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Research Article

Physical and Chemical Characterisics of Starch Nano crystal from Purple Sweet Potato var. Ayamurasaki

Elisa Julianti[1*,2], Zulkifli Lubis[1], Adrian Hilman[1,2], Abdul Rahman Nasution[1]

[1]Department of Food Science and Technology, Faculty of Agriculture, Universitas Sumatera Utara, Medan, Indonesia; [2]Center of Excellence of Tuber and Root Crops, Universitas Sumatera Utara, Medan, Indonesia

ABSTRACT

The natural starch of purple sweet potato has the disadvantage of being easily hydrated, losing viscosity, and producing a fibrous and highly cohesive starch paste. Modification of starch in the form of nanocrystals will produce starch with low suspension viscosity at relatively high concentrations, high binding capacity due to the large active surface area. In this study, an evaluation was carried out on the physical and chemical characteristics of purple sweet potato starch nano crystals obtained by acid hydrolysis using 3 different acids, namely acetic acid, citric acid, and lactic acid. The results showed that the highest yield of starch nanocrystals was obtained from starch from acetic acid hydrolysis.

Keywords: Nanocrystal; Purple sweet potato; Acid hydrolysis; Starch; Food security

INTRODUCTION

Sweet potato (*Ipomoea batatas L*. (Lam)) is an important crop in many countries. In 2018 world sweet potato production reached 91,945,358 tons, and in Indonesia it was 1,806,389 tons. Indonesia ranks as the 5th largest sweet potato producing country in the world after China, Malawi, Nigeria, and Uganda [1]. Sweet potatoes also play an important role in meeting the world's food needs, reducing poverty, and increasing food security [2].

Sweet potatoes contain starch (58-76% on a dry basis), with characteristics similar to potato starch. The functional characteristics of starch such as viscosity, shear resistance, gelatinization, solubility, gel stability and retrogradation are largely determined by the amylose/amylopectin ratio of starch [3]. Purple sweet potato starch contains amylose ranging from 30-38% and amylopectin 20-28% [4]. Natural purple sweet potato starch has the disadvantage of being easily hydrated, losing viscosity, and producing a fibrous and highly cohesive starch paste [5]. Therefore, it is necessary to modify starch to overcome this weakness.

Modified starch is a process of changing the structure of starch by influencing the hydrogen bonds in a controlled manner. Usually starch degradation can be carried out by several methods such as physical changes, chemical degradation, enzymatic modification or genetic transformation [6]. Modification of purple sweet potato starch can be done by changing the particle size into nano size with a size ranging from 10-1000 nm. Starch nanocrystals can be made by nanoprecipitation, emulsification, and homogenization. The nanoprecipitation process is a simple and reproducible process, so it is more widely used [7]. Starch modification in the form of nanocrystal are expected to produce starch with low suspension viscosity at relatively high concentrations, high binding capacity due to the large active surface area. This study aims to evaluate the manufacturing process and characteristics of nanocrystals from purple sweet potato starch.

MATERIALS AND METHODS

Materials

The main ingredient of this research is purple sweet potato from farmers in Phak Phak Barat Regency. The chemicals used are chemicals for the manufacture of starch, namely sodium metabisulfite, chemicals for hydrolysis of starch and the manufacture of starch nanocrystals, namely citric, acetic, and lactic acids, NH_3 and ethanol. Chemicals for analyzing the chemical characteristics of starch used were ethyl acetate, chloroform, methanol, hexane, aquadest, buffer (formic acid-sodium hydroxide), ascorbic acid, DPPH, phenolphtalein indicator, chloroform, KI, Na_2SO_3, KOH, HCl, lead (II) acetate.

Purple Sweet potato Production

Sweet potato starch extraction procedure refers to Julianti, et al.

*Correspondence to: Elisa Julianti, Department of Food Science and Technology, Faculty of Agriculture, Universitas Sumatera Utara, Medan, Indonesia, E-mail: elisa1@usu.ac.id

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[4]. The cleaned tubers were peeled manually with a stainless steel kitchen knife, the material was grated with a grater until the fine material became a slurry and diluted with a solution of starch isolating agent (0.2% sodium metabisulfite) with a ratio of slurry and solution 1: 3 w/v. The slurry is filtered using a filter cloth. The filtrate was allowed to settle for 12 hours at room temperature (27-30°C). The supernatant was discarded and resuspended in water for 3 hours and stored at room temperature for 3 hours to obtain starch. This process was repeated three times until a white starch sediment was obtained. The collected starch was dried in an oven at 50°C for 12 hours, cooled to room temperature. This coarse flour is then mashed using a blender and sieved with an 80mesh sieve. Sweet potato starch is produced and packaged in plastic tightly closed.

NANOCRYSTAL STARCH OF PURPLE SWEETPOTATO PRODUCTION

The procedure for making starch nanocrystals refers to Angellier [8] which was modified by acid hydrolysis. A suspension of starch was made in various types of acids (acetic acid, lactic acid, citric acid) with an acid concentration of 7.5% (w/V) with a ratio of starch and acid 1: 5 (w/w). The starch suspension was incubated at room temperature (30°C) for 7 days while stirring with mechanical stirring at 500 rpm using a magnetic stirrer. The starch suspension that had undergone acid treatment was then centrifuged and washed with distilled water. After that, it was neutralized using NH_3 until neutral (pH 7.0), followed by ultrasonification at 13000 rpm for 2 minutes. After that, it was washed with ethanol and then dried at 40°C for 24 hours. After drying, the starch is ground and filtered and then sieved and stored in the freezer until use.

Starch and starch nano crystals from purple sweet potato were observed for physicochemical characteristics including water content, ash content, protein content, fat content, starch content, amylose content, amylopectin content, and crude fiber content. Starch nano crystals were also observed using SEM, color, solubility, Swelling power, amylose content, digestibility, degree of crystallinity (XRD), and starch paste characteristics.

RESULTS AND DISCUSSION

Physicochemical Characteristics of Natural Starch from Purple Sweet potato

The physical and chemical characteristics of natural purple sweet potato starch can be seen in Table 1. The starch yield that can be obtained from purple sweet potato is 14.13%. The value of L* color indicates the brightness level of the starch, and the value of L* color of the resulting starch is 88.88. When compared with research conducted by Thai and Noomhorn [9] and Babu and Parimalavalli [10], the resulting L* value is much lower, because the results of the research show that the L* value of sweet potato flour color ranges from 90.27-93, 65. This difference is due to the different types of sweet potatoes used. In this study, the sweet potato used was purple sweet potato which contains high anthocyanin pigments.

Table 1 shows the moisture content (% w/w) of purple sweet potato starch, which is 14.40%. The water content of sweet potato starch is 11-17% [11]. Variations in the value of starch moisture content are caused by several different factors such as climate and the environment where it is grown.

Table 1 shows the ash content (%w/w) of purple sweet potato starch, which is 0.08%. The ash content of starch from sago, cassava, taro, and sweet potatoes ranged from 0.02 to 0.49% [11]. The lower ash content of sweet potato starch used can be caused by the repeated extraction, washing, and filtering processes using water in the manufacture of starch. This process can cause the minerals contained in the tubers and pith to be dissolved by water so that the mineral content is also wasted along with the pulp.

Table 1: Physicochemcial characteristics of natural starch from purple sweet potato.

	Amount
Yield (%)	14,13 ± 1,12
L* value of color	88,88 ± 0,21
Buld Density (ml/g)	0,41 ± 0,03
Moisture (%)	14,40 ± 0,85
Ash (%)	0,08 ± 0,01
Crude Fat (%)	0,32 ± 0,02
Crude Protein (%)	0,10 ± 0,00
Carbohydrate, by difference (%)	85,10 ± 0,84
rude Fiber (%)	0,91 ± 0,09
Starch (%)	88,91 ± 1,10
Amylose (%)	26,24± 0 ,97
Amylopectin (%)	62,66 ± 0,36

*) The value is an average from 3 replicates data ± standard deviation

Table 1 shows the fat content (%w/w) of purple sweet potato starch, which is 0.27%. Starch fat content ranged from 0.176 to 0.317% [11]. The value of the fat content of starch is quite low due to the fat that is dissolved with water and some is also wasted during washing the starch water and is wasted with the dregs.

Table 1 shows the protein content (%w/w) of purple sweet potato starch, which is 0.09%. The low protein content in starch is caused by the process of making starch which can cause the protein to dissolve in water and there is also protein in the dregs that is also wasted [11].

Table 1 shows the results of carbohydrate content (%w'w) of sweet potato starch, which is 85.16%. Carbohydrate content can be related to the water content of purple sweet potato starch. Carbohydrate content is also related to water content [12]. The lower the water content of the material, the higher the dryness of the material, so that it can cause the carbohydrate content to rise and vice versa. The water content of sweet potato starch is 14.40%. Polnaya, et al. [11] stated that the water content of sweet potato starch was 11-17%. Variations in the value of starch moisture content can be caused by several different factors such as climate and the environment in which it grows.

Table 1 shows the crude fiber content of purple sweet potato starch, which is 0.91%. Sweet potato starch contains 0.05-1.3% crude fiber [11]. Table 1 shows the purple sweet potato starch content of 88.91%. Sweet potato starch content ranged from 59.2-80.76% [13]. The difference in starch content in sweet potatoes is thought to be because each variety has a different starch content.

Table 1 shows that purple sweet potato contains lower amylose content than the amylopectin content of purple sweet potato starch. Starch consists of two components, namely amylose and amylopectin. In general, the amount of amylose is 20% and the amount of amylopectin is 80% of the total starch [11].

The functional characteristics of starch observed included water absorption, oil absorption, swelling power, and viscosity characteristics of starch paste and gelatinization temperature as shown in Table 2. The swelling power value of purple sweet potato starch was 8.22%. The results of research by Dewi et al. [14] stated that the swelling power value of sweet potato starch ranged from 6.408 to 9.518%. The higher the swelling power value, the higher the starch swelling power. Budiyati, et al. [15], stated that increasing amylopectin levels can cause swelling power to increase, while amylose and fat can inhibit swelling power.

Table 2 shows that the solubility of purple sweet potato starch is 0.95%. The solubility value of starch is about 0.8-0.9% [15]. Differences in solubility can be caused by different varieties and chemical compositions. Amylose content and the ease of granules to come out of starch grains greatly affect the solubility of starch.

Table 2 shows the clarity of purple sweet potato starch which is 16.93. The clarity of starch is related to its dispersion and retrogradation properties. Disperse occurs when starch is heated so that water enters and weakens hydrogen bonds. If it occurs continuously, over time the granules swell from several times their original volume until they finally burst, while retrogradation is the crystallization of dispersion. Naturally, starch has a high swelling power value and low retrogradation ability so that it has a higher paste clarity [16]. In purple sweet potato starch, the swelling power value is quite high, namely 8.22%.

The clarity of the starch paste was measured using a light transmittance with a spectrophotometer by reflecting light so as to reflect the homogeneity difference between starch granules in the solvent. The higher the level of transparency of the suspension, the higher the value of %T. Starch that has a high level of transparency has a high clarity value.

Table 2 shows the water absorption value of starch 0.71. The water absorption ability of flour or water absorption can be reduced if the flour has a high water content [17]. Oil absorption of purple sweet potato starch is 1.17. Oil absorption is related to water absorption [18].

Peak viscosity is the maximum point of paste viscosity produced during the heating process [19]. The peak viscosity of purple sweet potato starch was 3644 cP, while the results of Tsakama, et al. [20] on 11 varieties of sweet potato showed the peak viscosity values were in the range of 1947-2596 cP. The difference in peak viscosity values can be caused by differences in the size of the starch granules, where the larger the size of the starch granules, the higher the peak viscosity, because the increase in the size of the granules causes more sensitivity to the applied force.

Table 2: Functional characteristics of purple sweet potato starch.

	Amount
Water Absorption Capacity (g/g)	0,71 ± 0,03
Oil Absorption Capacity (g/g)	1,17 ± 0,08
Swelling Power (g/g)	8,22 ± 0,27
Solubility (%)	0,95 ± 0,09
Paste Clarity	16,93 ± 0,40
Peak Viscosity (PV) (cp)	3644
Hot Paste Viscosity (HPV) (cp)	2079
Final Viscosity (FV) (cp)	2860
Breakdown Viscosity (BD = VP-VPP) (cp)	1586
Setback Viscosity (SB = FV-VPP) (cp)	782
Gelatinization Temperature (°C)	69,23

*) The value is an average from 3 replicates data± standard deviation

Hot-paste viscosity (HPV) is the viscosity value of the paste after it reaches a temperature of 95°C (heating stage). This criterion is used to determine the ability of starch granules to maintain viscosity during heating. The HPV value of purple sweet potato starch produced was 2079 cP, and this was in accordance with the results of the study of Tsakama, et al. [20] which showed the HPV values of 11 sweet potato varieties ranged from 1541-2049 cP. HPV from flour/starch which is high tend to be resistant to heat during the cooking process [21].

Final viscosity (FV) is the viscosity value of the paste after the final cooling stage, where the paste has reached a temperature of 50 °C. This viscosity is used to indicate the quality of starch, the stability of starch paste when cooked, and the ability of starch to form a paste or gel after cooling [23]. In this study, the final viscosity value of starch paste was 2860 cP, while the results of Tsakama, et al. [20] showed that the FV values in 11 sweet potato varieties ranged from 2303-2762. The linear structure of amylose is easier to bond with fellow amylose through hydrogen bonds and the hydrogen bonds formed are stronger than amylopectin so that the gel viscosity is getting thicker [22].

The breakdown viscosity (BD) shows the level of stability of the starch paste against the heating process. The BD value of purple sweet potato starch in the study was 1586, while the research of Tsakama, et al [20] showed the BD value for 11 varieties of sweet potato was 221.67-889.33 cP. The high breakdown viscosity value indicates that the swollen flour granules are brittle as a result of not being able to withstand the heating process, resulting in a decrease in the viscosity of the paste.

The setback viscosity (SB) indicates the retrogradation ability of starch molecules in the cooling process. The SB value in this study was 782 cP. The high setback viscosity value indicates that the paste tends to harden at the end of the cooking process, so the processed product is not easily destroyed [21].

Starch Nanocrystal from Purple Sweet potato

The manufacture of nanoparticles can be carried out in several ways consisting of top-down and bottom-up processes. The top-down process is intended as a process of breaking particles into smaller sizes to produce nanoparticles. While the bottom-up process is carried out by assembling or combining molecules thermodynamically under controlled conditions. The process of making nanoparticles more often uses a top-down process because the bottom-up process tends to produce large particle sizes, which are above 100 nm and this is not expected in the manufacture of nanoparticles. The technology for making nanoparticles that are bottom-up in the form of nano precipitation [23,24] and cross-linked emulsion. According to Le Corre et al. [26], there are three ways of forming starch nano crystals/nanoparticles, namely acid or enzymatic hydrolysis, regeneration and mechanical treatment [25].

In this study, nano crystals from purple sweet potato starch were obtained through acid hydrolysis with 3 different acids, namely acetic acid, citric acid and lactic acid. Starch yields were 82.67%, 84.68% and 75% respectively for the yields produced by hydrolysis of citric, acetic, and lactic acids, respectively. These results indicate that hydrolysis using acetic acid produces the highest starch yield.

CONCLUSION

Nano crystalline starch products from purple sweet potato can be carried out by acid hydrolysis. The highest nano crystal starch yield was obtained in the hydrolysis process using acetic acid.

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Conflict of Interest

"Conflict of Interest: None to report."

REFERENCES

1. Food and Agriculture Organization. Crop Production Data. 2020; (Diakses 18 Oktober 2020).
2. El-Sheikha AF, Ray RC. Potential impacts of bioprocessing of sweet potato: Review. Crit Rev Food Sci & Nutr. 2009;57:455-471.
3. Kale RV, Shere DM, Sontakke MD, Gadhe KS. Effect of isolation methods on physicochemical and functional properties of sweet potato (Ipomoea batatas L.) starch. J. pharmacogn. phytochem.2017;6(4):223-227.
4. Julianti E, Rusmarilin H, Ridwansyah Yusraini E. Effect of isolation methods on physicochemical properties of purple-fleshed sweet potato starch. Proceedings of the International Conference of Science, Technology, Engineering, Environmental and Ramification Researches. 2018;1:37-41.
5. Kamenan A, Rolland-Sabaté A, Colonna P. Stability of yam starch gels during processing. Afr. J.Biotech. 2005; 4(1):94-101.
6. Truong VD, Avula RY, Pecota KV, Yencho GC. Sweetpotato production, processing, and nutritional quality. Handbook of vegetables and vegetable processing. 2018;2: 811-838.
7. Chin SF, Pang SC, Tay SH. Size controlled synthesis of starch nanoparticles by a simple nanoprecipitation method. Carbohydrate Polymers.2011; 86 (4): 1817-1819.
8. Angellier H, Putaux JL, Molina-Boisseau S, Dupeyre D, Dufresne A. Starch Nanocrystal filler in an acrylic polymer matrix. Macromolecular Symposia. 2005;221(1): 95-104.
9. Ho MT, Noomhorm A. Physiochemical properties of sweet potato and mung bean starch and their blends for noodle production. Journal of Food Processing and Technology. 2011;2(1)2-9.
10. Babu AS, Parimalavalli R. Effect of starch isolation method on properties of sweet potato starch. The Annals of the University Dunarea de Jos of Galati Fascicle VI – Food Technology.2014;38(1):48-63.
11. Polnaya FY, Bremer R, Augustin GKh, Tuhumor NDC. Karakteristik sifat-sifat fisiko-kimia pati ubi jalar, ubi kayu, keladi, dan sagu. Agrinimal. 2015;5(1) :37-42.
12. Herawati H, Widowati S. Karakteristik beras mutiara dari ubi jalar (Ipomoea batatas). Buletin Teknologi Pascapanen Pertanian. 2009;5:38-44.
13. Irhami C. Anwar, Kemalawaty M. Karakteristik sifat fisikokimia pati ubi jalar dengan mengkaji jenis varietas dan suhu pengeringan. J. Agric. Technol. 2019;20(1):33-44.
14. Dewi NS, Parnanto NHR, Ridwan AA. Karakteristik sifat fisikokimia tepung bengkuang (Pachyrhizus erous) dimodifikasi secara asetilasi dengan variasi konsentrasi asam asetat selama perendaman. Journal of Agricultural Products Technology. 2012;5(2): 104-112.
15. Budiyati CS, Kumoro AC, Ratnawati R, Retnowati DS. Modifikasi pati sukun (Artocarpus Altilis) dengan teknik oksidasi menggunakan hydrogen peroksida tanpa katalis. Teknik. 2016; 37(1):32-40.
16. Suharti N, O Suarmin,A Djamaan. Karakteristik pati umbi bengkoang (Pachyhizus erous (L.) Urban). Diakses pada . 2019.
17. Sihotang SN, Lubis JZ, Ridwansyah. Karakteristik fisikokimia dan fungsional tepung gandum yang di tanam di Sumatera Utara. J. Rekayasa Pangan dan Pert. 2015;3(3):330-337.
18. Apriliyanti T. Kajian sifat fisikokimia dan sensori tepung ubi jalarungu (Impomoea batatas blackie) dengan variasi proses pengeringan. 2010.
19. Kigozi J, Byaruhanga Y, Banadda N, Kaaya A. Characterisation of the physico-chemical properties of selected white sorghum grain and flours for the production of ice cream cones. The Open Food Science Journal. 2013;7(1):23-33.
20. Tsakama M, Mwangwela AM, Manani TA, Mahungu NM. Physicochemical and pasting properties of starch extracted from eleven sweetpotato varieties. African Journal of Food Science and Technology. 2010;1(4):090-098.
21. Munarso SJ, Muchtadi D, Fardiaz D, Syarief R. Perubahan sifat fisikokimia dan fungsional tepung beras akibat proses modifikasi ikat-silang. Jurnal Pascapanen. 2004; 1:22-28.
22. Shimelis EA, Meaza M, Rakshit S. Physico-chemical properties, pasting behavior and functional characteristics of flours and starches from improved bean (Phaseolus vulgaris L.) varieties grown in East Africa.2006.
23. Ma X, Jian R, Chang PR, Yu J. Fabrication and characterization of citric acid-modified starch nanoparticles/plasticized-starch composites. Biomacromolecules. 2008;9(11):3314-20.
24. Tan Y, Xu K, Li L, Liu C, Song C, Wang P. Fabrication of size-controlled starch-based nanospheres by nanoprecipitation. ACS applied materials & interfaces. 2009;1(4):956-959.
25. Fang YY, Wang LJ, Li D, Li BZ, Bhandari B, Chen XD, et al. Preparation of crosslinked starch microspheres and their drug loading and releasing properties. Carbohydrate Polymers. 2008;74(3):379-384.
26. Le Corre D, Bras J, Dufresne A. Starch nanoparticles: a review. Biomacromolecules. 2010;11(5):1139-1153.