Morphological, thermal, and pasting properties of cocoyam 
(Xanthosoma sagittofolium) starch from three locations in 
Mollucas Islands

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Abstract. This study investigated the morphological, thermal, and pasting properties of cocoyam starch from three locations in Mollucas islands. The islands are Buru, Porto, and Saumlaki. The results showed that starch granules were round and polygonal in shape, and the size varied significantly in range of 11.42 – 12.99 µm, while the range of crystallinity of the three cocoyam starches studied was 11.81% -16.61% and crystal type was A, this was a type for tubers. The thermal properties of cocoyam starch measured by DCS showed the results of onset (To), peak (Tp), endset (Te) and enthalpy (ΔH) in the range of To: 76-77 oC, Tp: 78-80oC, Te: 82-86oC and ΔH (J / g): -130.0 - (-) 175.76 respectively. The FTIR analysis showed the functional group profiles of native starches studied had the highest absorption spectra of 3286.70-3325.86 cm⁻¹ (O-H group vibrations). The peak, trough, breakdown, setback, and final viscosities were in the range of each PV: 4601 - 5155 RVU, TV: 2623 - 2874 RVU, BV: 1978 - 2287 RVU, FV: 4026 - 4176 RVU, SV: 1240 - 1403 RVU, Pt (Min) 7.87 - 8.40, PT (° C): 79.90 - 81.70.

1. Introduction
Keladi (Xanthosoma sagittofolium) is one of the tubers plant in Mollucas islands. Mollucas people only consume it in a simple processed form such as boiling or frying the tubers. This is conducted to complement the carbohydrate needs. It is known that it meets the daily energy needs of around 2100 kcal which is contributed by 10-15% protein, 35-45% fat, and 40-50% carbohydrate for all age groups, except for pregnant and lactating women [1]. Three sampling locations in this study were spread over 3 districts in Mollucas Islands. The distance between one district and another is limited by the sea. This location was the reason for studying characteristics of cocoyam starch from different locations on one island. Research and utilization of natural starch cocoyam still have not been done optimally, an important role of starch which is much needed in the world of food processing industries including starch can be used as raw materials and additives such as thickening agents, gelling agents, film-forming (filming agent), and...
stabilizing agent. Cocoyam contains carbohydrates which are quite high, with its main component being starch which is more than 30%. The main components of starch are amylose (30%) and amylpectin (70-80%) also contain minor components such as lipids, protein, phosphorus, and minerals. Physical and chemical characteristics of cocoyams are influenced by variety, place of grow, and soil fertility that will affect the use in food or non-food [2,3,4,5]. This research aimed to study the physical, thermal, and pasting characteristics of cocoyam native starches from three different locations on Mollucas islands.

2. Materials and methods

2.1. Material

Three cocoyam starches were taken from 3 locations in Mollucas islands, i.e Buru Island, Saumlaki Island and Saparua/Porto Island. Furthermore, the codes samples in this study were based on the location of the sample: Buru Starch, Saumlaki Starch, and Porto starch. The cocoyam tubers were peeled and washed with clean water. Then they were thinly sliced with a size of about 2 mm and washed with clean water repeatedly up to 8 times. Then the thin slices were extracted using a blender, squeezed using a filter, and precipitated for 8 hours drained and dried sediment using a dryer cabinet with a temperature of 50°C for 6 hours. Furthermore, the dried starch was reduced in size using a blender and 80 mesh sieve to get the cocoyam starch.

2.2. Method

Analysis of morphological characteristics of starch: granule shape with Scanning Electron Microscope, particle size with HORIBA Laser Scattering Particle Size Distribution Analyzer LA-960; crystallinity properties of starch granules with X-Ray Diffraction (XRD); FTIR spectroscopy; thermal characteristic with Differential scanning calorimetry (DSC); pasting properties with Rapid Visco Analyzer (RVA).

3. Results and discussion

3.1. Morphological properties

![Figure 1. Scanning electron micrographs (SEM) of three native cocoyam starch.](image)

Morphological characteristics of cocoyam starch from three locations in Mollucas island include the shape and size of starch particles. The shape of the cocoyam starch produced by scanning electronic microscopy on the three starches studied was rounded as well as polyhedral and truncated granules similar. This is in line with what was investigated by [2] on several cocoyam starches from Malawi [4]. The particle size of the three starches is in the range of 2.87 µm - 12.99 µm and the largest size (75%) is 11.4 µm - 12.9 µm. The particle size and shape of starch is affected by variety, growing environment, soil quality [6]. Based
on the particle size produced in the study are in small and medium sizes, this size is larger than the size of cocoyam and is the same as the size of the cassava and potato particles produced in the study [2,7].

3.2. X-Ray diffraction pattern

The crystalline structure of starch granules which forms a semi-crystalline system consisting of crystalline and amorphous regions studied using X-ray reactions [8]. According to Zhou [9], the starch crystal component is the sharp peak and the amorphous component as the dispersive peak is shown by the X-ray diffraction pattern. The range of starch crystallinity based on literacy is 15% to 45%, this value is based on the source and moisture content of starch and the measurement methods used [10]. The results of this study showed the degree of crystallinity of the three cocoyam starches was 11.81% Saumlaki starch, 13.69% Buru starch, and 16.61% Porto starch. This result was still very low when compared with the crystallinity value of other tuber starches, such as arrowroot starch 20.01% [11]. The difference in the level of crystallinity could be attributed to the amylose content in this starch, with previous reports showing that the percentage of low crystallinity in starch with high amylose content. The results from value of $2\theta$ showed that cocoyam starch was included in type A in the type of crystallinity with a value of $2\theta$ each cocoyam starch is 15.18°, 17.13°, 18.03°, 22.86° $2\theta$ (strong peak) [12]. These results are in line with Alvani [11] about Garut tuber and some of the other tubers from Srichuwong [13] research.

![Figure 2. FT-IR spectra of three native cocoyam starch](image)

3.3. FTIR of cocoyam starches

Spectrometer analysis was used to determine the chemical structure of natural starch and its changes after modification with various methods of starch modification. The results of FTIR analysis on the three starches showed the O-H group peaks at peaks of 3000 - 3600 cm$^{-1}$ as stated by Xu [14]. It can be seen in
figure 2 that the peak of the O-H group in the three cocoyam starches ranged from 3286.70 cm\(^{-1}\) - 3518.16 cm\(^{-1}\) while the C-H group was at the peak of 1419.61 cm\(^{-1}\) (Buru starch) and 1334.74 cm\(^{-1}\) (Saumlaki starch and Porto starch). As stated by Skoog et al., 1998 in Fiqtinovri [15] that the C-H bond was found at the peak of 1491.61 and 1365.60 cm\(^{-1}\).

3.4. Thermal properties
Table 1 presents that gelatinization temperature values of the three cocoyam starches studied were in the range of 76\(^\circ\)C - 77\(^\circ\)C with enthalpy values of 13.0-017.5 J/g. Gelatinization temperature values obtained were in the range of values studied by [2] in Malawi cocoyam (61,8 – 83,7\(^\circ\)C), [5] in Xanthosoma sagittifolium, Colocasia esculenta, (78,0  77,2 \(^\circ\)C). The gelatinization temperature of cocoyam starch results of the study was also higher compared to the gelatinization temperature of cassava starch and corn starch but the transition enthalpy starch values studied were higher than 2 references of cocoyam starches. The thermal characteristics of taro starch are higher than that of cassava and corn starch, showing that in the interior of the cocoyam starch granules there is a strong bonding strength [2].

| Thermal Properties | Native cocoyam starch |
|--------------------|-----------------------|
|                    | Buru starch | Porto starch | Saumlaki starch |
| To (\(^\circ\)C)    | 76         | 77          | 76              |
| Tp (\(^\circ\)C)    | 78         | 80          | 78              |
| Tc (\(^\circ\)C)    | 82         | 86          | 86              |
| \(\Delta H\) (J/g) | 14,3       | 17,5        | 13,0            |

\(To =\) Onset Temperature; \(Tp = \) Peak Temperature; \(Tc = \) Conclusion Temperature; \(\Delta H = \) Enthalpy of Gelatinization.

3.5. Pasting properties
Table 2. Pasting properties of native cocoyam starch from three locations in Mollucas Island.

| Pasting Properties       | Buru starch | Porto starch | Saumlaki starch |
|--------------------------|-------------|--------------|-----------------|
| Peak viscosity (RVU)     | 5155,00     | 4601,00      | 5126,00         |
| Trough viscosity (RVU)   | 2868,00     | 2623,00      | 2874,00         |
| Breakdown viscosity (RVU)| 2287,00     | 1978,00      | 2252,00         |
| Final viscosity (RVU)    | 4176,00     | 4026,00      | 4114,00         |
| Setback viscosity (RVU)  | 1308,00     | 1403,00      | 1240,00         |
| Peak time (min)          | 7,87        | 8,40         | 8,13            |
| Pasting temperature (\(^\circ\)C) | 79,90 | 81,70        | 80,20           |

Paste viscosity values of cocoyam native starch analyzed using RVA are presented in table 2. Peak viscosity was measured when the starch paste reached maximum viscosity during the heating phase, viscosity at 95\(^\circ\)C or hot paste viscosity. Breakdown viscosity showed stability of viscosity towards
heating, final viscosity after being maintained at 50°C. The viscosity of the setback indicated the tendency of starch to undergo retrogradation. Gelatinization temperature (°C) is the temperature at which the viscosity value begins to read which indicated the starch had begun gelatinizing. In general, native starch had a gelatinization profile with a maximum peak high enough with a sharp decreased in viscosity (breakdown viscosity) during the heating process. This is in line with the peak viscosity and viscosity breakdown values by the three cocoyam native starches (table 2). This showed that the cocoyam pasta was less stable in the heating process. Starch viscosity will increase again in the cooling process through the process of reassembling amylose, and amylopectin molecules by hydrogen bonds [11]. The three cocoyam starches studied had a peak of high viscosity with a sharp decrease, gelatinization temperature of 79.90°C (Buru starch), 81.70°C (Porto starch), and 80.20°C (Saumlaki starch), the initial temperature of starch gelatinization obtained was still in the temperature range reported by Pérez [16], which is 67.75°C – 81.40°C. The setback viscosity of three cocoyam starch was relatively high to facilitate retrograde of cocoyam starch. This condition indicated that the type A starch gelatinization profile was characterized by a high peak viscosity value and a fairly sharp breakdown viscosity. Gelatinization profiles obtained on the three cocoyam starches could be included in a group with arrowroot starch, tapioca starch, potatoes, sweet potatoes, sago, waxi corn and waxy barley Collado et al., 2001; Wattanachant et al., 2002; Singh et al., 2005 [11].

4. Conclusion
The granular starch granules form was rounded as well as polyhedral and truncated granules. OH group in the three cocoyam starches ranged from 3286.70 cm⁻¹ - 3518.16 cm⁻¹ while the CH group was at the peak of 1419.61 cm⁻¹ (Buru starch), and 1334.74 cm⁻¹ (Saumlaki starch and Porto starch). X-ray diffraction pattern showed crystalline of cocoyam starch classified as type A which was characterized by peaks at 2 tetras 15.18°, 17.13°, 18.03°, 22.86°. Type A gelatinization profile with high peak viscosity and sharp breakdown viscosity.

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