

# Program Book

## ICST 2019

### International Conference on Science and Technology

Sheraton Surabaya Hotel & Towers, Indonesia      October 17<sup>th</sup>-19<sup>th</sup>, 2019

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# The Mathematical Analysis of the Drying of Cassava Grater by Using Pneumantic (flash) Dryer with Heat Recirculation Method

*by* Budi Hariono

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## The Mathematical Analysis of the Drying of Cassava Grater by Using Pneumatic (flash) Dryer with Heat Recirculation Method

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## The Mathematical Analysis of the Drying of Cassava Grater by Using Pneumatic (flash) Dryer with Heat Recirculation Method

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**Abstract.** The abundance of cassava cultivation production in Indonesia needs to be balanced with the use of cassava itself to be a source of alternative food as rice substitute. In this research was done the drying of tubers grater which was cassava to be dried into flour. This drying used a mechanical dryer which was a pneumatic (flash) dryer by using the heat recirculation method (the heat produced from drying was reused). The drying in this research was carried out with a variation of 2 air openings, which were openings for air speed (blower) and openings in the heat recirculation pipe. For openings in the blower, this research used 2 variations of openings, which were openings 50% (air speed 0.0603 m/s) and openings 75% (air speed 0.0768 m/s). For openings in the recirculation pipe, 4 variations of openings were used, which were openings 0% (without recirculated the heat), openings 25% (the heat returned was only 25%), 50% and 75%. The drying time was based on how long the material was in the duct drying. The results showed that, by doing heat recirculation, the value of heating and drying efficiency would increase. The drying in air recirculation 25% could increase the value of drying efficiency for about 5-6%, while in air recirculation 50% could increase the efficiency value for about 3-4%. The value of the heating efficiency of this research ranged from 57-86%. The drying rate constant of the cassava grater moisture content ranged between 0.16 to 0.194%/second.

### 1. Introduction

The food coverage in Indonesia independently is still a serious problem that we must face now and in the future. The main staple is still based on rice. Although in some areas a small portion of the population consumes non-rice staple foods such as corn or other commodities (cassava). Many Indonesian local foods have good nutritional potential, but have not been used optimally. One of the causes is the limited knowledge of the community about the benefits of these food commodities.

Cassava is Indonesia's local natural resource. Cassava is known in Indonesia by its other names ketela pohon, singkong, or ubi kayu. Cassava has botany name that is *Manihot esculenta* Crantz but is better known by another name *Manihot utilissima*. Cassava plants belong to the kingdom plantae, Spermatophyta division, Angiospermae subdivision, Dicotyledonae class, Euphorbiaceae family, *Manihot* genus with *Crantz esculenta* species with various varieties [1].

Cassava is one of the plants that is widely grown in Indonesia, especially in the tropics and is the cheapest source of food calories in the world. This plant is consumed as a staple by approximately 400 million people in humid tropics in Africa, Asia and America. Logically cassava will occupy an important position in the food system in Java.

In Indonesia, cassava is the second largest food crop production after rice, so cassava has the potential as an important raw material for various food and industrial products. Cassava is one of the



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foods that are rich in carbohydrate, besides that there are nutrients such as protein, vitamin C, calcium, calories, fat, iron, and vitamin B1. With various nutritional content found in cassava, cassava is very good to be consumed by the community. Cassava tubers are not resistant to storage even though they are placed in a refrigerator. In this case, cassava tubers are easily damaged, the damage symptom is characterized by the appearance of dark blue colors due to the formation of cyanide acid which is toxic to humans. Besides that it is also easy to rot and must be consumed quickly or converted into products that can be stored [2].

The processing of semi-finished products is one of the ways to preserve yields, especially for commodities with high water content, such as various tuber and fruits. The other advantages of processing semi-finished products are as a flexible raw material for advanced processing industries, safe in distribution, and saving space and storage costs. This technology includes sawut manufacturing technique, flour making technique, separation or extraction technique and starch production [3].

The flour technology is one of the alternative processes recommended for semi-finished products, because it is more resistant to storage, easy to mix (made composite), enriched with nutrients (fortified), easy to form and cooked faster in accordance with the demands of modern life that wants to be practical. The procedure for making flour is very diverse, distinguished by the character and chemical components of food. However, in broad outline it can be grouped into two, which are food that is not easy to become brown when peeled (cereal group) and food that is easy to become brown (various kinds of tubers and fruits that are rich in carbohydrates) [4].

The problems related to the process of making cassava flour, among others: the process of the drying of cassava grater, cassava flour making technology, and the quality parameters of cassava flour. The mechanical drying method is expected to be better than the drying method. The potential for losses is smaller with the temperature that can be adjusted as needed. The traditional drying takes quite a long time which is 3 to 5 hours, thus extending the processing time of cassava flour as a whole. The drying process is directly proportional to the amount of energy used and the number of products produced per hour. Therefore, to reduce the use of greater energy and shorten the processing time of making cassava flour, it is necessary to use a flash drying method by using the high air speed and drying temperature. In this research the drying process was carried out by using recirculating pneumatic (flash) dryer [5].

The pneumatic or flash dryer is used for the process of quick (flash) drying of material particles that can be transferred in a pneumatic way (with air). The pneumatic dryer consists of a tube with a height (5-30 m), a cyclone system, and a heater. The time during drying using air (pneumatic) can be increased by the shape of the tube or drying chamber in a continuous rotation (pneumatic ring dryer). The air heating on a pneumatic dryer can be directly (gas) or indirect (steam heat exchanger) [6].

This pneumatic (flash) dryer recirculation is a type of drying machine that utilizes high-speed hot air in the drying process of the material by reusing the hot air that coming out of the output hole. The types of materials that can be dried using a pneumatic (flash) dryer are materials that have small particle sizes such as cassava grater. With the optimum air speed and drying temperature using a pneumatic (flash) dryer, the process of drying cassava can be done faster with good quality. Therefore, the researchers developed this research with the expectation of obtaining a very efficient dryer machine.

## 2. Literature Review

Literature review that will be used for this research are

### 2.1 Determining the Material Moisture Content

The moisture content can be stated based on wet weight (wet basis) or based on dry weight (dry basis). There are two types of water content measurement, which are :

$$K (w) = \frac{M_0 - M_1}{M_0} \times 100\% \quad (1)$$

### 2.2 Determining the Drying Rate Constant

The water evaporation rate in drying was divided into two that were the constant rate and the falling rate. The calculation of the constant drying rate was based on the following equation:

$$\frac{d}{dt} = -k \quad (2)$$

The drying rate constant ( $k$ ) of the constant rate period could be found by making a graph of the first-order linear function where  $M_t - M_o$  was ordinate and drying time ( $t$ ) as abscissa. To find the predicted water content at a constant rate using the formula  $M_{\text{prediction}} = -k \cdot t + M_o$ .

And the equation for falling rate became:

$$\ln \frac{M - M_o}{M_o - M} = -k \cdot Q \quad (3)$$

### 2.3 The Drying Efficiency

The drying efficiency was a comparison between the total amount of heat that was used for evaporation with energy to heat the air. The equation of drying efficiency can be written [7]:

$$\eta = \frac{Q \cdot t}{\Delta h \cdot m} \times 100\% \quad (4)$$

### 2.4 Heating Efficiency

The heating system efficiency is the comparison between the amount of heat supplied to the drying room with the heat that provided from the used fuel :

$$\eta = \frac{(h_2 - h_1)m_u}{P} \times 100\% \quad (5)$$

Where  $m_u$  = hot air flow rate (kg/s),  $h_2$ = air enthalpy after heated (kJ/kg),  $h_1$ = outside air entalphy (kJ/kg) and  $P$  = heater power (kW).

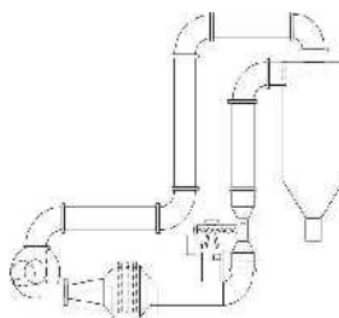
## 3. Working Methodology

### 3.1 Research Location

This research was conducted at the Laboratory of Energy and Agricultural Machinery (EMP) Faculty of Agricultural Technology, Gadjah Mada University.

### 3.2 Tool and Material

The pneumatic (flash) dryer was equipped with three fin heaters installed in parallel inside a heater box. The power of one fin heater reaches 1500 watts. To blow the air, a single suction type sirrocco blower was used. At the air inlet section, a blower was installed to cover the speed of the air being blown. Meanwhile for the modified equipment, the heat output holes that had been used for drying were recirculated into the drying system by being connected by existing pipes to become a heat source for the next drying. By using a pipe that connected the heat waste outlet with the inlet hole of hot air entry, it is expected that the efficiency value of the tool would be higher than the unmodified one (Fig 1).



**Fig 1.** Pneumatic (Flash) Recirculation type dryer

### 3.3 Research Methodology

The implementation of this research basically consisted of the stages of stripping, scaling, centrifuge, drying, and sifting. The whole process can be seen in Fig 2.

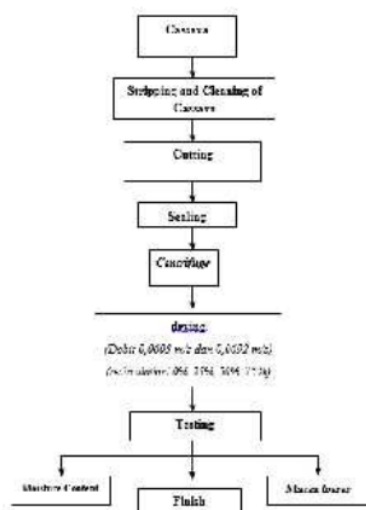


Fig 2. Research flow diagram

#### 4. Experiment and Result

Flash dryer was a drying machine that relied on the air speed to flow the material vertically. The wet material that was put into the hopper was then pushed by the screw conveyor that would spin so that it could push the material to enter the drying column. The dryer air flow speed was used to deliver the heat to the material convectionally so that the hot air was used to evaporate the material as well as brought the water vapor out of the drying column.

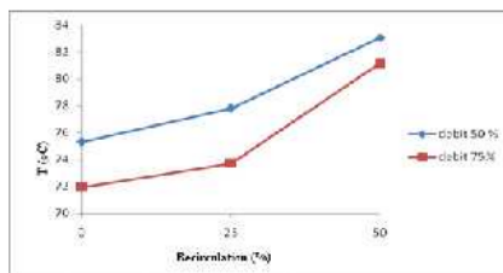
##### 4.1 The Effect of Recirculation openings on The Drying Temperature

The speed or air discharge on the pneumatic (flash) dryer was set by using a lid on the inlet part of the air blower with two openings variations that were variations of openings 50 % and 75%. To exhale the cassava grater vertically within the drying duct, it needed minimum speed of 9 m/s. the speed could be reached on openings 50% with 10.45 m/s speed. In the other hands, it could be done with variation of openings 75% with 12 m/s speed.

The two variations of openings had different air discharge. The higher the air inlet was opened, the faster the air flow blew by the blower. Successively, openings 50% and 75% produced air speed in venturi section as much as 0.0603 m<sup>3</sup>/s and 0.0692 m<sup>3</sup>/s. The air discharge produced by each openings resulted in different drying temperature on each heat variations of openings recirculation. The three variations of openings were openings 0% (no heat recirculated), 25% (the recirculated heat was 25%), and 50% (the recirculated heat was 50%). Fig 3 showed the air recirculation openings on the drying temperature.

Figure 3 showed that the more heat recirculated, the higher the dryer air temperature produced. air speed openings 50% which produced 0.603 m<sup>3</sup>/s air discharged was the openings that showed the highest air temperature followed by the air speed openings 75%. At speed openings 50% (air discharge 0,0603 m<sup>3</sup>/s), the drying temperature by using three heaters in recirculation variations 0%, 25%, and 50% were 75.31oC, 77.79oC, and 83.07oC. The recirculated heat addition made difference on the water level evaporation ability of cassava grater. At speed openings 75% (air discharge 0,0692 m<sup>3</sup>/s), the drying temperature with three heaters in recirculation variations 0%, 25%, and 50% were 71.93 oC, 73.71 oC, dan 81,14 oC.

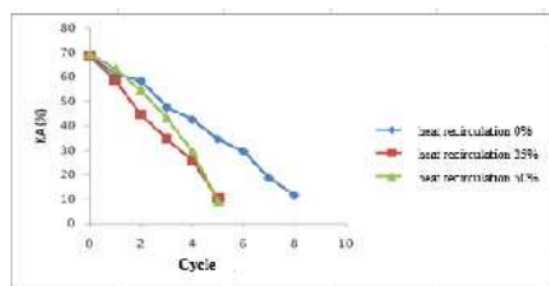




**Fig 3.** The Effect of recirculation openings on the drying temperature

#### 4.2 The Effect of Heat Recirculation on the Decrease in Water content of each Cycle.

The decrease in water content of cassava grater based on variations of recirculation heat can be seen in Fig 4.



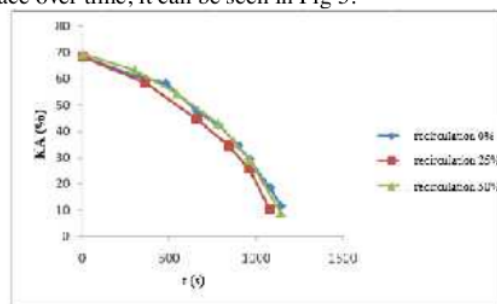
**Fig 4.** The relationship of recirculation openings on the decrease of water content

Fig 4 showed the decrease of water level was increasing along with the increase of heat recirculation variations during the drying on each openings variations because the drying temperature was also increasing. The drying at the air discharge openings 75% (0.0603 m<sup>3</sup>/s) successively from recirculation variations 0%, 25%, 50% could dry the cassava grater up to water content of 11.53%, 10.24%, and 9.12% from the initial water content of 68.41%.

Drying air discharge openings at 50% (discharge air 0.0603 m<sup>3</sup>/s) successively from recirculation variations 0%, 25%, 50%, and 75% are capable of drying cassava grater until the moisture content of 13.82%, 8.81%, 8.72% and 14.98% of initial moisture content of 32.39%.

#### 4.3 The Effect of the Air Recirculation on the Drying Time

The drying by using pneumatic dryer could reduce the water content of cassava grater up to 8-12% although the time of the drying process in the drying duct is quite short. The decrease in water content of cassava grater took place over time, it can be seen in Fig 5.



**Fig 5.** The Relationship of the drying time on the decrease in water content

Fig 5 showed that the longer the drying time, then the water content obtained will be lower to the point of balance. The variations in recirculation 25% and 50% were the best variations in reducing the

cassava grater water content, it was based on the number of conducted drying cycles, whereas in the variation of recirculation 0%, the drying cycle was done more than the others.

#### 4.4 Drying Rate Constant ( $k$ )

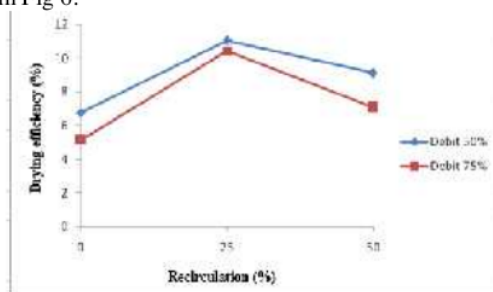
The drying rate constant ( $k$ ) was a quantity which referred to the speed of water in diffusing out, leaving the material per unit time. The greater the value of  $k$  was, the faster the drying process would be. In the process of drying cassava grater at air flow rate of 0.0603 m<sup>3</sup>/s, the obtained value of  $k$  was 0.16 (for 0% heat recirculation), 0.183 (for 25% heat recirculation), and 0.198 (for 50% heat recirculation). The process of drying cassava grater at air flow rate of 0.0692 m<sup>3</sup>/s got  $k$ - value of 0.181 (for 0% heat recirculation), 0.193 (for 25% heat recirculation), and 0.194 (for 50% heat recirculation). This result can be seen in following table 1:

**Table 1.** The Constant of Drying Rate of Cassava Grater on Various Heat Recirculation and Air Discharge

Air Discharge (m <sup>3</sup> /s)	$k$ (%/s)		
	0	25	50
0,0603	0,160	0,183	0,198
0,0692	0,181	0,193	0,194

#### 4.5 Drying Efficiency

Three fin heaters that were used as heaters had 4500 watts or 1500 watt as its total power for one heater. The heaters were able to heat the air to high temperature (influenced by air speed). The success of drying could be determined from how much water content of evaporated material during the drying process. The relationship between the efficiency and the evaporated water content or the decreased water content can be seen in Fig 6.



**Fig 6.** The Relationship between the Variation on Heat Recirculation and Drying Efficiency

Fig 6 showed the greater the recirculated heat was, the smaller the drying efficiency would be at 50% and 75% of openings speed variation. The figure also showed the drying with 50% of speed variation which had the highest efficiency when it was compared to 75% of speed variation.

Drying with 50% of air speed variation (0.0603 m<sup>3</sup>/s of air discharge) on the recirculation variation of 0%, 25%, and 50% produced drying efficiency of 6.78%, 11.06%, and 9.13% respectively. Drying efficiency at 75% air speed variation (air discharge was 0.0692 m<sup>3</sup>/s) on recirculation variation of 0%, 25%, and 50% obtained drying efficiency of 5.16%, 10.43%, and 7.11% respectively. The value of drying efficiency would decrease along with the increasing air discharge since the water evaporation occurred at large air discharge was very small. From the chart above, it can be seen that the use of recirculation pipes were capable to increase the value of drying efficiency. The recirculation openings variation of 25% could increase the efficiency value around 5-6%, but there was a decrease in the increase of efficiency value which was at 50% of variation. The efficiency value fell from the variation of 25% to 50% around 2-3%. This was due to the amount of evaporated water which was brought back

to this recirculation drying system. It can also be said that the more air vapor recirculation was carried out, there would be reduction of drying efficiency value.

#### 4.6 Heat Efficiency

The discharge and drying temperature had an effect on heat efficiency during the drying process. Fig 7 shows the relationship between variation on heat recirculation and heat efficiency.

Figure 7 showed the increase of recirculation variation which could raise the value of the heat efficiency. Besides, the greater the air discharge or speed openings variation, the greater the heat efficiency would be and the more recirculated heat would be obtained, the lower the heat efficiency would be.

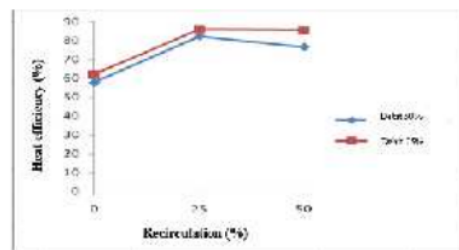


Fig 7. The Relationship between Variation on Air Recirculation and Heat Efficiency

#### 5. Conclusion

1. The drying at 50% of openings air discharge (0.0603 m<sup>3</sup>/s) was able to produce higher drying temperature as it was compared to 75% of openings air discharge (0.0692 m<sup>3</sup> / s).
2. The best variation in reducing water content was the variation of 25% of openings heat recirculation.
3. The drying rate constant of water content on rate period constant ranged from 0.16 to 0.194% / second.
4. The drying at variation of 25% increased the value of drying efficiency around 5-6% and the variation of 50% reached the efficiency value about 2-3%..

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