Studies on Some Properties of Starch from Taro Corm

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Abstract
Taro corms from Pyin Oo Lwin Township in Mandalay Region were collected for study on its properties. Experimental parameter such as pH, moisture and protein contents in taro starch were determined as 7.81, 13.78 % and 5.61% respectively. Hydration capacity and moisture sorption capacity were 1.7 and 15.00 % respectively. Viscosity of taro starch solution (1.0%) was found to be 2.15 cP. Swelling power of taro starch increased with increasing temperature and rapid swelling was observed at 80°C. Similar trend of increasing solubility of taro starch was also observed. By SEM, taro starch showed small, irregular shape and polygonal. Semi-crystalline nature of taro starch was shown by X-ray diffraction analysis. The degradation temperature of taro starch was observed as 310°C by TG-DTA thermogram.

Key words: Taro starch, swelling power, solubility, SEM, TG-DTA

Introduction
Taro is a common name for the corms and tubers of several plants in the family Araceae. Of these, Colocasia esculenta is the most widely cultivated. Taro is native to southeast Asia (Kolchaar, 2006). It is a perennial, tropical plant primarily grown as a root vegetable for its edible starchy corm, and as a leaf vegetable and is considered a staple food in African, Oceanic and Asian cultures. It is believed to have been one of the earliest cultivated plants.

A large number of starch resources are found in the tropic and subtropics regions which are being used as food while their properties remain to be determined. The taro (Colocasia esculenta) is one of those starch rich sources. Figure 1 shows the taro plants and corms.
Figure 1. Taro plants and corms

Kingdom - Plantae
Order - Alismatales
Family - Araceae
Genus - Colocasia
Species - esculenta

Scientific name - Colocasia esculenta (L.) Schott

Taro corms contain considerable amount of starch (70-80 g/100g dry taro) (Quach et al., 2000). It has been reported that the carbohydrate content of taro cultivated in different locations varied (Jane et al., 1992).

Taro starch forms hard coating layer and its solution has clarity at even high solid concentration. It has high swelling power, high gel strength and peak viscosity (Adebayo and Itiola, 1998). Taro starch, in view of its small granule size (0.5 - 5 μm) form smooth textural gel and has been found to be easily digestible (Sugimoto et al., 1986). Due to ease of assimilation infants and the persons with digestive problems can use taro starch (May and Nip, 1983).

Taro starch has also been studied as a filling agent for the biodegradable polyethylene film and as a fat substitute (Daniel and Whistler, 1990; Jane et al., 1992).
Raw taro corms contain a considerable amount of oxalic acid (H₂C₂O₄) in forms of soluble oxalic acid and insoluble oxalate salts (Huang et al., 1992). Soluble oxalic acid can form complexes with calcium, magnesium (or) potassium and hence reduces mineral availability in the diet.

It has also been reported that insoluble oxalate salts cause skin irritation and a pungent odor in unwashed taro corms (Maga, 1992). Continuing consumption of taro with a high oxalate salt content can lead to gallstone deposition in the gall-bladder. In a careful extraction of taro starch from its corm, both soluble and insoluble forms of oxalic acid can be removed.

The main aim of this study was to extract taro starch and to determine its physicochemical properties, morphological and thermal properties and semi-crystalline properties.

**Materials and Methods**

**Sample Collection**

Fresh taro corms in medium size, obtained upon harvest from Pyin Oo Lwin Township were purchased.

**Extraction of Starch from Taro Corms**

Taro starch was extracted from taro corm according to the procedure of Moorthy et al. (1993). Fresh taro corms were washed, peeled, and cut into small pieces and disintegrated in a blender at low speed using 0.03 M ammonia solution. The suspension was passed through 250 mesh screen twice and allowed to settle overnight. The supernatant was decanted off and this starch was subjected to a second washing and settled overnight. The starch cake formed was removed, powdered and dried at 45-50°C for 24 hr.

The starch obtained was analysed for its characteristics.

**Determination of pH**

Taro starch (1.0 g) was made into mucilage with 100 ml of distilled water and it was determined for pH with a pH meter (Oyster-15), which was previously calibrated with standard buffers of pH 4 and 7.
Determination of Moisture Content

Taro starch powder (5.0 g) was weighed and then dried in an oven at 110ºC for about 2 hr and then weighed again until constant weight was obtained and the percentage loss on drying was calculated.

Determination of Protein Content

Taro starch powder (1.0 g) was introduced to a Kjeldahl flask. The catalyst mixture (9.0 g anhydrous potassium sulphate and 1.0 g copper sulphate) and concentrated sulphuric acid (15 mL) were then added. The flask was partially closed by means of a funnel and then the contents were digested by heating the flask in an inclined position. At first, it was gently heated for about 30 min and then heating was continued vigorously for about 3 hr until the solution was totally digested and became clear. The flask was shaken occasionally during the digestion process.

Then the flask was allowed to cool and about 10 mL of distilled water were added and Kjeldahl distillation apparatus was set up. Into the flask, 70 mL of 40% sodium hydroxide solution was poured through the side arm together with 200 mL of distilled water. The contents were distilled by direct heating. The ammonia evolved was allowed to absorb in 25 mL of 4% boric acid solution that was in a receiver flask. The ammonia distillate was titrated with 0.05 M sulphuric acid, using methyl red as an indicator until a red colour just appeared.

Determination of Viscosity

Into 1.0 g of taro starch powder, a few mL of distilled water was added to make a paste. The paste was added into 100 mL boiling water and then boiled for 10 min to obtain 1 % starch solution. Using a U-tube viscometer the viscosity of starch solution was determined.

Determination of Hydration Capacity

Hydration capacity was determined according to the method of Kornblum and Stoopak (1973).

Taro starch powder (1.0 g) (Y) was placed in a centrifuge tube and covered with 10 ml of distilled water. The tube was shaken intermittently for about 2 hr and left to stand for 30 min before centrifugation at 3000 rpm for ten minutes. The supernatant was decanted and the weight of the powder after water uptake and centrifugation (X) was determined. Hydration capacity was calculated as;
Hydration capacity = \( \frac{X}{Y} \)

**Moisture Sorption Capacity**

Moisture Sorption Capacity was determined according to the method of Ohwoavworhua et al., (2004).

Taro starch powder (2.0 g) (W) was weighed and put into a Petri dish. The Petri dish was then placed in a desiccator containing distilled water at room temperature and the weight gained by the exposed sample at the end of a five-day period (Wg) was recorded and the amount of water absorbed (Wa) was calculated from the weight difference as

\[ W_a = W_g - W \]

**Determination of True Density of Taro Starch**

The true density (Dt), of taro starch powder was determined by the liquid displacement method using xylene as the immersion fluid and computed according to the following equation.

\[ D_t = \frac{W_p}{[(a + W_p) - b] \times SG} \]

where \( W_p \) is the weight of powder, SG is specific gravity of solvent, 'a' is weight of bottle + solvent and 'b' is weight of bottle + solvent + powder.

**Determination of Swelling Power and Solubility**

Swelling power and solubility of taro starch were determined by the method described by Leach et al., (1959) over a temperature range of 50-90°C.

In a graduated tube (15 mL), 2 g of starch was added to 50 mL distilled water followed by stirring for 1 min. The tube was placed in a water bath of desired temperature for 15 min, whereby the tube was mixed thoroughly every 5 min for 20s. After 15 min, the tube was cooled in an ice bath to 25°C after which it was centrifuged at 3000 rpm for 25 min. The supernatant was carefully removed using a pipette and its amount as well as its dry matter content were determined. Starch solubility was calculated as the amount of dry matter present in the supernatant divided by the initial starch weight. The weight of the sedimented paste was also recorded and the swelling power was calculated as the weight of the sediment divided by the weight of the original sample.
Surface Morphology of Taro Starch

Surface morphology of the taro starch sample was examined using a scanning electron microscope (Jeol-JSM-5610LV, Japan) at Universities' Research Center, Yangon. The SEM image of taro starch was received at 15.5 kV accelerating voltage and magnified 5500 times.

X-Ray Diffraction Studies on Taro Starch

The structure of taro starch was investigated by using Rigaku X-ray powder diffractometer (Rigaku, Tokyo, Japan) at Universities' Research Center, Yangon. The powder taro starch was scanned using Cu Kα radiation (λ =1.54056 Å) at 40 kV and 40 mA. The scanning region of the angles (20) was from 10° to 70°.

Thermal Stability

Thermal stability of taro starch was investigated by thermogravimetric differential analysis (TG-DTA) employing Shimadzu DTG 60H differential thermal analyzer at Universities' Research Center, Yangon.

Results and Discussion

Physicochemical Properties of Taro Starch

Table 1 shows the physicochemical properties of taro starch. The pH of taro starch was found to be 7.81, i.e., slightly alkaline. It was reported that maize starch has slightly acidic pH while rice and wheat starch was nearly neutral (Olayemi et al., 2008).

Moisture content of taro starch was 13.78%. It was greater than those of maize starch, rice starch and wheat starch which were reported as 4, 6 and 12 respectively (Olayemi et al., 2008). The moisture content of taro starch was higher than maize, rice and wheat starch. This may be due to its larger pore sizes and this may trap water and result in high moisture contents. Protein content of taro starch was found to be 5.61%.

Hydration capacity of taro starch is 1.70. It means that taro starch is capable of absorbing 1.7 times of its own weight of water. Moisture sorption capacity of taro starch was 15.00%. The moisture sorption capacity is a measure of moisture sensitivity of a material. True density of taro starch was 1.81 and viscosity of 1% taro starch solution was 2.15 cP.
Table 1. Physicochemical properties of taro starch

<table>
<thead>
<tr>
<th>No</th>
<th>Parameter</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>pH</td>
<td>7.81</td>
</tr>
<tr>
<td>2</td>
<td>Moisture content (%)</td>
<td>13.78</td>
</tr>
<tr>
<td>3</td>
<td>Protein content (%)</td>
<td>5.61</td>
</tr>
<tr>
<td>4</td>
<td>Hydration capacity</td>
<td>1.70</td>
</tr>
<tr>
<td>5</td>
<td>Moisture sorption capacity (%)</td>
<td>15.00</td>
</tr>
<tr>
<td>6</td>
<td>True density</td>
<td>1.81</td>
</tr>
<tr>
<td>7</td>
<td>Viscosity (1% solution)(c P)</td>
<td>2.15</td>
</tr>
</tbody>
</table>

Effect of Temperature on Swelling Power and Solubility

The swelling power is contributed by the content of amylopectin and the solubility is contributed by the content of amylose (Tester and Morrison, 1990).

The swelling power of taro starch was found to be a function of temperature (Table 2 and Figure 2). Prior to gelatinization, there was some increase in swelling capacity of starch. At 50°C and 60°C, swelling power of taro starch was only 2.05% and 2.90% respectively. However, once the gelatinization process sets in at 80°C, swelling power increased rapidly with increasing temperature. At 70°C and 80°C, the swelling power is 6.40% and 14.15% respectively. At 90°C the swelling power increased about 8.5 fold over its initial value.

Solubility of taro starch was observed to be a function of temperature between 50°C-90°C as shown in Table 3 and Figure 3 and. It followed a pattern similar to that of swelling power characteristic. Below the gelatinization temperature taro starch was less soluble. From 50°C to 70°C, the solubility of taro starch was less than 10%. However, as the temperature increased to 80°C, the solubility increased markedly and found to be 29.2%. When the temperature was raised to 90°C, more increase in solubility of taro starch was observed. This may be attributed to loss of granular structure and release of amylose fraction of the starch as the amylose molecules are preferentially solubilized and leached from swollen
starch granules (Stone et al., 1984). At 80°C and 90°C, complete gelatinization was also observed.

Starch could not be dissolved in cool water due to the starch crystal structure. The starch molecule started to disintegrate in water as the temperature increased. Amylose and amylopectin were dissociated in suspension, and the solubility of starch was increased. The insoluble starch started to swell because of hydration.

Table 2. Relationship between temperature and swelling power of taro starch

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Swelling power (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>2.05</td>
</tr>
<tr>
<td>60</td>
<td>2.90</td>
</tr>
<tr>
<td>70</td>
<td>6.40</td>
</tr>
<tr>
<td>80</td>
<td>14.15</td>
</tr>
<tr>
<td>90</td>
<td>16.90</td>
</tr>
</tbody>
</table>

Figure 2. Effect of temperature on swelling power of taro starch
Table 3. Relationship between temperature and solubility (%) of taro starch

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Solubility (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>2.4</td>
</tr>
<tr>
<td>60</td>
<td>3.2</td>
</tr>
<tr>
<td>70</td>
<td>7.6</td>
</tr>
<tr>
<td>80</td>
<td>29.2</td>
</tr>
<tr>
<td>90</td>
<td>39.0</td>
</tr>
</tbody>
</table>

Figure 3. Effect of temperature on solubility (%) of taro starch solution

Morphology of Taro Starch

Scanning electron micrograph (Figure 4) shows that taro starch granules were small, irregular shapes, and polygonal.

Figure 4. Scanning electron micrograph of taro starch
X-Ray Powder Diffraction

Semi-crystalline nature of taro starch was observed in X-ray diffractogram (Figure 5) because of the presence of both sharp and diffuse diffraction peaks. Taro starch showed strong diffraction peaks at 15.3°, 17.9°, 23.4°, and 24.5° of 2θ. Parallel double amylopectin molecules result in the formation of crystalline regions, while amylose molecules result in the formation of amorphous regions in the starch structure.

Thermogravimetric Differential Thermal Analysis (TG-DTA)

TG-DTA thermogram of taro starch is shown in Figure 6. It was noted that initial weight loss began at approximately 50°C and reached a constant weight plateau after losing about 19.665 % of its initial weight. The weight loss corresponds to the loss of moisture content from the taro starch. Between 140 °C and 290 °C, taro starch was found to be thermally stable. DTA curve shows an endothermic peak at 70.9°C. Moreover, another weight loss was started at approximately 310°C. At this temperature the taro starch began to degrade. This temperature is the degradation temperature of taro starch. DTA curve shows two exothermic peaks at 386.41°C and 550.54°C due to degradation of starch. At the end of the experiment (559.72°C), weight loss % was 81.684% and thus 18.316% residue was left. The nature and remarks regarding the TG-DTA thermogram profile is presented in Table 4.

Figure 5. X-ray diffractogram of taro starch
Table 4. Thermal analysis data of taro starch

<table>
<thead>
<tr>
<th>Temperature range(°C)</th>
<th>TGA</th>
<th>DTA</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>weight loss (%)</td>
<td>Break in temperature</td>
<td>Nature of peak</td>
</tr>
<tr>
<td>37.70-282.61</td>
<td>16.003</td>
<td>70.09°C</td>
<td>endothermic peak</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Loss of moisture</td>
</tr>
<tr>
<td>282.61-559.72</td>
<td>81.684</td>
<td>386.41°C, 550.54°C</td>
<td>exothermic peak</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Degradation of starch</td>
</tr>
</tbody>
</table>

Conclusion

Fresh taro corms in medium size, obtained upon harvest from Pyin Oo Lwin Township in Mandalay Region, were purchased. Physicochemical investigations revealed that pH of taro starch was 7.81 and found to be slightly basic. Moisture content was observed as 13.78% and protein content was determined as 5.61%. The hydration capacity and moisture sorption capacity were 1.70 and 15.00% respectively. The true density of taro starch was found to be 1.81.

Swelling power of taro starch increased with increasing temperature, however, it increased rapidly when the gelatinization process set in.
Moreover, the solubility of the taro starch increased with increasing temperature and at 80°C and 90°C complete gelatinization was observed. Surface morphology of taro starch was examined by SEM at 5500 X magnification and found to be small, irregular shapes and polygonal. Taro starch showed characteristic crystalline peaks at 15.3°, 17.9°, 23.4° and 24.5° of 2θ. From TG-DTA thermogram the degradation temperature of taro starch was 310°C. By DTA one endothermic and two exothermic peaks were observed due to the loss of moisture and degradation of starch respectively.

This research contributes information on the physicochemical, morphological and thermal properties of taro starch. These findings would be useful in the handling of taro starch for its applications.

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References


