Characteristic of Comparison Partially Pregelatinized Starch and Fully Pregelatinized Starch from Cassava Starch

Aton Yulianto, Sigit Purwanto, Ferdy Pradana, and Galuh Hendhitya Wicaksono

Abstract—**Modified starch from cassava starch is still rarely developed in the pharmaceutical industry. Various modifications of cassava starch are needed, in order to improve the starch properties according to the application. This research was conducted to evaluate the physico-chemical and functional characteristics of Partially Pregelatinized from Cassava Starch (PPCS), Fully Pregelatinized from Cassava Starch (FPCS) and Starch 1500 as a benchmark. Analysis includes bulk density, tapped density, cold water soluble, whiteness, birefringence properties, loss on ignition, viscosity, compressibility, angle of repose and flowability. The results show that the bulk density of the PPCS is greater than the bulk density of the FPCS. While tapped density from PPCS is bigger than tapped density from FPCS. Cold water soluble percentage of FPCS indicates a higher value than the PPCS. The results of microscopic observations showed that PPCS and Starch 1500 still had intact granules, where as FPCS all granules were not intact. When polarized, most of the PPCS and the birefringence properties of Starch 1500 is still visible, while the FPCS all birefringence properties have been lost. PPCS has good compressibility, while Starch 1500 has a pretty good compressibility, The angle of repose of PPCS is very good while the FPCS is good. The flow rate of PPCS is good but the FPCS is very difficult to flow.**

Index Terms—**Cassava starch, partially pregelatinized starch, fully pregelatinized starch, functional characteristics.**

I. Introduction

Natural resources, especially cassava starch, have great potential to be developed as industrial raw materials. Production of cassava in Indonesia in 2011-2015 averaged 23.9 million tons per year [1]. However, native starch has weaknesses in specific characteristics, including high viscosity, retrogradation, compressibility and poor of flow rate. Therefore, further modifications are required to obtain certain specific characteristics that suit the user. Modified starch is commonly used by the paper and food industry.

Modification of starch can be done by physical, chemical, enzymatic and biological methods. In general, physical modifications are carried out by heating and mechanical friction. This physical modification process aims to determine the characteristics of starch which is adjusted to the treatment temperature, heating time, and water content during the treatment process [2]. Pregelatinized Starch is a physical modification of starch which involves the appropriate temperature to achieve gelatinization conditions. Pregelatinized Starch is divided into two categories, Partially Pregelatinized Starch and Fully Pregelatinized Starch. Partially pregelatinized starch is a modified starch where most of the starch granules are still intact, while Fully pregelatinized starch no longer has whole starch granules. In the modified starch industry, the pregelatinized process can be performed by drum drying or extrusion technology [3].

Extrusion method on starch modification is a mechanical process that involves the transfer of heat, pressure and shear forces on the materials to produce products with different functional properties. In addition, the shape of the screw and the rotation speed also affects the performance and productivity of the extruder. Extruder flexibility to process various kinds of raw materials, can expand its application to various types of modified products from starch [4]. Pragelatinized starch produced extrusively, has a large decrease in molecular weight of amylose and amylopectin, while pragelatinized starch produced in drum dryers has a lower intrinsic viscosity to native starch [5].

Drum dryer technology is a physico-chemical modification of native starch. The process of pregelatinization using a drum dryer produces products in the form of thin sheets. This starch modification process runs continuously starting from the gelatinization stage until drying. The heat source of the drum dryer from the steam transferred through the drum surface to the paste material. During the drum dryer operation, input parameters such as steam pressure, drum rotation speed and pregelatinization puddle slurry level have complex interactions. When the drum speed increases, the vapor pressure response used for the drying process will be different. The input parameters affect temperature changes significantly. When vapor pressure increases, moisture content, mass flow rate and specific dry product load will decrease.

The characteristics of pregelatinized starch products determine the suitability of the application in the industry. Based on the above description, the selection of pregelatinized starch production process technology, either extruder technology or drum drier, will produce significantly different characteristics of pregelatinized starch products. Therefore, it is necessary to compare the characteristics of pregelatinization starch from cassava using extruder technology and drum dryer. As a comparison, commercial pregelatinized starch product was chosen, starch 1500. The

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characteristics observed were physical, chemical and functional characteristics of pregelatinized starch. Physical characteristics are bulk density, tapped density, cold water soluble, whiteness, and birefringence. Chemical characteristics are loss on ignition, and viscosity. While the functional characteristics are compressibility, angel of repose and flowability.

II. Methodology

A. Material

The raw material used in this study is cassava starch obtained from the National Laboratory for StarchTechnology and starch 1500 from PT Mensa.

B. Equipment

The first equipment used for this research was an extruder machine with type DS 50-IIIA. Capacity production for pregelatinized production of this type extruder machine is 12.5 kg/hr. The second equipment for this research was the drum dryer machine. Capacity production for pregelatinized production of this type odrum drier machine is 50 kg/hr.

C. Production Procedure of Pregelatinization Starch

The production of pregelatinized starch from cassava starch was carried out through two different machines. The first machine is an extruder machine that is used to produce Partially Pregelatinized Starch from Cassava Starch (PPCS). the second machine is a drum dryer machine that is used to produce Fully Pregelatinized Starch from Cassava Starch (FPCS). The initial stages of PPCS production using an extruder machine are cassava starch preparation with a water content of 30%, then cooked using a mixer - steamer machine. The controlled process conditions include 3 bar steam boiler pressure and stable material temperature at 70 to 75 ℃. This mixer has an agitator which functions to stir the ingredients to homogeneous.

The process is continued by using a twin screw extruder machine. The cooked starch is fed to the twin screw extruder, with the specified process parameters. The heating temperature for the first heating zone and the second heating zone is 45 ℃, while the temperature for the third heating zone is 55 ℃. At the extruder output a mold head is installed which functions as a pressure change. This machine is equipped with a rotating blade that functions to cut extrudates. So that the pregelatinized starch product obtained is flake. The PPCS drying and grinding process uses a mill dryer machine, so that a fine and white flour product is obtained.

FPCS production using a drum dryer machine is started by preparing steam which is used to transfer heat to the drum dryer machine. The temperature and steam pressure required are 140 ℃ and 4 bars. The next process dissolves cassava starch with cold water in a ratio of 1:1.5. The process of dissolving water and cassava starch is carried out in a stirred tank so that it is completely dissolved and no longer forming starch deposits. Starch solution can be fed if the operating temperature on the drum dryer surface has been reached 80 ℃. Drying of FPS products occurs on the surface of the drum dryer. Then the product was ground using mill disk to obtain a product that was in the form of fine powder, white and lighter.

III. Results and Discussion

The physical, chemical and functional characteristics of PPCS, FPCS and Starch 1500 products are shown in Table 1. Results of bulk density PPCS measurements were 0.8 g/ml and tapped density of 0.65 g/ml, while FPCS bulk density was 0.5 g/ml and tapped density of 0.4 g/ml. Starch 1500 benchmark has a bulk density of 0.5 g/ml and tapped density of 0.4 g/ml. Bulk density PPCS is greater than the bulk density of FPCS, this is influenced by the increase in pressure and temperature of cassava starch during the extrusion process. In addition, moisture dough material is a factor that can affect mass density [6]

TABLE I: Characteristics of PPCS, FPCS and Starch 1500

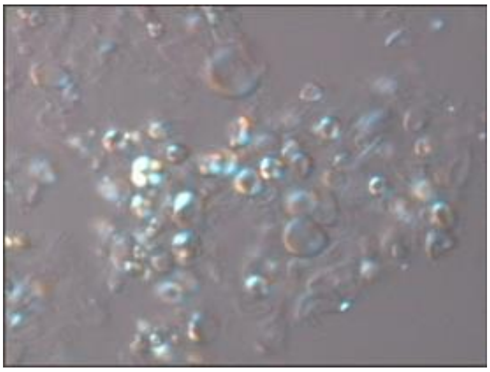
No	Parameter	PPCS	FPCS	Starch 1500
1	Bulk density (g/ml)	0.8	0.5	0.9
2	Tapped density (g/ml)	0.65	0.4	0.65
3	Whiteness (%)	86	56.3	-
4	Cold water soluble (%)	19.5	59.7	15
5	Loss on ignition (%)	0.18	0.16	0.15
6	Viscosity (cP)	100	10,000	800
7	Compressibility (%)	15.3	24.2	20.42
8	Angel of repose (°)	21.4	29.1	28.22
9	Flowability (g/s)	5	1.45	2

The bulk density of PPCS shows greater than the FPCS, this indicates that PPCS products are heavier than FPCS products. In addition, the bulk volume of FPCS products is greater than the bulk volume of PPCS. A smaller bulk volume will produce a large bulk density. While tapped density is a material's ability to compress themselves to the fullest. Tapped density of PPCS is greater than FPCS, because the FPCS's incompressible volume produces smaller tapped density.

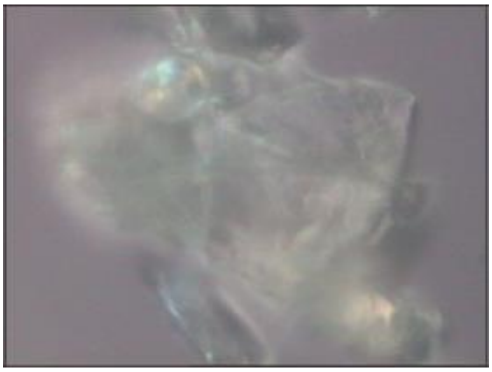
The whiteness measurement results in Table 1 show that PPCS products have a higher whiteness value (86%), while FPCS products are only 56.3%. This is due to the influence of temperature during the FPCS production process. The temperature of the gelatinization process in the drum dryer reaches 80 ℃, while the extrusion process temperature is 55 ℃.

The percentage of cold water soluble FPCS products (59.7%) showed a higher value compared to 19.5% PPCS products. This is due to the influence of temperature and the addition of water during the starch pregelatinization production process using a drum dryer machine. In addition, the breakup of hydrogen bonds, which functions to stabilize the starch structure during the heating process, makes starch granules expand and easily dissolve in water.

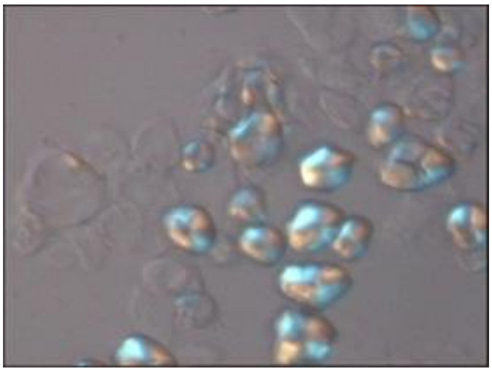
The results of polarization microscope observation, especially birefringence, on PPCS, FPCS and Starch 1500 products can be seen in Fig. 1. Fig. 1 shows that there are still intact granules in PPCS and Starch 1500 products. While FPCS products, intact starch granules and starch granules are also has lost the properties of birefringence. The temperature in the FPCS production process exceeds the temperature of the gelatinization, causing massive damage to starch granules which impact to the loss of birefringence properties.



(a) PPCS



(b) FPCS



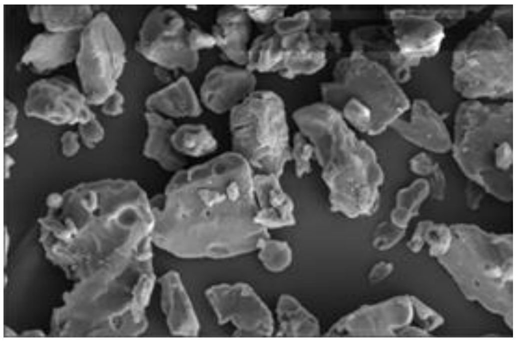
(c) Starch 1500

Fig. 1. Properties of birefringence (400x magnification).

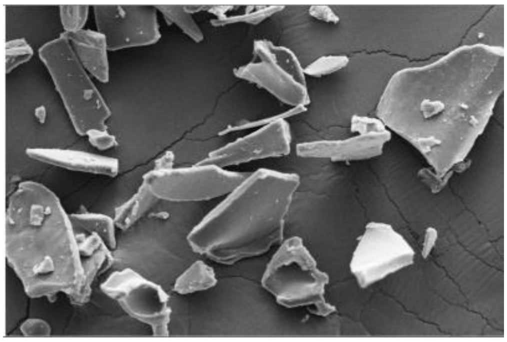
The test results of residual on PPCS products are 0.18%, FPCS 1.16% and starch 1500 by 0.15%. This shows that there is no significant difference in the total ash content of all these products. So that the ash content does not affect the properties of the product. The fourth edition of Indonesian Pharmacopoeia requires that the total ash content in cassava starch should not exceed 0.6%. Viscosity measurements obtained results are PPCS 100 cP, FPCS 10,000 cP and Starch 1500 800 cP. FPCS products have high viscosity so that they can affect the flow velocity pattern. Because the viscosity of the material is thicker, the flow rate decreases.

The results of the compressibility calculation show that each product has good compressibility. PPCS products have good compressibility, while the 1500 starch is categorized quite well. The compressibility value has a correlation with the bulk density and tapped density values. FPCS products have great compressibility (24.2%). These results indicate that the FPCS has very difficult flowability, thus allowing the aplication as an additional tablet material using wet granulation method [7].

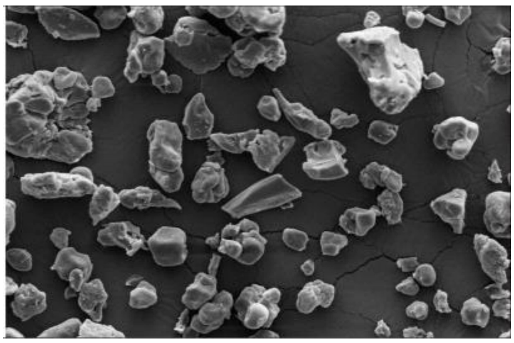
Results Measurement of angle of repose for PPCS obtained 21.4 °, FPCS 29.1 ° and Starch 1500 28.22 °. The angle of repose value of the PPCS is categorized as very good while the angle of repose from the FPCS is categorized as good. This shows that physical modification using extrusion technology can improve the angle of repose properties of PPCS and FPCS products. Even the angle of repose value of PPCS is better than Starch 1500. PPCS flowability measurement is 5 g/s and categorized as having good flow properties. while FPCS 1.45 g/s flowability and categorized as having flow properties are very difficult. If both are compared with Starch 1500 which has a flowability value of 2 g/s, PPCS has better flow properties while FPCS has worse flow properties. FPCS products are very difficult to flow because they are influenced by the properties of light materials.



(a) PPCS



(b) FPCS



(c) Starch 1500

Fig. 2. Scanning Electron Microscope photos.

Changes in the granule structure of PPCS, FPCS and starch 1500 products can be seen from the results of SEM (Scanning Electron Microscope) can be seen in Fig. 2. The structure of the PPCS granules undergoes a change in shape, in the form of holes on the surface and also debris. This condition is similar to the 1500 starch granule structure. Whereas in the FPCS, the starch granule structure undergoes extreme changes. The structure of FPCS starch granules forms thin plate flakes. This is due to an increase in temperature and excessive amount of water which causes the granules to expand and amylose begin to diffuse out of the granules. In addition, the setting of the heating zone temperature and screw speed during the extrusion process also greatly affect the degree of starch gelatinization.

IV. Conclusion

1) The pregelatinized starches that have been observed are Partially Pregelatinized Starch from Cassava Starch (PPCS) and Fully Pregelatinized Starch from Cassava Starch (FPCS)
2) Results of bulk density PPCS measurements were 0.8 g/ml and tapped density of 0.65 g/ml, while FPCS bulk density was 0.5 g/ml and tapped density of 0.4 g/ml
3) PPCS products have a higher whiteness value (86%), while FPCS products are only 56.3%.
4) The percentage of cold water soluble FPCS products (59.7%) showed a higher value compared to 19.5% PPCS products
5) PPCS and Starch 1500 have intact starch granules, while FPCS has starch granules that are not intact.
6) PPCS and FPCS have good compressibility, while the compressibility of the 1500 starch is categorized quite well.
7) Angle of repose from PPCS is categorized as very good while the angle of repose from FPCS is categorized as good.
8) PPCS has better flow properties than Starch 1500 while FPCS has worse flow properties than Starch 1500.

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