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Calculation Of the Heating System for Cassava Pulp Dryer Using Rotary Dryer with Capacity Of 5 kg/hour

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Abstract. Drying cassava pulp is an important stage in the cassava processing process so that the final product has good quality and high shelf life. This research aims to calculate the heating system in a cassava pulp drying machine based on a rotary dryer with a capacity of 5 kg/hour. The methods used include preliminary studies and field observations, literature review, and technical calculations including air flow velocity, moisture content, heat required, drying efficiency, and fuel requirements. The calculation results show that the total heat energy required to reduce the water content of cassava pulp from 20% to 5% is 2176.73 kJ, while the heat provided by the heating air is 4493.88 kJ with a thermal efficiency of 48.44%. The fuel used is LPG with a requirement of approximately 50 grams per drying cycle. The system shows potential as an effective alternative to traditional drying methods, especially for household or micro-enterprise scale. Further optimization is required to improve the thermal efficiency and heat distribution.

Keywords: heating system; dryer; cassava pulp; rotary dryer

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1. Introduction

Cassava (Manihot esculenta) is a tropical tuber plant that is widely cultivated in Indonesia and has an important role both as a source of staple food and raw material for various food or processed industries (1). Cassava plants have good nutritional content and are quite complete. The chemical content and nutrients in cassava plants are carbohydrates, fat, protein, dietary fibre, vitamins (B1, C), minerals (Fe, F, Ca) (2). One of the processed products from cassava is cassava rice, which is often consumed by people in areas such as Cireundeu, South Cimahi, where cassava is a major component in the diet (3).

The stages of making cassava rice are carried out by first grinding the cassava with a grater. Then, the grated cassava is placed in a filtering container. After that, the cassava is filtered and deposited for approximately 3 to 4 hours. The result of the precipitation of the grated cassava is called cassava starch juice. While the rest is called cassava pulp. The processing of cassava pulp, especially in the process of making cassava rice, still faces various challenges, one of which is in the drying process. If the cassava pulp is not dried immediately, the quality will be damaged, because it will trigger the growth of spoilage microorganisms (4). The drying process is to reduce the moisture content of the material by using heat energy to a certain extent so that it is safe to store for a long period of time(5).

The traditional sun drying method is still commonly used, especially in the Cireundeu area, but this method is less efficient because it is highly dependent on weather conditions, long drying time, and uneven drying results (6). According to one of the residents of Cireundeu Village, efforts to use a cabinet dryer have been made but are still limited. This cabinet-type dryer has disadvantages such as long drying time and inconsistent quality due to uneven heat distribution (7).

To overcome this problem, the use of a cassava pulp dryer based on a rotary dryer is proposed. Rotary dryer or can be called a drum dryer is a dryer in the form of a continuously rotating drum that is heated and equipped with a furnace or gasifier (8). Rotary dryer consists of a stainless steel cylin-

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der that rotates so that the material contained in it will rotate, not only the top surface undergoes the drying process, but also on all parts, namely top and bottom alternately. Rotary dryers are commonly used to dry materials in the form of powder, granules, lumps of solid particles in large sizes (9). Cassava pulp drying machine rotary dryer system with a capacity of 5 kg/hour has a design as shown in Figure 1. The design of the machine design is made using AutoCad 2007 software. The function of this drying machine is to dry cassava pulp, so that it can be made into cassava flour and cassava rice. The heating system used is an LPG burner, while the driving power uses an electric motor.

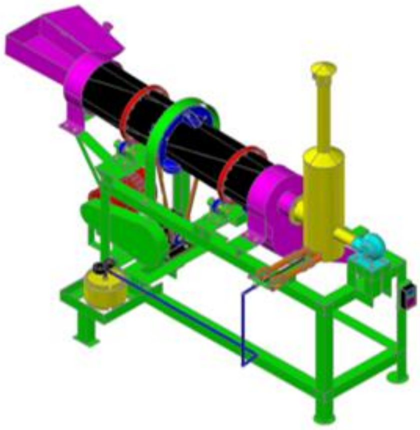

Figure 1. Cassava pulp drying machine rotary dryer system capacity 5 kg/hour

Rotary dryer has the advantages of even drying results (10), improving product quality (low moisture content), clean and hygienic and environmentally friendly processing (11). The rotary dryer machine consists of several components, one of which is the heating system. The purpose of this study is to focus on the calculation of the heating system of cassava pulp drying machine with a 5 kg/hour capacity rotary dryer system. The results of this study ensure that the heating system used will make the drying process efficient and evenly distributed.

2. Methodology

The research adopts an engineering design methodology comprising several structured phases:

- Preliminary Study and Observation: Field observations were conducted in Cireundeu to identify user needs and limitations of existing drying systems. Interviews with cassava processors and expert consultations provided context-specific requirements.
- Literature Review: Technical references related to rotary dryers, drying kinetics, cassava pulp characteristics and heating mechanisms were gathered to inform design decisions.
- Engineering Calculations: Mechanical calculations were conducted to determine heat transfer efficiency.

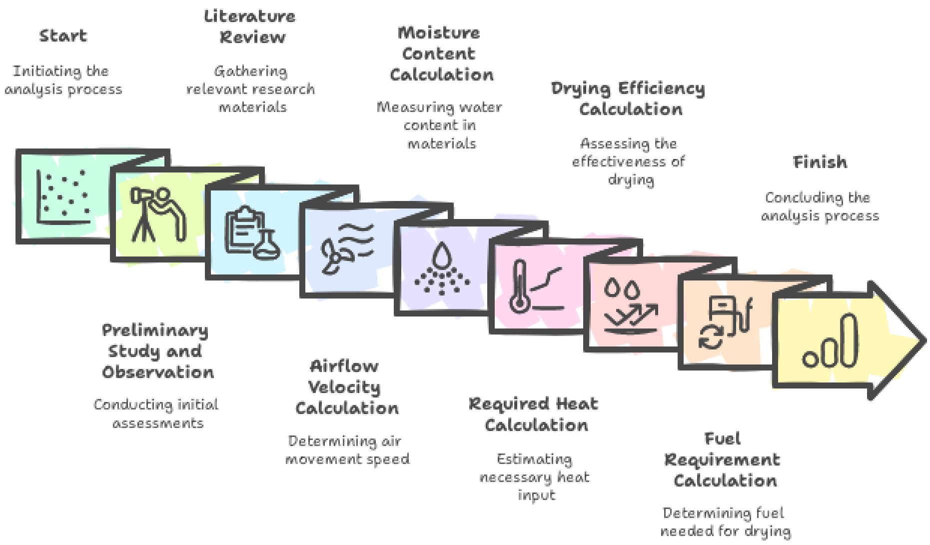

Figure 2. Research phase

This methodology ensures that the rotary dryer is not only technically feasible but also suitable for practical implementation in small-scale or household cassava processing industries.

3. Equations

To design a heating system for the cassava pulp drying machine rotary dryer system, calculations are needed regarding the airflow speed, moisture content and the heat required. The following formulas are used:

3.1 Airflow Velocity Calculation

To calculate the air flow velocity in the drying chamber, the variables used are the volume value of the drying chamber and the Air Change per Hour (ACH). The ACH value can be found in the blower selection table for a room. Meanwhile, the volume of the drying room can be calculated with the following formula:

$$V = \pi \; x \; r^2 \; x \; t \tag{1}$$

then the air flow velocity in the drying chamber can be calculated by the following formula:

$$\text{Airflow Velocity} = V \; x \; ACH \tag{2}$$

3.2 Calculation of Moisture Content

Based on the experiments that have been carried out, the moisture content (X) of cassava pulp can be calculated using the following formula:

$$X = \frac{m_w}{m_s} \; x \; 100\% \tag{3}$$

$$X = \frac{0.2}{1} \; x \; 100\%$$

$$X = 20\%$$

Which are:

m_w : water mass in the product (kg)

m_s : product solid mass (kg)

Based on the calculation, the moisture content in cassava pulp is 20%. This cassava pulp drying machine is expected to reduce the moisture content from 20% to 5%.

3.3 Calculation of Required Heat, Drying Efficiency and Fuel Requirement

To calculate the heat required, there are several variables that must be known such as the weight of cassava pulp to be dried, the temperature of the drying air, the temperature of the drying room, the speed of the air entering the dryer, the specific heat of cassava pulp, the specific heat of water, the initial water content, the desired water content, the time required and the density of air (r). After these variables are known, the dry weight, dry material part and the amount of water vapor that must be evaporated to 5% moisture content can be calculated. Dry weight is the weight where the moisture content of the material is 0%. For heat utilization, there are several calculations that must be done, among others (12):

- Cassava pulp sensible heat (Q_1) is the amount of heat used to heat the material (13):

$$Q_1 = m_k \; x \; C_p \; x \; (T_2 - T_1) \tag{4}$$

$$= 4 \text{ x } 3.64 \text{ x } (80-65)$$

$$= 218.4 \text{ kJ}$$

Which are:

m_k : dry weight (kg)

C_p : specific heat of cassava pulp (kJ/kg°C)

T_2 : dryer air temperature (°C)

T_1 : dryer room temperature (°C)

- Water sensible heat (Q_2) is the heat used to raise the temperature of the water in the material:

$$Q_2 = m_a \; x \; C_a \; x \; (T_2 - T_1) \tag{5}$$

$$= (5-4) \text{ x } 4.2 \text{ x } (80-65)$$

$$= 63 \text{ kJ}$$

Which are:
m_a : water weight (kg)
C_a : specific heat of water (kJ/kg°C)
T_2 : dryer air temperature (°C)
T_1 : dryer room temperature (°C)

- Latent heat of evaporation of water (Q_3) is the heat used to evaporate the water of the material:

$$Q_3 = m_w \; x \; h_{fg} \tag{6}$$
$$= 0.79 \text{ x } 2307.52$$
$$= 1822.94 \text{ kJ}$$

Which are:
m_w : amount of water vapour to be evaporated to 5% moisture content (kg)
h_{fg} : latent heat of evaporation of water (kJ/kg)

- Heat in the drying chamber (Q_4) (14):

Before calculating the heat load in the drying chamber, determine the heat coefficient (U) of the drying chamber first. Based on the drying chamber material used, the heat coefficient (U) can be calculated with the following formula:

$$U = \frac{1}{\left(\frac{1}{f_1} + \frac{x^1}{k} + \frac{x^2}{k} + \frac{1}{f_2}\right)} \tag{7}$$
$$U = \frac{1}{\left(\frac{1}{6{,}92} + \frac{0.0032}{15} + \frac{0.0032}{0.038} + \frac{1}{2.82}\right)}$$
$$U = \frac{1}{(0.14+0.00021+0.084+0.35)}$$
$$U = \frac{1}{0.57}$$
$$U = 1.75 \text{ W/m}^2.^\circ\text{C}$$

To calculate the heat load on the drying chamber wall, calculate the surface area of the drying chamber wall first assuming that the drying chamber wall is plate-shaped, where:

- $A_1 = p \text{ x } l$ (8)
  $A_1 = 1 \text{ x } (3.14\text{x}0.22)$
  $A_1 = 0.69 \text{ m}^2$
- $A_2 = \pi \text{ x } r^2 \text{ x } 2$ (9)
  $A_2 = 3.14 \text{ x } 0.11^2 \text{ x } 2$
  $A_2 = 0.076 \text{ m}^2$

then,

$$Q_4 = (A_1 \; x \; U \; x \; \Delta T) + (A_2 \; x \; U \; x \; \Delta T) \tag{10}$$
$$= (0.69 \text{ x } 1.75 \text{ x } (80\text{-}65)) + (0.076 \text{ x } 1.75 \text{ x } (80\text{-}65))$$
$$= 18.11 + 1.995$$
$$= 20.105 \text{ W} = 72.39 \text{ kJ}$$

Which are:
A : drying chamber wall surface area (m²)
U : heat coefficient (W/m².°C)
ΔT : temperature difference (°C)

Based on the above calculations, it can be determined that Q_{total} is 2176.73 kJ. The air discharge used in the drying process is 0.076 m³/s and the amount of air volume for 60 minutes is 273.6 m³. While the Heat Provided by Air to Heat the Material can be calculated by the formula:

$$Q_{air} = r \; x \; V_{air} \; x \; C_u(T_2 - T_1) \tag{11}$$
$$= 1.095 \text{ x } 273.6 \text{ x } 1.00 \text{ } (80\text{-}65)$$
$$= 4493.88 \text{ kJ}$$

Which are:
r : mass density of air (kg/m³)
V_{air} : amount of Air Volume for 60 minutes (m³)

C_u : specific heat of air ((kJ/kg°C)

After the amount of heat required and the heat provided by the air is known, the Drying efficiency of the heating system can be calculated, which is as follows:

$$\boldsymbol{\eta} = \frac{Q_{total}}{Q_{air}} \; x \; 100\% \qquad (12)$$

$$\boldsymbol{\eta} = \frac{2176.73}{4493.88} \; x \; 100\%$$

$$\boldsymbol{\eta} = 48.44\ \%$$

In drying cassava pulp, the author will use LPG fuel gas as a heater. This LPG gas fuel has a fuel calorific value of 11.220 kcal/kg. To find out how much fuel is needed, use the following formula:

$$\text{Fuel requirements} = \frac{Q_{total}}{NKB_k} \qquad (13)$$

$$= \frac{520.24}{11.220}$$

$$= 0.05 \text{ kg} = 50 \text{ gram}$$

Based on the calculation results above, the author uses 3 kg LPG gas to dry the cassava pulp.

4. Discussions

The calculation results show that to dry 5 kg of cassava pulp from the initial moisture content of 20% to 5% within 60 minutes, a total heat energy of 2176.73 kJ is required. Of the heat component, most of it is used to evaporate water (Q_3 = 1822.94 kJ), while the rest is to raise the temperature of the material and the drying environment. From the efficiency results, only 48.44% of the total heat provided by the hot air is actually absorbed for the material drying process. This indicates that there are still heat losses, especially to the environment and the walls of the drying chamber, which are common in simple drying systems. In this system, the amount of LPG required for one drying cycle is about 50 grams, so the use of a 3 kg cylinder will be able to be used in several drying cycles. This rotary dryer heating system shows potential as an alternative to slower and uneven traditional drying methods.

5. Conclusions

Based on the results of the calculations that have been carried out. The rotary dryer system designed for a capacity of 5 kg/hour was able to reduce the moisture content of cassava pulp from 20% to 5% within 60 minutes. The total heat energy required for this process is 2176.73 kJ, and the heat provided by air is 4493.88 kJ, with a thermal efficiency of 48.44%. The amount of LPG fuel required for a single drying process is about 50 grams, indicating a feasible energy efficiency for a household scale. The system provides advantages in drying speed and uniformity over conventional drying methods that are highly dependent on the weather. Optimization of the thermal insulation and heat distribution is still required to further improve the efficiency of the system.

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