

Chemical and Physical Properties of Taro Starch *Colocasia esculenta* (L.) Schott Grown in Thailand

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Abstract

This research aimed to determine the chemical and physical properties of taro *Colocasia esculenta* (L.) Schott starch extracted from different sized taro cultivated in 4 locations (Chiangmai, Saraburi, Kanchanaburi and Trad). Taro flour composed of 84.6 – 91.5% carbohydrates, 5.1 – 8.7% protein, 1.1-3.2% fiber, 2.0 – 5.0% ash, and 0.4 – 0.9% fat. The flour contained calcium oxalate in the 317.0 – 435.8 mg/100 g range. It was found that using 0.05% NaOH in the starch extraction method yielded taro starch with lower protein content compared to water extraction method. The carbohydrates content of taro starch was not affected by corm size, but cultivating location. Taro starch contained 96.9 – 98.2% carbohydrates, 0.7 – 1.9% protein, 0.1 – 0.3% fat, 0.1 – 0.9% fiber, 0.1 – 0.4% ash, and 182.0 – 200.1 mg/100 g calcium oxalate. All taro starches had 18.8 – 22.4% amylose with an average degree of polymerization of 195 – 238. The starch granule was small and polygonal having an average diameter of 1.3 – 2.2 μm . With an A-type crystalline structure, the starch had a low swelling power of 11.0 – 17.4 g/g dry starch and low solubility of 8.1 – 13.2% at 80°C. The pasting temperature and peak viscosity of taro starch were 78°C – 87°C, and 264 – 441 RVU respectively.

Introduction

Taro *Colocasia esculenta* (L.) Schott is cultivated in the tropical area. Taro corms contain considerable amount of starch (70%-80% dry basis) (Quach, Melton, Harris, Burdon & Smith, 2000). It has been reported that the carbohydrate content of taro cultivated in different locations varied (Jane, Shen, Lim, Kasemsuwan & Nip, 1992). The starch extracted from taro corms has been reported to have fine granules (0.5-5 microns) (Perez, Schultz & de Delahaye, 2005) and, thus, offers smooth-textured starch gel. Moreover, it has been reported that fine granule-starch improved binding and reduced breakage of snack products (Huang, 2005). In addition, taro starch was reported to be more susceptible to pancreatin hydrolysis than other tuber and root starches (Sugimoto, Ohnishi, Takaya & Fuwa, 1979).

Raw taro corms contain considerable amount of oxalic acid ($\text{H}_2\text{C}_2\text{O}_4$) in forms of soluble oxalic acid and insoluble oxalate salts (Huang & Tanudjaja, 1992). Soluble oxalic acid can form complexes with calcium, magnesium, or potassium and, hence, reduces the mineral availability in the diet. It has also been reported that insoluble oxalate salts cause skin irritation and pungent odor in unwashed taro corms (Lee, 2002; Maga, 1992). Continuing consumption of high oxalate salts content taro can lead to gallstones deposit in the gallbladder. In a careful extraction of taro starch from its corm, both soluble and insoluble forms of oxalic acid can be partially removed. Iwuoha & Kalu (1994) reported that boiling taro corm at 90°C for 30 minutes and steeping in water at 30°C for 24 hours can reduce the oxalate salts content to 32.7% and 56.7% of its original content, respectively.

In Thailand, taro pricing is based on corm size. A mature sound taro; 6-month old at harvest, weighs up to 1.2 kilograms is priced higher than taros of smaller corm size. The smallest taro corm can be as small as 160 grams and is not preferred for commercial use. However, it has been reported that smaller corm taro (60-100 g) is rated higher quality for Japanese consumers (Vinning, 1995). By far, no study on the effect of corm size on physical and chemical properties of taro starch has been found.

This study aimed to determine the chemical and physical properties of taro *Colocasia esculenta* (L.) Schott starch extracted from commercially large, medium, and small corm taro cultivated in four locations representing the northern (Chiangmai province), central (Saraburi province), western (Kanchanaburi province), and eastern (Trad province) regions of Thailand.

Materials and methods

Material

Fresh taro corms; large (L), medium (M), and small (S) sizes, were obtained upon harvest from a northern province (Chiangmai; CH), a central province (Saraburi; SB), a western province (Kanchanaburi; KB), and an eastern province (Trad; TR) through Talard Tai fruit and vegetable outlet in Patumtani province. Due to regional variability, the weight range of each size from different provinces was slightly different (Table 1). Fresh taro corms were peeled, washed, and sliced. Taro slices were dried in a hot air oven at 40°C for 20 hours. The chips were, then, ground and sieved through a 35-mesh sifter to obtain taro flour. The flour was stored in a desiccator for further processing and analyses.

Table 1 Taro corm size related to cultivating area

Cultivating area	Harvest month	Corm weight (g)		
		Large (J)	Medium (M)	Small (S)
Chiangmai (CH)	January	450-1050	300-400	200-300
Saraburi (SB)	March	800-1100	400-500	300-400
Kanchanaburi (KB)	August	675-1320	380-600	160-340
Trad (TR)	May	600-1200	350-500	200-340

Starch extraction

Water extraction method

One part of taro flour was dispersed in five parts of distilled water and let stand for 2 hours. The suspension was later screened through a 200-mesh and 300-mesh sifter, respectively. The suspension was centrifuged at 3000xg and 4°C for 10 minutes, after which the supernatant was decanted. The sediment was re-suspended in five parts of distilled water. The centrifugation step was repeated 4 times. The sediment was finally dried in a hot-air oven at 40°C for 16 hours, ground, and sieved through a 100-mesh sifter. The starch was sealed in a plastic bag and kept in a desiccator for further analyses.

Alkaline extraction method

In alkaline extraction method, 0.05% (w/v) NaOH solution was used in place of distilled water. Extraction procedure was carried out in the same manner as that in water extraction method.

Chemical analysis

Proximate composition. The proximate composition of all starch samples was determined following the official method of analysis (AOAC, 1995).

Calcium oxalate content. The calcium oxalate contents of flour and starch samples were determined following the method of Iwuoha & Kalu (1994).

Amylose content. The amylose contents of all starch samples were determined following the method of Juliano (Juliano, 1971).

Degree of polymerization of amylose

Fractionation of starch was carried out following the method modified from Tsai & Lii (2000). The amylose fractions were collected and filtered through a microfilter (0.42 µm) before they were examined in a Dawn multi-angle laser photometer (Wyatt Technology Inc., USA) with a He-Ne laser operating system at 632 nm equipped with 18 detectors at angles ranging from 3.3 to 158° followed by a refractive index concentration detector (Optilab DSP, Wyatt Technology Inc., USA) and using a dn/dc value of 0.152 mL/g. The average molecular weight of amylose was calculated

using the following equation:
$$M_w = \frac{\sum C_i M_i}{\sum C_i} \quad (1)$$

where, C_i is the concentration of fraction I and M_i is the average molecular weight of amylose of fraction i.

Scanning electron microscopy (SEM)

Images of taro starch granules mounted on a stub and gold-coated were recorded using a Scanning Electron Microscope (JEOL model JSM-5800 LV) operating at 20 kV with 5000x magnification.

X-ray diffraction pattern

Crytalographic patterns of taro starch samples were recorded using an X-ray diffractometer (JEOL model JDX-8030) equipped with Ni-filtered Cu K(radiation and operating at 40 kV and 30 mA. Data were recorded over an angular range of 5° to 45° (2 θ) with a step angle of 0.04°.

Swelling power and solubility determination

Known amount of dry starch (m_0) (~0.5 g) was dispersed in 15 mL of water. The starch dispersion was heated under mild agitation at 80°C for 30 minutes. The gelatinized starch dispersion was then centrifuged at 3000xg for 15 minutes. After which, the supernatant was decanted and dried at 100°C until a constant weight (m_s) was reached. The swelling power and solubility were calculated following eq. 2 and 3.

$$\text{Swelling power [g/g dry starch]} = \frac{m_{sw}}{m_0(1 - \text{solubility})} \quad (2)$$

$$\text{Solubilty [g/g dry starch]} = \frac{m_s}{m_0} \quad (3)$$

where, m_{sw} is the weight of swollen starch granules.

Pasting characteristics

Pasting behavior of starch dispersions was investigated using Rapid Visco Analyzer (RVA) (series 4 D, Newport Scientific, Australia). The dispersions were prepared by dispersing ~3 g of starch (~ 14% MC) in 25 mL of distilled water. The following time-temperature profile was employed: Hold at 50°C for 1.25 minute, ramp to 95 °C over 3.75 minute (heating rate 12.0 °C per minute), hold at 95 °C for 2.5 minute, cooling back to 50 °C over 3.75 minute and hold at 50 °C for 1.25 minute. The measurements were done in duplicates.

Results and discussion***Chemical properties of taro flour***

Taro flour composed of 84.6 – 91.5% carbohydrates, 5.1 – 8.7% protein, 1.1-3.2% fiber, 2.0 – 5.0% ash, and 0.4 – 0.9% fat. The flour contained calcium oxalate in the 317.0 – 435.8 mg/100 g range. When considering chemical composition of taro cultivating within the same area (data not shown), it was observed that medium size taro from each cultivating area comprised less carbohydrates and more protein content. An exception was found in SB taro which showed no significant difference in carbohydrates and protein contents between flours from taro of different corm sizes. However, there was no correlation between taro corm size and carbohydrates content or other chemical compositions. Moreover, calcium oxalate contents of taro flour from taro of different sizes and from different cultivating locations were not significantly different ($p>0.05$).

It is observed that KB and TR taros had relatively higher carbohydrates content with an average value of 89.2% and 89.0%, respectively, while SB taro had the lowest average carbohydrates content of 84.5%. SB taro also contained the highest amount of calcium oxalate (420.9 mg/100 g flour), protein (8.3%), fat (0.7%), and ash (4.6%). The variation was attributed to the variation in local climate. It has been reported that taros cultivated in arid area contained more protein compared to that grown in humid area (Jane, Shen, Lim, Kasemsuwan & Nip, 1992). With additional information on average rainfall in the area where taros were cultivated and in the same cultivating year (the Meteorology department, 2003), it can be seen clearly that average rainfall in millimeter affected calcium oxalate content and carbohydrates content of taro flour (figure 1). The calcium oxalate content of taro flour increased while the carbohydrates content decreased with decreasing average rainfall in the area.

Chemical composition of taro starch

It was found that alkaline extraction method reduced the protein content in taro flour to approximately 1.3% while water extraction method reduced it to 3.3%. This was mostly because of that the protein present in taro flour is alkaline-soluble protein. Therefore, alkaline extraction method was employed for taro starch extraction in this study. It is noted that, the protein content was reduced to the lowest value of 0.7% in small size KB taro. The difficulty in taro starch extraction arose from the mucilage content in taro flour. Several washing steps needed to be carried out in order to remove slimy mucilage. As a result, the starch yield, calculated as percentage on dry flour, was relatively low (30.1-47.4 % of dry flour) (Table 2).

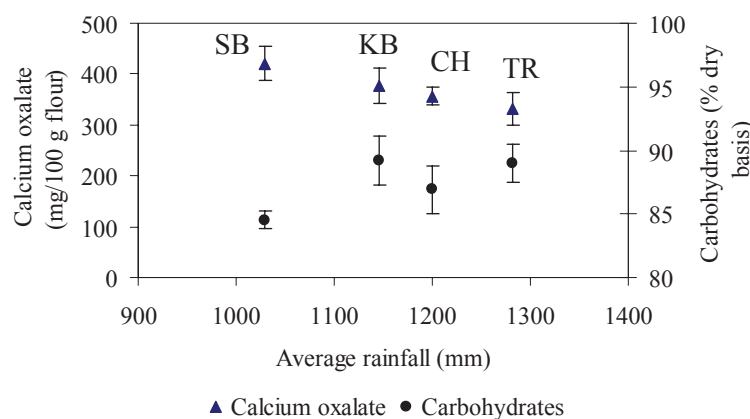


Figure 1 Average rainfall in the region where the taros were grown in 2003 versus calcium oxalate content of taro flour.

Table 2 Average chemical compositions of taro starch from taro of different origins¹

Cultivating area	Starch yield of dry (%) (flour)	(dry basis)Percentage					Calcium oxalate (g 100 /mg) of initial (%) (content)
		Protein	Fat	Ash	Fiber	Carbohydrates	
CH	^c 2.9 ± 30.1	^b 0.2 ± 1.2	^b 0.0 ± 0.2	^{ab} 0.1 ± 0.2	^a 0.2 ± 0.6	^b 0.4 ± 97.6	^b 3.8 ± 185.2 (%52.0)
SB	^B 3.0 ± 38.0	^a 0.2 ± 1.7	^a 0.1 ± 0.2	^{bc} 0.1 ± 0.2	^a 0.2 ± 0.7	^c 0.3 ± 97.1	^{ab} 6.0 ± 194.7 (%46.3)
KB	^A 7.8 ± 44.6	^c 0.2 ± 0.9	^a 0.1 ± 0.2	^c 0.0 ± 0.2	^a 0.2 ± 0.7	^a 0.2 ± 98.0	^a 12.5 ± 198.3 (%52.5)
TR	^A 4.1 ± 47.4	^b 0.3 ± 1.3	^c 0.0 ± 0.1	^a 0.1 ± 0.3	^b 0.2 ± 0.3	^a 0.1 ± 98.0	^{ab} 15.4 ± 191.4 (%57.8)

^{a, b, c} Mean values in each column with different superscripts are significantly different ($p \leq 0.05$).

From proximate analyses of taro starches, it was found that carbohydrates content of the starch extracted from different sizes taro grown in the same area was not different significantly ($p > 0.05$) (data not shown). The protein content of taro starch ranged from 0.7% to 1.9%. The result was consistent with the result on taro flour proximate composition in that there was no relationship between taro corm size and chemical composition. Table 3 shows chemical composition of the starch from taro grown in four locations. The values shown in table 3 are the average value from 3 sizes of taro from each cultivating area. Taro starch composed of 97.1-98% carbohydrates, 0.9 – 1.7% protein, 0.3-0.7% fiber, 0.2-0.3% ash, and 0.1-0.2% fat. The starch contained 185.2 – 198.3 mg calcium oxalate/100 g starch, which was below 60% of initial calcium oxalate content in taro flour. It can be deduced that the starch extraction process reduced calcium oxalate content of taro flour by more than 40% in general.

It is noted here that, from this study, taro starch contained more protein than did other starches such as potato starch (0.06% protein) and tapioca starch (0.1% protein) (Swinkles, 1985). The initial protein content in taro flour strongly influenced the amount of residual protein after starch extraction.

Amylose content and average degree of polymerization

Table 3 shows amylose content of taro starch and average degree of polymerization of the amylose. The values indicated that taro starch has low amylose content (18.8-22.4%) that is similar to taro grown in Hawaii (Jane, Shen, Lim, Kasemsuwan & Nip, 1992). Data on amylose content of starch from different sizes taro indicated that starch from medium size taro of each cultivating area had the lowest amylose content (data not shown). Moreover, it can be seen from table 3 that taro starch from taro cultivated in different areas had different amylose contents ($p \leq 0.05$), with SB taro starch containing the lowest amylose content (19.4%).

In addition, it was observed that average degree of polymerization (DP_{avg}) of taro starch from different areas varied in the 195 – 238 range. In comparison to DP_{avg} of amylose from Hawaiian taro starch (150-550) (Jane, Shen, Lim, Kasemsuwan & Nip, 1992), the DP_{avg} of Thai taro amylose varied in a narrower range.

Table 3 Amylose content and average degree of polymerization (DP_{avg}) of taro amylose

Cultivating area	(% Amylose content)				of amylose DP_{avg}
	Large	Medium	Small	Average amylose	
CH	^{ab} 0.6 ± 20.8	^b 0.2 ± 19.9	^a 1.2 ± 22.4	^A 1.3 ± 21.02	207
SB	^{ab} 0.3 ± 20.0	^b 0.3 ± 18.8	^a 0.1 ± 19.2	^B 0.6 ± 19.37	195
KB	^{ab} 1.0 ± 19.4	^b 0.2 ± 19.4	^a 0.5 ± 22.3	^{AB} 1.5 ± 20.4	203
TR	^{ab} 0.2 ± 20.5	^b 0.2 ± 19.7	^a 0.2 ± 20.2	^{AB} 0.4 ± 20.1	238

^{a, b, c} Mean values in each row with different superscripts are significantly different ($p \leq 0.05$).

^{A, B, C} Mean values in the fifth column with different superscripts are significantly different ($p \leq 0.05$).

Granule size and morphology

Scanning electron micrographs showed that taro starch granules were small, irregular shapes, and polygonal. The surface-average diameter of granules from taro of different sizes and grown in different areas ranged from 1.3 μm to 2.2 μm . In two (SB and TR) out of the taros studied, large size taro had a smaller average starch granule size. SB taro starch granules had the smallest average granule size (1.8 μm) and KB taro starch had the largest average granule size (2.1 μm) among taro starches from 4 different locations.

X-ray diffraction pattern

X-ray diffractogram (not shown) of taro starch confirmed that taro starch had an A-type crystallographic pattern which is similar to that of Hawaiian taro (Jane, Shen, Lim, Kasemsuwan & Nip, 1992). In general, A-type starch has double helices densely packed in an orthogonal form in the crystalline region with only 4 water molecules present in the cavity between adjacent double helices (Hoover & Vasanthan, 1994). This resulted in stronger starch granules that could sustain in high heat and high shear conditions.

Swelling power and solubility

When heated in presence of water at 80°C, taro showed low swelling power of 11.0-17.4 g/g dry starch and low solubility of 7.0% - 13.2%. This result agreed with the previous result on x-ray

diffraction study of the starch which showed that all taro starches studied had an A-type crystallographic pattern. The swelling data of CH, SB, and KB taro starches showed that starch from the small size taro had higher swelling power. The average swelling power of taro starches from different locations indicated that CH taro starch had the lowest swelling power (1.1 ± 11.9 g/g dry starch) while KB taro starch had the highest swelling power (1.5 ± 15.8 g/g dry starch). It was observed that swelling power of taro starch was not proportional to granule size.

The solubility of taro from three locations (SB, KB, and TR) showed that starch from large size taro had higher solubility. Among all samples tested, medium size KB starch had the lowest solubility of 7.0%. On the average, KB taro starch exhibited the lowest solubility (8.2%) while SB taro starch had the highest solubility (10.8%). There was no correlation between swelling power and solubility of taro starches observed.

Pasting characteristics

Figure 2 shows pasting temperature and peak viscosity of all taro starches. It was observed that CH taro starch gelatinized at lower temperature range (78°C -81°C) when compared to SB (83°C -84°C), KB (84°C -85°C), and TR (85°C -87°C) taro starches. This explained why CH taro starches had a higher swelling power at 80°C in comparison with other starches.

On the average, KB taro starch had the lowest peak viscosity while SB taro starch had the highest peak viscosity. The higher peak viscosity of SB taro starch could be explained by its higher amylose content. However, the same reason could not explain why KB taro starch had the lowest peak viscosity. In search for an answer to this question, it was found that the calcium oxalate content of KB starch was the highest among all. The high amount of calcium oxalate could delay water absorption in the granule and prevented amylose leaching from the starch granules. This, in turn, resulted in the lower solubility of KB taro starch as mentioned earlier. As a consequent, the peak viscosity of KB taro starch was lowered.

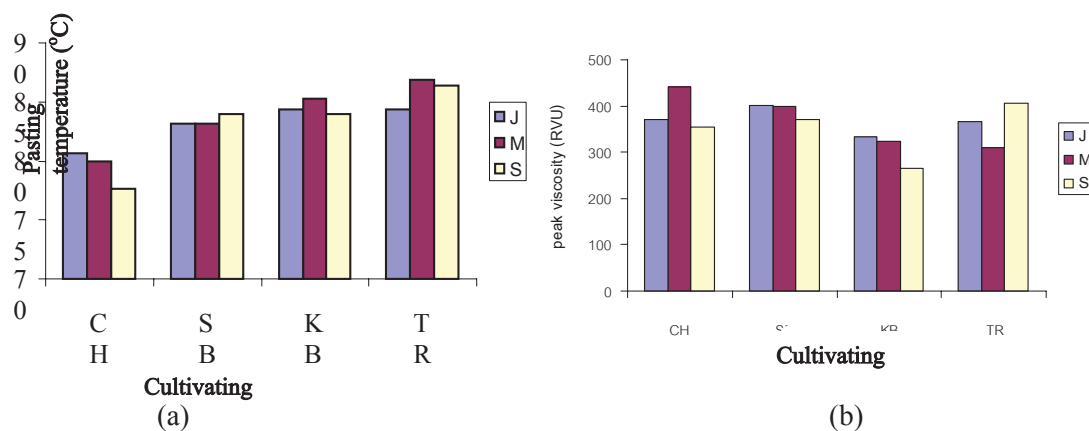


Figure 2 (a) pasting temperature and (b) peak viscosity of taro starch from taro grown in four locations; CH = Chiangmai, KB = Kanchanaburi, SB = Sarabusi, and TR = Trad.

Conclusion

Alkaline extraction method yielded taro starch with lower protein content compared to water extraction method. The extraction process reduced the calcium oxalate content to 46.3% of its initial content. The carbohydrates content of taro starch was not affected by corm size, but cultivating location. Taro starch contained 96.9 – 98.2% carbohydrates, 0.7 – 1.9% protein, 0.1 – 0.3% fat, 0.1 – 0.9% fiber, 0.1 – 0.4% ash, and 182.0 – 200.1 mg/100 g calcium oxalate. All taro starches had 18.8 – 22.4% amylose with an average degree of polymerization of 195 – 238. The starch granule was small and polygonal having an average diameter of 1.3 – 2.2 μ m. With an A-type crystalline structure, the starch had a low swelling power of 11.0 – 17.4 g/g dry starch and low solubility of 8.1 – 13.2% at 80°C. The pasting temperature and peak viscosity of taro starch were 78°C – 87°C, and 264 – 441 RVU respectively. The solubility and, thus, peak viscosity of taro starches was influenced by both amylose content and calcium oxalate content.

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