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Evaluation Performance of Pneumatic Dryer for Cassava Starch

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Abstract

In small and medium industries, cassava starch is dried using conventional method by drying it directly under the sun. However, the main drawback of conventional method is low drying rate. Therefore, in this study, cassava starch with a water content of 40% (wet basis) was dried using a pneumatic dryer to a moisture content below 13% (wet basis). The aim of this research is to analyze the influence of drying air temperature, drying air flow rate and rate of feeding in relation to drying rate and energy analysis. Energy analysis was performed to determine the performance of pneumatic dryer. The energy analysis itself is done in the form of energy utilization and energy efficiency. The energy analysis shows that the increase of dryer temperature from 60 to 100°C will increase the utilization of energy from 0.34 to 0.76 J/s, while the energy efficiencies ranged between 30-40%. Proximate analysis shows that the dried cassava starch has an ash content of 0,24, grain fiber of 0,12, and degree of whiteness of 98%, which fulfills the SNI standard of cassava starch.

Keywords: *cassava starch; energy analysis; pneumatic dryer*

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INTRODUCTION

Cassava starch is one of Indonesia's main agricultural products. It occupies the fourth position in the world, with a capacity of about 22 million tons per year. Cassava has high nutritional and economical value. Its carbohydrate content is 40% larger than rice and 20% higher than corn (Tonukari, 2004). In Indonesia, cassava is a food crop with the second largest production after rice. The production of fresh cassava in 2014 is about 23,436 thousand tons (BPS, 2015). Cassava starch is often processed into glucose and dextrin syrup that is needed in the confectionery industry, ice cream, and beverage. Other than that, cassava starch is widely used in cosmetics, oil, pharmaceutical and even chemical industry.

Small medium enterprises (SME) that produce cassava starch often encounter one of the major problem in the processing step, which is drying. After extraction process, cassava starch contains about 40% (wb) of water. This wet cassava starch has to be dried until the water content becomes less than 14%. Usually, in most SME, the wet cassva starch is arranged on the cement floor and dried under the sun. This drying method will cause the product to be contaminated by impurities such bacteria and dust. The quality of products are not uniform and below standard to be used as a food product, making it difficult to sell to large food industries, and this will decrease the selling price of the product due to being rejected by buyers when they arrive at their location. Discontinuation of production activities (mainly because it depends on the weather) will also results in low selling prices and making it difficult to compete in the market. Therefore, the application of the mechanical drying technology is needed.

One of the dryer types that can be used for cassava starch drying is pneumatic dryer. Pneumatic dryer utilizes high-speed air and high temperature. The use of high-speed air and high temperature will cause the product to dry in very short time. Pneumatic dryers may be characterized as continuous drying with a solid feed (Levy and Borde, 1999; Dragisa et al., 2010). Hot air will supply energy to the dryer and transporting solids through a vertical pipe. Tthe solid is separated from the drying gas and followed by the scrubber. Pneumatic dryers can also reduce the particle size of the product (due to friction). Pneumatic dryers are also particularly suitable for the treatment of heat sensitive, explosive, degradable or flammable materials, because the average residence time of the solid is relatively short (usually a few seconds) (Baeyens et al., 1995).

Drying is a process of evaporation of moisture content in materials involving heat transfer between the surface of the product and the environment (Aghbashlo, Kianmehr and Arabhosseini, 2009; El-behery et al., 2012). Drying is widely used in various thermal applications such as food. According to Aghbashlo (2008) the purpose of drying is to remove moisture content in the solids by means of evaporation. In addition, drying can extend shelf life, simplify the transportation and storage of materials.

There has been a lot of batch drying researches published (Akpinar et al., 2006; Colak & Hepbasli, 2007; Corzo et al., 2008). However, few information about continuous drying can be found, considering that pneumatic dryer is a continuous dryer. Energy analysis can be interpreted as the calculation of the flow of energy in a production process, which usually done to achieve an economical process.

Energy analysis is based on the first law of thermodynamics, where the first thermodynamic law assumes that energy cannot be created and destroyed so that all incoming energy will be converted into another form of energy. Energy is the maximum quantity without regard to friction so it can be called the absolute amount of energy. This energy analysis aims to estimate the ratio of energy use and the amount of energy produced (Akbulut and Durmus, 2010).

Some researchers have conducted energy analyzes on drying primarily on agricultural products and food products such as potato drying (Akpinar, 2005; Aghbashlo et al. 2008), green olive drying (Colak and Hepbasli, 2007), drying of palm oil coroba (Corzo et al. , 2008), drying of carrots (Aghbashlo et al., 2009) drying Mulberry (Akbulut and Durmus, 2010), drying beans and nuts (Karaguzel et al., 2012), drying wheat (Assari et al., 2013), and drying of seaweed (Fudholi et al., 2014). Information on energy analysis on food drying has been widely described, but the use of energy analysis in continuous system drying is rare.

Energy analysis is a calculation of systems that consume energy that aims to know the balance of energy use, energy conversion equipment efficiency, specific energy consumption. The purpose of this research is to understand the performance of pneumatic dryer for dry cassava drying by performing the energy analysis. Energy efficiency calculations can be used to evaluate the performance of the dryer.

RESEARCH METHODS

Sample preparation

The material used in this experiment is cassava starch, which is taken from Pati, Central Java. Cassava is peeled and cleaned of dirt, then grated and water is added to the grated cassava. After that, the grated cassava is extracted to obtain the starch. The extraction product is filtered to separate the extract and fiber. The extraction fluid is then allowed to stay idle for ± 4 hours to separate the sediment and water part. Water at the top is removed and starch deposit is taken.

Drying equipment

The main equipment in this research is the pneumatic dryer. The schematic diagram of the dryer is shown in Figure 1. Air is streamed using a blower from environment via air filter. The air flow rate is regulated through the scale of the blower openings. Then air is heated with an electric heater. The air will flow upwards towards the drying chamber. From the bottom side of the drying chamber, solids are flowed using a screw conveyor. The solid sample flow rate is regulated by setting the screw conveyor rotary rate. Furthermore, this solid sample will also rise above the drying air to the drying chamber. The length of drying chamber is 1 m. The dryer duct is divided into 5 parts, then each length of part is 0.2 m. At each point has a hole that can be opened and closed to take samples. Samples taken at each of these points are then measured for moisture content. In this holse also is equipped with a thermometer to measure temperature in each section. Finally, the exit air of the dryer is passed to the cyclone (93 cm in diameter) to separate solid sample and air.

The pneumatic dryer is calibrated first before the drying process. Calibration is conducted by turning on the dryer and measuring the temperature and air flow rate until they reach constant values. In the calibration process, the air velocity is measured with anemometer.

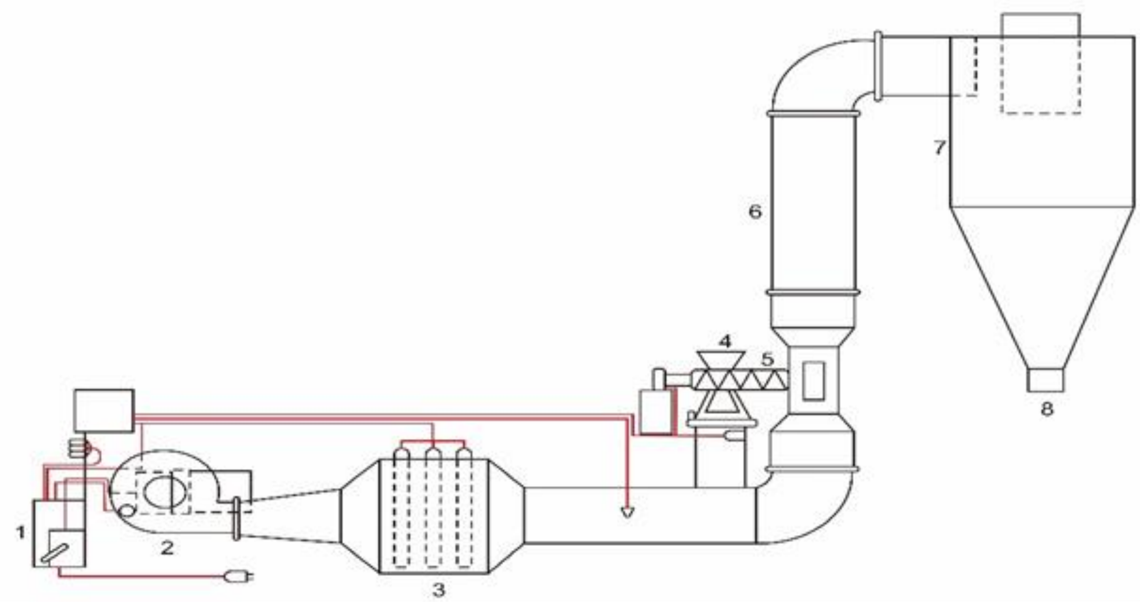


Figure 1. Schematic diagram of pneumatic dryer (1) temperature controller, (2) blower, (3) heater, (4) feeder, (5) screw conveyer, (6) drain dryer, (7) cyclone, (8) output product

Drying procedure

The drying process is carried out by varying the dryer air temperature (60, 70, 80, 90 and 100 ^oC). The solid feed flow rate of 10 g / min is inserted to drying chamber. Before the experiment begins, air temperature and speed are set first. After turning on the blower, set the desired temperature. Wait for a while until the drying air from the blower reaches the desired temperature. The cassava starch feed is inserted after the dryer condition (temperature and air velocity) is constant. The feed from the feeder will then be pushed upward through a cylindrical drying tube with a total length of 170 cm and an inner diameter of 12 cm. During drying, the feeder continuously feeds the wet cassava starch into the drying duct. The measured air temperatures are inlet temperature, temperature in each section of drying chamber, and outlet temperature. The measured air temperatures are dry and wet bulb temperatures using humiditymeter. Out of the drying duct, the dried cassava will be passed to the cyclone to separate the solid from hot air. Further dried cassava starch was collected to be analyzed. The residence time is determined by division of measured air velocity with dryer length.

The variables used in this experiment are drying temperatures (60,70,80,90 and 100 ^oC), feed flow rate (10, 20 and 30 gram/min) and air flow rate (2.8, 3.7, 4.1 and 5.1 m/s). Cassava starch with 300 g of weight is used for each variable. 60 minutes drying time for each variable is applied, and moisture content of cassava is measured every 5 minutes.

Analysis Method

Calculation of energy analysis with Energy analysis method following the formula derived by Aviara et al (2014). EU (Energy Utilization) can be determined by applying the first law thermodynamics

$$EU = Ma\ (hai - hao) \qquad (1)$$

where hai is the air dryer enthalpy at the inlet temperature (J / kg) and hao is the air dryer enthalpy at the exit temperature (J / kg) and the EU is Energy Utilization (J / s)

The mass flow rate can be calculated using the equation:

$$Ma = \rho a\ Va \qquad (2)$$

where ρa is the density of dry air in kg / m3, Va is the volumetric air-drying rate in m3 / s. The enthalpy of drying air at the entry and exit temperature of hi and ho can be calculated by the equation:

$$h = Cpa\ Tda + W\ hsat \qquad (3)$$

where Cpa is the specific heat of dry air in J / (kg ^oC), T is the drying air temperature in ^oC, W is the ratio of the humidity of water and humidity of drying air (kg H2O / kg da) and hsat is the saturated vapor enthalpy in J / kg

The specific heat of the dryer air can be calculated by the equation:

$$Cpa = 1.0029 + 5.4 \times 10\text{-}5\ Tda \qquad (4)$$

The ratio of energy utilization can be calculated using equation:

EUR = Ma.(hai-hao) / Ma.(hai-ha∞) (5)

where EUR is the ratio of energy utilization and ha is the enthalpy of the drying air at ambient temperature (J / kg)

The energy efficiency (%) can be calculated using the ratio of energy used and given energy:

ηE = [(Ei - Eo) / Ei] * 100 (6)

Ei is the incoming energy and Eo is the energy output.

RESULTS AND DISCUSSION

Effect of temperature on the drying curve

The average baseline moisture content on wet cassava prior to insertion into a pneumatic dryer is 40%. The influence of drying air temperature along the drying chamber to the cassava drying curve is shown in figure 1. The drying air temperature is defined as the average air temperature used to dry the amount of material measured in the drying chamber. During the drying process, the temperature of drying air plays a significant role in the evaporation process of water, whether on the surface of the material or on the inside of the material. The dryer air temperature should be adjusted as high as possible without exceeding the critical limits of thermal sensitivity of the material, this is done so that the quality of the material during the drying process can be well maintained. The drying curve shows the change in moisture content in the cassava floor along the drying chamber with different drying conditions. In the experiment, the operating temperature of the dryer air was varied at 60, 70, 80, 90, and 100 ^{o}C. Within every 5 minutes, the moisture content along the dryer duct is measured.

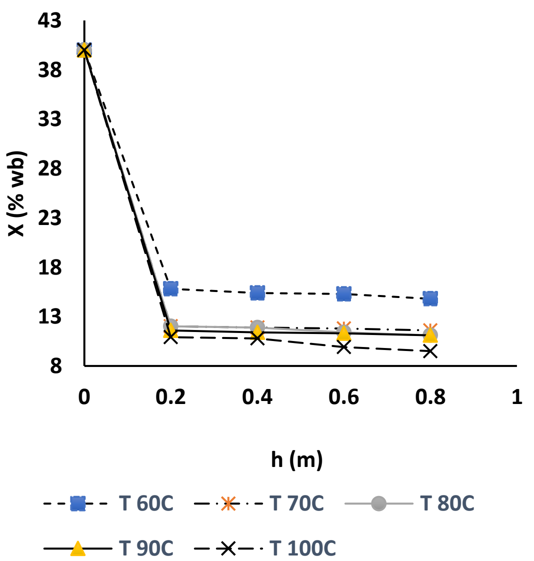


Figure 2. Effect of dryer air temperature on the moisture content profile of cassava starch along the dryer duct (10 gr/min)

The results showed that there was a decrease in the drying curve along the drying duct (altitude 0.2-0.8 m) at each drying air temperature. The cassava's moisture content of each temperature decreased significantly on the duct of 0.2 m until a constant drying occurred at 0.8 m duct. The drying curve shows a decrease in cassava moisture content along the dryer duct until the small decrease is almost constant. The drying curve at the dryer temperature of 100°C has the fastest moisture decline The mean final moisture content reached 9.5% at a temperature of 100°C, with solid feed rate of 10 gr/min and an inlet air opening rate of 0.25. This is because the higher the air temperature of the dryer, the higher the driving force to remove the moisture content in the product. This result is in accordance with the research on cassava drying by means of continuous fluidization fluidized bed fluid dryer at a drying distance divided into 3 zones of decreasing moisture content throughout the zone (Suherman, 2006).

Effect of air flow rate

In this study, variations were made to the air velocity of the dryer as a heat carrier medium. Air velocity variation is carried out by arranging the air inlet opening located on the front side of the blower, i.e. by using the cover plate with 4 openings variation ie openings 0.25 (2.8m / s) 0.5 (3.7m / s), 0.75 (4.1m/s) and 1 (5.1 m/s).

The larger the air inlet opening, the air velocity exhaled by the blower will be higher. In order to achieve an efficient drying process, the dryer airflow rate used should be greater than the minimum speed required to remove the material. So the determination of the air velocity to be used to dry a material must be observed. The air velocity exhaled by the blower must be greater than the free fall speed of the particles to be dried (wet material).

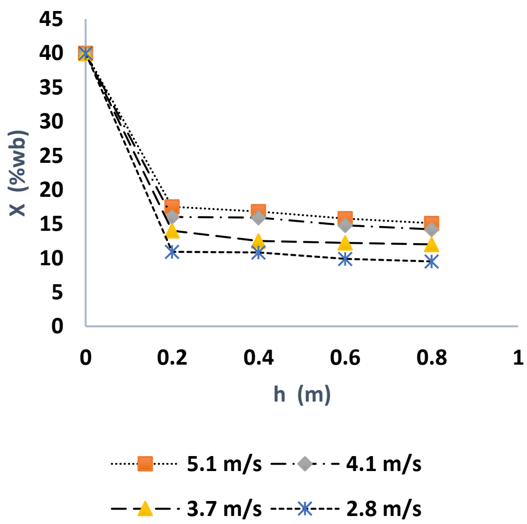


Figure 3. Effect of air-drying inlet openings on the moisture content profile of cassava starch along the dryer duct (10 g / min)

Airflow rate during the drying process using pneumatic (flash) dryer should not be too low or too high. At a low speed, the material particles cannot be lifted by the airflow, so the drying process cannot run perfectly. If the air velocity is too high, the heat contact between dry air and the material will be too short, therefore the drying process becomes ineffective because only a small amount of water is vaporized, and the final water content of the product is usually still high. This phenomenon is in accordance with research performed by Nugroho (2012) on drying cassava with pneumatic dryer that the higher the rate of air flow rate then the moisture content is getting bigger, this is because the contact between hot air and solids is shorter, so the drying is not optimal

Effect of feed flow rate

This cassava drying research applies a continuous system. Cassava starch with moisture content ± 40% is fed continuously into the dryer. The cassava flow rate is varied by 10 gr / min, 20 gr / min and 30 gr / min.

The drying curve shows that the feed flow rate of cassava starch may affect the moisture content along the drying duct in dry cassava products. Figure 4 shows that if more cassava is fed to the dryer, the decrease of water content will be longer to reach a constant value. This is due to the faster saturation of dryer air. At the same drying capacity, the higher addition of wet cassava feed will saturate the drying air faster. This saturation will cause longer drying time, because the drying air will need more time to decrease the moisture content in the cassava. This trend is similar to research performed by Temple et al. (2000) where feed flow controlling is necessary to control the final moisture content of the product.

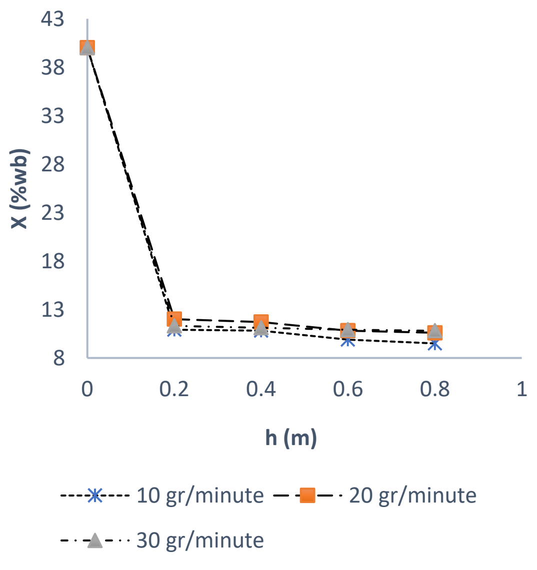


Figure 4. Effect of solid feed flow rate on the water content profile of the material along the dryer duct (100°C)

Volumetric water evaporation rate (N)

Volumetric water evaporation rate (N) increases with increasing air temperatures because higher air temperatures will lead to greater difference between air temperature and starch surface temperature, which is the driving force for heat transfer.

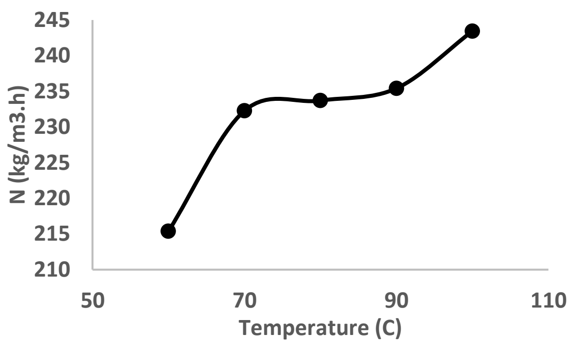


Figure 5. Effect of temperature on volumetric water evaporation rate

Changes in air temperatures will lead to clearer changes in moisture levels. Increased feed flow rates at a constant temperature will cause a volumetric increase in the rate of water evaporation. Despite using a lower drying temperature, the final moisture content of cassava starch obtained by using a pneumatic dryer system is acceptable. This indicates significant energy saving potential.

Energy Utilization

The energy utilization variation on drying cassava using pneumatic dryers with an air temperature of 60 - 100 ° C is shown in Figure 6. This energy analysis uses the data obtained from the experiment. The picture shows the effect of temperature on energy utilization where energy usage increases as drying air temperature increases. The higher the temperature indicates that more moisture is evaporated. This is due to the high temperatures causing heat transfer.

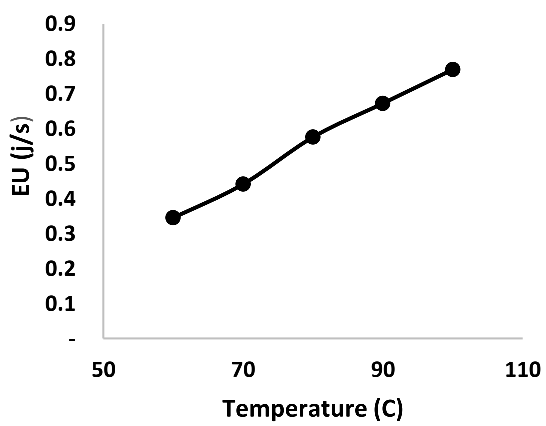


Figure 6. Effect of dryer air temperature on cassava starch energy utilization

Also, longer drying time will increase the usage of energy in reducing the product water content, proven by the average energy usage obtained from the experiment, from 0.34 to 0.76 J / s. The energy used in this study shows a relation that is directly proportional to the drying air temperature. The results of this study are similar to the results of drying cassava research using a drying rack by Aviara et al. (2014) and carrot drying using continuous band dryer by Aghbashlo et al. (2009).

Energy efficiency

Figure 7 shows the effect of increased drying air temperature on energy efficiency. Energy efficiency to dry cassava starch were increased from 30% to 40% at a temperature increase of 60-100^{o}C.

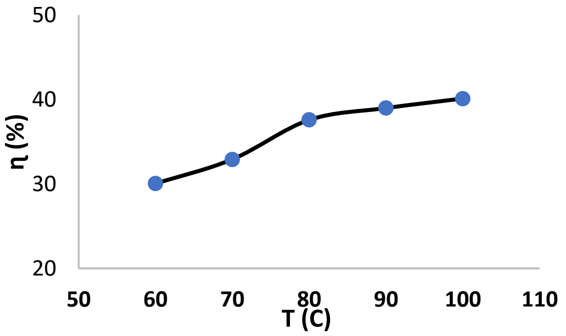


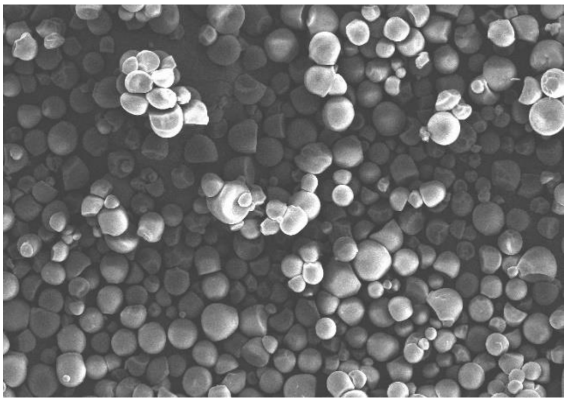
Figure 7 Effect of dryer air temperature on energy efficiency

The increase in energy usage per temperature will cause the efficiency of energy used to dry cassava to increase. The effectiveness of energy usage is influenced by the energy used from the available energy. Researches performed by Aviara et al. (2014) and Assari et al. (2013) also showed a similar effect between increased drying air temperature and energy efficiency. The same trend is indicated by all types of dryers (convective dryers, microwave dryers, vacuum dryers, solar dryers, and dryer joints) that energy efficiency increases with increasing dryer air temperature (Motevali et al., 2014).

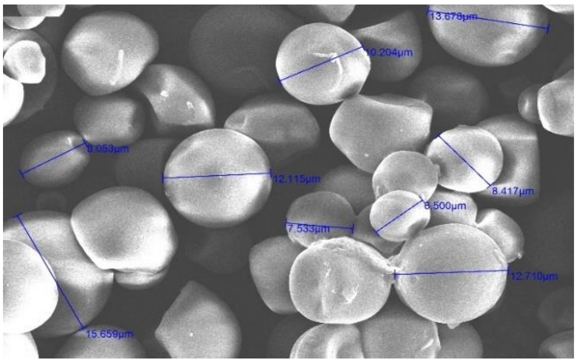
Characterization of cassava starch

Determination of the characteristics of the material structure, either in solid or particle, crystalline or amorphous form can be done using Scanning Electron Microscopy (SEM) and X-Ray Diffraction (XRD) tools. Structure analysis of nano-sized objects requires a microscope with high resolution. The electron microscope used in SEM analysis is able to see objects at 200 nanometers because it has electron beams whose wavelengths are shorter than light. SEM and XRD result of scanning electron microscopy (SEM) test can be seen in Figure 8. In SEM result with 2000x magnification, it can be seen that cassava starch granules have mostly spherical shape with average particle diameter of 12 μm. This size of starch is smaller than size starch produced by Aviara et al. (2010) using a rack dryer or Suherman (2016) using a fluidized bed. This proves that the pneumatic dryer is able to break the granules into smaller ones. Differences in the size of starch are affected by the condition and harvesting time of cassava. The average size of 15 μm granules has a 14 months harvest time while the mean size of 12 μm granules has a 16 months harvest time whereas in the average diameter starch is 23-30 μm. The granular shape indicated by SEM results is similar to that of starch granules in general that is round and oval.

Electromagnetic radiation has an important role in the analysis of crystalline solids using diffraction methods. Electrons shot in a vacuum will produce X-rays. X-rays that have shorter wavelengths of visible light can create a line spectrum according to the characteristics of the shot metal. In Figure 9, X-ray diffraction test results using 1.5406 A^o wavelength indicate the strongest peak of cassava are located at 17.21; 18.09; 23.06^o. Based on Join Committee Powder Diffraction Spectro # 46-1978 it can be seen that this cassava starch structure is a type of Orthorhombic crystal structure (ICDD, 1997). From the data generated by the XRD test, the average crystallite size can also be calculated using the Deby Schrerrer equation. The starch crystal size obtained is 41,376 nm.



(a)



(b)

Figure 8. Result of cassava characterization using SEM (a) 500 x and (b) 2000x magnification

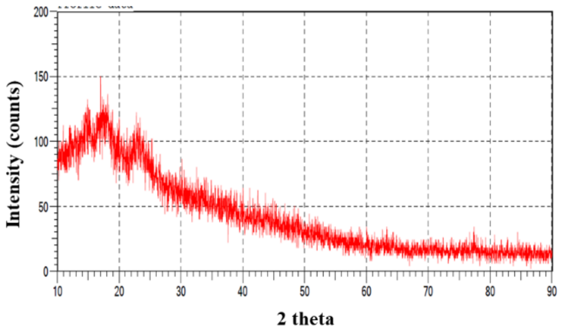


Figure 9. Result of cassava characterization using X-Ray Diffraction

Quality of Cassava Products

Table 1 is the result of cassava quality testing. The quality of cassava starch is determined by the standard requirements for the resulting cassava starch product to reach the marke, whether domestically or overseas.

Table 1. presents the results of the feasibility test of cassava quality

Test criteria	Unit	Require-ments	Test Result
color	-	White	White
Water content (b/b)	%	Max.14	±11,47
Ash (b/b)	%	Max. 0,5	0,24
Coarse fiber	%	Max. 0,4	0,12
Starch	%	Min. 75	87,24
White degrees (MgO = 100)	-	Min. 91	98,82
Protein	b/b		0,66
Fat	b/b		1,63

The criteria of cassava qualities can be seen from the result of physical analysis (color), proximate analysis (ash content, fiber, starch content, protein content, fat content), physicochemical analysis (whiteness degree). The results show that all test criteria have met the cassava quality standards as food products. Cassava starch is made by extracting the cassava bulbs. If the manufacturing process is done correctly, the starch product will be clean white (Moorthy, 2004). Based on the degree of whiteness, the white cassava starch has better quality. The test results showed that the white grade of cassava product has fulfilled the requirement, which is 98, while the standard value governed by National Standard of Indonesia (SNI) is 91. The whiteness degree of cassava starch products is important, considering that it is frequently used as a raw material of natural white dye in the food and textile industry.

One process of cassava starch which may cause different values of ash content is starch extraction stage. The minerals contained in the cassava can be wasted along with the dregs from the starch extraction process, so that the measured ash content becomes lower. The amount of fiber and impurities affects the quality of cassava. The test results showed that the cassava fiber content obtained is 0.12, which is lower than the standard value (max. 0,4). The more fiber and impurities it contain the lower the quality, while higher viscosity value of cassava indicate a good quality.

CONCLUSIONS

The results of the cassava starch proximate analysis used in drying research using pneumatic dryers showed that starch had a starch content of 87%, 98% whiteness, and 0.12 fiber content.

Energy analysis of the drying process indicates that (i) the energy usage increases with increasing temperature, (ii) the higher the temperature the moisture content will be lower (iii) the air flow rate is very important because if it is too low, the material cannot be lifted by the airflow, if it is too high, it will cause the heat contact between dry air and the material to be short (iv) the higher the temperature the more energy utilization increases.

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