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ORIGINAL RESEARCH PAPER

EFFECT OF STARCH ISOLATION METHOD ON PROPERTIES OF SWEET POTATO STARCH

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Isolation method of starch with different agents influences starch properties, which provide attention for studying the most appropriate method for isolation of starch. In the present study sweet potato starch was isolated by Sodium metabisulphate (M1), Sodium chloride (M2), and Distilled water (M3) methods and these were assessed for functional, chemical, pasting and structural properties. M3 yielded the greatest recovery of starch (10.20%). Isolation methods significantly changed swelling power and pasting properties but starches exhibited similar chemical properties. Sweet potato starches possessed C-type diffraction pattern. Small size granules of 2.90 µm were noticed in SEM of M3 starch. A high degree positive correlation was found between ash, amylose, and total starch content. The study concluded that isolation methods brought changes in yield, pasting and structural properties of sweet potato starch.

Keywords: isolation methods, sweet potato starch, swelling power, particle size analysis, SEM, crystallinity

Introduction

Starch is a major carbohydrate source with immense economic and nutritional value. Starch from different plant sources exhibits different physicochemical properties. The products in which starch is used are determined by the properties of that particular starch including the amylose/amylopectin ratio and the structure of the starch (Kenji *et al.*, 2002). It is essential for the food industry to search for a new starch source to meet the requirements of the consumers. Sweet potato (*Ipomoea batatas)* comes under the family Convolvulaceae and it is one such crop that has shown potential as a source of starch (Woolfe, 1992; Tsakama *et al.*, 2011). Sweet potato tubers or starch have been used to produce diverse foods such as vermicelli, noodles, jelly sheets, fried chips, specially flavoured yoghurt, alcoholic drinks, jam, cake, and steamed bread (Avula, 2005; Zhu *et al.*, 2011). However industrial use of sweet potato starch has been limited. The utility of sweet potato starch can be increased by developing appropriate processing techniques to prepare sweet potato starch with desirable properties (Jangchud *et al.*, 2003). Food

industries exploit some tubers such as cassava, potato and sweet potato for their starch products. Utilization of starch in food industries was chiefly determined by physical, functional and pasting characteristics (Adebowale and Lawal, 2002). In general, starch is isolated from roots and tubers through rasping, sieving and decantation or centrifugation (Daiuto *et al.*, 2005). A study was conducted by Wang *et al*. (2011) where yam starch was isolated using alkali or enzyme and studied the morphological, structural and pasting characteristics. In another study, the starch was isolated by four methods using water, pectin, oxalic acid/ammonium oxalate, sodium hydroxide to find the effect of isolation methods on starch properties (Daiuto *et al.*, 2005). Some other authors including Babu and Parimalavalli (2012) and Correia *et al.* (2012) also investigated the influence of isolation method on functional properties of yam and chestnuts starches respectively. By reviewing the previous literature, it is evident that extremely little research was carried out in the characterization of these tuber starches and mainly the investigation on the role of isolation methods in modifying the starch properties. A study of sweet potato starches isolated from different methods is useful because different isolation methods may change the chemical, functional, and pasting properties of starch to suit its end use. The present work was done to determine the functional, chemical, pasting and structural properties of starches isolated from sweet potato by different methods.

Materials and Methods

Sample preparation

Pink Skin Sweet potatoes were purchased from local market in Salem, Tamil Nadu. The tubers were placed in a polyethylene bag to prevent loss of moisture during transportation to the laboratory of Department of Food Science and Nutrition, Periyar University where analysis was conducted. Non edible portion (peel) had been eliminated before the samples were washed with running cold water to remove impurities and edible portion of the sweet potato was cut into small pieces. Starches were isolated from the edible portion by three different methods and the isolated starches were analysed for functional, chemical, pasting and structural properties.

Methods of isolation of starch

Isolation using Sodium metabisulfite – Method 1 (M_1)

Starch was extracted from the sweet potato as described by Vasanthan (2001). Blending of sweet potato with water was done at a ratio of 1:10 until smooth slurry was formed. Sodium metabisulfite of 0.01% (w/v) was added during slurrying. After slurrying, the filtration was done with double-layered cheesecloth then filtered through a series of polypropylene screens (250, 175, 125, and/or 75 µm) and centrifuged for 20 min at 5000 × g at 20°C. Starch settled at the bottom of centrifuge tube was washed with toluene, oven dried at 30° to 40°C and the dried starch was ground with mortar and pestle into fine powder.

Isolation using Sodium chloride – Method 2 (M_2)

According to the method of Riley *et al*. (2006) the edible portion of sweet potato was cut into small pieces and homogenized with 1 M NaCl solution using a blender. The mixture was filtered through triple layered cheesecloth; starch was washed with distilled water. The granules were allowed to settle and water was decanted. The sediment was centrifuged at 3,000 x g for 10 min. Starch was removed, allowed to dry overnight at room temperature and the dried starch was ground with mortar and pestle into fine powder

Isolation using Distilled water – Method 3 (M_3)

As described by Wickramasinghe *et al.* (2009) with slight modification, the edible portion of sweet potato was cut into small pieces and homogenised with distilled water for 1-2min. The slurry was then passed through double-layered cheesecloth and the filtrate was allowed to settle for a minimum of 3h at room temperature. The precipitated starch was washed three times with distilled water, dried at room temperature for two days and then the dried starch was kept in an oven at 50^{o}C for three hours and ground with mortar and pestle into fine powder

Functional properties of sweet potato starch

Water Absorption Capacity (WAC) and Oil Absorption Capacity (OAC) of sweet potato starches were analyzed according to the method described by Abbey and Ibeh, 1988. Ten ml of water/oil was added to 1 g of the starch sample in a centrifuge tube of known weight. The mixture was allowed to stand for 30 min, centrifuged (3500 g, 15 min) and the supernatant was discarded. The tube and the residue were weighed and the gain in weight was regarded as water/oil absorption capacity.

Paste Clarity (PC) was measured according to the method of Reddy and Seib (1999). Starch (0.05g, db) was suspended in distilled water (5ml) in a glass-stoppered tube and heated at 95^{o} C for 30min with shaking every 5 min. After cooling, the starch clarity was measured on a spectrophotometer at 650nm against water blank.

Swelling Power (SP) and Solubility(S) of sweet potato starches were studied by the method of Leach *et al.* (1959). A 2 g (dry basis) sample was mixed with 180 ml of distilled water in a centrifuge tube and heated in a water bath at 50-90°C for 30 min with 10^{o}C interval. After heating, the suspension was centrifuged at 2200rpm for 15 min. The supernatant was drawn off by suction and dried for 4 hours at 120^{o}C in an oven and the percentage of soluble extracted from the starch was calculated. Swelling power was calculated as the weight of the sedimented paste per gram of dry starch.

Chemical analysis of sweet potato starch

Moisture Content (MC) and Dry Matter (DM) were determined by the method of Adebayo *et al.* (2010). Ash, Crude Protein and Crude Fat contents were determined according to AOAC (AOAC, 1990 & 2000). pH was determined according to the method of Benesi (2005).

Amylose was determined by the method of Williams *et al*. (1958). A 0.1g of the starch sample was weighed into a 100ml volumetric flask, and then 1ml of 99.7 – 100% (v/v) ethanol and 9ml 1N sodium hydroxide (NaOH) were added. The mouth of the flask was covered with parafilm or foil and the contents were mixed well. The samples were boiled for 10 min in a boiling water bath to gelatinize the starch. The samples were removed from the water bath and allowed to cool very well, then made up to the mark with distilled water and shaken thoroughly. A portion (5ml) of the mixture was pipetted into another 100ml volumetric flask and 1 ml of 1N acetic acid and 2 ml of iodine solution were added. The flask was topped up to mark with distilled water. Absorbance (A) was read using a Spectrophotometer at 620nm. The blank contained 1ml of ethanol, 9ml of sodium hydroxide, boiled and topped up to the mark with distilled water. Finally 5ml was then pipetted into a 100ml volumetric flask, 1ml of 1N acetic acid and 2ml of iodine solution were added and then topped up to the mark. This was used to standardize the spectrophotometer at 620nm. The amylose content was calculated as:

Amylose content (%) = 3.06 × A × 20; Where: A = Absorbance value

Total starch was measured by the method described and Dubois *et al.* (1956). A portion (0.2g) of the sample was weighed into a centrifuge tube with 1ml of 100% ethanol, 2ml of distilled water and 10mlof hot ethanol. The mixture was vortexed and centrifuged for 10 minutes at 2000 rpm using centrifuge. The supernatant was decanted and the sediment taken. Perchloric acid (7.5ml) was added to the sediment and allowed to stand for 1 hour; then17.5ml of distilled water was added to it and vortexed. An aliquot (0.05ml) of the solution was pipetted into a test tube, 0.95ml of distilled water, 0.5ml of phenol, and 2.5ml of H_2SO_4 were added and vortexed. The mixture was allowed to cool and the absorbance read on a spectrophotometer at 490nm. The total starch content was estimated as:

%Total starch = (Abs – Intercept · Dilution factor · Volume · 0.9)/(Weight of sample · Slope · 10000)

where: Abs. = Absorbance; Dilution factor = 20; Volume = 25; Slope = 0.0055, and Intercept = 0.004

Pasting properties of sweet potato starch

Pasting properties of sweet potato starches were evaluated with a Rapid Visco Analyzer (RVA) (RVA Tech Master, Perten Instruments, Japan) according to the method described by Noda *et al*. (2004).

Particle Size Analysis

Starch granule analysis was accomplished by using a particle size analyzer (Malvern Instruments Ltd, USA) Starch samples were prepared for particle size analysis using the method described by Wilson *et al.* (2006).

Powder X-ray Diffraction (XRD)

X-ray diffraction patterns of the starches were obtained using a Powder X-ray diffractometer (Rigaku Mini Hex-II, Japan). Crystallinity index (CI) was calculated using Equation proposed for cellulose by Segal *et al.* (1959) and applied to starch, by using the equation with slight modification:

$$CI = 100 \cdot \frac{I_{\max} - I_{am}}{I_{\max}}$$

where I_{max} is the maximum intensity of the principal peak and I_{am} is the intensity of diffraction attributed to amorphous starch.

Scanning Electron Microscope (SEM)

Starch granules were observed using a Scanning Electron Microscope (SEM) (JEOL-Model 6390, Japan). The starch granules were sprinkled on a double-sided tape mounted on a SEM stub. The samples were coated with gold and placed in the SEM chamber. Photomicrographs were taken using a scanning electron microscope apparatus at an accelerating voltage of 15 kV.

Statistical Analysis

All data obtained were subjected to One Way Analysis of Variance (ANOVA) using MS Excel 2007 and means were compared by Critical Difference (CD). Differences at $P<0.05$ were considered to be significant. Pearson correlation (r) was also calculated using Statistical Package for Social Sciences (SPSS version 16.0) to know the relationship among the chemical and functional properties of sweet potato starches.

Results and Discussion

Starch was isolated from sweet potato using Sodium metabisulphate (M_1), Sodium chloride (M_2) and Distilled water (M_3) and these three starches were compared for starch yield. Isolation with only distilled water yielded the greatest amount of starch (10.20%) followed by Sodium chloride (8.72%) and Sodium metabisulphate (6.96%).The range of starch yield of sweet potato obtained in the study was supported by the report of Brabet *et al*. (1997). The starch content of sweet potato ranged from 12.38 to 17.52% according to the finding of Thao and Noomhorm, (2011). The results of functional properties of sweet potato starches extracted by the three methods are given in Table 1. Water Absorption Capacity (WAC) of sweet potato starches was in the range of 0.62-0.66 ml/g. WAC is related to the interactive forces among starch components, weak interactive forces results in high WAC (Riley *et al.*, 2006). OAC of sweet potato starch was in the range of 0.66-0.73 ml/g but it was higher than the OAC (0.15ml/g) of sweet potato starch accounted by Chibuzo (2012). It might be due to greater hydrophobic tendency than hydrophilic tendency of isolated starches. Shine and colour of a product is influenced by the paste clarity of starch. The paste clarity of sweet potato starch ranged from 0.44 to 0.46 which is similar to Abo-El-Fetoh *et al.* (2010) who reported that the paste clarity of sweet potato starch was 0.33. No significant differences were observed in functional properties such as water absorption capacity, oil absorption capacity and paste clarity among the three isolated starches. The results of swelling power and solubility of sweet potato starch are shown in Table 2. The swelling power of isolated starches ranged between 3.01and14.30g/g. A significant ($P < 0.05$) difference was observed in swelling power at 50 and 60^{o}C among the starches isolated through different methods. This

result is similar with Huang *et al.* (2010) who reported that the swelling power of sweet potato starches was found to be 5.23-16.38g/g with temperature range of 65-95^{o}C. Swelling power of a starch can be associated with starch and its minor components (e.g., proteins and lipids), pre-treatment and processing conditions (Prinyawiwatkul *et al.*, 1997). Strong bonded micellar network of starch polymer was the primary factor in influencing the swelling property (Gujska *et al.*, 1994).

Table 1. Functional Properties of sweet potato starches

Properties	Starch Isolation		
	M_1	M_2	M_3
WAC (ml/g)	0.66±0.03 [a]	0.62±0.06 [a]	0.63±0.06 [a]
WAC (ml/g)	0.66±0.03 [a]	0.62±0.06 [a]	0.63±0.06 [a]
OAC(ml/g)	0.66±0.05 [a]	0.73±0.05 [a]	0.70±0.06 [a]
Paste Clarity	0.45±0.04 [a]	0.44±0.04 [a]	0.46±0.02 [a]

Mean values followed by the same letters within the row are not significantly different (P> 0.05), M_1= Isolation using Sodium metabisulfite, M_2= Isolation using Sodium chloride, M_3= Isolation using Distilled water, WAC=Water Absorption Capacity, OAC= Oil Absorption Capacity

Table 2. Swelling power and Solubility of sweet potato starches at different temperature

Temperature (^{o}C)	Starch Isolation		
	M_1	M_2	M_3
Swelling power(g/g)			
50	3.01^{ac}	3.55^{b}	3.01^{c}
60	4.04^{ac}	4.60^{b}	4.18^{c}
70	5.00^{a}	5.04^{a}	5.01^{a}
80	9.48^{a}	9.96^{a}	9.60^{a}
90	12.08^{a}	14.30^{b}	13.43^{ba}
Solubility (%)			
50	0.77^{a}	0.94^{a}	0.83^{a}
60	1.00^{a}	1.19^{a}	1.02^{a}
70	2.36^{a}	2.47^{a}	2.34^{a}
80	5.52^{a}	5.68^{a}	5.53^{a}
90	6.18^{a}	6.35^{a}	6.13^{a}

Mean values followed by the same letters within the row are not significantly different (P> 0.05), M_1= Isolation using Sodium metabisulfite, M_2= Isolation using Sodium chloride, M_3= Isolation using Distilled water

As temperature increased, swelling power was also raised. This might be attributed to the distraction of starch granules at elevated temperature and subsequent release of all the amylose from the amylopectin network (Charles *et al.*, 2007). Low swelling power of M_1 and M_3 starches might be due to the existence of huge number of crystallites formed by the association between long amylopectin chains. Starch granular stability is increased as a result of crystallite formation and swelling decreases (Singh *et al.*, 2004). Solubility values were ranged from 0.77-6.18% for M_1, 0.94-6.35% for M_2 and 0.83-6.13% for M_3 starches. Starch solubility increased with increasing temperature to 90^{o}C. Similar range of

solubility for sweet potato starch was reported by Abegunde *et al.* (2012). Mweta (2009) also reported the solubility of sweet potato starch was in the range of 0.41-6.43.

Chemical composition of the sweet potato starches are shown in Table 3. Moisture content of starch ranged from 14.11-17.76% similar to the results of Tsakama *et al.* (2010) and it was within the range of 10-20% that is recommended for commercial starches (Soni *et al.*, 1993). Dry matter of starches was in the range of 82.22-85.88 % and this was comparable to the report of Garcia and Walter (1998). Ash content of sweet potato starches ranged from 0.20 to 0.33% and the same value is reported in literature (Abegunde *et al.*, 2012). A significant difference was observed in pH (4.53-4.75) of the starch samples and this result is agreed with Tsakama *et al.* (2011).

Table 3. Chemical composition of Sweet potato starches

Parameters	Starch Isolation		
	M_1	M_2	M_3
Moisture (%)	17.76±2.04[a]	14.44±2.69[a]	14.11±2.71[a]
Dry matter (%)	82.22±2.03[a]	85.55±2.69[a]	85.88±2.71[a]
Ash (%)	0.33±0.11[a]	0.20±3.39[a]	0.26±0.11[a]
P^H	4.60± 0.03[ca]	4.75±0.09[a]	4.53±0.06[b]
Protein (%)	0.20±0.11[ac]	0.13±0.04[b]	0.25±0.14[c]
Fat (%)	0.06±0.03[a]	0.07±0.01 [a]	0.07±0.02 [a]
Amylose (%)	18.21±3.06[a]	18.17±1.54[a]	18.56±1.06[a]
Total starch (%)	95.26±22.00[a]	96.73±9.62[a]	95.91±5.13[a]

Mean values followed by the same letters within the row are not significantly different ($P>0.05$), M_1= Isolation using Sodium metabisulfite, M_2= Isolation using Sodium chloride, M_3= Isolation using Distilled water

Protein content of M_2 starch varied significantly because addition of NaCl removed the protein component which adhered with starch material. Fat content was found to be 0.06% for M_1 starch, 0.07% for M_2 and M_3 starches and these values are similar to previous report of Thao and Noomhorm, (2011). Amylose and total starch content of starch samples were ranged between 18.17-18.56% and 95.26-96.73%, respectively. These results are on par with Tsakama *et al.* (2011).

RVA analysis of starch samples is given in Table 4. Peak viscosity of M_2 sweet potato starch was greater ($P<0.05$) than M_3 sweet potato starch. Pasting properties of sweet potato starch in the present study are in comparable with the previous reports of Tsakama *et al.* (2011). Pasting properties of starch are influenced by the starch granule size and structure, amylose content and amylopectin structure (Akinwande, 2005). Protein shows a negative correlation with peak viscosity of the starch which determines the pasting characteristics of the starch (Lim *et al.*, 1999). A significant difference was observed in trough and break down viscosities among the starches and BD viscosity of starches decreased with increased drying temperature of starch (Aviara *et al.*, 2010). Final viscosity of M_1, M_2 and M_3 starches was 3107.33cP, 3558.33cP and 3487.00cP respectively. The final viscosity of M_2 starch which was open air dried was significantly higher than M_1 starch dried

at 30-40°C analogous to previous report of Aviara *et al.* (2010). Similarly a significant difference in final viscosity was observed between open air dried starch (M_2) and starch dried in an oven at 50°C (M_3) and this result does not agreed with Aviara *et al.*, 2010

Table 4. Rapid Visco Analyser analysis of sweet potato starch

Parameters	Starch Isolation		
	M_1	M_2	M_3
Peak Viscosity(cP)	4462.00±384.07^{ac}	4906.66±505.02^{c}	3494.00±332.15^{b}
Trough viscosity(cP)	2166.33±19.13^{ab}	2514.00±135.07^{b}	2385.00±175.76^{b}
Break down(cP)	2295.66±365.17^{a}	2392.66±370.93^{b}	1109.00±156.67^{ca}
Final viscosity(cP)	3107.33±76.55^{a}	3558.33±213.35^{b}	3487.00±126.37^{bc}
Set back(cP)	941.00±57.41^{a}	1102.66±49.70^{b}	1044.33±81.30^{ba}
Peak time(min)	4.35±0.04^{a}	4.87±0.00^{b}	4.47±0.00^{c}
Pasting temperature(°C)	82.85±0.47^{a}	70.68±17.46^{a}	81.26±0.57^{a}

Mean values followed by the same letters within the row are not significantly different (P> 0.05), M_1= Isolation using Sodium metabisulfite, M_2= Isolation using Sodium chloride, M_3= Isolation using Distilled water

Set back viscosity of M_2 starch which was open air dried was significantly higher than that of starch dried in an oven at 30-40°C (M_1) and 50°C (M_3) which is analogous with the results of Aviara *et al.*, 2010. Peak time of M_1, M_2 and M_3 starches was 4.35min, 4.87min and 4.47min respectively. Drying starch at high temperature (60°C) reduced the peak time. This result is consistent with report of Aviara *et al.*, 2010. Pasting temperature indicates the minimum temperature required for cooking a sample, energy and cost involved. The pasting temperature of M_2 starch was 70.68°C. Though the pasting temperature was found to be high in M_1 (82.85°C) and M_3 (81.26°C), no significant difference was observed in pasting temperature among the starch samples. It is clear from the results that the M_2 starch could be cooked faster by consuming minimum energy, thereby saving cost and time compared to the counter parts.

The X-ray diffractograms of the three sweet potato starch samples are presented in Fig. 1. The X-ray patterns of A type starches represent the strong diffraction peaks at around 15, 17, 18 and 23°.2θ. The B type starch showed the sharp peak at 17° 2θ and few small peaks at around 2θ values of 20, 22 and 24. The C type starch is a combination of both A and B type starches (Elsenhaber and Schulz, 1988). The 2θ values of sweet potato samples that were isolated by different methods are shown in Table 5. The 2θ values of corn and potato starches were obtained from the JCPDS (Joint Committee on Powder Diffraction Standards) database for comparison; diffraction pattern of sweet potato starch was not available in JCPDS. Corn starch represents A type diffraction pattern as the 2θ values were around 15, 18 and 23. Whereas Potato starches showed B-type diffraction pattern with 2θ values of 17, 22 and 24. Sweet potato starches showed peaks at the 2θ diffraction angles around 10, 11,15,17,20 and 23. These patterns were considered as characteristic feature of sweet potato starch, which presents a combination of A and B type crystalline structures. The 2θ values 10,11,15,20,23 were common for both sweet potato and corn starches peak providing the evidence that it has the

characteristic of A type crystallinity similar to corn starch. Nevertheless sweet potato starches showed 2θ values of 17 and 19 unlike potato starch proving that it possess B type crystallinity. From these observations, sweet potato starches revealed C type diffraction pattern.

Ramesh-Yadav *et al.* (2006) reported that sweet potato starch possess C-type diffraction patterns with characteristic peaks at 9.9°, 10.9°, 15.1° and 17.1° 2 θ angles. Previous literature (Osundahunsi *et al.*, 2003; Noda *et al.*, 1995) showed that sweet potato starch had 2θ values at 15.4°, 17.2°, 18.3° and 23.4°. The crystallinity of sweet potato starches was 0.36 for M_1 starch, 0.35 for both M_2, and M_3 starches. This result revealed that isolation method didn't affect the diffraction pattern of sweet potato starch. Vieira and Sarmento, 2008 also reported similar range of crystallinity for sweet potato starch.

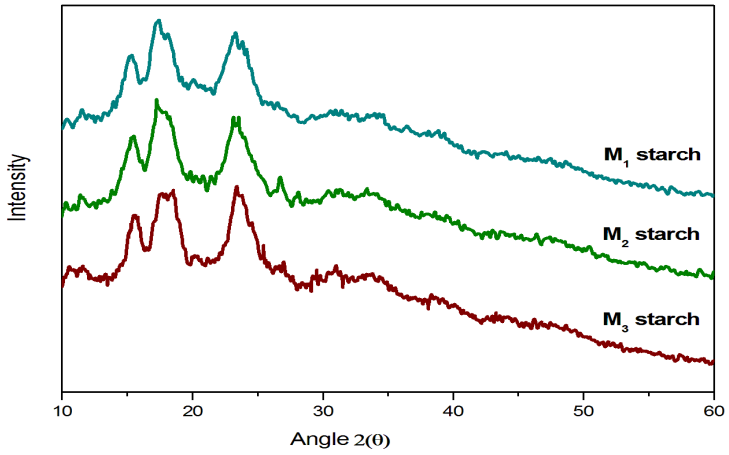

Fig.1. X-ray diffractograms of sweet potato starches

Table 5. Comparison of 2θ values of sweet potato starches with corn and potato starches of JCPDS database

Sweet Potato starches			Corn starch	Potato starch
M_1 starch	M_2 starch	M_3 starch		
10.38	10.28	10.56	10.10	05.356
11.53	11.40	11.58	11.50	14.814
15.26	15.47	15.48	15.30	17.051
17.39	17.25	17.65	18.20	19.728
20.06	19.82	20.15	20.30	22.224
23.32	23.13	23.38	23.50	24.052
-	-	-	27.00	-
-	-	-	31.00	-

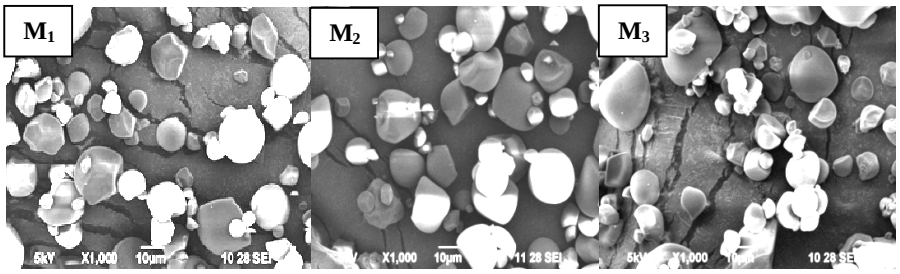

Fig.2 Scanning electron micrograph of sweet potato starches isolated by different methods at 1000X magnification.

Scanning Electron Micrographs (SEM) of the starch granules isolated through different methods are illustrated in Fig.2. Illustrations of three starch samples showed the presence of starch granules from small to large sizes. Granule surface of three starches appeared to be smooth with no sign of any fissure. Zhu *et al.*, 2011 also observed smooth granule surface of sweet potato starches without cracks. Most of the sweet potato starch granules were polygonal in shape, however round and irregular shapes were also noted. Polygonal shape for sweet potato starch granules was reported by Huang (2009). Single individual granules as well as compound granules were observed in the illustrations. According to Newman *et al.* (2007), residual proteins may create slight gelatinization over the surface of starch granules and that might make the granules to adhere together to form a compound granule. In comparison with M_1 and M_2 starches M_3 starch might be associated with high degree of residual proteins resulting in compound granules. On the other hand, a larger number of small size granules was observed in SEM of M_3 starch. Results of Particle size analyser confirms the mean granule sizes of M_1, M_2 and M_3 starches which were 4.862, 4.086 and 2.908 µm, respectively. Jane *et al.* (1992) explained that the small starch granules (2.0 µm) isolated from amaranth and acid treated corn starch can be applicable as fat substitutes as the small size starch granules may act similarly to those of lipid micelles. This indicates that the M_3 starch might be used as fat substitute in food industry.

Correlation among the chemical and functional properties of sweet potato starches

Pearson correlation coefficients amongst chemical and functional variables are presented in Table 6, 7 and 8. Ash content had low degree positive correlation with Moisture and Dry matter of M_1, M_2 and M_3 starches which is analogous to results of Nuwamanya *et al.* (2010). A negative correlation was found between ash and crude protein of sweet potato starches while a positive correlation existed with crude fat of starches. This result is supported with the earlier study of Nuwamanya *et al.* (2010). Ash content showed a high degree positive correlation with amylose, total starch and solubility while negatively correlated with swelling power of starches. These results agree with earlier reports of Thao and Noomhorm (2011), Abegunde *et al.* (2012) and Elsenhaber and Schulz (1988). It showed a low degree positive correlation between ash and paste clarity of starches and it is on par with

Singh *et al.*, 2004. Paste clarity showed a positive correlation with swelling power and negative correlation with solubility of sweet potato starches. Similar result is reported by Mweta *et al.* (2008). Swelling power shared a negative correlation with amylose content. Similar negative correlation was reported between swelling power and amylose content (Noda *et al.*, 1995). While high degree positive correlation was noticed between swelling power and total starch content of M_1 (r = 0.88), M_2 (r = 1.00) and M_3 (r = 0.71) starches. In addition to this swelling power and solubility of sweet potato, starches shared a positive correlation similar to prior report (Osundhahunsi *et al.*, 2003). Amylose was positively correlated with crude fat and negatively correlated with protein, this result is in agreement with the prior report of Nuwamanya et al, (2009) and contradicted with the results of Thao and Noomhorm, 2011. The amylose content was positively correlated to the starch content and solubility in the starch samples unlike the result of Sandhu and Singh, 2007. Correlation study revealed that amylose was negatively correlated with WAC and the result is in consistent with previous study (Wani *et al.*, 2010).

Table 6. Correlations coefficients of functional properties with chemical composition of sweet potato starch isolated by Method 1

	pH	Ash	M	DM	CP	CF	A	TS	SP (70°C)	S (70°C)	PC	WAC
Ash	-0.96											
Moisture	-0.88	0.59										
DM	0.09	0.68	-1.00									
CP	0.18	-0.44	0.96	-0.96								
CF	-0.26	0.84	-0.69	-0.68	0.85							
A	0.29	0.72	-0.97	0.97	-0.88	0.51						
TS	-0.79	0.93	-0.90	0.91	-0.76	-0.32	0.97					
SP(70°C)	0.83	-0.65	0.61	0.62	-0.38	0.14	-0.77	0.88				
S(70°C)	-0.70	0.47	0.76	0.77	-0.57	-0.06	0.88	0.96	0.97			
PC	0.02	0.30	0.99	-0.99	0.98	0.77	0.94	-0.85	0.52	0.69		
WAC	0.19	-0.92	0.18	-0.19	-0.88	-0.58	-0.39	-0.57	0.58	0.77	0.07	
OAC	-0.96	1.00	0.19	-0.18	-0.44	-0.84	-0.02	-0.23	-0.65	-0.47	0.30	-0.92

M=Moisture, DM=Dry matter, CP=Crude Protein, CF=Crude Fat, A=Amylose, TS=Total Starch, SP (70°C) =Swelling Power at 70°C, S (70°C) =Solubility at 70°C, WAC=Water Absorption Capacity, OAC= Absorption Capacity.

Table7. Correlations coefficients of functional properties with chemical composition of sweet potato starch isolated by Method 2

	pH	Ash	M	DM	CP	CF	A	TS	SP (70°C)	S (70°C)	PC	WAC
Ash	-0.88											
Moisture	-0.99	0.42										
DM	0.19	0.72	-1.00									
CP	0.15	-0.50	-0.78	-0.78								
CF	-0.29	0.40	-0.99	-0.99	0.82							
A	0.33	0.66	-0.89	0.89	-0.98	0.92						
TS	-0.64	0.92	-0.72	0.72	-0.74	-0.68	0.83					
SP 70°C	0.62	-0.92	0.71	0.71	-0.12	0.66	-0.72	1.00				
S 70°C	-0.80	0.39	0.86	0.86	-0.37	-0.83	0.55	0.97	0.96			
PC	0.18	0.30	0.07	-0.06	0.67	0.13	0.50	-0.63	0.65	0.43		
WAC	0.28	-0.09	0.28	-0.28	-0.81	-0.33	-0.68	-0.46	0.47	0.73	-0.97	
OAC	-0.88	1.00	0.92	-0.92	-0.50	-0.90	-0.66	-0.92	-0.92	-0.99	0.30	-0.79

M=Moisture,DM=Dry matter, CP=Crude Protein, CF=Crude Fat, A=Amylose, TS=Total Starch, SP (70°C)=Swelling Power at 70°C , S(70°C)=Solubility at 70°C,WAC=Water Absorption Capacity, OAC= Oil Absorption Capacity.

Table 8. Correlations coefficients of functional properties with chemical composition of sweet potato starch isolated by Method 3

	pH	Ash	M	DM	CP	CF	A	TS	SP (70°C)	S (70°C)	PC	WAC
Ash	-0.92											
Moisture	-0.71	0.38										
DM	0.11	0.39	-1.00									
CP	0.17	-0.86	0.12	-0.12								
CF	-0.11	0.27	-0.77	-0.77	0.72							
A	0.45	0.92	-0.70	0.70	-0.61	0.10						
TS	-0.91	1.00	0.36	0.87	-0.87	-0.29	0.91					
SP(70°C)	0.93	-0.72	0.91	0.91	-0.28	0.45	-0.93	0.71				
S(70°C)	-0.62	0.28	0.99	0.99	-0.23	-0.84	0.62	0.26	0.86			
PC	0.11	0.46	0.12	-0.12	1.00	0.72	0.61	-0.87	0.28	0.23		
WAC	0.05	-0.42	0.66	-0.66	-0.82	-0.48	-0.50	-0.44	0.31	0.74	0.82	
OAC	-0.79	0.90	-0.99	0.99	-0.50	-0.69	-0.78	-0.48	-0.95	-0.97	0.00	-0.56

M=Moisture, DM=Dry matter, CP=Crude Protein, CF=Crude Fat, A=Amylose, TS=Total Starch, SP (70°C) =Swelling Power at 70°C, S (70°C) =Solubility at 70°C, WAC=Water Absorption Capacity, OAC= Oil Absorption Capacity.

Conclusion

The greatest amount of starch was isolated from SP while using distilled water and its viscosity was low, which is an ideal type for the manufacture of weaning foods

and it can be used as fat substitute because of its small granular size. Nevertheless three starches showed identical XRD pattern with no change in crystallinity. SEM analysis showed that few compound granules in M_3 starch associated with residual protein. Correlation analysis also indicated a significant interdependence of chemical and functional properties in all the starches. Starch isolated with distilled water exhibited lower peak viscosity in addition to lower swelling. It may be concluded that distilled water could be used to isolate starch with desirable properties, suitable for many food products.

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