in equation (5):

Ash content = 0.0971A – 1.08083B + 0.787251 --[5]

Description

A = Drying temperature (℃)

B = Thickness of slices (mm)

In this equation, it is clear that the drying temperature has a more dominant effect than the slice thickness. The coefficient B has a value of -1.08, implying a decreased impact compared to coefficient A with a value of +0.097.

IV. CONCLUSION

The combined drying temperature of 69.83℃ and a slice thickness of 1 mm, produced measurable results, including a moisture content of 8.23% wb, water activity of 0.153, and an ash content of 5.05%.

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Conflict of Interest
There is no conflict of interest among the authors or with other parties

REFERENCE

[1]. Arini, L.D.D., 2017. Factors causing and characteristics of expired food which have a negative impact on public health. JITIPARI (UNISRI Scientific Journal of Food Technology and Industry), 2 (1): 15 – 24, https://doi.org/10.33061/jitipari.v2i1.1531

[2]. Asgar, A. and D. Musaddad. 2006. "Optimization of blanching method, temperature and duration." 16(3):245–52.https://dx.doi.org/10.21082/jhort.v16n3.2006.p%p

[3]. National Standards Agency. 2014. Indonesian National Standard (SNI) Number: 7953: 2014 concerning Turmeric.

[4]. Erwanto. 2018. Studying the Drying Characteristics of Red Ginger (Zingiberofficinale var. rubrum) Using a Rack Type Mechanical Dryer. Thesis. Faculty of Agriculture. Lampung University.

[5]. Haryani, Kristinah, Suherman, and Suryanto. 2015. Thin Layer Drying Model Using the Rack Dryer Method. Vol 10, No 1 (2015)..http://dx.doi.org/10.32497/teknis.v10i1.671

[6]. Hepi DA, Yuianti NL, Yohanes S. 2020. Optimization of Drying Temperature and Slice Thickness in the Drying Process of Red Ginger (Zingiberofficinale var. rubrum) using Response Surface Methodology (RSM). .Journal of Beta Biosystems and Agricultural Engineering. [9,1] 2021 66-75,DOI : https://doi.org/10.24843/JBETA.2021.v09.i01.p07

[7]. Intan O, Yulianti NL, Gunadnya I.B. 2020. The Effect of Varying Temperature and Thickness of Turmeric Slices in the Drying Process on the Physical Properties of Turmeric Flour. Journal of Beta Biosystems and Agricultural Engineering.vol 8 no 2 September 2020.https://doi.org/10.24843/JBETA.2020.v08.i02.p10

[8]. Legowo, A.M. and Nurwanto. 2004. Food Analysis. Lecture Diktat. Animal Technology Study Program. Faculty of Animal Husbandry, UNDIP. Semarang. 54 pp.

[9]. Montgomery, C.D. 2001. Design and Analysis of Experiments 5th Edition. Singapore:John Wiley & Sons.

[10]. Myers RH, Montgomery DC. 1995. Response Surface Methodology: Process and Product Optimization Using Design Experiments. New York (US): John Wiley & Sons, Inc.

[11]. Nurmiah, Sitti, Rizal Syarief, Sukarno Sukarno, RosmawatyWarinangin, and Budi Nurmata. 2013. Application of Response Surface Methodology in Optimizing Alkali Treated Cottonii (ATC) Process Conditions. Vol. 8. JPB Maritime Affairs and Fisheries Vol. 8 No. 1 of 2013: 9-22.http://repository.ipb.ac.id/handle/123456789/69835

[12]. Pan, Hai Feng, Wen Na Bao, Zhi Peng Xie, and Jian Guo Zhang. 2010. Optimization of Medium Composition for Cis-Epoxysuccinate Hydrolase Production in Escherichia Coli by Response Surface Methodology. African Journal of Biotechnology Vol. 9(9), pp. 1366-1373, 1 March, 2010 Available online at http://www.academicjournals.org/AJB

[13]. Priastuti, Rita Catur. 2016. The Influence of Direction and Thickness of Turmeric Slices on the Physical Properties of Turmeric Flour Produced. Faculty of Agriculture, University of Lampung

[14]. Saenab, A., E. B. Laconi, Y. Retnani, and M. S. Mas'ud. 2010. Evaluation of the quality of complete ration pellets containing shrimp by-products. Journal of Animal and Veterinary Sciences. 15(1): 31-39.

[15]. Sampaio C.P., R.M. Nogueira, C.D. Roberto. dan J.S. Silva. 2007. Development of a dryer with airflow reversal and a pneumatic system for grain movement. Journal Biosystems Engineering 98: 33-38.http://dx.doi.org/10.1016/j.biosystemseng.2007.02.014

[16]. Sudarmadji. 2003. Analysis of Food and Agricultural Ingredients. Yogyakarta (ID): LibertiSyahrul, S., Syarief, R., Hermanianto, J., &Nurtama, B. (2018). The Optimization of Frying

[17]. Syahrul, Rizal S, Joko H, Budi N., 2017. Process of Tumpi-tumpi from Milkfish used Response Surface Methodology. Indonesian Fishery Products Processing Journal, 20(3), 432-445.https://doi.org/10.17844/jphpi.v20i3.19762

[18]. Verschuuren G., 2014. Excel 2013 for Scientists. Chicago (US). Holy Macro Book