Physical and Functional Properties of Purple Sweet Potato Starch as Affected by Isolation Methods

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Abstract: Purple sweet potato (PSP) is a guber plant which is a potential source of starch. The starch extraction using different methods of isolation will produce starches with different physical and functional properties. In this study, the extraction and isolation process of starches were carried out using water, sodium metabisulfite 2000 ppm, and citric acid 2000 ppm. The resulting starch was analyzed for its physical characteristics including granule shape and size, as well as its functional characteristics including swelling power, water absorption index, and oil absorption index, the viscosity of starch paste, and gelatinization temperature. The results concluded that the starch produced from citric acid isolation had a smaller size of granule, and a higher water and oil absorption index, swelling power, paste viscosity, and gelatinization temperature. Purple sweet potato is a tuber plant which is a potential source of starch.

1 INTRODUCTION

Starch is a plant carbohydrate that is found in corn, wheat, potatoes, rice, and others (Englyst and Englyst, 2005). Starch granules consist of amylose polymers that have straight chains and amylopectin which have branched chains. Root crops such as cassava, yam, and sweet potato are also potential sources of starch for starch-based industries (Moorthy, 2002). The process of extracting starch from tubers through the process of grating, sieving, and sedimentation or centrifugation (Daiuto et al., 2005). Starch quality is influenced by the extraction process and starch source (Liu et al., 2016). Therefore, new starch sources are needed to obtain quality starch that meets industrial requirements.

Sweet potato is the 6th most important food commodity in the world (FAO, 2010). Sweet potato plants are very tolerant of high temperatures, infertile and dry soil conditions (Laurie et al., 2012), so they have the potential to be developed as a source of food raw materials. Sweet potato contains a large number of carbohydrates, especially starch, which is between 25-30%, and 98% of the starch is easy to digest (Antonio et al., 2011). Purple sweet potato (PSP) contains high amounts of starch and anthocyanins (Oswal et al., 2019). The use of purple sweet potato as raw material for starch is still very limited, usually it is still consumed directly with simple cooking or used as flour.

The increasing of PSP starch utilization can be done through suitable starch processing to produce starch with suitable properties for industrial needs (Jangchud et al., 2003). The physical and functional properties of starch are important properties for its application in food and industrial products, such as the shape and size of starch granule, as well as the characteristics of paste and gelatinization (Adebowale and Lawal, 2002). The results of previous studies indicated the isolation of starch from yam can be carried out using alkalis or enzymes (Wang et al., 2011), or using water, oxalic acid or ammonium oxalate, pectin, and sodium hydroxide (Daiuto et al., 2005). Research on the effect of the starch isolation method on the functional characteristics of starch has also been carried out (Babu and Parimalavalli, 2012; Babu and Parimalavalli, 2014; Correia et al., 2012). The current study aimed to study the effect of the starch isolation method on the physical and functional characteristics of purple sweet potato starch.

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2 MATERIALS AND METHODS

Purple sweet potato (PSP) tubers were procuredfrom farmers in Phak-Phak Barat Regency, North Sumatera Province, Indonesia. Isolation agents used in this research were distilled water, sodium metabisulfite, and citric acid.

2.1 Isolation of PSP Starch

PSP tubers were washed and cleaned by using tap water to remove impurities. The cleaned tuber was peeled by using stainless steel knife, and rasping by using a rasping machine. Starch isolation was performed according to Tharise *et al.* (2014) with modification in isolation agent of starch. The starch isolation agents used in this study ware distilled water, 2000 ppm sodium metabisulfite solution, and 2000 ppm citric acid solution. The blending of rasped tubers with starch isolation agents was done at a ratio of 1:3 until fine slurry was obtained. The slurry was filtered using double-layered cheesecloth. The filtrate was settled at 27-30 ºC (room temperature) for 12h. The supernatant was poured and the starch was collected and resuspended in isolation agent solutions for 3h at room temperature to settle. This process was repeated three times until the white wet starch sediment was obtained and collected. The wet starch was dried in a convection oven at 50 ºC for 12h and then cooled to room temperature. The dried starch was pulverized and sieved through an 80-mesh sieve, packed and sealed in polyethylene plastic bags before using for further analysis.

2.2 Determination of Starch Granule Shape and Size

The shape and size of PSP starch granules were studied on a Scanning Electron Microscope (SEM) (FEI-type Quanta 650) at an accelerating voltage of 10.0 kV and magnification at 1000x. The granule size of starch was predicted from SEM image at a magnification of 40x by using Image J software.

2.3 Determination of Water and Oil Absorption Index

Water absorption index (WAI) and Oil Absorption Index (OAI) were determined by the method described by Niba et al. (2001). Starch samples (1g) were suspended in 5ml of water (for WAI) or 5ml vegetable oil (for OAI) in a centrifuge tube. The slurry was stirred for 1 min at room temperature and centrifuged at 3000 rpm for 10 min. The supernatant was decanted and discarded, and the sediment was weighed, WAI and OAI were expressed as the weight of sediment/initial weight of the starch sample (g/g).

The swelling power of starch was determined according to Leach et al. (1957) method. 0.1g sample was put into a weighed 50ml centrifuge tube, and distilled water was added to give a 10 ml of total volume, then the mixture was stirred gently by hand for 30s at room temperature, and heated at 60 ºC for 30 min. After cooling to room temperature, the sample was centrifuged for 30 min at 3000 rpm, and the sediment then was weighed.

2.4 Determination of Pasting Properties of PSP Starch

The pasting characteristics of PSP starch were evaluated by the Rapid Visco Analyzer (RVA-Model Tecmaster Newport Scientific, Australia). The slurry was made at a concentration of 10% dry solids in an aluminum container, and held for 1 minute at 50oC, heated from 50 to 95 ºC at 6 ºC / min, and held at 95 ºC for 5 minutes. The parameters recorded were paste temperature (PT), peak viscosity (PV), viscosity at the end of the holding time at 95 ºC (HPV), breakdown viscosity (BD) calculated as PV-HPV, viscosity at the end of the holding time at 50 oC (CPV); regression viscosity (SB) was calculated as CPV-HPV, stability ratio (SR) was calculated as HPV / PV, and regression ratio (SBR) was calculated as CPV / HPV.

2.5 Statistical Analysis

All measurements were done in triplicate. All data obtained were subjected to One Way Analysis of Variance (ANOVA) using, and the Duncan Multiple Range (DMR) was performed using SPSS Version 26. A Statistically significant difference was established at $p<0.05$.

3 RESULTS AND DISCUSSIONS

3.1 PSP Starch Granule Size and Shape

The starch granules shape from different isolation methods were shown in Figure 1. The three starch samples had a small to large sizes of granule. Most of PSP starch granules were polygonal in shape, however round and irregular shapes were also found. These shapes were similar to previous studies (Ngoc et al., 2017; Soison et al., 2015; Babu and Parimalavalli, 2014). The granule surface of starches samples isolated by distilled water and sodium metabisulfite looked smoother without any fissure. This result is in line with the Babu and Parimalavalli (2014) research results. In PSP starch isolated by citric acid, there are some compound granules. This may be caused by the residual protein which undergoes gelatinization on the surface of the starch grains and sticks to one another to form compound granules. (Newman et al., 2007). PSP starch isolated by distilled water had a larger number of small size granules. Similar results were also found in Babu and Parimalavalli (2014) results.

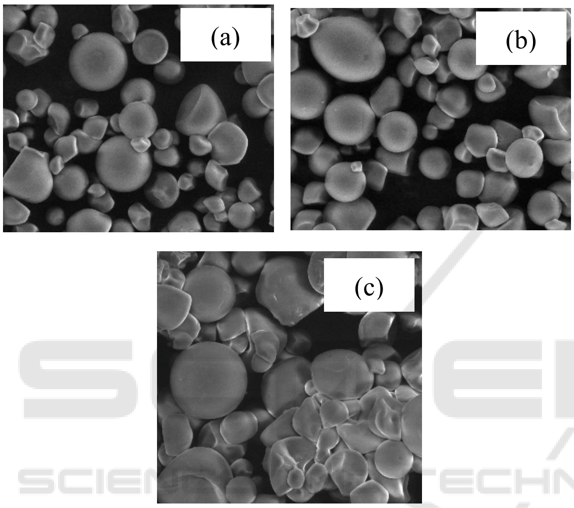

Figure 1: Scanning Electron Microscopy (SEM) of PSP starch from different isolation methods : (a) Distilled water; (b) Sodium metabisulfite; (c) Citric acid at 1000 x magnification.

The effect of isolation methods on the size of PSP starch granules is shown in Table 1. The size of the starch granules varies from 7.0-27.3 µm. Granule size of sweet potato starches from previous studies widely varied from 2 to 60 µm (Babu and Parimalavalli, 2014; Soison et al., 2015; Ngoc et al., 2017; Babu et al., 2015). Starch granules isolated with citric acid tend to have a larger size, this is due to the formation of compound granules.

Table 1: Granule Size of Sweet potato starch from different isolation methods.

Isolation Methods	Granule Size (µm)		
	Mean	Minimum	Maximum
Distilled Water	16.6	7.0	24.0
Sodium Metabisulfite	19.4	13.6	21.7
Citric Acid	20.2	14.5	27.3

3.2 Functional Properties of PSP Starch

The water absorption index (WAI) of sweet potato starch was in the range of 0.72-1.03 ml/g. Table 2 showed that PSP starch isolated with citric acid tends to have a higher WAI. WAI is related to the interactive forces among starch components, weak interactive forces result in high WAI. WAI is an important parameter that determines starch viscosity (Oswal et al., 2019).

Table 2: Effect of isolation methods on functional properties of PSP starch.

Parameters	Isolation Methods		
	Distillation Water	Sodium Metabisulfite	Citric Acid
Water Absorption Index (g/g)	0.90±0.17[b]	0.72±0.12[c]	0.73±0.04[a]
Oil Absorption Index (g/g)	1.09±0.14[c]	1.21±0.09[b]	1.46±0.07[a]
Swelling Power (g/g)	7.69±0.18[c]	9.58±1.09[b]	13.35±2.47[a]

[a)] Value reported as the mean ± Std. Dev. of three replications

[b)] Means followed by same letter superscripts within a row are not significantly different ($p<0.05$)

Oil absorption index (OAI) of PSP starch as affected by isolation methods ranged from 1.09-1.46 ml/g, and it is was higher than the results of Babu and Parimalavalli (2013) research which found that the OAI values ranged from 0.52-0.82 ml/g. The Higher OAI might be due to greater hydrophobic tendency than hydrophilic tendency of isolated starches.

The swelling power (SP) of starch at 60 ^{o}C is ranged from 7.69-13.35 g/g. The previous research found that the swelling power of sweet potato starches was 5.23-16.38g/g with temperature range of 65- 95^{o}C (Huang et al., 2010).

3.3 Pasting Properties of PSP Starch

Pasting properties determined by RVA are shown in Table 3. There are no significant differences in pasting properties of starch with different isolation methods. Table 3 shows that the viscosity of starch isolated with citric acid tends to be higher than other isolation methods. Balasubramanian et al. (2014) reported that acid-modified starch would have a higher peak viscosity.

Table 3: Effect of isolation methods on pasting temperature of PSP starch.

Parameters	Isolation Methods		
	Distillation Water	Sodium Metabisulfite	Citric Acid
Peak Viscosity (cp)	3786.00± 350.53[a]	3664.33 ±129.40[a]	3992.00 ±458.75[a]
Hot Paste Viscosity (cp)	2300.00± 271.81[a]	2078.67 ±79.96[a]	2419.00 ±466.13[a]
Final Viscosity (cp)	3184.67± 316.25[a]	2860.33 ±127.34[a]	3414.67 ±694.32[a]
Breakdown Viscosity (cp)	1486.00± 112.30[a]	1585.67 ±187.43[a]	1573.00 ±311.17[a]
Setback (cp)	884.64± 45.09[a]	781.67± 48.00[a]	995.67± 228.23[a]
Gelatinization Temperature (°C)	68.88± 0.49[a]	69.23± 0.38[a]	70.05± 1.06[a]

a) Value reported as the mean ± Std. Dev. of three replications

b) Means followed by same letter superscripts within a row are not significantly different ($p<0.05$)

Pasting properties in this research are following the results of previous studies (Tsakama et al., 2010; Babu and Parimalavalli, 2014). Pasting properties of starch is determined by granule size and structure, amylose content, and amylopectin structure. PSP starch isolated with citric acid has a larger granule size so that it has a higher viscosity.

The pasting temperature is the minimum temperature required to cook a starch sample. Although statistically there was no difference in the pasting temperature of the three isolation methods, the pasting temperature of PSP of starch isolated with citric acid also tended to be higher. The lower pasting temperature indicates that the starch can be cooked faster and requires less energy (Babu and Parimalavalli, 2014).

4 CONCLUSIONS

Each isolation method had its own physical and functional characteristics, which affect the end-use quality of starch-based foods. Starch isolated with sodium metabisulfite exhibited lower peak viscosity in addition to lower swelling. It may be concluded that sodium metabisulfite could be used to isolate starch with desirable properties, suitable for many food products.

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