Performance Analysis of Tray Dryer to Reduce the Drying Process Time of Cayenne Pepper

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***Abstract*— Chili is a type of vegetable that is easily damaged and difficult to maintain in fresh form. The durability of fresh chilies if stored at low temperatures can last up to 14 days, but if stored at room temperature chilies only last about 2-4 days. Because of this, chili prices are always erratic, when chili prices are low, farmers will overcome losses by drying chilies using natural methods of sunlight. This method is considered less effective because it requires a large drying area and relatively long drying time. Therefore, it is necessary to manufacture and test chili drying ovens to speed up the drying process time and increase the durability of chilies. This research method focuses on the process of testing the performance of the drying oven. The test parameter used is using temperature of 70 [℃] with 3 variations of drying process time, namely 6 hours, 7 hours, and 8 hours to produce dry chili water content according to the standard, which is a maximum of 11%. The results of the chili drying oven research are the best drying time for 8 [hours] with a temperature of 70,5 [℃] which produces a water content of 9.33% cayenne pepper. In addition, the drying oven testing process resulted in a drying efficiency of 31,15%.**

Keywords—chili, drying, drying oven, moisture contenct, processing time

I. INTRODUCTION

East Java is one of the largest cayenne pepper producing centers. Every year, the frequency of harvesting can take place 15 to 18 times after the cayenne pepper is 2.5 – 3 months after the seeds are planted. Chili itself is classified as a vegetable that is easily damaged and difficult to maintain in fresh form [15]. Because of this, the price of chili is always fluctuating or erratic, when the price of chili is low, the farmers will overcome these losses by drying the chili..

Farmers in the chili drying process still use sunlight to increase the durability of the chili itself. However, using the sunlight method is considered less effective, due to the relatively long drying time, which is about 7-8 days if the weather conditions are hot, and about 12-14 days if the weather is bad. According to Ref. [14], the effect caused by the long drying process results in 30% - 50% of dried chilies rotting and drying unevenly. This causes the selling value of dry chilies to be lower than the selling value of dry chilies in good condition. In addition, drying carried out on open land is considered less hygienic because the dried chili will be in direct contact with dust or dirt from the free air.

Based on this background, a rack-type drying oven was made using a rose burner and LPG gas as a source of heat energy. The performance of the tray dryer can be known after testing. The test was conducted to determine the decrease in processing time before and after the drying oven and to determine the drying efficiency of the drying oven.

Other studies related to the design of the rack-type drying oven have been carried out in previous studies. Ref. [1] in his research entitled "Development of Tray Dryer for Pumpkin Seed". This study discusses the design of a tray-type drying machine used to dry pumpkin seeds. Ref. [5] in his research entitled "Analysis of Performance of a Gas-Based Coffee Dryer (LPG)". This study discusses the design of a bed-type coffee drying oven using gas fuel (LPG) as its energy source. Ref. [12] in his research entitled "Design of a 75 Kg Lomek Fish Drying Oven With Waste Fuel". This study discusses the design of a drying oven with a separate heating chamber for drying Lomek fish. Ref. [13] in his research entitled "Effect of Time and Temperature on Moisture Content, Shrinkage, and Rehydration of Dried Onion". This study discusses the analysis of the effect of time and temperature of the drying process on humidity, moisture content shrinkage, and rehydration of dried onions.

II. METHODS

The method used in this research is the manufacture and testing of a rack-type drying oven as shown in Figure 1. flow chart of the research method. Starting with designing a tray drying oven with a stove and LPG gas as a heat energy source using Solidworks software, the process of making components and assembling, then testing the function of a tray dryer on processing time, cayenne pepper moisture content, and drying efficiency. If in terms of function there are still shortcomings, it will be redesigned and modified some of its parts. Furthermore, if the test has been achieved, the analysis and discussion of the results of the drying process time and moisture content of dried cayenne pepper will be continued and the efficiency of the drying process is carried out, then conclusions are drawn.

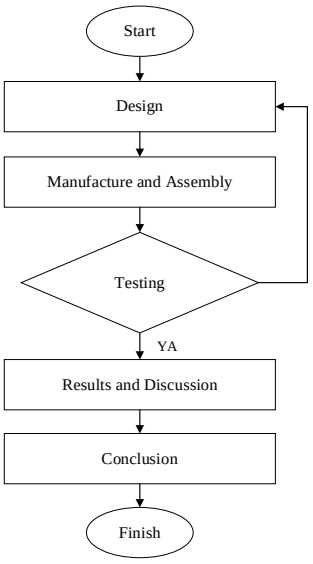

Fig. 1. Research methodology flow chart

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III. Results and Discussion

A. Design

The design process for the drying type oven uses the Shigley design flow. The design was carried out using the Solidworks 2017 software. Solidworks is a 3D Computer Aided Design (CAD) program that uses the windows platform [6]. The main frame using ASTM A36 (Hollow square) can be easily welded using all types of welding methods, one of which is SMAW welding [8]. The drying chamber cover wall uses AISI 304 Stainless Steel plate which has low thermal conductivity so as to minimize the heat loss that occurs. The heating element uses a stove and LPG gas as a source of heat energy. An electric blower is used as a diverter of hot air produced by the heating plate and stove to the drying room [5]. As a heat absorber or insulation aluminum bubble foil is used which has a very small conductivity value so that it can reduce and reduce the rate (transfer) of heat energy that comes out of the environment [17].

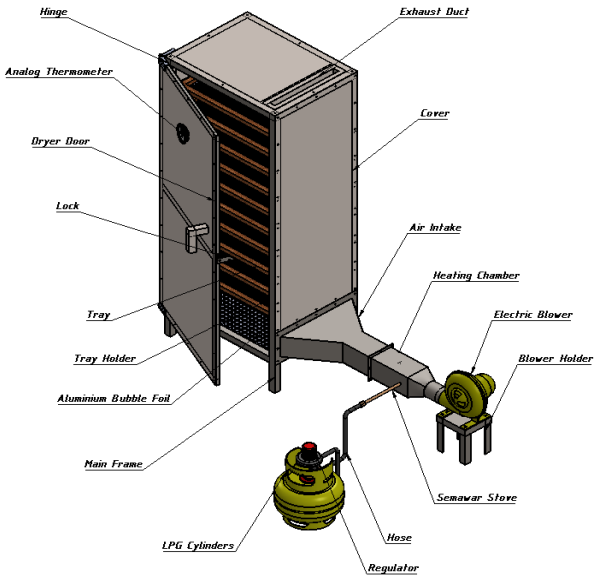

Fig. 2. Tray dryer design

The mechanism of this tray dryer oven is to use a stove and LPG gas as a source of heat energy. The cylindrical heating plate in the heating chamber is heated by the stove and then air flows from the blower. The air that passes through the heating plate will become hot air, which goes to the drying chamber. Hot air will increase the temperature in the drying chamber which causes differences in the humidity of the drying chamber and the humidity of the chili, so that the water content of the chili will begin to decrease.

B. Manufacture and Assembly

The manufacturing and assembly processes are carried out after the design process is complete. Components in the design of a rack-type drying oven for the drying process of cayenne pepper consist of components that are fabricated through the manufacturing process and procurement of standard components. The components that undergo the manufacturing process are the drying chamber, cover cover, heating chamber, main frame, pan, door, hinge, and blower holder. The manufacturing process carried out such as cutting, grinding, drilling, and bending. After procuring materials and processing, the assembly process is carried out with 2 assembly processes, namely welding using SMAW welding and assembly using screws.

C. Testing

The tests carried out are testing process time and water content, where this test aims to find the best processing time for drying cayenne pepper, which can produce cayenne pepper with a standard dry moisture content of a maximum of 11% [4]. This testing process is carried out with the chili drying temperature not exceeding 80 [°C], because it can damage the vitamin C content in the chili itself and the best temperature is 70°C [7]. Based on research from Ref. [10] the drying time carried out was 6 [hours], while based on research from Ref. [11] the drying time carried out was 8 [hours]. Therefore, the researchers carried out the drying process using the highest temperature of 70 [°C] with 3 time variants, namely 6 [hours], 7 [hours], and 8 [hours]. The following are the results of testing the processing time and moisture content of cayenne pepper as well as the parameters of heat energy requirements and heat loss for calculating the efficiency of drying performance:

Test Result

a. Result of Testing Processing Time and Water Content of Dried Cayenne Pepper

TABLE 1 RESULT OF TESTING PROCESSING TIME AND WATER CONTENT

Product	Testing Result	
	70,5 [°C]	
	Drying Time	Final Water Content
Cayenne Pepper	6 [hours]	17,8%
	7 [hours]	12,8%
	8 [hours]	9,33%

The final moisture content value was obtained after performing calculations using the initial moisture content of fresh cayenne pepper, which was 75.13% [9], which was reduced from the results of the decrease in water content during the chili drying process. Based on Table 1. the best drying results of cayenne pepper occurred at a temperature of 70.5 [°C] during a processing time of 8 hours, which resulted in the final water content of cayenne pepper which was 9.33%. These results have met the standard criteria for the allowable moisture content of dry cayenne pepper, which is a maximum of 11% [4].

b. Test Parameter Calculation Results

- Heat Energy Requirement

TABLE 2 HEAT ENERGY REQUIREMENT

Drying Load	Parameter	
	Laten	Sensible
Water	9.334.022,4 [J]	693.880 [J]
Cayenne Pepper		71.679,63 [J]
Total	10.099.582,03 [J]	

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The heat energy requirement is calculated based on the latent heat system and sensible heat contained in the drying object, such as evaporation of water contained in cayenne pepper and heating cayenne pepper, each of which is a total drying load. The required equations are: The sensible heat equation is as follows [3]:

$$q_x = m.C_p.\Delta T \quad (1)$$

Where q_x is the heating energy of the product [J], m is the mass of the product [kg], C_p is the specific heat of the product [J/kg. K], and ΔT is the difference between the initial and target temperatures [K].

In general, the latent heat used to change the phase of a substance is formulated as follows:

$$q_p = \dot{m}.h_{fg} \quad (2)$$

Where q_p is the energy of evaporation of water in the product [J], $\dot{m}$ is the mass of the product, [kg], and h_{fg} is the latent heat of vaporization of water, [kJ/kg. K]

Based on Table 2. the heat energy requirement is in cayenne pepper with a temperature of 70.5 [℃] for 8 [hours], is 10.099.582,03 [J].

- Heat Loss

TABLE 3 VALUE OF HEAT LOSS

Heat Loss Area	Product	Unit
	Cayenne Pepper	
Exhaust Duct	5.379.120	[J]
Cover	5.357.664	[J]
Heating Chamber	2.630.016	[J]
Total	13.366.800	[J]

Loss of heat energy is the effect of the exhaust duct, which is used to remove the steam drying and the engine cover to prevent heat energy from being wasted quickly during the drying process. The equations needed to calculate the heat loss that occurs are:

For composite walls where $T_{\infty 1}$- $T_{\infty 4}$ is the overall temperature difference, and the sum includes all thermal resistances, so the equation [2]:

$$q_x = \frac{T_{\infty 1} - T_{\infty 4}}{\left[\left(\frac{1}{h_1 A}\right)+\left(\frac{L_A}{K_A A}\right)+\left(\frac{L_B}{K_B A}\right)+\left(\frac{L_C}{K_C A}\right)+\left(\frac{1}{h_4 A}\right)\right]} \quad (3)$$

Meanwhile, to calculate the loss of heat energy in the design of the stator drying machine through exhaust ventilation, it can be stated as follows [16]:

$$q_v = \frac{1}{3600\ s}.V.\rho.C_p.(T_w - T_\infty) \quad (4)$$

Where q_v is the energy dissipated from the vent [W], V is the velocity of air flow in the vent $[m^3/s]$, ρ is the density of air [kg/m^3], C_p is the specific heat of air [kJ/kg. K], T_w is the temperature inside the engine [K], and T_∞ is the temperature outside the engine [K].

In Table 3. shows the value of heat loss that occurs during the drying process of cayenne pepper with the highest total heat loss with a temperature of 70.5 [℃] is 13.366.800 [J].

Analysis of Test Result

a. Analysis of Decrease in Drying Process Time

TABLE 4 DRYING PROCESS TIME COMPARISON

Drying Process	Time [Minutes]
Natural Method of Sunlight	2400
Tray Dryer Methode	480

The presentation of the decrease in drying process time in cayenne pepper is as follows:

$$\% \text{ Decrease} = \frac{\text{Natural method time} - \text{Dryer method time}}{\text{Natural method time}} \text{ x } 100\%$$

$$= \frac{2.400 \text{ Menit} - 480 \text{ Menit}}{2.400 \text{ Menit}} \text{ x } 100\%$$

$$= 80\%$$

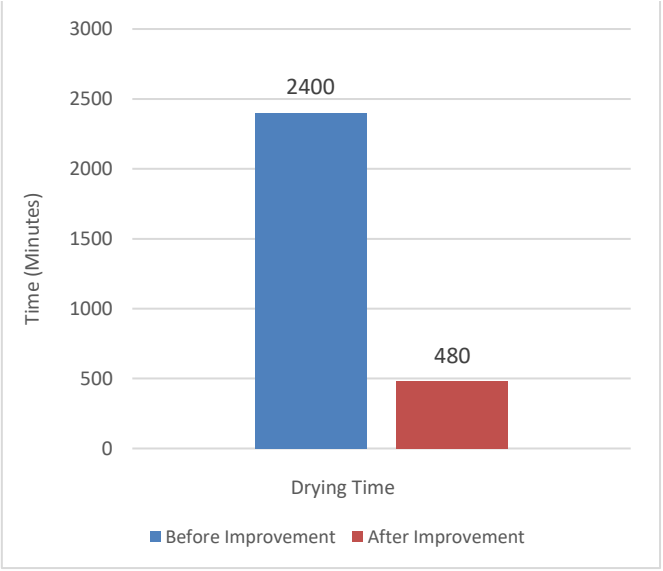

Fig. 3. Drying process time decrease diagram

In Fig. 3. shows a decrease in the drying process time for cayenne pepper. Before the improvement of the drying process was carried out using the natural method of sunlight, which required a processing time of 2,400 [minutes], while after the design of the chili drying oven the drying process only required a processing time of 480 [minutes]. This shows the drying process has decreased by 80%.

b. Drying Process Efficiency Analysis

Drying efficiency is the ratio between the energy required to carry out the drying process with energy that enters the tool or system [5]. Energy consumption (Q_{input}) can be calculated using the heat energy capacity during the drying process of cayenne pepper. While the value (Q_{output}) can be

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calculated from the amount of energy to heat and evaporate the water contained in a material and the value of heat loss that occurs during the drying process.

Energy consumption during the drying process of cayenne pepper takes place:

Energy consumption = 2.615,6 [W] x Drying Time

$$= 2.615{,}6\ [W] \times 8\ [h] \times \frac{3600\ [s]}{1\ [h]}$$

$$= 75.329.280\ [J]$$

Based on the efficiency equation for the drying process of cayenne pepper:

$$\eta_p = \frac{Q_{output}}{Q_{input}}\ x\ 100\%$$

$$\eta_p = \frac{23.466.382{,}03\ [J]}{75.329.280\ [J]}\ x\ 100\% = 31{,}15\%$$

The efficiency of the drying process of cayenne pepper was obtained at 31,15% with a temperature of 70.5 [℃] in the cayenne pepper drying test which lasted for 8 hours.

IV. CONCLUSION

The design of tray dryer is used as a problem solving solution to reduce the drying time of cayenne pepper. The best drying time is 8 hours to a temperature 70,5 [℃] with a final moisture content of 9,33% dry cayenne pepper, which already meets the standard of dry cayenne pepper moisture content. The decrease in processing time experienced before and after improvement is 80%. In addition, the drying efficiency in the test was obtained at 35,4%

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