Physicochemical and prebiotic properties of champedak (*Artocarpus integer* Merr.) seed starch

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Abstract

Chempedak (*Artocarpus integer* Merr.) belongs to the *Moraceae* family, which is a native fruit in southern Thailand. Chempedak seeds are considered as waste and composed mainly of starch. Physicochemical and prebiotic properties of champedak seed starch were analyzed in this study. The chemical compositions of champedak seed starch were investigated. It contained 0.47% protein, 0.37% fat, 0.32% ash, 27.31% amylose, and 3.75% resistant starch. The starch morphology was round and polygonal in shapes with average granular size of 6.50±1.25 µm analyzed by scanning electron microscopy (SEM). The swelling power and solubility of champedak seed starch were 11.52 and 10.71%, respectively. Pasting properties analyzed using a rapid visco analyzer (RVA) displayed that the peak and trough viscosity of champedak seed starch were 157.28 and 107.69 RVU, respectively. In addition, the gelatinization temperature monitoring by differential scanning calorimetry showed a range of 77.1-86.7°C. Champedak seed starch also exhibited essential prebiotic property of resistant under mimic gut stresses. It showed 16.66, 14.85, and 13.00% hydrolysis after sequential exposure to upper part of gastrointestinal tract in stomach at pH 1, 2, and 3, respectively for 4 h and duodenum (pancreatic α-amylase) for 6 h. These results suggest that the champedak seed starch could be used for development in functional food products.

Keywords: champedak seed starch, physicochemical, prebiotic

INTRODUCTION

Chempedak (*Artocarpus integer* Merr.) belongs to the *Moraceae* family, which is a native fruit in southern Thailand. At mature state, it has a strong unique aroma which is preferable among consumers (Buttara et al., 2014). Fruit of chempedak is similar to jackfruit (*Artocarpus heteropyhllus* Lam.) but it is smaller, with length and diameter are 20-35 cm and 10-15 cm, respectively (Chong et al., 2008). The fruit pulps can be consumed immediately while seeds are normally discarded or steamed and eaten as a snack or used in some local dishes. The nutritional values of the pulps, based on dry weight basis, are approximately: 3.5-7.0% of protein, 84.0-87.0% of carbohydrates, 5.0-6.0% of fiber and 2.0-4.0% of ash (Suranant, 2001). The fresh seeds cannot keep for a long time and composed mainly of carbohydrates at 79.74% (Zabidi and Aziz, 2009), which may contribute to the formation of resistant starch (RS).

RS consists of starch and products of starch digestion that are poorly absorbed by the small intestine and are completely or partially fermented in the colon (Zhang et al., 2014). RS was reported to have physiological as prebiotic. However, there has been a rare study on chempedak seeds. In the present study, some physicochemical characteristics and prebiotic property of champedak seed starch were investigated.

MATERIALS AND METHODS

Preparation of champedak seed starch

Champedak seeds were extracted from mature fruits purchased from a local market in

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Surat Thani, Thailand. The brown spermoderm covering the cotyledons was removed by immersing champedak seeds in a 5% sodium hydroxide solution and sodium metabisulphite solution, followed by washing with running water. The starch was extracted from the cotyledons. The extraction of starch from champedak seeds was conducted according to the slightly modified methodology of Rengsutthi and Charoenrein (2011). The dried starch was stored in a plastic container under refrigeration until use.

Chemical composition of champedak seed starch

The chemical composition of champedak seed starch was determined according to the methodology described in the AOAC (2000). Analyses of moisture were conducted by desiccation in an oven at 105°C until a constant weight was achieved; total lipids by extraction with hexane in Soxhlet; ash by incineration in a muffle furnace at 550°C; and total protein by the Kjeldahl method (N×6.25). Amylose and RS content were determined by method of Juliano (1971) and McCleary and Monaghan (2002), respectively.

Morphological characteristics of champedak seed starch granules

The shape of champedak seed starch granules was analyzed by a digital scanning electron microscope (SEM). Starch dispersions were placed on double-sided tape and coated with gold (sputtering). The mean particle size was determined. Twenty fields were randomly selected and photographed and 10 granules from each field were measured (for a total of 200 granules).

Physicochemical of champedak seed starch

The swelling power and solubility of champedak seed starch were determined according to the method described by Nwokocha and Williams (2009) with a slight modification. Briefly, 0.5 g of sample was dispersed in 25 mL of distilled water to form a suspension. The starch suspension was heated to 80°C for 30 min in a water bath. After centrifuging at 5000 rpm for 15 min, the supernatant was dried and weighed to measure the amount of dissolved starch and the sediment was used to calculate the swelling power. The swelling power and solubility were calculated as follows:

$$\text{Swelling power (\%)} = \frac{\text{Weight of sediment} \times 100}{\text{Weight of dry starch} - \text{Weight of dissolved starch}} \quad (1)$$

$$\text{Solubility (\%)} = \frac{\text{Weight of dissolved starch}}{\text{Weight of dry starch}} \quad (2)$$

The pasting properties of 10% champedak seed starch suspensions in distilled water were determined by using a rapid viscosity analyzer (RVA 4D, Newport Scientific, Australia). The determination was started at 50°C; the suspension was then heated to 95°C, maintained for 5 min, cooled to 50°C and held for 2 min (Li and Corke, 1999).

The gelatinization parameters were determined by differential scanning calorimeter (DSC1 instrument, Mettler Toledo, Switzerland) using the method described by Kim et al. (1995).

Champedak seed starch (7.5 mg) was weighed in an aluminum pan and deionized water was added to obtain a 30% starch suspension. Sample pan was placed in the calorimeter and heated from 25 to 130°C at 3°C min^{-1}. An empty pan was used as a reference and the instrument was calibrated using indium control. Endothermal curves exhibiting onset (T_0), peak (T_p) and end (T_c) temperatures and melting enthalpy (J g^{-1} of the sample weight on dry basis) of samples were recorded.

Prebiotic property

Prebiotic property in term of resistance to acidic and enzymatic digestion was tested in this study. Champedak seed starch was diluted into 10% solutions (w/v) HCl buffer at pH 1, 2, 3 and 7 containing 0.3% pepsin and incubated at 37°C for 4 h according to the modified procedure of Korakli et al. (2002). Thereafter, it was adjusted to pH 6.9 using 1 M NaOH followed with addition of 1 unit mL^{-1} of pancreatic α-amylase was further incubated for another 6 h. All digestions were done in triplicates. Reducing sugar content in the sample was determined by DNS method (Robertson et al., 2001) and total sugar was determined by phenol-sulphuric acid method (Fox and Robyt, 1991). Percentage hydrolysis of sample was calculated based on reducing sugar liberated and total sugar content of the sample:

$$\text{Hydrolysis (\%)} = \frac{\text{Reducing sugar release (Final – Initial sugar)} \times 100}{\text{Total sugar content – Initial reducing sugar}} \quad (3)$$

Statistical analysis

The data of each experiment was obtained in triplicate. Results were expressed as mean ± standard deviation and analysis of variance and Duncan's multiple range tests were performed using SPSS 16 software. Statistical significance was accepted at $p<0.05$.

RESULTS AND DISCUSSION

Chemical composition of champedak seed starch

The chemical compositions of champedak seed starch are shown in Table 1. Moisture content of starch generally depends on the duration of the drying process. It is also an index of storage stability of the starch (Ocloo et al., 2010). The moisture content of champedak seed starch was 10.33% (Table 1). It provided a measure of the dry weight and water contents of this starch. The protein, fat and ash contents were 0.47, 0.37 and 0.32%, respectively, higher than the chemical compositions of jackfruit seed starch described by Madruga et al. (2014) and Rengsutthi and Charoenrein (2011). The contents of amylose and resistant starch in champedak seed starch were 27.31 and 3.75%, respectively. Amylose content of 32.14% (dry matter basis) has been reported for jackfruit seed starch (Rengsutthi and Charoenrein, 2011) and it contained 30% (w/w) RS (Kittipongpatana and Kittipongpatana, 2015). These results indicated that the differentiations in chemical compositions between chempedak and jackfruit seed starch were observed.

Table 1. Chemical compositions (g 100 g^{-1} db) of champedak seed starch.

Parameters	Champedak seed starch (%)
Moisture content	10.33±0.42
Protein content	0.47±0.08
Lipid content	0.37±0.05
Ash content	0.32±0.03
Amylose content	27.31±0.71
Resistant starch content	3.75±0.94

Mean values ± standard deviation.

Morphological characteristic of starch granules

Scanning electron microscopy image of champedak seed starch granules revealed round and polygonal in shape and exhibited rough surfaces or pores (Figure 1). The average granule size was 6.50±1.25 µm. It is in good agreement with Tongdang (2008) reporting the similar average granule size of chempedak seed starch (6.47 µm). This result suggests that the average size observed for starch in the present study is typical of the champedak seeds.

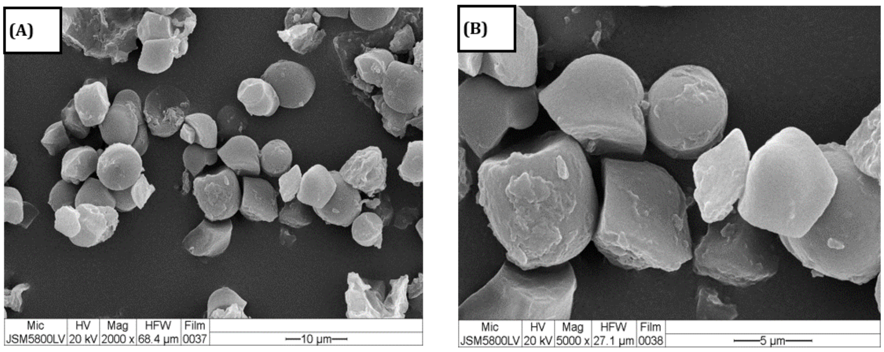

Figure 1. Scanning electron micrographs at 2,000× (A) and 5,000× (B) of chempedak seed starch.

Physicochemical characteristics of champedak seed starch

The physicochemical characteristics of champedak seed starch are shown in Table 2. The swelling power and solubility are the important properties of starch that are related to the quality of food products. The swelling power was dependent on water absorption by the amorphous starch regions, which was related to the channels and crystal structure or hydrogen bonding, whereas the solubility was used as an indicator of the destruction of starch components, which was greatly dependent on the source, the ratio of amylose and amylopectin, crystallinity and thermal stability reported by Zeng et al. (2018). In the present study, the swelling power and solubility at 80°C champedak seed starch were 11.52 and 10.71%, respectively.

Table 2. Physicochemical charecteristics of champedak seed starch.

Parameters	Champedak seed starch
Swelling power (%)	11.52±0.62
Solubility index (%)	10.71±0.18
Pasting properties	
- pasting temperature (°C)	78.8±0.1
- peak viscosity (RVU)	157.28±0.71
- though viscosity (RVU)	107.69±0.49
- breakdown (RVU)	49.54±0.44
- final viscosity (RVU)	187.53±0.58
- setback (RVU)	79.83±1.02
Gelatinization	
- onset temperature [T_0] (°C)	77.1±0.1
- peak temperature [T_p] (°C)	81.3±0.1
- completion temperature [T_c] (°C)	86.7±0.4
- enthalpy change [ΔH] (j/g)	8.1±0.0

Mean values ± standard deviation.

The pasting characteristic represents the behavior of the starch during heating and allows evaluation of the characteristics of the paste formed by structural modifications of starch molecules and the tendency for retrogradation to occur during cooling (Lustosa et al., 2009). The temperature at which granules begin to swell is called the pasting temperature, which was 78.8°C in this study (Table 2). It was slightly lower than jackfruit seed starch (81.58°C) reported by Rengsutthi and Charoenrein (2011). Because of the higher amylose content, jackfruit seed starch (32.14% amylose) exhibited higher pasting temperature than the champedak seed starch. Moreover, the setback (tendency for retrogradation) of champedak seed starch was 79.83 RVU (Table 2). It is lower than jackfruit seed starch (148.21

RVU), which had granules sizes from 7 to 11 μm reported by Rengsutthi and Charoenrein (2011). The higher setback values are found in large granules starch because of the increased fragility found in larger granules (Yuan et al., 2007).

The starch gelatinization temperature is related to the structural characteristics of crystallinity (Shamai et al., 2003). Increases in gelatinization parameters (77.1-86.7°C) are presented in Table 2. This results are in agreement with other starches (Chung et al., 2009; Vatanasuchart et al., 2012; Kittipongpatana and Kittipongpatana, 2015) suggesting that the reduced mobility of starch chain within amorphous region caused by structural changes within starch granule due to amylose-amylose, amylose-amylopectin, and/or amylose-lipid interactions (Chung, et al., 2009) as well as the difference in the size, form and distribution of starch granules (Vatanasuchart et al., 2012). In addition, onset temperature of champedak seed starch was 77.1°C, which related to the pasting temperature (78.8°C) reported above.

Prebiotic property

Prebiotic is a non-digestible food ingredient that beneficially affects the host by selectively stimulating the growth and/or activity of one or a limited number of bacteria in the colon and thus improves host health, defined by Gibson and Roberfroid (1995). It must be able to resist digestive processes prior to reaching the colon to have these effects (Gibson et al., 2004). Digestion in the stomach occurs under a very acidic condition (pH 1-3) and involves various enzymes secreted by pancreas, such as α-amylase in small intestine (Macfarlane and McBain, 1999). Therefore, in the initial estimation of the prebiotic properties of champedak seed starch was subjected to acidic and then enzymatic hydrolysis using HCl buffer and pancreatic α-amylase, respectively, to determine % hydrolysis.

The result in Figure 2 indicated that champedak seed starch exhibited essential prebiotic property of resistant under mimic gut stresses. It showed 16.66±0.14, 14.85±0.22, 13.00±0.27, and 2.65±0.17% hydrolysis after sequential exposure to upper part of gastrointestinal tract in stomach at pH 1, 2, 3, and 7 (control), respectively with 0.3% pepsin for 4 h and duodenum (1 U mL^{-1} pancreatic α-amylase) for 6 h. These results suggest that more than 80% of champedak seed starch could reach to the colon to have prebiotic effects in host. It was therefore proposed as a potential prebiotic candidate that can be used for development in functional food products.

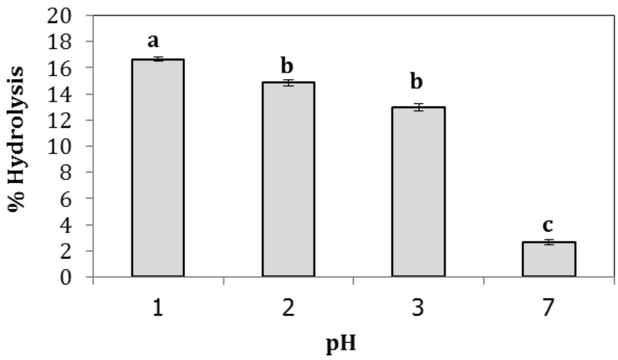

Figure 2. Percent hydrolysis of champedak seed starch after sequential exposure to gut stresses in stomach at pH 1, 2, 3, and 7 (control) with 0.3% pepsin for 4 h and duodenum (1 U mL^{-1} pancreatic α-amylase) for 6 h.

CONCLUSIONS

The chemical compositions, morphology and physicochemical characteristics, and prebiotic property of seed starch in chempedak (*Artocarpus integer* Merr.), which is a native fruit in southern Thailand, are firstly reported in this study. The champedak seed starch could be used for development in functional food products. Hence, more research is needed to exploit other potential functional properties.

ACKNOWLEDGEMENTS

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