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Physical and chemical properties of corn, cassava, and potato starchs

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Abstract. Starch-based plastic is developed for petroleum-based plastic material replacement. Thus, basic knowledge of starch properties is important. This research aimed to evaluate the physical and thermal properties of various potential starch, i.e. corn, cassava, and potato starch. Granule size, thermal property, and functional group of starch were determined by optical microsopy, DSC, and FTIR, respectively. Our results demonstrated that the properties of starch (e.g. granule morphology and thermal property) varied according to its different sources. Potato starch has a bigger granule size and lower gelatinization temperature compare to corn and cassava starch. This implied that the granule size of starch affected gelatinization temperature. The larger the granule size, the more easily the starch to be gelatinized.

1. Introduction

Plastic consumption in Indonesia in 2014 is about 4.2 million tonnes or approximately 10 kg per capita per year [1]. Indonesia Plastic Association (Inaplast) estimates that these numbers will increase up to 7 million tonnes by 2018 [1]. Meanwhile, more than 99% of plastic raw materials are still dominated by petroleum [2]. Several commonly used plastics such as polyethylene (PE), polypropylene (PP), low density polyethylene (LDPE), high density polyethylene (HDPE), and polyvinylchloride (PVC) have caused abundant of waste which cannot be decomposed. It will accumulate and causes environmental pollution [3,4]. In addition, due to the non-renewable resources, these plastic materials are constantly diminished in the nature [5]. In terms of environmental and sustainability issues, therefore, it is urgent to develop biodegradable plastic as a substitute for non-biodegradable conventional plastic.

Starch as a common polysaccharide is a polymer made of large number of saccharide molecules and potential to be developed as biodegradable plastic [6-10]. Starch is available in nature from various types of commodities such as corn, cassava, and potato. Structure of starch is a semi-crystalline granular shaped molecule composed of two types polysaccharides namely amylose and amylopectin. Amylose has relatively straight chain structure, whereas amylopectin is a polysaccharide molecule that has a branched chain structure [10]. The size and shape of the starch granules is determined by the branched structure of amylopectin rather than amylose. While the strength of the starch granules is determined by the degree and value of the polydispersity index of amylose [11]. The ratio between amylose and amylopectin in every starch's granule depends on the type of starch. However, in general, starch contains 75-80% amylopectin. The amount of amylose is smaller than amylopectin due to molecular size of amylose which is smaller than amylopectin [12].

The small granular size of amylose and amylopectin allows them to link with protein matrix, and changes their thermal properties such as gelatinization temperature. This will lead to reduce the quality of plastics made [13]. The size and shape of granular particles will vary depending on the source and part of the plant. Furthermore, plants with the same variety can produce different sizes and shapes of granules depending on the growing conditions of the plant [14].

In the manufacture, the size of the granules will affect the bioplastic properties. The larger the granule, the thicker the bioplastic could be made, and further lowering strength, elongation, and tensile strength [15]. Herein, we report the granule morphology, thermal property, and a range of functional groups of three types of potential local starches (i.e. corn, cassava and potato). We have shown that these three starches exhibited different morphology structures and gelatinization temperatures.

2. Method

2.1. Materials

All chemicals and reagents were used as received. Corn, cassava, and potato starch were purchased from PT. Markaindo Selaras, PT. Budi Starch, and PT. Makmur Food, respectively.

2.2. Starch characterization

The size distribution of starch granules was examined using Optical Microscope (OM) Type Meiji Techno MT6000 combined with ImageJ software. About 1 mg of starch powder was fixed on microscope glass holder. The thickness of powder layer was made as thin as possible (< 0,1 mm) for clearly observation. The starch granules were observed by using a white light of optical microscope. The obtained data was then processed by ImageJ software to get the granule size distribution.

The gelatinization temperature was determined using Differential Scanning Calorimetry (DSC, NETSCH DSC 214). The sample was suspended in distilled water with mass ratio 1:1 (starch:H_2O) and then put into the aluminum crucible as much as ~5 mg for DSC experiment. The temperature range of DSC experiment was 30-100 °C with the heating rate 5 °C/min.

To evaluate and identify the functional group of starch, the Fourier Transform Infrared (FTIR, Shimadzu IR Prestige-21) technique was utilized. In this experiment, the starch powder was used as received.

3. Results and Discussion

3.1. Morphology of starch's granule

The OM image, which is presented in Figure 1, reveals that each starch possess a different granule shape and size. However, the surface of the corn and cassava granules (Figure 1a and b) are almost similar which tended to separate from each other and had the shape of oval - angular - spherical. Meanwhile, the shape of the potato granules tend to be ellipsoid and oval (Figure 1c). The analysis by using Image J software resulted distribution and average of granule size of corn, cassava and potato starches are 15.9, 15.3, and 26.9 µm, respectively ((Figure 2). As shown in Figure 2a and b, the size distributions of corn and cassava granules were medium and narrow distribution. Whereas, potato granules were bimodal with two general distribution namely medium and large distribution at 8-40 and 50 µm, respectively. The overall results of this experiment inform that the smallest granular size was owned by cassava starch, followed sequentially by corn and potato starch.

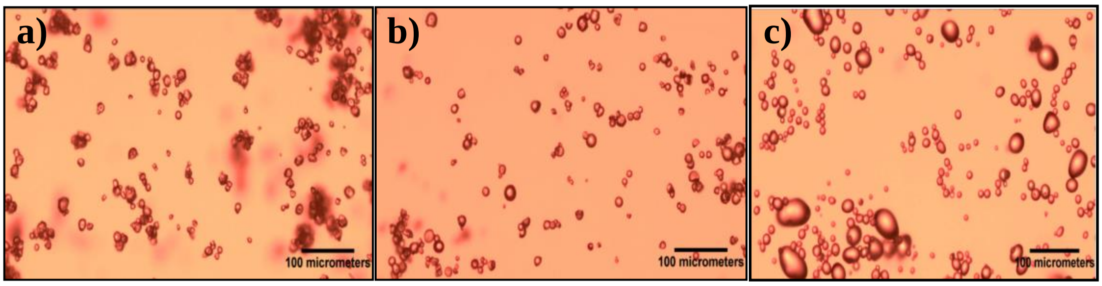

Figure 1. OM image of various types of starch: a) corn starch, b) cassava starch, and c) potato starch.

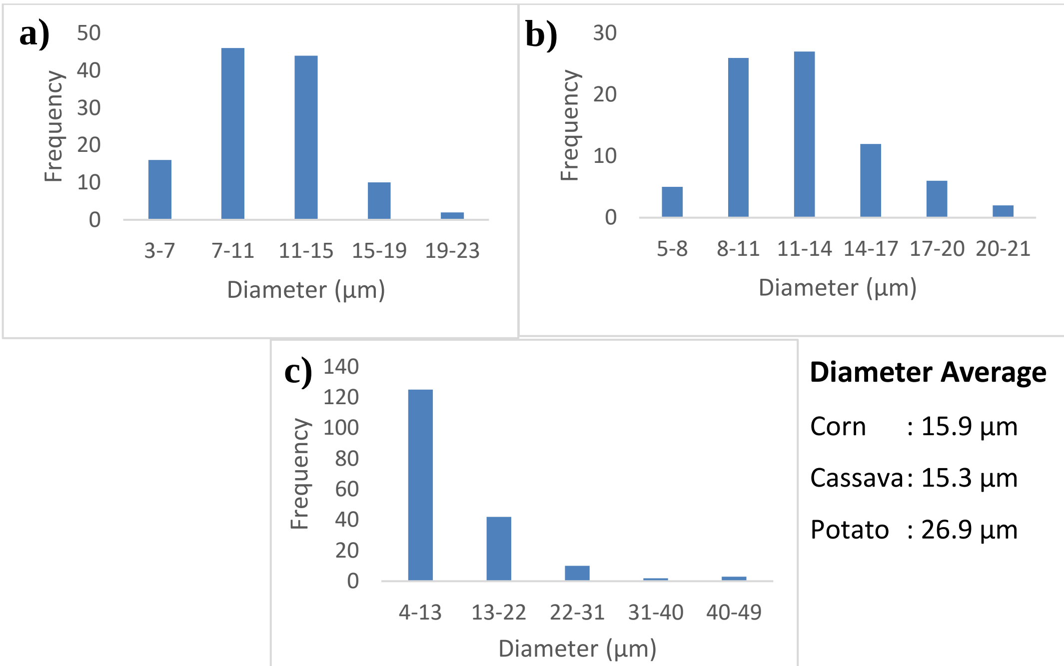

Figure 2. Distribution of granule size of various types of starch: a) corn starch, b) cassava starch, and c) potato starch.

3.2. Thermal properties of various types of starch

Gelatinization of starch is indicated by the thermal property as shown in Figure 3. The lowest gelatinization temperature is shown by potato starch, approximately 62 °C, whereas corn and cassava starch at about 66 and 68 °C, respectively. Higher of temperature gelatinization derived from a higher degree of crystallinity, which provides thermal stability of granule against gelatinization. Crystallinity is influenced by chain length of amylopectin [16,17]. The smaller the starch granule, the higher the gelatinization temperature.

In the bioplastic production, the gelatinization temperature of starch is crucial. If the gelatinization temperature is too low (≤ 60 °C), the starch slurry might be gelatinized in the drying process and this condition is undesirable. Conversely, if the gelatinization temperature is too high, it causes the high energy consumption in the bioplastic production.

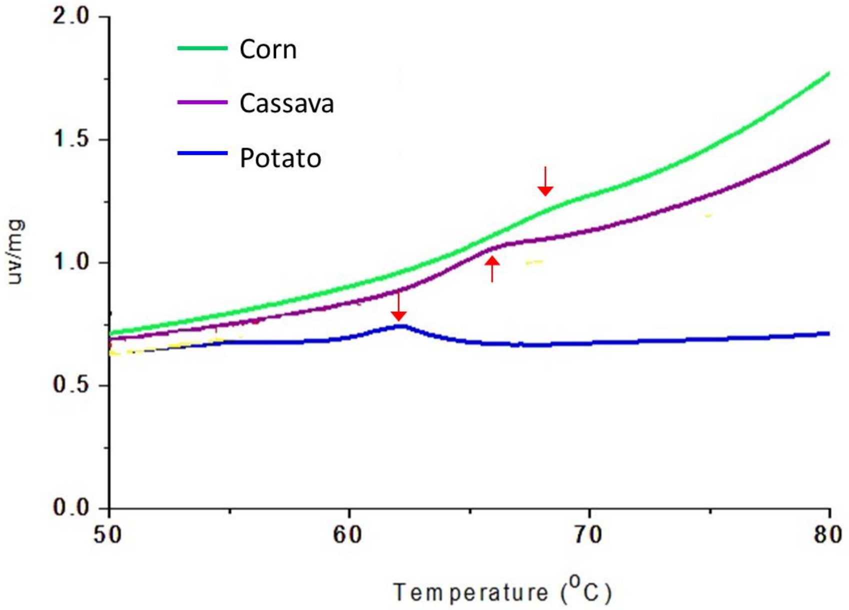

Figure 3. DSC spectrum of corn, cassava, and potato starch. Red arrow denotes the gelatinization temperature.

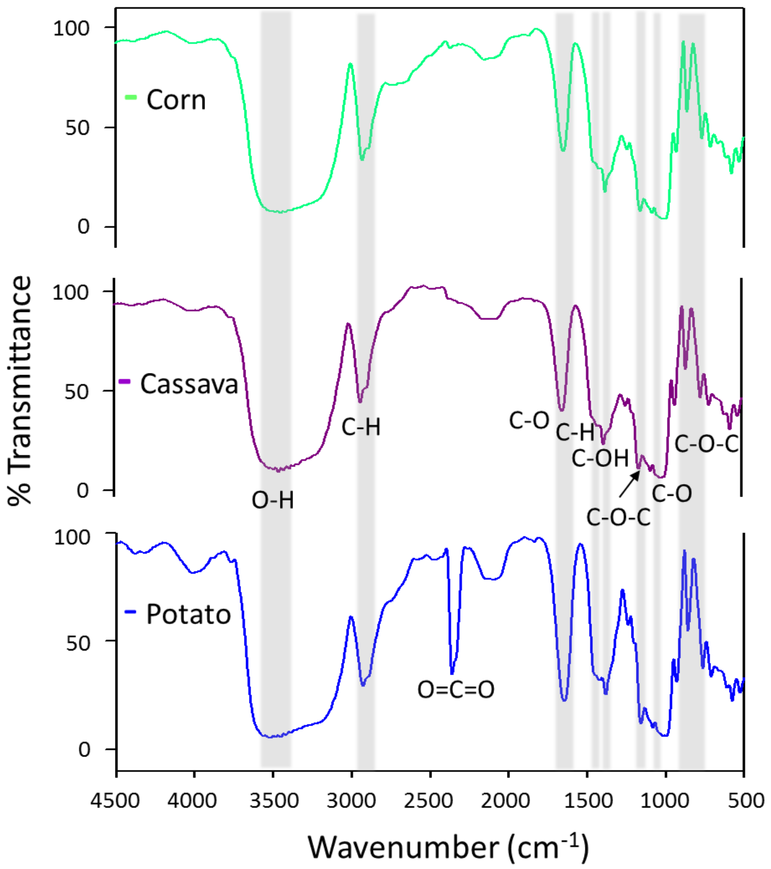

Figure 4. FTIR spectra of corn, cassava, and potato starches.

Table 1. Band assignment of corn, cassava, and potato starches.

No	Functional groups	Wave number literature	Corn	Cassava	Potato
1	O - H stretching	3600 – 3300	3448	3448	3523
2	C - H stretching	2931	2929	2930	2927
3	C-O bending associated with OH group	1637	1647	1646	1645
4	CH_2 symmetric deformation	1458	1437	1437	1437
5	CH_2 symmetric scissoring	1415	1415	1417	1419
6	C -H symmetric bending	1385-1375	1381	1381	1381
7	C - O - C asymmetric stretching	1149	1157	1157	1157
8	C - O stretching	1200 – 800	1082, 1016	1082, 1018	1082, 993
9	C - O - C ring vibration of carbohydrate	920, 856, 758	929,860, 763	929, 860, 763	929, 858, 763
10	O = C = O	2350	-	-	2358

3.3. FTIR analysis
The FTIR spectra of starches are presented in Figure 4 whereas the interpretation of each peak is given in Table 1. As shown in the Figure 4, the presence of absorption band at around 3300-3600, ~2900, ~1150, and 1000-1100 cm^{-1} in the three spectra indicated that all starches possess an OH, C-H, C-O-C, and C-O functional group, respectively. In addition, the characteristic C-O-C ring vibration on starch lead to an absorbance peak at around 700-900 cm^{-1}. The C-O bending associated with the OH group would cause an absorbance peak at around 1648 cm^{-1}. Furthermore, the absorbance peak at 1415 cm^{-1} implied the presence of C-H symmetrical scissoring of CH_2OH moiety. The uncommon CO_2 peak in starch (λ 2358 cm-1) was observed in the potato starch IR spectrum (Figure 4). Its might be results from measuring conditions. From this FTIR analysis, it shows that starch of corn, cassava, and potato possess similar chemical structure.

4. Conclusion
We have demonstrated here some physical and chemical properties of three types of corn, cassava, and potato starch). Those starches have a similar chemical structure. However, compared with cassava and corn, the granule size of potato is the biggest and possessed the lowest gelatinization temperature. The granule size appeared to correlate with gelatinization temperature. The smaller the size of starch granule, the higher the gelatinization temperature. This study provides additional information for bioplastic development in the future.

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