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Optimization of Tapioca Crackers Drying Condition to Improve the Energy Efficiency

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Abstract

Crackers are consumed as a snack that has the potential to be developed because of its high market demand. One type of cracker that is popular with the public is tapioca crackers which are made from tapioca flour. The most crucial stage in the production of tapioca crackers is drying. Drying determines the final product's quality, nutritional content, taste, and texture. In the small cracker industry, drying is done using sunlight. However, this type of dryer has disadvantages in terms of weather dependence and low energy efficiency. The introduction of convective dryers in the small-scale tapioca cracker industry needs to be done. However, in its application a study of the appropriate drying operating conditions (temperature and drying time) is required. This research aims to examine drying operating conditions such as temperature and drying time using the Response Surface Method (RSM) to improve product and drying efficiency. The research used an experimental Central Composite Design (CCD) design and required 13 trials. The process variables in the research are drying temperature and drying time. Meanwhile, for the research response, energy efficiency and the moisture content in the drying process were selected. Studies have shown that raising the drying temperature reduced moisture content and improved energy efficiency. It is possible to reach the optimum drying condition with an energy efficiency of 51.60% at 76.21°C and 2.45 hours of drying time.

Keywords: Drying, Energy Efficiency, Tapioca Crackers

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1. Introduction

Crackers are one of the traditional processed food products that have the potential to be developed as a local economic product. Crackers are consumed as a snack or complement to side dishes. One type of cracker that many people are interested in is tapioca crackers. Tapioca crackers are a snack made from tapioca flour [1]. Tapioca flour is flour produced from processing the roots of cassava or cassava plants [2]. Tapioca crackers generally have a crunchy texture and are usually fried until fluffy. This food is popular in Indonesia and other Southeast Asian countries.

The most important step in the manufacturing of tapioca crackers is drying, which has an impact on the crackers' flavor, texture, nutritional value, and overall quality. [3]. The drying process also influences the texture of crackers. The more water that evaporates, the porousness of the crackers will increase so that the crispiness also increases [4]. The process of drying requires the use of heat to reduce or completely remove a material's moisture content. In order to increase a material's shelf life, the drying process entails simultaneous heat and mass transfer in a multiphase system [5]. The process of drying involves using heat to reduce or completely remove a material's water content. In order to increase a material's shelf life, the drying process entails simultaneous heat and mass transfer in a multiphase system. [6]. RH, surface area, temperature differential with the ambient air, airflow speed, and air pressure are some of the factors that affect the effectiveness of drying [7]. In the tapioca cracker home industry, the main obstacle to the success of the drying process for tapioca crackers is the environmental RH factor and the continuity of the process where drying in sunlight is very dependent on the weather [8], [9], [10]. Long drying times due to rain and high air humidity can reduce the quality of tapioca crackers. Furthermore, it can cause losses for business owners. Apart from being constrained by weather, solar drying also has low energy efficiency even though it has been optimized with the presence of a solar collector [11]. Drying efficiency relates to how quickly and efficiently the moisture from the crackers is removed during the drying process. For the disadvantages of sun drying, it is necessary to use a convective dryer with high drying efficiency while producing high quality tapioca crackers. To optimize drying efficiency, producing tapioca crackers with low water content and high physical quality (texture) is important to understand the interaction between temperature and time used. Drying operating conditions such as temperature and drying time were optimized using the Response Surface Method (RSM) to improve the drying process of tapioca crackers to achieve the desired results in terms of product quality and production efficiency.

2. Materials and Methods

2.1. Materials

The main ingredient used in this research is tapioca flour from PT Budi Starch & Sweetener Tbk. Lampung, Indonesia.

2.2. Methods

In order to achieve a high energy efficiency drying process, this research focuses on optimizing the drying operating parameters (drying temperature and drying time) of tapioca crackers. This research was carried out in three stages, namely the tapioca cracker formulation process, drying, and optimization using response surface methodology (RSM).

2.2.1. Tapioca Cracker Formulation

Tapioca crackers are produced with the formulation as in Table 1. The ingredients in Table 1 are mixed evenly. Water is added in a ratio of 1:3 to the total raw materials. Then put the dough into a molded pan with a thickness of 1 cm. The baking sheet containing the dough is then placed in a steamer for 25 minutes (temperature 80C). The dough in the pan is cooled for 30 minutes then cut with a chopper to a uniform size. The dimensions of wet tapioca crackers are 3 x 0.5 x 1 cm.

2.2.2. Drying Process

The drying process for tapioca crackers is carried out in a food dehydrator. Drying is carried out using air media (ambient air) with a relative humidity of 80%. Ambient air at a certain speed (0.22 m/s) is heated to the inlet air temperature (40, 55, 70°C) using a heater. The drying air temperature is kept constant during the drying process. Hot air enters the drying room and a baking sheet containing tapioca crackers is placed in the drying room. The drying process takes place for a certain time (see Table 2). During the drying process, every 30 minutes, the tapioca crackers are weighed to determine the moisture content or water that evaporates during drying. Every 30 minutes, the air temperatures at the input and the output were also measured. Energy efficiency will be determined using data on water content, input air temperature, and output air temperature during the tapioca cracker drying process. Data on water content, inlet air temperature and outlet air temperature during the tapioca cracker drying process will be used to calculate energy efficiency. Energy efficiency is usually calculated using an energy balance equation based on the first law of thermodynamics. It is defined as the ratio of the energy utilized to evaporate moisture from the sample to the total energy used [12].

2.2.3. Optimization using Response Surface Methodology (RSM)

The process variables in the research are drying temperature (X1) and drying time (X2), see Table 2. Meanwhile, for the research response, energy efficiency (Y1) and moisture content (Y2) was chosen. The CCD design consisting of 13 runs was used in the optimization study of drying tapioca crackers (see Table 3). The correlation of factors and responses is expressed as a second order polynomial model, see equation 1. [8].

$$\boldsymbol{Y_i} = \boldsymbol{\gamma_0} + \boldsymbol{\gamma_1 X_1} + \boldsymbol{\gamma_2 X_2} + \boldsymbol{\gamma_{11} X_1^2} + \boldsymbol{\gamma_{22} X_2^2} + \boldsymbol{\gamma_{12} X_1 X_2} \quad (1)$$

Where $\boldsymbol{Y_i}$ are the energy efficiency and moisture content. $\boldsymbol{\gamma_0}$ is the intercept, $\boldsymbol{\gamma_1}$ and $\boldsymbol{\gamma_2}$ are single effect coefficients, $\boldsymbol{\gamma_{11}}$ and $\boldsymbol{\gamma_{22}}$ are quadratic effect coefficients, and $\boldsymbol{\gamma_{12}}$ is the combination coefficient between the interactions of the effects $\boldsymbol{X_1}$ and $\boldsymbol{X_2}$. Statistical analysis and optimization of multiple responses was carried out using Minitab® version 19 (trial version).

3. Results and Discussions

Table 3 displays the Central Composite Design's (CCD) experimental design and response. There were variations in the drying temperature from 40 to 70°C. Drying time levels throughout the drying process ranged from 2 to 6 hours. Thirteen runs of the experimental design were conducted to identify the optimum drying conditions.

3.1. Effect of Drying Temperature and Drying Time

Equations 2 and 3 show the optimization applying orthogonal CCD linked to the process variable and response stated in a second-order polynomial equation. R^2 was employed to evaluate the equation. R^2 was quite close to oneness. The more closely the model fit the data, the higher the R^2 score. Considering Tables 4 and 5 the R^2 percentage is more than 88%. Showed that the model could explain the moisture content and energy efficiency phenomena during the drying of tapioca crackers. Table 4 shows that the process variable, drying times, X_2, has a significant impact on the energy efficiency of tapioca cracker drying, with a P-Value < 0.05. The amount of moisture in the tapioca crackers decreases as they dry, and the product absorbs less energy. As a result, throughout the drying process, energy efficiency decreases.

$$\boldsymbol{Y_1} = 42.6 + 0.58X_1 - 0.58\,X_2 + 0.00259\,{X_1}^2 - 0.6186{X_2}^2 - 0.0512X_1X_2 \quad (2)$$

$$\boldsymbol{Y_2} = 42.6 + 0.58X_1 - 0.58\,X_2 + 0.00259\,{X_1}^2 - 0.6186{X_2}^2 - 0.0512X_1X_2 \quad (3)$$

Table 5 shows that the drying temperature (X_1) and drying times (X_2) have a significant impact on the moisture content of tapioca crackers drying, with a P-Value < 0.05. Equation 3 shows the relationship between the response and process variables. Higher drying temperatures resulted in quicker moisture evaporation and a stronger driving force for drying [11].

Table 1. Ingredient Formulation in the Production of Rambak Tapioca Crackers

Material	Quantity (grams)
Tapioca	1000
Wheat	250
Fine garlic	25
Salt	5
Sugar	5

Table 2. Experimental design of tapioca crackers drying

Factor	Level				
	-α	-1	0	1	α
Drying temperature (°C)	40	55	70	33.78	76.21
Drying time (hours)	2	4	6	1.17	6.82

Table 3. Process Variables in Research

Run	Drying temperature (°C)	Drying time (hours)	Energy Efficiency (%)	Moisture Content (%)
1	40	2	56.90	17.03
2	70	2	62.93	10.02
3	40	6	25.94	12.66
4	70	6	25.83	8.4
5	33.78	4	39.47	15.22
6	76.21	4	33.69	9.8
7	55	1.17	49.35	16.99
8	55	6.82	16.25	10.11
9	55	4	41.24	11.01
10	55	4	42.14	11.022
11	55	4	43.11	11.03
12	55	4	41.46	11.12
13	55	4	41.31	11.02

Table 4. Results of ANOVA for energy efficiency

Source	P-value	Note
$Model$	0.00	Significant
X_1	0.61	Not Significant
X_2	0.00	Significant
X_1^2	0.54	Not Significant
X_2^2	0.19	Not Significant
X_1X_2	0.41	Not Significant
R^2	88.62 %	

Table 5. Results of ANOVA for moisture content

Source	P-value	Note
$Model$	0.00	Significant
X_1	0.00	Significant
X_2	0.000	Significant
X_1^2	0.14	Not Significant
X_2^2	0.02	Significant
X_1X_2	0.11	Not Significant
R^2	94.02 %	

Table 6. Results of optimization

Drying temperature (℃)	Drying time (hours)	Energy Efficiency (%)	Moisture Content (%)	Composite Desirability
76.21	2.45	51.60	10.02	0.78

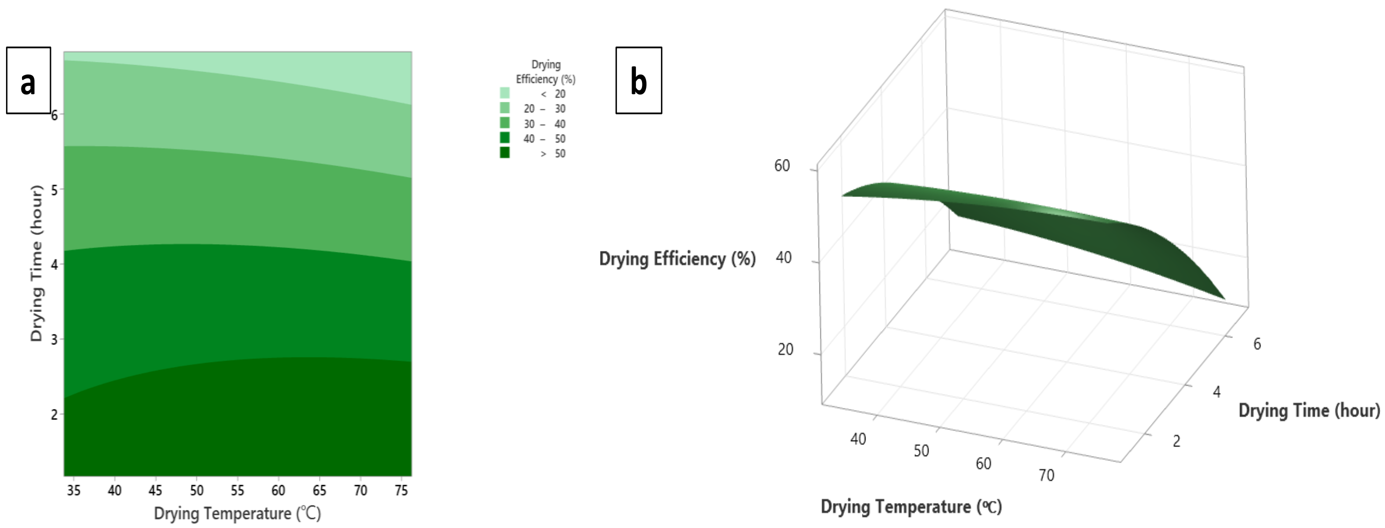

Figure 1. Tapioca cracker drying energy efficiency: (A) Two-dimensional plots and (B) three-dimensional plots

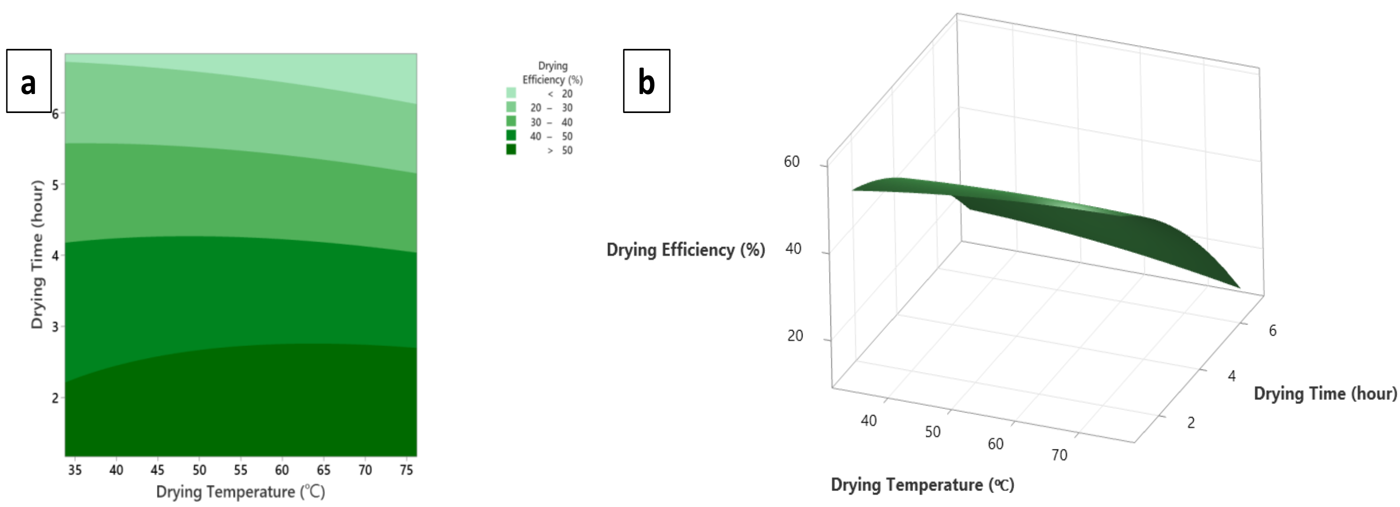

Figure 2. Tapioca cracker drying moisture content: (A) Two-dimensional plots and (B) three-dimensional plots

3.2. Optimum Condition

Equation 2 and Table 4 generated two- and three-dimensional charts representing the energy efficiency of tapioca cracker drying, as shown in Figure 1. While the two- and three-dimensional charts of the tapioca cracker drying moisture content, produced by equation 3 and Table 5, are shown in Figure 2. The optimization was used to find the optimum condition for tapioca crackers drying. The optimization goal was to find favorable conditions for maximum energy efficiency and minimum moisture content. The most common drying parameter, the energy efficiency coefficient, is measured for every drying process assessment [14]. The result of optimization was listed in Table 5. It is possible to reach the optimal conditions with an energy efficiency of 51.60% at 76.21°C and 2.45 drying time. The energy efficiency coefficient for dryers of the convective type ranges from 20 to 60% [15]. This study's outcome resulted the comparable drying with reasonable energy efficiency.

4. Conclusions

In this study, tapioca crackers prepared from tapioca flour formulations then was dried at various temperatures and drying times levels. The results showed that increasing the drying temperature increased the energy efficiency and reducing the moisture content. The optimal condition with a energy efficiency of 51.60% may be achieved at a drying temperature of 76.21°C and the drying time of 2.45.

Acknowledgments

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