Effect of different banana pseudostem parts on their starch yield, morphology and thermal properties

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Abstract. Since banana tree cannot produce fruit twice, there is an abundance of pseudostem left as abandoned crop waste and this leads to environmental pollution. This research was conducted to evaluate the effect of different parts of banana pseudostem on the yield, morphology and thermal properties of the starch. The pseudostem was divided into three parts, which are the outer part of pseudostem (OPS), inner part of pseudostem (IPS) and the whole part of pseudostem (WPS). The starch yield from different parts was evaluated. The morphological and thermal properties of each starch were determined by scanning electron microscopy and thermoanalytical technique, respectively. The result shows that yield of starch obtained were 0.08 % higher in OPS compared to IPS. The yield of starch obtained range from 0.12 - 0.20 %. The iodine test had confirmed the presence of starch obtain from the pseudostem. All the starch showed irregular and spherical shape based on morphology observation. The gelatinization temperature of starch was between 71.15 °C - 76.50 °C. The gelatinization temperature of starch obtained from IPS is 3.6 % higher compared to OPS and WPS. The results from this finding show that the starch obtained from pseudostem could be a potential source of starch that can be commercialized, and thus increase the sources of starch in the food industry.

Keywords. banana, pseudostem, starch, yield, morphology, thermal

1. Introduction

On January 30, 2020, the World Health Organisation (WHO) declared the COVID-19 outbreak as a global emergency [1]. It is a pandemic that gives great impacts towards the activities of humanity and it also includes the activities of agriculture and food industry. In the food industry, mobility restrictions and reduction in the purchasing power had greatly affected by food demands [2]. Besides, as the demands for food increase within this period, the sources of food need to double up. Thus, some new sources of food need to discover to cover the limitation in the food sources. One of the new sources of food sources is starch from banana pseudostem.

Banana or its scientific name is Musa acuminate belongs to family Musaceae [3]. The banana plant is planted to harvest for their fruit. This plant is normally tall and sturdy. In Malaysia, banana trees are
widely planted around Pahang, Johor and Sabah. In 2016, the planted area of the banana trees was 28,036.43 hectare while in 2017, the planted area had increased to 34,894.06 hectare [4].

The banana pseudostem is formed from leaf sheaths that tightly packed and become thicken due to modification of the lower part of the midrib until the plant reaches maximum height. It started when the reproductive organ begins to form. The colour of banana pseudostem is reported to have a red, reddish-green colour and yellowish colour [5]. At the centre of pseudostem, there is tube-like tender core (Figure 1) with a diameter of approximately 5–6 cm [6].

![Figure 1. Cross-section of banana pseudostem](image)

The increment in the planted area of banana can be used as an indicator of the wastage increment. The banana plant can be categorized as one of the resources of annual agricultural residues. Once the banana fruits are harvested, the pseudostem is cut down and most are left in the soil plantation or being dumped at another place for decomposition as it cannot produce fruit twice. This abandoned crop waste would lead to environmental pollution [7].

Banana pseudostem has the potential to be a feedstock for energy generation [8]. Moreover, the fibre extracted from banana pseudostem can be used as a food additive [9]. In addition, several studies showed that starch exists in banana pseudostem [10][11][12]. Starch is a polymer used in food industries such as in concentrated drinks and mayonnaises. In addition, starch forms a stable gel suitable for food products that require cooling process [13]. Starch is also widely used in the processing of food products as it is edible polymers. Besides, starch can be used as a coating film as a protective layer or an alternative of food preservative on food product [14].

The objective of this study is to identify the yield, thermal properties and morphological properties of starch from different parts of banana pseudostem. The identification of the starch’s properties would be useful for further application in the food industry.

2. Material and Methods

2.1. Sample
The banana pseudostems from ‘Pisang Boyan’ were obtained from a farm located at Parit Sulung, Batu Pahat, Johor.
2.2. Chemical
Sodium disulfite (Na$_2$S$_2$O$_5$) (R&M, Malaysia), iodine solution (R&M, Malaysia) and sodium hydroxide pellets (NaOH) (QRec, Malaysia) were purchased from local suppliers.

2.3. Starch isolation
Banana pseudostem starch was extracted by sugar cane extractor (TFS 377, Hisaki, Malaysia). Then, the pseudostem was rinsed with distilled water with ratio 1:2 and the water was drained. The stem was milled with another distilled water with ratio 1:3 to form a slurry. The distilled water was added with ratio 1:2 into a blender to form finely slurry. The slurry was filtered by using gauze. The slurry was stirred while distilled water was added until the total volume had reached 1.5L. The starch was left to precipitate at room temperature for 24 hours.

The precipitate formed was separated from the filtrate and was deposited with distilled water twice in 2 hours. For the last precipitation process, 0.1N NaOH solution was added and the starch was precipitated for another 3 hours. The filtrate was separated from the starch and the starch was washed with distilled water to remove the residual NaOH. The washing process was repeated for 5 times until the pH of the starch is neutral. The obtained starch was transferred to trays and will be dried in an oven at temperature 50°C for 24 hours. The starch was crushed and sieved using a 100-mesh sieve [15].

2.4. Determination of starch yield
The yield of starch was calculated according to Equation 1 based on the amount of starch extracted and the total weight of stem used [16].

\[
\text{Yield (\%)} = \left(\frac{\text{mass of dried starch (g)}}{\text{total mass of stem used (g)}}\right) \times 100\%
\]  \hspace{1cm} (1)

2.5. Presence of starch
The presence of starch was determined by using the iodine test. 3 g of starch sample was diluted in 50 ml of water while another 50 ml of distilled water was the control. The mixture was mixed by using a vortex mixer and the change of iodine colour was recorded [16].

2.6. Starch morphology
The surface morphology of starch granule was observed by using scanning electron microscopy (SEM) (EM-30, COXEM, South Korea). The sample was mounted on bronze stubs using double-sided tape, and their surfaces were coated with a gold layer before analyzing its morphology [17].

2.7. Thermal properties
Differential scanning calorimeter (Q20, TA Instruments, United States) was used to analyze the thermal properties of banana pseudostem starch. 5 mg of starch was weighed in aluminium pan (901683.901, TA Instruments, United States) and 1.5 µL of deionized water was added. The sample was mixed, sealed and held at 4 °C for overnight. The sample was held at room temperature for 2 hours and was heated from 20 °C to 120 °C at a rate of 10 °C/min (Li et al., 2018). The onset temperature (T$_{\text{onset}}$), peak temperature (T$_{\text{peak}}$) and end temperature (T$_{\text{end}}$) was recorded [18].

2.8. Statistical analysis
The results obtained were expressed as mean ± SD to show variations in the various experimental. The differences are considered significant when $p < 0.05$.

3. Results and Discussion
The banana pseudostem starch was isolated from three different parts, which are the outer part of pseudostem (OPS), inner part of pseudostem (IPS) and the whole part of pseudostem (WPS). The yield
of starch obtained (Table 1) from OPS, IPS and WPS was 11.97 g ± 0.52, 6.86 g ± 0.04 and 10.35 g ± 0.76, respectively. The range of starch yield was 0.12 % - 0.19 %. The study from Etxeberria et al. [19] on orange trees shows that starch is highly accumulated in stems and bark. This study stated that starch is mostly accumulated in xylem parenchyma cells meanwhile there are scattered accumulation of the starch inside phloem tissue. The role of parenchyma cells is to store and transport carbohydrates as soluble sugar and starch and the banana pseudostem, mainly the outer part contains plenty amount of parenchyma cells compare to inner part [20] [21]. In this study, the result obtained showed that OPS had the most yield of starch. Thus, due to the abundance and huge amount of this postharvest waste, it is significant to obtain starch from this resource.

Table 1. Yield of banana pseudostem starch according to different parts

| No. | Part | Yield (g)   | % of starch |
|-----|------|-------------|-------------|
| 1   | OPS  | 11.97 ± 0.52 | 0.20        |
| 2   | IPS  | 6.86 ± 0.04  | 0.12        |
| 3   | WPS  | 10.35 ± 0.76 | 0.19        |

a,b Different small case superscript letters in the same column indicate a significant difference (p < 0.05).

The most well-known method to detect the presence of starch is the iodine test. The change in the yellow colour of the iodine can be detected visually when the sample was dispersed in distilled water and drops of iodine solution were dropped into the aqueous solution [22]. The result (Figure 2) obtained showed that the starch powder obtained had confirmed the presence of starch as the yellow colour of the iodine solution turn into purple-black colour. As starch molecules consist of amylose and amylopectin molecules, the solution turns purple-black colour as the iodine binds inside the helical shape of the amylose chain [23].

Figure 2. Iodine test colour for (a) control, (b) OPS, (c) IPS and (d) WPS

The thermal properties of three different parts of banana pseudostem were determined by using differential scanning calorimeter (DSC). They were analyzed based on the onset (T<sub>o</sub>), peak (T<sub>p</sub>) and endset temperature (T<sub>c</sub>) of the starch gelatinization in the presence of water. The result of this study (Table 2) showed that the starch obtained from OPS and WPS had no significant differences compared with IPS. The T<sub>p</sub> temperature for the starches from the three parts had range 71°C to 76 °C. However, previous studies showed that the T<sub>p</sub> of these three starches is low compared to other starches [18]. The starch which has low T<sub>o</sub>, T<sub>p</sub> and T<sub>c</sub> had high amylose content and low in degree of crystallinity. These properties indicate a less stable starch structure that makes the gelatinization process occur at lower temperature and less energy is needed for this process [24].

The morphology of starch was observed by using scanning electron microscopy and is presented in Figure 3. The starch from three different parts of banana pseudostem showed irregular and spherical
shape. Previous studies showed that the morphology of green banana starch is oval, elongated and cylindrical in shape [20]. The morphology of banana pseudostem is similar to the green banana starch but different from other starches due to differences in botanical sources [25]. The plants’ organelles that influence the morphology of the starch granules are chloroplast and amyloplast. It is stated that different starch sources have different physiology of these two organelles depends on the climatic condition and the geographical distribution [26].

Table 2. The onset, endset and the gelatinization temperature of banana pseudostem starch

| No. | Part  | $T_o$ (°C) | $T_c$ (°C) | $T_p$ (°C) |
|-----|-------|------------|------------|------------|
| 1   | OPS   | 70.55 ± 0.50$^b$ | 83.65 ± 2.06$^a$ | 71.30 ± 0.14$^b$ |
| 2   | IPS   | 75.15 ± 1.34$^a$  | 86.75 ± 0.78$^a$  | 76.50 ± 0.28$^a$  |
| 3   | WPS   | 71.80 ± 0.56$^{ab}$ | 88.70 ± 0.42$^a$  | 71.15 ± 0.35$^b$  |

$T_o$ is the onset temperature; $T_c$ is the endset temperature; $T_p$ is the peak temperature.

$^a,b$ Different small case superscript letters in the same column indicate a significant difference ($p < 0.05$).

Magnification

|     | x1.0k | x2.0k |
|-----|-------|-------|
| (a) | OPS   |       |
| (b) | IPS   |       |
| (c) | WPS   |       |

Figure 3. Morphology of starch; (a) OPS, (b) IPS and (c) WPS
4. Conclusion
In conclusion, the starches extracted from different parts of banana pseudostem show different starch characteristics including their morphological and thermal properties. The starch morphology of the banana pseudostem starch is different from other starch due to different sources and composition. Starch from OPS has a higher yield and lower gelatinization temperature. Further studies have to be conducted to identify the application of the banana pseudostem starch based on the properties that had been obtained in this study. This study is expected to contribute toward the new sources of starch that can be commercialized and help to increase the economy towards food industries.

Acknowledgement
This research was supported by the Ministry of Higher Education Malaysia under Fundamental Research Grant Scheme for Research Acculturation of Early Career Researchers (FRGS-RACER) Vot K162 (RACER/1/2019/WAB01/UTHM//1) and the Universiti Tun Hussein Onn Malaysia (UTHM) under Postgraduate Research Grant (GPPS) Vot H554.

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