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Physicochemical properties and starch digestibility of *Scirpus grossus* flour and starch

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Abstract

Flour and starch isolated from the tubers of *Scirpus grossus* were investigated for their physicochemical properties and starch digestibility. The flour was extracted using two different processes namely peeled and unpeeled processes. Proximate analysis revealed that the flours from both processes contain considerably high total starch, more than 80%, which indicate their potential use as starchy foods. The amylose content of the flours and starches ranged from 29 to 32%. Starch granules of *S. grossus* were oval in shape with smooth surface and small diameters ranging from 6 to 15 μm. All samples exhibited high swelling pasting behaviors with pasting temperatures ranging from 78 to 79 °C, indicating the strong bonding forces within the granule interiors. Differential scanning calorimetry (DSC) results suggested that the samples gelatinized at temperatures ranging from 71 to 81 °C. In vitro starch digestion assay found that all samples provided the estimated glycaemic index (GI) values of approximately 55 or less.

Highlights

•The flour and starch of *Scirpus grossus* have the potential to be used as starchy foods.

•Their functional properties have not yet been investigated.

•This study determined their physicochemical properties.

•The findings here suggested that it could be used in low GI food products.

Keywords

- *Scirpus grossus*;
- Starch;
- Flour;
- Physicochemcal property;
- Starch digestibility

1. Introduction

Wetlands are vital ecosystems which perform some important functions in relation to climate changes such as their ability to sink carbon, store and regulate water. The plants of wetland ecosystems played fascinating role in the life of human beings in earlier days as food, fodder, medicine, etc. But with the advancement of life pattern, the uses of wetland plants are foregone and they are treated as noxious weeds (Swapna, Prakashkumar, Anoop, Manju, & Rajith, 2011). Currently, with rising concerns on climate changes and food security, wetland plants have gained interest with particularly as food sources. The potentials of these plants for use as foods rely on their tuber and root starches. Recent researches have investigated structure and physicochemical properties of several underutilized tropical tuber and root starches (Hoover, 2001 and Jayakody et al., 2005, Jayakody, Hoover, Liu, & Donner, 2007).

Scirpus grossus, is a wetland weed of the family Cyperaceae which are perennial grass-like plants and can grow to 3 m tall in shallow water or in moist soils. The most important reserve substance in the rhizome of Cyperaceae is starch, which accounts for 15% of fresh weight in winter. During the formation of new shoots in spring almost all the starch is mobilized (Steinmann & Brändle, 1984). Local people who make use of these rhizomes harvest them during winter. Like other tuber and root starches, many of the developing world's poorest and most food insecure households look to these crops as a contributing, if not the principle, source of food, nutrition and cash income. Among other things, farm households see the value of roots and tubers in their ability to produce edible energy and in their capability to generate yields under conditions where other crops may fail.

Among many species of the family Cyperaceae, *Cyperus rotundus* has received much attention. The plant is one of the most invasive weeds known, having spread out to a worldwide distribution in tropical and temperate regions. *C. rotundus* has been called “the world's worst weed” as it is known as a weed in over 90 countries and infests over 50 crops worldwide. On the other hand, it is a traditional herbal medicine used widely as analgesic, sedative, antispasmodic, antimalarial, stomach disorders and to relieve diarrhea (Zhu, Luk, Fung, & Luk, 1997). The tuber part of *C. rotundus* is one of the oldest known medicinal plants used for the treatment of dysmenorrhea and menstrual irregularities (Bhattarai, 1993). Infusion of this herb has been used in pain, fever, diarrhea, dysentery, an emmenagogue and other intestinal problems (Uddin, Mondal, Shilpi, & Rahnan, 2006). Umerie and Ezeuzo (2000) have reported that the *C. rotundus* starch is used in the food and confectionary industries. Phytochemical studies have shown that the major chemical components of this herb are essential oils, flavonoids, terpenoids, mono- and sesquiterpenes (Ohira et al., 1998 and Kilani et al., 2005). Several investigators have reported its potential in antibacterial, antioxidant, cytotoxic and apoptotic activities (Ardestani and Yazdanparast, 2007 and Kilani et al., 2008).

In the Cyperaceae family, *S. grossus* which is found extensively in South East Asia has not yet been investigated for its potential application. Though, local people extract its tuberous flour and use as foods. The yields are considerably high due to the large size of the tubers when compared to other species in the family (Fig. 1). This study investigated the physicochemical properties and starch digestibility of *S. grossus* flour and starch isolated from the tubers in order to find the potential as functional food source.

Fig. 1.

Appearances of *S. grossus* (dried stems and leaves) and their tubers.

2. Materials and methods

2.1. Materials

S. grossus tubers were purchased from local markets in Phitsanulok Province, Thailand during winter of 2011.

2.2. Flour preparation

The tubers were brushed in tap water to remove adhering dirt. Flour was prepared by two different methods (peeled and unpeeled). These two processes represent the methods used by local people and industry. The peeled and unpeeled tubers (wet forms) were ground using a mortar. Distilled water was added at the ratio of 1:3 (sample:water) and the samples were ground using a blender until fine particles were obtained. The ground samples were sieved through a 100-mesh screen and rewashed with water for three times. The extracted flour was dried at 50 °C until the moisture content reached 10–13%. Notably that drying at 50 °C in this study cannot anneal starches in the samples as the water content is not sufficient, only excess water (more than 60%, w/w) can induce annealing process (Tester & Debon, 2000). The samples were sieved through a 100-mesh screen.

2.3. Starch extraction

Starch was isolated from the flour (unpeeled samples) using the alkaline extraction method (Lee, Htoon, & Paterson, 2007). The flour was dispersed in water (1:10, w/w) and pH was adjusted to 9 by adding 0.1 M NaOH, and then stored at 30 °C for 2 h. The slurry was filtered through a 100-mesh sieve. The filtrate was centrifuged at 3000 × *g* for 30 min. After centrifugation, the supernatant was discarded and the yellow layer (fat) was manually scraped off. The sediment or starch portion was washed with 0.01% sodium metabisulfite. Subsequently, it was washed three times with water and centrifuged at 3000 × *g* for 15 min. The starch portion was filtered again through a 100-mesh sieve and dried in a hot-air oven at 50 °C for 16 h. The dried starch samples were ground using a hammer mill fitted with a 0.5-mm sieve and sifted through 100 mesh sieve.

2.4. Physicochemical properties

2.4.1. Proximate analysis, total starch and amylose content

Proximate analysis was determined using standard AOAC methods (AOAC, 2000). Total starch was determined enzymatically using the total starch assay kit (Megazyme International, Ireland) following the standard AOAC Method 996.11. About 100 mg of sample was wetted with ethanol, mixed in KOH and sodium acetate buffer (pH 3.8). The samples were digested with thermo-stable α-amylase and amyloglucosidase and incubated at 50 °C for 30 min. The glucose released was determined using an enzymatic glucose reagent (GOPOD method), and the absorbance of the coloration was measured spectrophotometrically at 510 nm. For amylose, it was determined by colorimetric measurement of the blue amylose–iodine complex (Juliano, 1971). The samples were analyzed in triplicate.

2.4.2. Scanning electron microscope (SEM)

Dried samples were dispersed on double-stick adhesive tapes mounted on SEM aluminum stubs, coated with a thin layer of gold in a vacuum evaporator (EMITEX K 550X), and examined with the SEM (Phillips XL30) at 1000–1500 magnifications.

2.4.3. Swelling power and solubility

The solubility and swelling power were obtained using the method from Schoch (1964) with slight modifications. Samples (0.5 g) were dispersed in 15 mL distilled water. The suspensions were heated to 55, 65, 75, 85 °C in a water-bath with periodic mixing over a 30 min period. The cooked paste samples were centrifuged at 2200 rpm for 15 min. The supernatants were taken and placed in pre-weighed aluminum can before drying at 105 °C to gain constant weight. The dried supernatants were weighed as soon as the samples reached room temperature. After the supernatants were removed the swollen sediment samples were weighed. The solubility and swelling power were then calculated using Eqs. (1) and (2):

equation(1)

$$\text{Solubility}\,(\%) = \frac{\text{Weight of soluble matter in supernatant (g)}}{\text{Weight of sample (g dry basis)}} \times 100$$

equation(2)

$$\text{Swelling power}\,(\%) = \frac{\text{Weight of swollen matter (g)}}{\text{Weight of sample (g dry basis)} \times (100 - \text{solubility})} \times 100$$

2.4.4. Pasting properties by Rapid Visco-Analyser (RVA)

Pasting properties were investigated using the Rapid Visco-Analyser (RVA-4D, Newport Scientific Pvt. Ltd., Australia) following the approved method 61.02 (AACC, 2009). A 13-min RVA profile was used with 3.0 g ground samples (adjusted to 14% moisture content) in 25 mL distilled water. The RVA Thermocline™ software (ver. 2.6) was used to obtain the RVA profiles and pasting characteristics. Each sample was analyzed in triplicate.

2.4.5. Differential scanning calorimetry (DSC)

Distilled water was added into the dried samples at the ratio of 3:1 (w/w). The DSC (Mettler Toledo DSC 1) equipped with a refrigerated cooler was used. The hydrated samples (20 ± 5 mg) were weighed into the aluminum DSC pans and hermetically sealed. An empty pan was used as the reference, and DSC analysis was done by scanning from 30 to 120 °C, ramping at 10 °C/min. Nitrogen was used as a purged gas. The resulting thermograms were analyzed using Mettler Toledo Star^e software (ver. 9.20) for the onset temperature (T_o), peak temperature (T_p), conclusion temperature (T_c) and transition enthalpy (ΔH). Each sample was analyzed in triplicate.

2.5. In vitro starch digestibility and modeling of starch digestogram

Time-course starch digestion in the samples was determined using a rapid in vitro digestibility assay based on glucometry (Mahasukhonthachat et al., 2010 and Sopade and Gidley, 2009). About 0.5 g of ground sample was treated with artificial saliva containing porcine α-amylase (Sigma A-3176 Type VI-B) before pepsin (Sigma P-6887; pH 2.0) was added and incubated at 37 °C for 30 min in a reciprocating water bath (85 rpm). The digesta was neutralized with NaOH before adjusting the pH to 6 (sodium acetate buffer) prior to the addition of pancreatin (Sigma P1750) and AMG (Sigma A-7420). The mixture was incubated for 4 h, during which the glucose concentration in the digesta was measured with an Accu-Check® Performa® glucometer at specific periods (0, 10, 20, 30, 45, 60, 90, 120, 150, 180, 210 and 240 min). Digested starch per 100 g dry starch (*DS*) was calculated as in Eq. (3):

equation(3)

$$DS = \frac{0.9 \times G_G \times 180 \times V}{W \times S[100 - M]}$$

where G_G = glucometer reading (mM/L), V = volume of digesta (mL), 180 = molecular weight of glucose, W = weight of sample (g), S = starch content of sample (g/100 g sample), M = moisture content of a sample (g/100 g sample), and 0.9 = stoichiometric constant for starch from glucose contents.

The digestogram (digested starch at a specific time period) of each sample was modeled using a modified first-order kinetic model, Eq. (4), as described before (Mahasukhonthachat et al., 2010):

equation(4)

$D_t=D_0+D_{\infty-0}(1-\exp[-Kt])$

where D_t (g/100 g dry starch) is the digested starch at time t, D_0 is the digested starch at time $t = 0$, D_∞ is the digestion at infinite time ($D_0 + D_{\infty-0}$), and K is the rate constant (min^{-1}).

The Microsoft Excel Solver® was used to compute the parameters of the model by minimizing the sum of squares of residuals (SUMSQ) and constraining $D_\infty \leq 100$ g per 100 g dry starch, and $D_0 \geq 0$ g per 100 g dry starch. In addition to the coefficient of determination (r^2), the predictive ability of the models was assessed with the mean relative deviation modulus (MRDM) as described elsewhere (Mahasukhonthachat et al., 2010).

In order to calculate the estimated glycaemic indices (GIs) of the samples, the areas under the digestograms (AUC_{exp}) were computed with Eq. (5):

equation(5)

$$AUC_{exp} = \left[D_\infty t + \frac{D_{\infty-0}}{K} \exp(-Kt) \right]_{t_1}^{t_2}$$

The hydrolysis index (HI) of each sample was calculated by dividing the area under its digestogram by the area under the digestogram of a fresh white bread, which was calculated to be about 13,000 min g/100 g dry starch from 0 to 240 min (Yong, Chan, Garcia, & Sopade, 2010). Single-point measurement of starch digestion at 90 min in the samples was also used to calculate GI (H_{90}). Hence, using the parameters of the modified first-order kinetic model for both the samples and fresh white bread, GIs of the samples were also calculated, and the average GI (GI_{AVG}) for each sample (Goni, Garcia-Alonso, & Saura-Calixto, 1997) was defined as Eq. (6):

equation(6)

$$GI_{AVG} = \left[\frac{((39.21 + 0.803H_{90}) + (39.51 + 0.573\,HI))}{2} \right]$$

2.6. Statistical analysis

Analysis of variance (ANOVA) and test of significance were performed using SPSS® ver. 16 with confidence level of 95%. The samples were randomized for all the analyses described above.

3. Results and discussions

3.1. Physicochemical properties

3.1.1. Proximate analysis, total starch and amylose content

Proximate analysis, total starch and amylose content are shown in Table 1. *S. grossus* flours (both peeled and unpeeled samples) contain considerably high total starch content, more than 80%, which indicate their potential as carbohydrate foods. Notably that total starch from peeled-process flour is as high as total starch from isolated starch sample. Hoover (2001) reviewed the published literatures and found that starch yield of many tuber and root starches ranged from 30 to 88%. It is highlighted here again that *S. grossus* contain high starch yield as compared to other tuber and root starchy plants.

Amylose content of starch from *S. grossus* ranged from 29 to 32% and processing methods affected the amylose content. Peeled process provided the flour with high amylose content as this process had less contaminants.

Table 1. Total starch, amylose and proximate analysis of the samples (g/100 g dry sample).

Samples	Total starch	Amylose	Protein	Fat	Crude fiber	Ash
Starch	87.69 ± 0.77^{a}	32.33 ± 0.58^{a}	0.17 ± 0.02^{c}	0.06 ± 0.01^{b}	0.08 ± 0.01^{c}	0.09 ± 0.00^{c}
Flour-peeled	87.37 ± 2.28^{a}	30.44 ± 0.51^{b}	0.32 ± 0.01^{b}	0.12 ± 0.01^{a}	1.43 ± 0.18^{b}	0.34 ± 0.09^{b}
Flour-unpeeled	80.43 ± 1.29^{b}	29.49 ± 0.50^{b}	0.36 ± 0.01^{a}	0.10 ± 0.05^{ab}	2.44 ± 0.18^{a}	0.48 ± 0.03^{a}

Values are means ± standard deviations. For each parameter (column), values with the same letters are not significantly different ($P > 0.05$).

Amylose content of starch from *S. grossus* ranged from 29 to 32% and processing methods affected the amylose content. Peeled process provided the flour with high amylose content as this process had less contaminants.

3.1.2. SEM

SEM images of the flour samples showing starch granules attached with other components e.g. protein (smaller sizes) are shown in Fig. 2. The granules were found to be oval in shape with smooth surface similar to potato starches. The diameter of starch granules ranged from 6 to 15 μm which is considered to be small when compared to other starch types e.g. potato (10–65 μm) (Yuan, Zhang, Dal, & Yu, 2007). Morphological characteristics of starches from different plant sources vary with the genotype. The variation in the size and shape of starch granules is attributed to the biological origin (Svegmark & Hermansson, 1993). Physicochemical properties, such as percent light transmittance, amylose content, swelling power and water-binding capacity were significantly correlated with the average granule size of the starches separated from different plant sources (Singh et al., 2003 and Zhou et al., 1998). The smaller granule sizes have been found to improve the digestibility because smaller granules have a greater surface area and are more rapidly digested by enzymes (Cone and Wolters, 1990, Franco et al., 1992 and Riley, 2004).

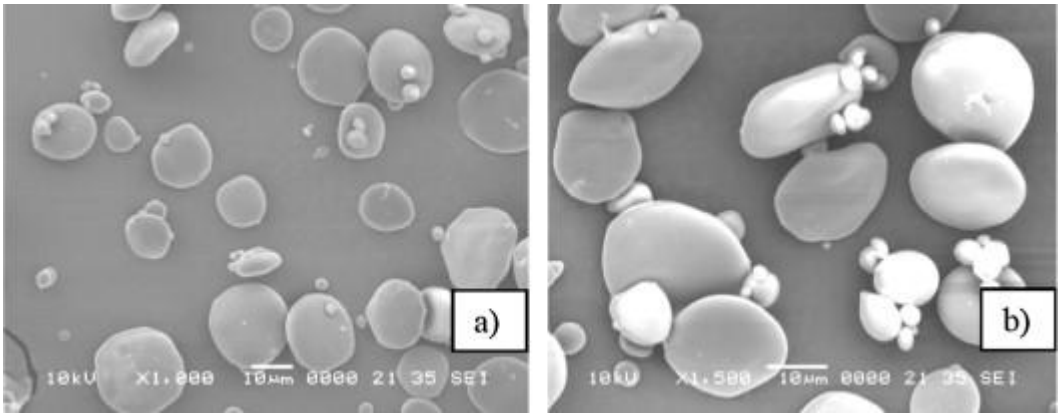

Fig. 2. SEM images of *S. grossus* flours, (a) unpeeled and (b) peeled sample.

Apart from morphological properties, molecular structure of starches as obtained by size exclusion chromatography and/or fluorophore-assisted capillary electrophoresis is suggested.

3.1.3. Swelling power and solubility

Swelling power and solubility of the samples are shown in Fig. 3. The solubility is contributed by the content of amylose, and the swelling power is contributed by the content of amylopectin (Tester & Morrison, 1990). The swelling power of all samples increased as the incubation temperature increased from 55 to 85 °C. As been known, starch could not be dissolved in cool water attributed to the starch crystal structure. However, when starch was heated in excess water, the crystalline structure was disrupted and water molecules became linked by hydrogen bonding to exposed hydrogen group of amylose and amylopectin. Then the amylose and amylopectin were dissociated in suspension, and the solubility of starch was increased (Yuan et al., 2007). From Fig. 3, *S. grossus* (both in the forms of flour and starch) swelled quickly from 65 to 75 °C, and they had dissolved well when temperature increased from 65 to 75 °C. From this study, the swelling power and solubility patterns of *S. grossus* flour and starch samples were found to be similar to those of other tuber starches. Yuan et al. (2007) reported that, as temperatures increased from 55 to 85 °C, swelling power of potato starch increased from 8 to 68% while solubility increased from 3 to 35%. Thus, the results from this paper indicated that the granule structure of *S. grossus* starch has single-step swelling process which is similar to potato and tapioca starches and this is different from cereal starches. Generally, cereal starches have two-step swelling process. The first stage of swelling (45–55 °C) occurs when heating starch from 55 to 60 °C and dissociation of amylopectin double-helices is exhibited. This makes amylopectin swells in highly extent, while the starch granules still exist through intermolecular (might be hydrogen) bonding. From this evidence, amylopectin would promote starch swelling, especially at the early stage of swelling. Amylose would leach out during heating process particularly at the higher temperature (the later stage of swelling).

Comparing among all studied samples, the flour (unpeeled process) exhibited the lowest swelling power and solubility. This could be influenced by a strong interaction between the yarn fibers and starches (Umerie & Ezeuzo, 2000).

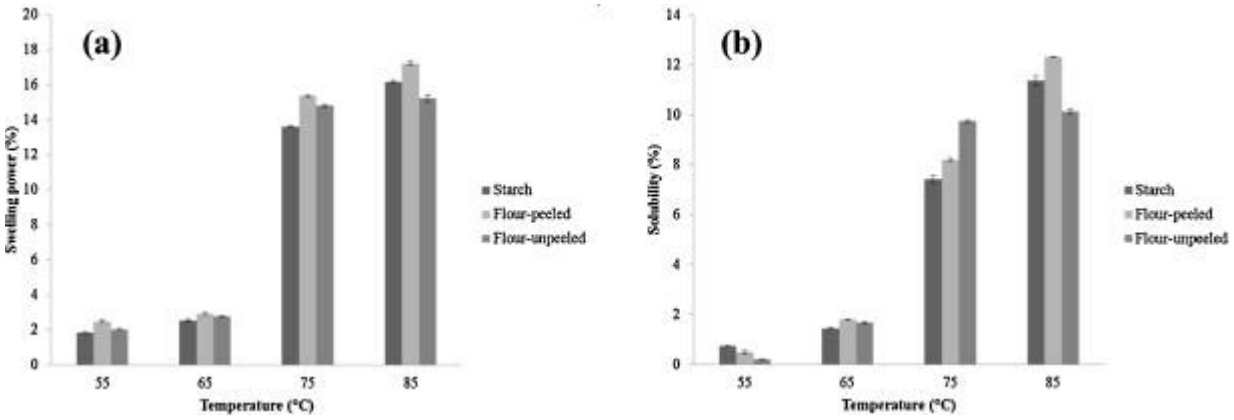

Fig. 3. Swelling power and solubility of *S. grossus* starch.

3.1.4. Pasting properties by RVA

Table 2 shows the pasting properties of *S. grossus* flour and starch samples. All the samples exhibited high pasting temperatures and thermal stability as indicated by breakdown values. Notably that the pasting temperatures of all samples ranged from 78 to 79 °C which were high when compared to other tuber and root starches as summarized by Hoover (2001). This suggests the strong bonding forces within the granule interiors. In addition, with its high in peak viscosity and final viscosity, it can be said to have high water biding capacity. Similar pasting pattern was found in another root starch, edible canna (Piyachomkwan et al., 2002, Srikaeo et al., 2011, Thitipraphunkul et al., 2003, Watcharatewinkul et al., 2009 and Yanika et al., 2009). Generally, starches with high viscosity are desirable for industrial uses, for which a high thickening power at high temperature can be obtained (Kim, Wiesnborg, Orr, & Gant, 1995). However, it should be noted that *S. grossus* starch showed considerably high setback values. This indicated that it provided a cohesive paste. It is less stable during cooling and retrograded more (Karim, Norziah, & Seow, 2000). Thus, the pasting properties showed that starch from *S. grossus* was not suitable for products in which stability is required at low temperatures e.g. fillings and refrigerated products.

3.1.5. DSC

DSC results suggested that *S. grossus* flour and starch samples gelatinized at the temperatures ranging from 71 to 81 °C (Table 3). Onset temperatures of the samples were found to be slightly higher than those found in most tuber and root starches (Bernabé et al., 2011, Hoover, 2001, Jane et al., 1992, Pérez and Lares, 2005 and Srikaeo et al., 2011). This result seems to support the findings from RVA, though DSC and RVA measure different properties of starch in excess water. It could be summarized in this study that *S. grossus* flour and starch are high in thermal stability and gelatinized at high temperatures when compared to other tuber and root starches. Gelatinization temperatures of the starchy samples can vary due to factors that include genetic origin, environmental conditions and age of the parent plant (da Mota et al., 2000, Hung and Morita, 2005, Jane et al., 1999 and Moorthy, 2002). High-amylose starches with longer average chain have been reported to exhibit higher transition temperatures (Jane et al., 1992).

Table 2. RVA parameters of the samples.

Samples	Peak temperature (°C)	Peak viscosity (RVU)	Trough viscosity (RVU)	Breakdown viscosity (RVU)	Final viscosity (RVU)	Setback viscosity (RVU)
Starch	78.33 ± 0.22^{b}	285.8 ± 0.25^{b}	207.4 ± 0.35^{a}	78.70 ± 0.99^{c}	280.4 ± 0.21^{a}	73.02 ± 0.56^{b}
Flour-peeled	78.37 ± 0.15^{b}	293.6 ± 0.52^{a}	173.5 ± 0.47^{c}	120.1 ± 0.17^{a}	249.6 ± 0.38^{c}	76.06 ± 0.57^{a}
Flour-unpeeled	79.14 ± 0.05^{a}	262.7 ± 0.31^{c}	180.5 ± 0.48^{b}	82.53 ± 0.71^{b}	254.5 ± 0.02^{b}	74.02 ± 0.52^{b}

Values are means ± standard deviations. For each parameter (column), values with the same letters are not significantly different ($P > 0.05$).

Table 3. DSC parameters of the samples.

Samples	T_o (°C)	T_p (°C)	T_c (°C)	ΔH (J/g dry sample)
Starch	73.34 ± 1.03^{a}	75.48 ± 0.21^{a}	81.14 ± 0.14^{a}	16.48 ± 0.28^{a}
Flour-peeled	70.74 ± 0.25^{b}	73.23 ± 0.25^{c}	77.51 ± 0.10^{c}	12.74 ± 0.14^{b}
Flour-unpeeled	70.95 ± 0.07^{b}	73.79 ± 0.08^{b}	78.85 ± 0.13^{b}	16.58 ± 0.76^{a}

Values are means ± standard deviations. For each parameter (column), values with the same letters are not significantly different ($P > 0.05$).

3.2. In vitro starch digestibility and modeling of starch digestogram

Fig. 4 shows the starch digestogram while Table 4 shows the digestion data of the samples. It was found that the modified first-order kinetic model, was suitable (r^2 = 0.95–0.99; MRDM = 1–14%; SUMSQ = 5–87) in describing the digestograms. Generally, all samples provided the average GI values for about 55 or less which indicate that most of them are low in GI. It is widely recognized that low GI foods are valuable for use in controlled glucose release applications and in lowering insulin response, and greater access to the use of stored fat is expected (Nugent, 2005 and Sajilata et al., 2006). This is important for diabetes and its dietary management. The present study showed that native *S. grossus* flour and starch can have the potential of being used as functional food ingredients for low GI foods. This appears to support the conclusions of Moorthy (2002) and Srikaeo et al. (2011) that some tropical tuber and root crop starches have the potential to be used in low GI foods. Comparing among all samples, *S. grossus* starch has higher digestion rate than those of the flours. However, the starch sample contains more amylose than the flour samples. Amylose content was reported to have an obvious impact on GI values. Slow digestion rate and consequently low GI values were expected with increased amylose content as studied in rice (Hu, Zhao, Duan, Linlin, & Wu, 2004). In this study, the starch sample which contained higher amylose gave higher digestion rate than those observed from

the flour samples. Starch digestion rate and the GI of foods depends upon various factors such as starch granule morphology, amylose to amylopectin ratio, molecular structure, degree of branching in terms of steric hindrance, and consequently mass transfer resistance (Fuentes-Zaragoza et al., 2010 and Singh et al., 2010). The other components in the flour samples of *S. grossus* could also have the impact on digestion rate.

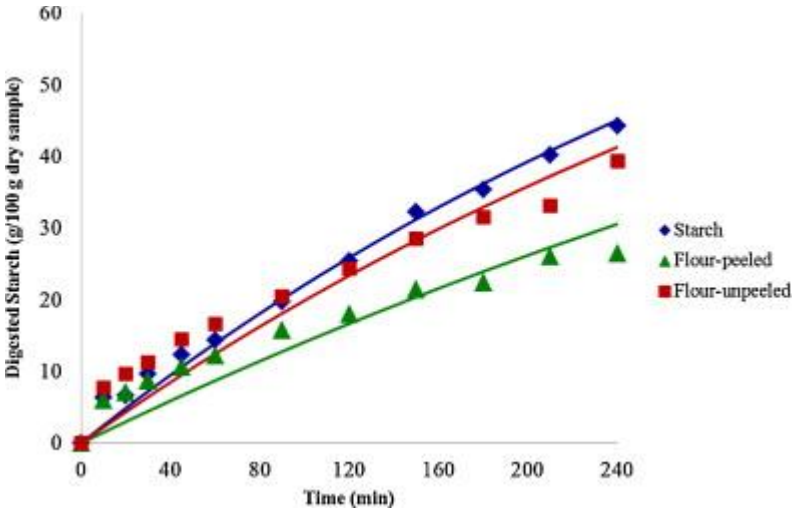

Fig. 4.

Digestograms of *S. grossus* starch and flours.

It should be noted that the digestion data in this study were based on the raw starch and flour samples. They can be different for cooked flour and starch. Generally, in the absence of retrogradation or structural changes, starch gelatinization enhances starch digestibility. Therefore, cooked samples could exhibit higher GI values than raw samples. Moreover, the results were also based on in vitro starch digestion assay. It is valid for comparison and useful for preliminary study of starch digestibility. Real digestion data and GI can be obtained by the in vivo assay. Further study is recommended.

Table 4. Model parameters, hydrolysis index (HI) and glycaemic index (GI) of the samples.

Samples	D_0 (g/100 g dry starch)	$K \times 10^{-3}$ (min^{-1})	GI_{H90}	GI_{HI}	Average GI
Starch	4.13 ± 0.91^{b}	2.20 ± 0.53^{a}	56.4 ± 0.29^{a}	54.4 ± 0.15^{a}	55.4 ± 0.23^{a}
Flour-peeled	5.44 ± 0.21^{ab}	1.13 ± 0.01^{c}	51.0 ± 0.12^{c}	49.6 ± 0.08^{c}	50.3 ± 0.10^{c}
Flour-unpeeded	6.68 ± 0.18^{a}	1.75 ± 0.05^{b}	55.5 ± 0.18^{b}	53.5 ± 0.18^{b}	54.5 ± 0.18^{b}

Values are means ± standard deviations. For each parameter (column), values with the same letters are not significantly different ($P > 0.05$).

4. Conclusion

S. grossus, is a wetland weed of the family Cyperaceae which has the potential of being used as a starchy food source. Physicochemical properties of its flour and starch revealed some unique characteristics such as thermal stability and granule structure stability. These properties suggested the application of its flour and starch to appropriate products. In vitro starch digestibility also found that it might be suitable for use in low GI foods. These findings could help in promoting the use of *S. grossus* as an alternative starchy food. It could also add the values to this crop and enhance food securities, as it is abundantly grown in wetlands or areas that other crops cannot grow well.

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