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Physicochemical characterization of Cocoyam (*Xanthosoma sagittifolium*) starch from Banjarnegara highland as a local source of carbohydrate

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Abstract. Cocoyam (*Xanthosoma sagittifolium*) from Banjarnegara highland (and then called busil), is less utilized as a starch source even though it is easily found and locally used as a snack. The objective of this study was to determine the physicochemical properties and recommends suitable utilization of busil starch. This research was conducted in two steps, the first step was busil starch extraction, and the second was the physicochemical characterization and utilization recommendations. Busil had 14% yield of starch, contained 15.4% amylose, and 81.5% amylopectin with 88.1% of whiteness index. Scanning electron microscopy (SEM) showed that they are mostly round, and the granule size was about 11.8 µm. Rapid Visco Analyzer (RVA) analysis showed that busil starch had 74.3°C on pasting temperature. X-ray diffraction (XRD) studies showed that busil starch exhibited an A-type diffraction pattern. Native busil starch was suitable to make amorphous and crispy food texture. It was also ideal for thickener or filler agents. Apart from being used as native starch, busil starch also potential to be modified and can be used more widely.

1. Introduction

Food availability is one of the important factors in public food security, especially in the Covid-19 pandemic situation where people are suggested to stay at home. Local food is the easiest resource to ensure food availability, especially from local tubers as a source of carbohydrate. Cocoyam (*Xanthosoma sagittifolium*) or locally known as busil is one of the local tubers that can easily find in Banjarnegara, Central Java, Indonesia, especially in the northern highland area. Traditionally, busil corm is eaten as steamed, fried, and chips [1–3]. Recently, some domestic industries also produce busil flour and use it as an ingredient of various food products, especially snack products. But many consumers say that busil flour-based product is still less acceptable rather than wheat flour-based product. Besides, an old perception presumes that busil is a “second class” food; which made busil less interesting, especially for millennial consumers [4]. Regardless of low busil utilization, its corm has high starch content, but it has not been utilized as a whole corm itself. Starch has a unique characteristic owing to its wide range of utilization [5]. Low utilization of busil starch is mainly due to a lack of information on its properties. Unfortunately, the physicochemical characteristics of busil from Banjarnegara are currently unknown.



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This research aim is to characterization the physicochemical properties of busil starch from Banjarnegara highland. This information is essential to evaluate the potential characteristics of busil that can be explored and developed further to meet the best purposes of busil starch. It also can be primarily data to do further research about busil starch modifications.

2. Materials and methods

2.1. Materials

Local variety of cocoyam (*Xanthosoma sagittifolium*) or busil, was obtained from the local farmer in Kali Bening, Banjarnegara, Central Java, Indonesia at 11 months of age. The samples were selected from busil that has good quality and without any physical defects. To ascertain the busil variety, busil samples was identified at the Plant Systematics Laboratory, Departement of Biology, Faculty of Mathematics and Natural Sciences, Gadjah Mada University, Indonesia. Analytical grade reagents were used in this research.

2.2. Starch isolation and yields

Starch was isolated as described by Falola, *et al.* [6] with slight modifications. Busil that have no physical defects were selected. They were peeled, washed, and then grated. The grated busils were collected in a container and mixed with water (1:3) until it forms a homogenous busil slurry. The slurry was squeezed and filtered using a filter cloth, and the supernatant was collected. After overnight sedimentation, busil starch would settle on the bottom of the container. Busil starch was decanted, dried on the cabinet dryer at 60°C overnight, grounded into powder using a blender, then sieved through 100 mesh. Busil starch was packed and kept in a sealed container for further analysis. Busil starch yield was obtained by calculating the amount of starch recovered from 100 g of fresh busil sample [7].

2.3. Physico-chemical properties

2.3.1. Granule morphology and size. Granule morphology of starch was determined by scanning electron microscopy (SEM) using Hitachi SU 3500 (Japan). The starch sample was mounted on a sample holder and then coated with gold-palladium. The magnification, accelerating voltage, and other important technical observation data were displayed on the micrograph. The size distribution of busil starch granules was measured using a Horiba laser scattering particle size analyzer (Horiba LA-960, Japan). Water was used as a dispersing medium. The refractive index values used were 1.33. Dv (50) value of granule busil starch was used as a mean size of busil starch.

2.3.2. Color. Color parameter, including 'L' (lightness), 'a' (redness to greenness), and 'b' (yellowness to blueness) values of busil starch powder were measured with Chroma Meter (Konica Minolta CR-400, Japan). Busil starch samples were put in a quartz silica cylinder, and the lightness values were measured [8]. The L, a, and b parameters then used to obtain the degree of whiteness (or next called whiteness index) of busil starch with the equation as described by [9].

2.3.3. Amylose and amylopectin. Amylose and amylopectin content of busil starch were analyzed according to AOAC standard method [10]. Data displayed on the percentage of dry basis.

2.3.4. Pasting properties. Pasting properties of busil starch were determined using a Rapid Visco Analyzer (RVA 4500, Perten Instruments, Sweden) method [11]. The starch sample (3.5 g) was weighed into a sample container and then added with 25 g of distilled water. Starch slurries were held at 50 °C for 1 min, heated to 95 °C at a rate of 6 °C/min, held at 95 °C for 5 min, cooled to 50 °C at a rate of 6 °C/min, and held at 50 °C for 2 min. The speed was 960 rpm for the first 10 s, then 160 rpm for the remainder of the experiment.

2.3.5. *X-ray diffraction*. XRD patterns were determined using Rigaku MiniFlex600 (Japan) operated at 40 kV and 30 mA with a scan rate of 4 °C/min. The diffraction angle (2θ) ranged from 5° to 50°.

3. Results and discussion

3.1. Starch yield

The yield of starch extracted from busil was around 14%. This yield was close (17%) as stated by Wanita [12] and even higher than the cassava starch yield (12.5%) reported by Erika [13]. This yield result is lower than the result of moorthy [14] which mentioned that *Xanthosoma* starch yield can more than 20% when water was used as an extraction medium. Other studies even stated that *Xanthosoma* starch could reach 43.81% [15]. Many factors can affect the starch yield amount, but generally, it can be more improved by modification of the extraction method [16]. It should also be noted that the quantity of starch yield is important, but good physicochemical and functional properties coupled with economic extraction are thus important as well [17]. From our research, there is an opportunity to develop a study about busil extraction techniques to extend starch yield that meets with industrial characteristic purposes.

3.2. Granule morphology and size

Busil starch granules and comparison with other tubers starch are shown in Figure 1 and Table 1. Busil granules are mostly round, and granule size is about 11.8 μm . Other results mentioned that stated *X. sagittifolium* has granule size about 10-50 μm and ranged between 2.8-50 μm , respectively [15] [17]. The relatively small size of granule size is an added value for busil starch due to the high flour hydration rate and smooth structure formed [18]. Scanning electron micrographs of busil (Figure 1) show that starch granules are not entirely round, and there are not of homogenous size. Some granules seems broken, and the other look bigger or smaller than the other one. The broken part of granule and diversity of granules size occurs due to the grating effect in the starch extraction method. This method produces heterogeneous starch granules, but it can produce maximal starch yield [12].

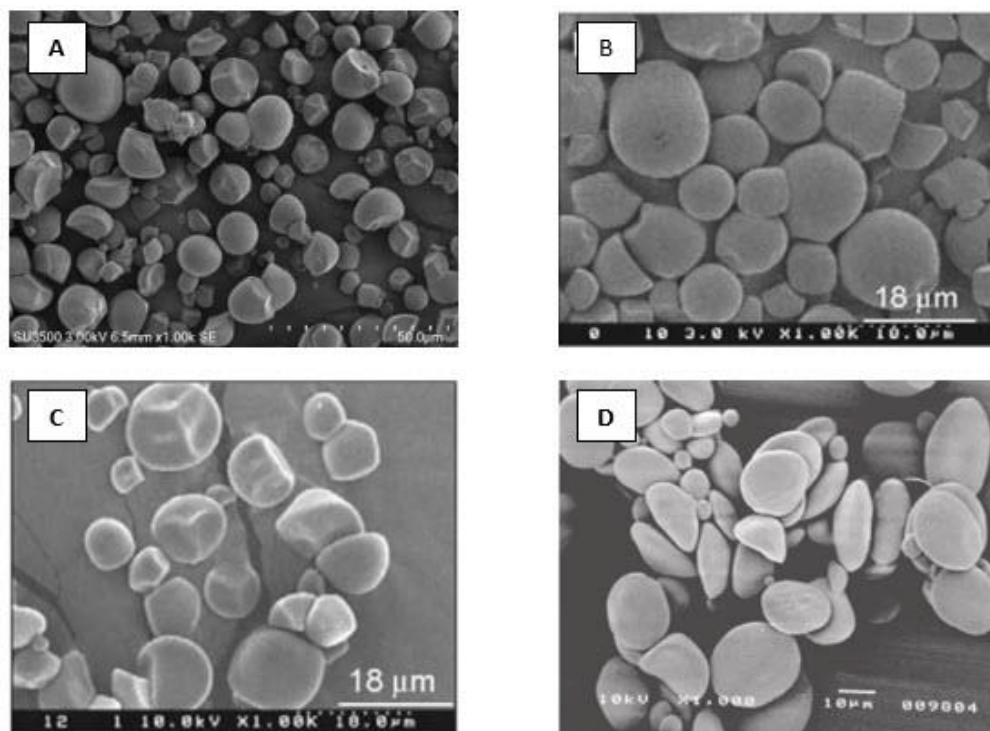


Figure 1. Scanning electron micrographs of starch: (A) Busil, (B) cassava [19], (C) sweet potato [19], and (D) potato [20]

3.3. Amylose & amylopectin content

Amylose and amylopectin affected the gelatinization process, retrogradation, and characteristics of starch paste [21]. Busil starch has 15.1% amylose and 80.2% amylopectin. Busil starch amylose content are reported to vary between 23.7% [15], 11.5-33.7% [22], and around 18.1% to 18.25% [23] [24]. Differences in amylose content can occur because of different origins, fertility, climate condition, planting periods, and also planting techniques. Data in Table 1 also showed that busil amylose content is lower than other tubers starch. The starch that contains a low amylose component is suitable for thickener or filler agents on food products [21].

Table 1. Physicochemical properties starch from busil and other tubers

Parameter	Busil	Cassava [19]	Sweet potato [19]	Potato [19]
Mean size (μm)	11.8	23.2	22.7	42.3
Shape	Round	Round	Round, polygonal	Oval, spherical
XRD starches pattern	A	A	A	B
Amylose (%)	15.1	17.9	19.8	18.0
Amylopectin (%)	80.2	n.a	n.a	n.a

3.4. Color

The value of L^* , a^* , and b^* color parameter of the busil starch were 89.53, 4.96, and -2.55, respectively. The whiteness index of busil starch was about 88.1%. This whiteness index met with Indonesian Industrial Standard for Starch (min 85%) and close to the whiteness index of cassava starch (92%), based on Indonesian Standard Quality of cassava starch (SNI 01-3451-1994) [25]. The high whiteness index indicated that busil starch was suitable to mix with other food ingredients without significantly change the food color itself.

3.5. Pasting properties

Pasting properties values of starch from busil and other tubers, shown in Table 2. It is shown that busil starch pasting temperatures were higher than cassava and potato but lower than the sweet potato. Starch with higher amylose content had a higher final viscosity and pasting temperature values; this condition could be due to the greater hydrogen bonding interactions [26]. Busil starch also has a high peak time and set-back viscosity value, it indicates that busil starch need a relatively long time to get the right product consistency. But that consistency will remain longer at a lower temperature.

Table 2. Pasting properties starch from busil and other tubers

Parameter	Busil	Cassava [27]	Sweet potato [27]	Potato [28]
Peak viscosity (cP)	6,153.00	7,015.50	13,408.00	6,107.00
Trough viscosity (cP)	3,438.00	2,852.00	3,284.00	n.a
Final viscosity (cP)	4,748.00	3,977.00	4,933.50	n.a
Breakdown viscosity (cP)	2,715.00	3,558.00	16,123.50	3,190.00
Setback viscosity (cP)	1,310.00	6,68.00	1,649.00	374.00
Peak time (min)	7.07	5.41	4.37	3.93
Pasting temperature ($^{\circ}\text{C}$)	74.30	70.20	77.03	69.40

3.6. X-ray diffraction (XRD) pattern

Busil starch XRD pattern on Figure 2 shows 2 θ peak at 15 $^{\circ}$, 17 $^{\circ}$, 18 $^{\circ}$, and 23 $^{\circ}$. That peaks are characteristic of the "A" type of XRD pattern, and it is in line with [17]. This XRD pattern is like cassava and sweet potato starch, as seen in Table 1. Starch with "A" XRD pattern has more density at the helix structure. It shows double helix founded, and amylopectin short-chain proportion is higher [29]. XRD pattern from native starch tends to be constat; but it can be changed by pretreatment of the extraction method or by food processing [17].

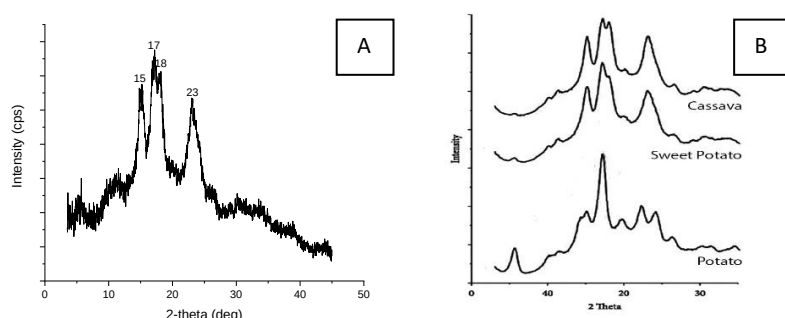


Figure 2. X-ray diffraction (XRD) pattern: (A) busil starch; (B) cassava, sweet potato, and potato starch [30]

4. Conclusions

Busil has a fair yield of starch and even more than cassava as a commercial starch source. Its granule is mostly round and has a small granule size. Busil also has low amylose content than other tubers. It has a similar color to other tubers starch, and also its whiteness index is in accordance with the Indonesian Industrial Standard for Starch. It has a relatively high pasting temperature and “A” type of XRD pattern. Busil starch characterization shows food that needs amorphous and crispy texture or baked products are the types of products that are suitable for busil starch. It was also ideal for thickener or filler agents on the food product.

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