OPTIMIZED PARAMETERS OF DRIED RED CHILI ON THE ROTARY DRYER PROCESS

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Abstract

This study evaluated the performance of hot air drying in the fresh Jinda red chili and the design of this semi-automatic fluidized bed rotary dryer machine. The hot air system can bake more than 20 kilograms of chili, and the pressure of hot air, up to 50 millibars, can adjust the speed of the baking drum to make the chili more exposed to hot air. This machine has a maximum temperature of 140 degrees and 5 hours of residence time, which is safe. The principle of the machine is hot air removal to remove moisture in the product and air evaporates. The remaining heat is sent returned to the reusable pipeline to save energy from the start to the last loop, and the final moisture content of the product can be evaluated. The drying parameters studied were hot air velocities between 1-3 mater per second operating temperatures 70–90 degree Celsius and moisture drum drain lead time between 10-30 minutes. The 3^k factorial experiment technique was employed to determine optimum variables. The multiple-response optimization revealed that the moisture of products is not fracture of dried chili, was 14.05 % wet basis, and 94.86% respectively not conducive to the growth of fungal pathogens that cause aflatoxins to cause cancer in the body, and a good product for cooking.

Keywords: Jinda chili, Rotary dryer, Moisture, Factorial design

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Received: 2 February 2023; Revised: 27 June 2023; Accepted: 4 July 2023

DOI: https://doi.org/10.14456/lsej.2023.21

Introduction

Chili is an important commodity used as a vegetable, spice, medicinal herb, and ornamental plant by billions of people every day. It is also used as an ingredient in industrial products. The diversity in its uses, forms, and shapes brings complexity into its production and distribution system (Ali M., 2006). In Thailand, chili has been widely cultivated with a total area of approximately 55,753 Hectare across the country, which results in an annual product of around 332,888 tons of the yield divided into dried chili exports amounted to 11,228 tons equal economic value is 391.8 million THB (Office of Agricultural Economics, 2015). For this reason, it is necessary to produce dried chilies to meet the increasing demand. Various drying methods can be used to dry chilies and other agricultural products, such as bananas, pepper, and black galingale. There are many techniques to dry them, for example, hot air drying (HA), infrared drying (IR), and combined HA and IR (Jaekhom et al., 2022). Red chilies were dried down from approximately 80% wet basis to 10% wet basis moisture content within 33 hours. The drying process was conducted during the day and it was compared with 65 hours of open sun drying (Othman et al., 2013). The power balance in each area of the proposed hybrid thermal system is maintained automatically by controlling the output of thermal generations (Rahman et al., 2017). Although the thermal efficiency is not that satisfactory, the dryer was found to be economical compared to other methods due to the quality of the final product and the ability to perform under adverse environmental conditions (Thanaraj et al., 2004). It can be found that the chilies are lighter when continuously drying. The temperature is an important factor in affecting the weight of the chilies. The velocity of hot air affects the movement of the chilies and their skin of them also (Charmongkolpradit et al., 2010). The drying behavior produced with the three operating modes was evaluated. The best mode was determined based on the parameters for evaluating the quality of chili, the power consumption, and the retention time. The results indicate that the optimal overall drying performance for chili was achieved at 70, 65, and 50 degrees Celsius drying temperatures in hot air, combined, and IR mode, respectively. A positive correlation was observed between retention time and power consumption with the hot air and the combined modes, while a negative correlation was identified in the IR mode (Mihindukulasuriya & Jayasuriya, 2015). Different drying techniques were studied in terms of drying kinetics, starting accessibility, and water-effective diffusivity during drying. Some of the physical and functional properties of dried peppers were studied as well, such as rehydration kinetics (capacity and rate), starting accessibility and water effective diffusivity during rehydration, and the water holding capacity (Téllez-Pérez et al., 2012). The best method to reduce the drying time is to decrease the vaporization pressure around the sample in the dryer and take the expelled moisture away from the product surface; this is accomplished with a selection of proper thickness and hot-air velocity around the surface of tomato slices (Akhijani et al., 2016). The comparison analysis of the relationship between moisture content and chili drying temperatures at 60, 70, 80, 90, 100, and 110 degrees Celsius drying of the most suitable drying temperature of chili sample, it was revealed that 80 degree Celsius is the most suitable drying temperature. During the 1^{st} –6^{th} hour, moisture content slightly decreased, and moisture content decreased to 14.53% wet basis (Tagong et al., 2016). Suitable models are identified to predict the moisture ratio of chilies at different drying air temperatures of a drum rotary dryer (Kaleemullah & Kailappang, 2005). The main objective of this study was to determine the physical properties of fresh red chili at moisture contents release moisture time, air velocity, and temperature of semi auto-metric rotary dryer machine. The physical properties were measured in terms of good unit mass, while the properties were represented by moisture optimal. This knowledge is necessary for designing and improving the rotary dryer used in the dried chili and preparation process of small and medium enterprises (SMEs) in Thailand.

This study aims to find the proportional value for work-in-process in order to have humidity equal to 15% wet basis and the best product.

Materials and Methods

The processes of this study were made step by step as the following:

1. Preparation of raw materials

The fresh Jinda red chilies used in this drying experiment were obtained from the locals in Phitsanuloke province of Thailand. The initial moisture content of the chili samples was 80± 0.5% (w.b.) shown in Figure 1.

Figure 1 Fresh Jinda red chilies a samples

2. Equipment

This semi-automatic rotary dryer consists of four main components. Part one, the hot air generator acts as electrical energy to convert heat into the air in the hot air boiler. Part two of centrifugal rotary bins preserves the thickness of the product layer during centrifugation with centrifugal force. Part three, the blower function is a hot air blower that adjusts the pressure control on the delivery to the baking tank. This allows the hot air flow rate to be adjusted to suit the product characteristics. Part four, control panel is the humidity control. Temperature and speed of hot air during product baking. The drying bin is double-stacked; the outer shell has a diameter of 1000 millimeters, and a length of 1200 millimeters placed horizontally made of stainless-steel material cylinders characterized by open and closed lids. It also had four port hot air inlets at the panel of the circle of the bin and the bottom had a port for moisture air to go out of the bin. Another is the inner rotary bin dryer rotate according to the speed of the electric motor has a diameter of 800 millimeters, and a length of 1000 millimeter installed on the inside of the outer shell made of stainless-steel material cylinder are characterized by open and closed lids which supports fresh chilies to keep load and unload the mass all thoroughly. Fresh chilies were loaded into the front of the machine. The hot air is fed into the opposite side by rotating the tank at the appropriate speed to control the mass of chilies of more than 20 kilograms. In the dryer, there is a hot air distribution pipe in four ways to dissipate the hot air's flow direction uniformly on the fluidized cylinder's cross-section, as shown in Figure 2. The two main drying process factors that control the rotary bin's dryer behavior are the electrical and hot air temperature in the rotary bin's dryer. Moisture content is important in regard to the quality of the final dried chili product should be less than 14% wet basis in this work) The fundamental requirement of dryer control is that the moisture content of the final product must be able to comply with accepted industry standards as a result of the product having to spend sufficient residence time inside the rotary dryer bin.The rotary dryer is a suitable device to remove water from wet starting material in situations of large mass production and very much water content in the product (Suntivarakorn & Radpukdee, 2013). The activation energy is generated from one accurate run and evaluated according to environmental temperature and humidity (Putranto & Chen, 2015) suitable adjustment of initial starting-up conditions for process control can reduce energy consumption (Sonsiri & Radpukdee, 2015). To find the starting operating point for the hot air and electrical supply controller, an experiment was done in the next section . It was found that the hot air temperature for drying the raw material to the kinetics of drying raw material at five level temperature settings :40, 50, 60, 70, and 80 degrees Celsius (Thamsala & Mahayothee, 2018). The hot air velocity settings for the 3 drying drums are 0.5, 1.0, and 1.5 meters per second (Sanhawat et al., 2015). As well as efficient drying the hot air velocity can be as high as 2.0-5.5 mater per second (Jeentada et al., 2018; Chokphoemphun & Chokphoephun, 2019). Hot air temperature control and hot air speed control in the experiment can be considered in the next section.

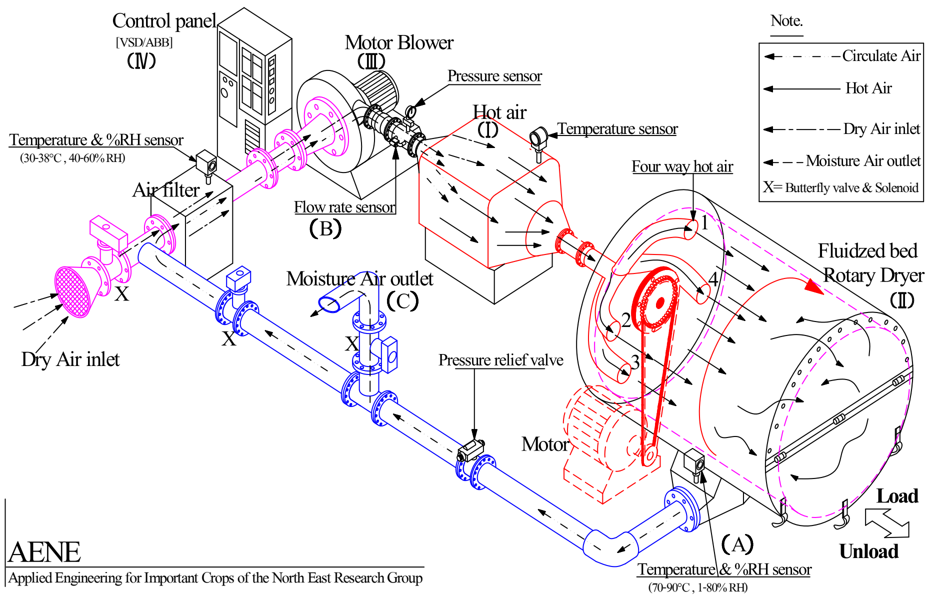

Figure 2 Equipment for chilies dried production

3. Experimental Produce

This experiment has divided all processes into 5 parts as follows:

3.1 Objective

The objective of this experiment aims to find the proportional value for work-in-process in order to have humidity equal to 15 % wet basis and most good product.

3.2 Identifying the variables

From the procedures, the controllable included Temperature (A), Air Velocity (B), and Release moisture time (C), which these three directly affected moisture content as well as the good product.

3.3 Finding the lowest and highest points of the parameter

From the trial of the chili dryer machine, it was found that the setting of the chili dryer machine was as follows, the low rate of Temperature (A), would be at 70 degrees Celsius and the high rate would be at 90 degrees Celsius, the low rate of Air Velocity (B) would be at 1 meter per second and the high rate would be at 3 meters per second, the low rate of Release moisture time (C) would be at 10 minute and the high rate would be at 30 minutes.

3.4 Design of experiment

This experiment used the 3^k factorial design, in which each factor had 3 levels. Testing by setting the mean in each block equaled to 5 which is shown in the design table in Table 1.

3.5 Collecting the data

Experimental Requirements 30 degree Celsius and relative humidity 40% (RH) of air inlet for changed the operation value in Table 1 and collected moisture content and percent of a good product.

Results

Finding the most proportional value to set the chili dryer machine**:** To find the value this is used to set up procedures for humidity equal to 15 % wet basis and most percent of a good product. The quadratic model of moisture content and percent of the good product was obtained as follows.

Table 1 Operation values and responses of 3^k factorial design

Standard order	Temperature degree Celsius (A)	Air Velocity (B)	Release Moisture time (C)	Moisture content	Chili good products not deformed (%)
1	70	3	20	23.80	98.80
2	80	1	30	19.00	89.00
3	80	3	10	17.57	95.57
4	70	1	20	24.13	92.13
5	80	3	20	15.5	95.50
6	70	1	30	28.91	93.91
7	90	2	10	10.83	88.83
8	70	3	10	25.27	96.27
9	90	2	20	7.53	85.53
10	80	2	30	18.40	90.40
11	90	3	10	11.22	84.22
12	90	2	30	12.34	83.34
13	90	3	30	13.41	85.41
14	90	1	10	10.50	87.50
15	90	3	20	10.24	88.24
16	70	2	20	19.61	96.61
17	80	1	20	17.67	89.67
18	70	2	10	21.09	97.09
19	80	1	10	14.07	91.07
20	70	3	30	29.53	96.53
21	90	1	30	14.19	81.19
22	80	2	20	13.29	95.29
23	80	3	30	19.58	91.58
24	70	2	30	26.87	97.87
25	70	1	10	21.75	92.75
26	80	2	10	15.65	93.65
27	90	1	20	9.91	84.91

$$\text{Moisture content} = 134.4 - 2.278A - 4.08B - 0.094C + 0.01144A^2 + 1.997B^2 + 0.02652C^2 - 0.0295A*B - 00818A*C - 0.0610B*C \quad (1)$$

$$\text{Percent of good product} = -27.2 + 2.948A + 12.27B + 1.118C - 0.01942A^2 - 1.422B^2 - 0.01101C^2 - 0.0712A*B - 0.01067A*C + 0.0390B*C \quad (2)$$

The research used Minitab software, a useful statistical tool to help with procedure analysis, it enables making the Interface easy and be used to analyze data and conduct the statistical models, including the regression, the design of experiments, quality control, etc. This research has been designed with a 3^k factorial design and analyzed by using Minitab. The results that the predictive model of moisture content and percent of good product includes the linear terms, two-factor interaction terms, and square terms as shown in equations (1) and (2), respectively. Moreover, the reliability coefficients (R^2-value) are acceptable and close to each other at 97.87 % and 93.52 %, respectively.

The results of the satisfactory analysis of the experiment to find the optimization with the Response Optimizer in Minitab which showed in Figure 3. In order to obtain the effectiveness of the chili dryer machine, it is important for the Temperature (A) to be set at 80 degrees Celsius, Air Velocity (B) to be set at 2.5 meters per second, and release moisture time (C) set at 16 minutes. Accordingly, the experiment set above made the moisture at 14.05% under the lower 15% of moisture criteria, and dried chilly was 94.86% perfect while the level of satisfaction was gauged at 82.3 %.

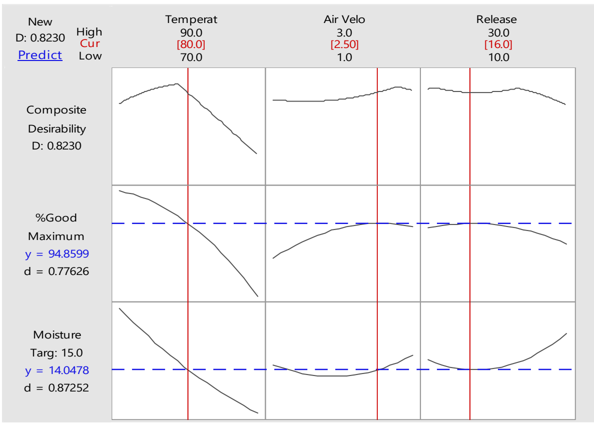

Figure 3 Optimization plot of chili dryer machine

The response surface plot for the moisture content in terms of three factors (Temperature (A), Air Velocity (B), and Release moisture time (C)) is constructed by using equations (1) and (2), as shown in Figure 4. Figure 4(A) showed that if let the released moisture time for 20 minutes, the moisture of dried chili was inversely varied with the temperatures; high temperatures make the moisture value lower. The temperature was constantly set at 80 degrees Celsius, and the figure was curved and pooled down. So, it helped to find out the optimization for setting Air Velocity (B) and the released moisture time (C) at the center as shown in Figure 4(B). When setting the Release moisture Time for 2 minutes in Figure 4(C), the result shown was the same as in Figure 4(A). The response surface plot for the percent of good products in terms of three factors is shown in Figure 5. Figure 5(A) shows that the released moisture time at 20 minutes made the moisture of dried chili inversely vary with the temperatures; high temperatures, lower the percent of a good product. When maintaining a consistent temperature of 80 degrees Celsius, the observation revealed that making slight adjustments to the air velocity had an impact on the proportion of acceptable products. The released moisture time would vary to the percent of a good product as shown in Figure 5(B), and when the released moisture time was 2 minutes in Figure 5(C) results as the same as in Figure 5(A), hence, it was able to conclude that the air velocity slightly affected the moisture content and the percent of a good product but the temperature varied inversely to the dryness and the released moisture time. Eventually, these surface plots confirmed the result of the optimization condition on the chili dryer machine.

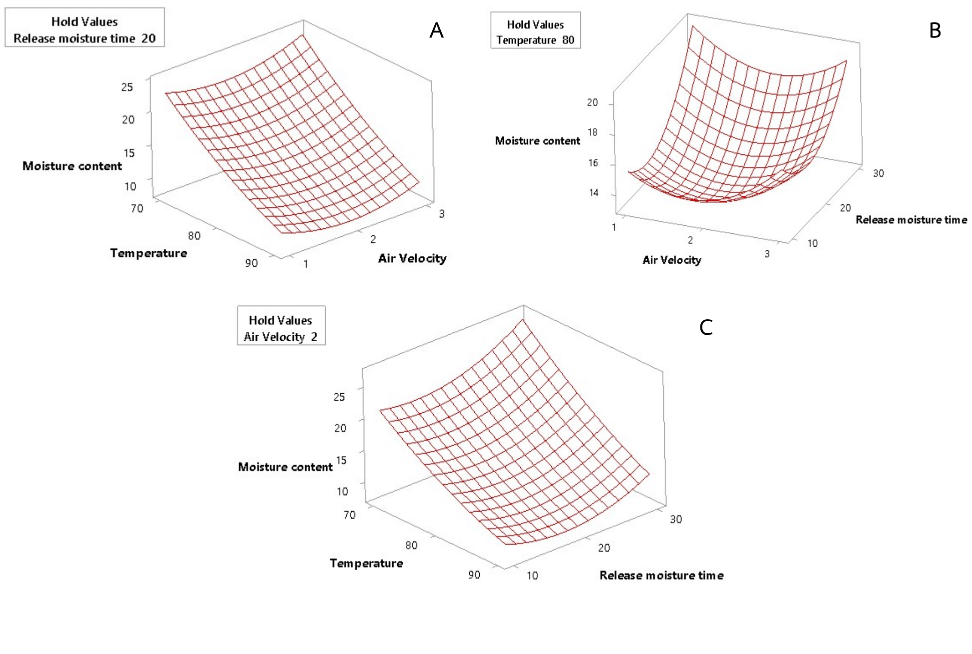

Figure 4 The surface plot of moisture content

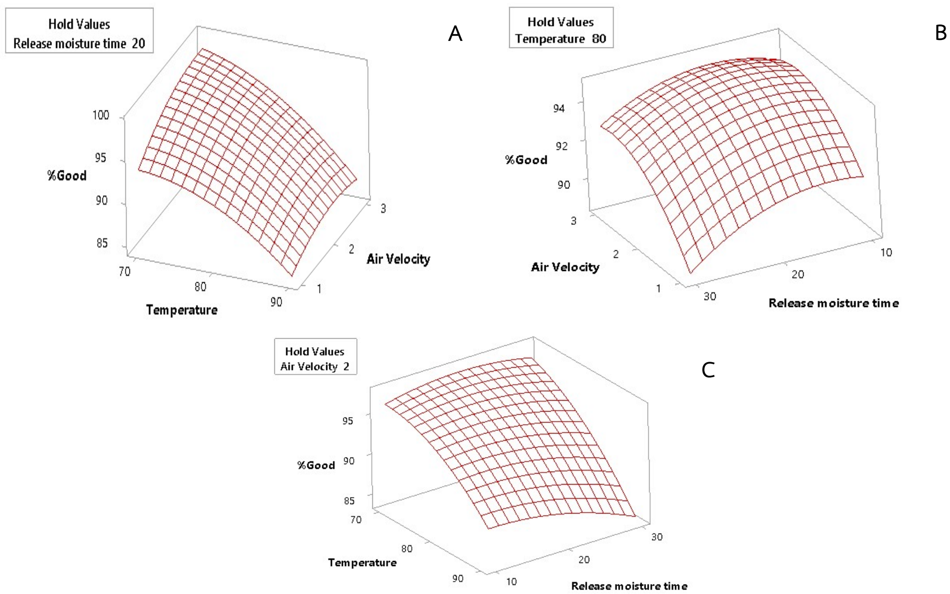

Figure 5 The surface plot percent of good products

Conclusions

This research adopted the factorial experiment design to collect data and analyze variables used in the chili dryer machine. The response surface method was used to identify the humidity equal 15 % wet basis and most good product shown in Figure 6. Moreover, the analysis of the satisfied function was used to find the appropriate variables in the chili dryer machine which showed the most satisfaction. The level of variables in the chili dryer machine was Temperature (A), Air Velocity (B), and Release moisture time (C) with the constraint of 70 < A < 90 degree Celsius, 1 < B < 3 meters per second and 10 < C < 30 minute. The result found that the most appropriate variable for the chili dryer machine was the Temperature (A) set at 80 degrees Celsius, Air Velocity (B) set at 2.5 meters per second, and release moisture time (C) set at 16 minutes. The consequence of the predicted moisture content is 14 % wet basis and 94.86 percent of good products with the max level of satisfaction at 82.30 percent. Therefore, the dispersion of Jinda chili at the higher moisture content is very important. It is recommended to design the flight addition in the inner rotary bin to minimize electric energy. Furthermore, the rotary dryer process in this research has still maintained the nutrient properties of dried chili products, and additionally, it helps to reduce the microbial content under the standard of dried food nutrition.

Figure 6 The good products Jinda chili not deformed

Acknowledgment

The authors would like to thank the Department of Industrial Engineering, Faculty of Engineering, Khon Kaen University, and the Department of Industrial Engineering, Faculty of Industrial Education, Rajamangala University of Technology Krungthep that supporting the research tools that supported this research.

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