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Physico-chemical characterisation of sago starch

Fasihuddin B. Ahmad[a], Peter A. Williams[a,*], Jean-Louis Doublier[b], Sylvie Durand[b], Alain Buleon[b]

[a]*Centre For Water Soluble Polymers, The North East Wales Institute, Plas Coch, Mold Road, Wrexham L11 2AW, UK*
[b]*Institut National de la Recherche Arronomique, B.P. 1267, 44316 Nantes Cedex 03, France*

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Abstract

The physico-chemical characteristics of various sago starch samples from South East Asia were determined and compared to starches from other sources. X-ray diffraction studies showed that all the sago starches exhibited a C-type diffraction pattern. Scanning electron microscopy showed that they consist of oval granules with an average diameter around 30 μm. Proximate composition studies showed that the moisture content in the sago samples varied between 10.6% and 20.0%, ash between 0.06% and 0.43%, crude fat between 0.10% and 0.13%, fiber between 0.26% and 0.32% and crude protein between 0.19% and 0.25%. The amylose content varied between 24% and 31%. The percentage of amylose obtained by colourimetric determination agreed well with the values obtained by fractionation procedures and potentiometric titration. Intrinsic viscosities and weight average molecular weight were determined in 1M KOH. Intrinsic viscosity for amylose from sago starches varied between 310 and 460 ml/g while for amylopectin the values varied between 210 and 250 ml/g. The molecular weight for amylose was found to be in the range of 1.41×10^6 to 2.23×10^6 while for amylopectin it was in the range of 6.70×10^6 to 9.23×10^6. The gelatinisation temperature for the sago starches studied varied between 69.4°C and 70.1°C. The exponent '*a*' in the Mark–Houwink equation and the exponent 'α' in the equation $R_g = kM^{\alpha}$ was found to be 0.80 and 0.58, respectively for amylose separated from sago starch and these are indicative of a random coil conformation. Two types of pasting properties were observed. The first was characterised by a maximum consistency immediately followed by sharp decrease in consistency while the second type was characterised by a plateau when the maximum consistency was reached.

Keywords: Sago starch; Proximate composition; Amylose; Amylopectin

1. Introduction

Starch is a mixture of two polymers, amylose, a linear (1 → 4)- linked -α-D-glucan and amylopectin a highly branched molecule which consists of short chains of (1 → 4)- linked -α-D-glucose with (1 → 6)-α- linked branches. Chain lengths of amylose are commonly in excess of 6000 D-glucopyranose units with molecular weight between 150 000 and 600 000 Da (Kennedy et al., 1983). Although amylose was considered to be linear, studies using pullulanase suggest that a small number of branches exist in the molecule (Kennedy et al., 1983). Amylopectin, on the contrary, is very branched with an average of 17–26 D-glucosyl units separating the α- (1 → 6) branch points (Kennedy et al., 1983). The molecular size of amylopectin is almost too large to be determined accurately but light scattering studies indicate a value of 10^6 D-glucosyl residues per molecule which makes amylopectin one of the largest naturally occurring macromolecules (Kennedy et al., 1983). All starches are made up of these two polysaccharides. The ratio varies with the starch source but is typically 20 : 80 amylose to amylopectin (Orford et al., 1987). For example corn starch has approximately 28% amylose; genetically manipulated high amylose corn starch can contain about 70% amylose while genetically modified waxy corn contains 90%–100% amylopectin (Kennedy et al., 1983; Cowburn, 1989). Starch accumulates as a complex granular structure with size ranging from 1 to 60 μm. The granule were shown to be made of stacks of amorphous and semi-crystalline growth rings (120–400 nm thick). The semi-crystalline shells are composed of alternating crystalline and amorphous lamellae repeating in 9–10 nm and superimposed to the architecture of amylopectin (French, 1984). Starches from different sources differ in overall structure through size distribution of the granules, shape, amylose and lipid content, distribution of chain length in amylopectin and crystalline structure (crystallinity, polymorphic type, crystal size).

* Corresponding author.

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Sago starch is isolated from sago palm (*Metroxylon* spp.) which is better known as 'rumbia' and distributed throughout South East Asia. Some of the important species widely used in sago starch production includes *M. longispinum*, *M. sylvestre*, *M. microcanthum*, *M. sagu* and *M. rumphii*. Sago palm is an important resource especially to the people in rural areas because it has various uses especially in the production of starch either as sago flour or sago pearl. Sago can compete economically on yield and price compared to other crops for example the yield of sago starch is 2000–3000 kg/HaYr compared to cassava 2000 kg/HaYr and maize 1000 kg/HaYr (Stantan, 1992). A mature palm can produce about 100–550 kg of sago flour. It is estimated that about 60 million tonnes of sago starch are produced annually in South East Asia (Wang et al., 1996). Although modern Factories use a fully mechanical process, traditional methods still play an important role in the starch production.

Although sago starch was used for a long time especially in South East Asia in the Food Industry for the production of vermicelli, bread, crackers, biscuits and many other traditional foods only a few limited studies on the physico-chemical characteristics and properties were reported (Arai et al., 1981; Kawabata et al., 1984; Sim et al., 1991; Takahashi & Kainuma, 1994). Besides the fact that sago starch is cheap some other important properties were reported such as its ease to gelatinise, its high viscosity if properly extracted and the ease with which it can be moulded. It has also been reported to undergo little syneresis (Takahashi, 1986).

The aim of the present work is to fully characterise sago starches from various sources in South East Asia and to obtain more detailed information on the physico-chemical properties.

2. Materials and methods

2.1. Materials

Nine sago starch samples were obtained from eight different manufacturers in Dalat, Mukah and Pusa in Sarawak, Malaysia (samples designated as sago 1–sago 9); sago 10 was obtained from Pekan Baru, Indonesia while sago 11 was obtained from Bangkok, Thailand. Sago 2 and sago 5 were food grade while the other samples were industrial grade. The grading is made according to the Standard Industrial Research Institute of Malaysia. All the starch samples were used as provided without any further treatment. Pea, potato, corn, waxy corn and tapioca starches (a gift from Cerestar, Trafford Park, UK) were used as received for comparison.

2.2. Methods

2.2.1. Scanning Electron Microscopy

Scanning Electron Micrographs (SEM) were obtained on a Deben Genie SEM using powdered starch suspended in 1 : 1 glycerol/water mixtures.

2.2.2. X-ray diffraction

Samples (5–20 mg) were sealed between two aluminum foils to prevent any significant change in water content during the measurement. Diffraction diagrams were recorded using Inel X-ray equipment operating at 40 kV and 30 mA. CuKα_1 radiation ($\lambda = 0.15405$ nm) was selected using a quartz monochromator. A curved position sensitive detecter (Inel CPS120) was used to monitor the diffracted intensities using 2 h exposure periods. Relative crystallinity was determined after bringing all recorded diagrams to the same scale using normalisation of the total scattering between 3° and 30° (2θ), following a method derived from Murthy & Minor (1990). The respective amounts of A- and B-types were determined using a multilinear regression assuming that the experimental diagrams are a linear combination of elementary patterns of amorphous, A- and B-types, following a method derived from Gernat et al. (1993). Recrystallised amylose and extruded potato starch were used for A, B and amorphous standards respectively. The measurements were made twice for each starch sample.

2.2.3. Proximate analysis

Standard AACC methods (American Association of Cereal Chemists, 1995) were used for the measurement of moisture, ash, fiber and nitrogen. Protein was determined from estimates of total nitrogen using a conversion factor of 6.25. Non starch lipids were extracted with petroleum ether (b.p. 40°C–60°C) for 12 h in a Soxhlet extractor and the solution dried to a constant weight. pH values were determined electrometrically on a suspension of 10 g dry solids in 50 ml of distilled water.

2.2.4. Fractionation of starch

Fractionation of starch samples was carried out according to the procedure of Banks & Greenwood (1975). The purity of amylose and amylopectin samples obtained were determined by potentiometric titration (Schoch, 1964).

2.2.5. Determination of amylose

Amylose in the starch samples was determined according to the colourimetric procedure of Chrastil (1987) except that the spectrophotometric measurement was carried out at 630 nm instead of 620 nm because the absorbance value was maximun at this wavelength. Standard amylose and amylopectin were purchased from Fluka Chemicals. Solutions of different concentrations were prepared from pure amylose and amylopectin. The amylose content in the starch samples was determined from the standard amylose graph prepared and amylopectin was obtained by difference.

2.2.6. Intrinsic viscosity

Amylose and amylopectin samples were dissolved in KOH solution according to the procedure of Kawabata et al. (1984). All measurements were carried out at 25°C. Solutions with concentration of 0.1%–0.4% were prepared,

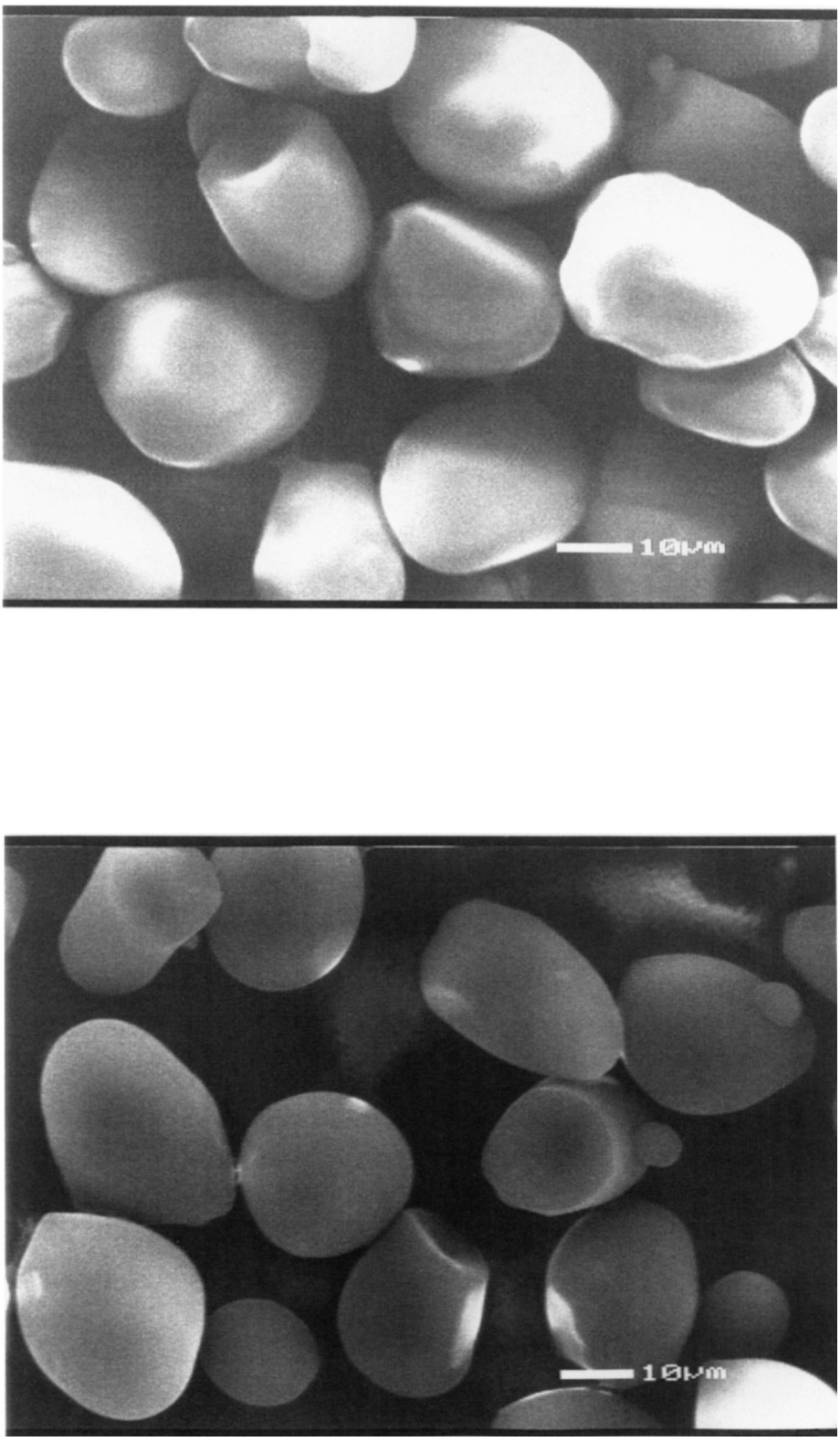

Fig. 1. SEM for sago starches (top picture sago 6, bottom picture sago 3)

filtered through a 3.0 μm millipore filter into clean containers and the viscosity determined using a Canon-Ubbelohde semi-micro dilution viscometer size 75. The actual concentration of the starch was determined according to the procedure of Dubois et al. (1956). Reduced viscosity and inherent viscosity were plotted against concentration and the intrinsic viscosity was obtained from the intercept of the graph at the ordinate. The viscosity average molecular

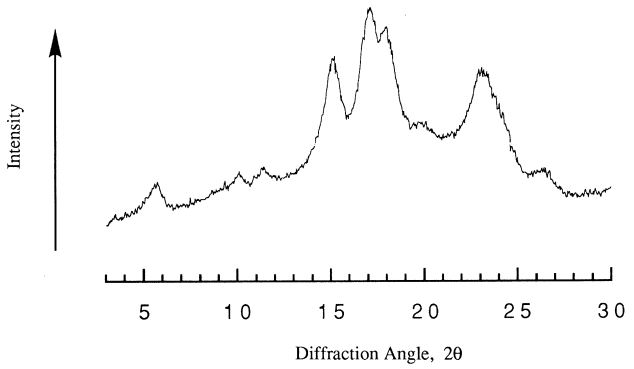

Fig. 2. X-ray diffraction diagram for sago 5

weight was determined using the Mark–Houwink relationship taking '*k*' as 1.18×10^{-3} and '*a*' as 0.89 (Cowie, 1961).

2.2.7. Light scattering

Amylose and amylopectin samples were prepared in 1 M KOH. The concentration range of the samples depended on the molecular weight. The initial samples and solvents were filtered through 3.0 μm Millipore filters into clean Burchard cells. The measurements were performed by static light scattering (K 7027, Malvern Instrument, Malvern, Worcester, UK) using a 10 mW He–Ne laser at λ632.8 nm.

Before measurement full temperature equilibrium was achieved. All measurements were performed at 25°C. All the samples were filtered directly into the measuring cell at least 3 times using a 0.45 μm millipore filter. The measuring cell was washed thoroughly with double distilled water and finally with an excess amount of freshly distilled acetone and then dried. During filtration, about 1 ml of the samples were discarded in order to avoid any dust particles from the filter being introduced into the measuring cell and then a few mls of the samples were filtered into the cell and the cell was closed using a clean stopper. The cell was then kept in the holder and the laser aligned carefully. The angular dependence of scattering was determined at 10° intervals between 30° and 150°. A value of 0.146 ml/g was employed as the refrective index increment, d*n*/d*c* (Pascall & Foster, 1952; Huglin, 1972) for amylose and a value of 0.142 ml/g was employed for amylopectin (French, 1984). The actual concentration for all the samples was determined using the phenol–sulphuric acid assay (Dubois et al., 1956). The weight average molecular weights, M_w were determined from Zimm plots.

2.2.8. Differential scanning calorimetry

Differential scanning calorimetry (DSC) was performed using a micro DSC (Setaram, Lyon, France). Starch samples at 5% on a dry weight basis were prepared and the pH of the suspension adjusted to 5.5 by adding dilute HCl or dilute NaOH. An aliquot of the samples (about 0.95 g) was added into the test cell, the top sealed and the weight recorded. An equal mass of water was added into the reference cell. The cells were heated from 10°C to 95°C at the rate of 0.5°C/min.

2.2.9. Gel strengths

Starch samples, 6% based on a dry weight basis were prepared by adding the appropriate amount of starch powder to distilled water with constant stirring (400 rpm) and the pH adjusted to 5.5 with dilute HCl or dilute NaOH as appropriate. The samples (200 ml) were immersed in a boiling circulating water bath for 30 min and were stirred at a constant rate of 400 rpm using a mechanical stirring rod. The beaker was reweighed and the volume corrected for any evaporation loss on heating using hot distilled water. The samples were transferred to a storage jar (30 ml) cooled at 25°C and stored at that temperature in a circulating water bath before the gel strengths were measured. Measurements were performed after intervals of 6 h, 1 day, 2, 4 and 7 days using a texture analyser (Stevens, Leatherhead Food Research, Surrey, UK) using a 1 cm diameter probe. The force required to break the gel was determined.

2.2.10. Viscograms

Starch dispersions, 4% (w/w) were pasted into the Brabender Viscograph. The samples were heated from 30°C to 96°C at the rate of 1.5°C/min and were held at 96°C for 15 min before cooling to 80°C at the rate of 1.5°C /min.

3. Results and discussion

3.1. Scanning electron microscopy

SEM showed that the sago starch consists of oval granules with diameters in the range of 20–40 μm. No significant differences were observed in the shape or average diameter for the various starch samples. Fig. 1 shows a typical SEM for sago starch.

3.2. X-ray diffraction

Fig. 2 shows an example of the sago starch X-ray diffraction diagram. All samples exhibited X-ray diagrams reminiscent of a mixture of two of the crystalline forms of starch, namely A and B-types. Such C-type diagrams (Sarko & Zugenmaier, 1980) were already described for smooth pea and broad bean starches (Colonna et al., 1981) and are encountered for some cereal starches grown in specific conditions of hydration and temperature. Typically, A-type spectra are shown by cereal starches and B-type spectra are displayed by tuber starches such as potato starch and high amylose starches. The latter are characterised by a small peak at 5.6°, only one peak at 17° instead of a doublet at 17° and 18° for the A-type and a doublet at 22° and 24° instead of a single peak at 23° for the A-type. These diffraction spectra suggest that the crystalline type of sago starch is

Table 1
Proximate composition of starches

Starch samples	Moisture, %	Ash, %	Crude fat, %	Crude protein, %	Fiber	Aqueous pH
Sago 1	10.6	0.07	0.10	0.25	0.28	5.30
Sago 2	13.9	0.08	0.12	0.19	0.29	3.69
Sago 3	14.7	0.25	0.12	0.19	0.28	4.78
Sago 4	11.2	0.12	0.11	0.19	0.30	5.40
Sago 5	14.7	0.11	0.13	0.19	0.27	5.90
Sago 6	16.9	0.43	0.12	0.25	0.32	5.90
Sago 7	12.7	0.15	0.13	0.13	0.29	5.30
Sago 8	14.0	0.07	0.11	0.19	0.28	3.94
Sago 9	10.7	0.06	0.12	0.19	0.26	5.96
Sago 10	20.0	0.15	0.13	0.19	0.29	5.30
Sago 11	10.9	0.07	0.12	0.19	0.20	5.90
Pea	7.9	0.10	0.10	0.25	0.20	5.89
Potato	18.5	0.25	0.12	0.63	0.28	6.22
Corn	12.2	0.20	0.20	0.88	0.24	5.90

intermediate to that of cereal or potato starches. The degree of crystallinity was very similar for all the studied starches (around 28% + 5%). The respective amounts of A- and B-types were found to be also very similar: 65% + 5% of A-type and 35% + 5% B-type.

No clear difference could be seen between the samples, meaning that the crystallinity and the polymorphic type did not differ despite some differences in amylose content. These differences are probably not high enough to induce a change in the crystalline structure. It is well known that an increase in the amylose content induces an increase in the B-type amount and a decrease in the crystallinity. On the another hand, it should be mentioned that C-type diagrams (i.e. a mixture of A- and B-types) are obtained for starches of relatively high amylose contents (around 30% in smooth pea and faba beans) similar to those of the sago starches studied.

3.3. Proximate composition

The proximate composition of the starch samples analysed is given in Table 1. The moisture contents of the sago starch ranged between 10.6% and 20.0% which is typical for commercial starches. Under average ambient temperature and humidity conditions the moisture content of most unmodified starches is around 12%. The ash contents for all the sago starches studied were low except for sago 3 and sago 6. All commercial starches either from cereal or tuber sources contain minor or trace quantities of uncombined inorganic materials. The inorganic material normally originates in the crop from which the starch is isolated and also from the water used to process the starch. The fiber contents for all the sago starch studied were low and comparable to fiber contents from other starches.

The quantity of crude fat in the samples were low and in the sago samples ranged from 0.10% to 0.13% while for potato starch it was 0.12% and for corn starch 0.20%. Commercial starches normally contain trace amounts of fatty acid glycerides usually less than 0.1% which can be removed by Soxhlet extraction using ether or hexane. Starches also contain about 0.5%–0.6% free fatty acid which is complexed with the amylose (Schoch, 1942). The complexed fatty acids will not be removed by normal fat

Table 2
Amylose content in starch samples

Samples	Amylose, % (apparent amylose)	Amylose, % (total)	Amylose, % (fractionation)	Amylose, % (potentimetric titration)[a]
Sago 1	28	29	29	27
Sago 2	30	31	30	30
Sago 3	26	26	25	26
Sago 4	25	25	25	25
Sago 5	26	28	27	27
Sago 6	25	25	24	25
Sago 7	28	30	29	27
Sago 8	26	27	27	27
Sago 9	28	30	29	28
Sago 10	24	24	24	24
Sago 11	27	28	28	27

[a] Amylose content based on potentiometric titration was calculated by assuming that indine affinity of pure amylose is 19.5

Table 3
Intrinsic viscosity and M_w for amylose and amylopectin

Sample	Intrinsic viscosity, ml/g	$M_v \times 10^{-6}$, Da (based on Mark–Houwink equation)	$M_w \times 10^{-6}$, Da (light scattering)
Amylose 1	350	1.39	1.41
Amylose 2	310	1.23	1.24
Amylose 5	460	1.91	2.07
Amylose 8	300	1.18	1.46
Amylose 9	400	1.64	2.23
Amylopectin 1	210	nd[1]	6.92
Amylopectin 2	220	nd[1]	8.64
Amylopectin 5	210	nd[1]	9.23
Amylopectin 8	230	nd[1]	6.70
Amylopectin 9	250	Nd[1]	7.19

[a] nd – not determined

solvent such as hexane but require extended extraction by using hot methanol or ethanol to give fat-free starches. The crude protein for the sago starches studied varied between 0.13% and 0.25% and the crude protein contents are low compared to pea, potato or corn starches. The pH of the starch suspensions were around 5–6 except for sago 2 which had a pH of 3.69 and sago 8 which had a pH of 3.94. Resulting from the different pH values all the physico-chemical measurements were made by adjusting the pH to 5.5.

3.4. Determination of amylose

The amylose content for the starch samples studied are given in Table 2. The total amylose contents (lipid free starch) in sago starches ranged between 24% and 31% while the apparent amylose content (starch with lipid) was slightly lower and in the range of 24% to 30%. The amylose content obtained by colourimetric procedure agreed well with the amylose content obtained by fractionation and potentiometric titration (Table 2). There are no lipids present in the sago starches studied able to complex the amylose (i.e. fatty acids and monoglycerides) since no melting endotherm of such species (melting temperature: 90°C – 110°C) can be seen in the thermograms. Moreover, the lipids are not covalently linked to amylose to form this type of complex. Apparent amylose in the starches was determined as such without any treatment. Real amylose content was determined after removal of the lipids by extracting the starch in hot 85% methanol. The amylose obtained from the fractionation procedure was pure amylose based on its iodine binding capacity of 19.5 %. For amylopectin fractions the iodine binding capacity was around 0.3%. The amylose contents for sago starches found in this study agree well with the published values of 22%–31.7% (Bates et al., 1943; Howling, 1980; Kawabata et al., 1984; Sim et al., 1991).

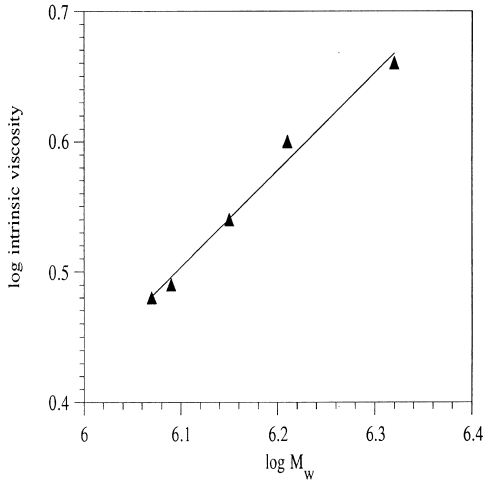

Fig. 3. Plot of log intrinsic viscosity against log M_w for amylose from sago starch

3.5. Intrinsic viscosity and molecular weight

Intrinsic viscosity and molecular weight data for the isolated amylose and amylopectin components is given in Table 3. Intrinsic viscosity for amylose ranged from 310 to 460 ml/g in 1 M KOH, while for amylopectin under similar conditions the intrinsic viscosity was 210 to 250 ml/g. The intrinsic viscosities for amylose obtained from sago starch are high compared to that from corn starch but quite similar to potato, 250–570 ml/g (Colonna & Mercier, 1984) and cassava, 367 ml/g (Roger & Colonna, 1993). The intrinsic viscosity values for amylopectin from sago starch are much lower than amylose but agree well with the values for amylopectin from other sources. The M_w obtained by light scattering for amylose ranged between $1.41 \times 10^6$to 2.23×10^6 while for amylopectin the value was around 6.70×10^6 to 9.23×10^6. The $M_w$values obtained agree well with the values obtained by viscometry. The values for intrinsic viscosity and molecular weight are comparable to other reported values for amylose and amylopectin from other sources (Everett & Foster, 1959; Biliaderis et al., 1979; Colonna & Mercier, 1984; Roger & Colonna, 1993; Ong et al.,

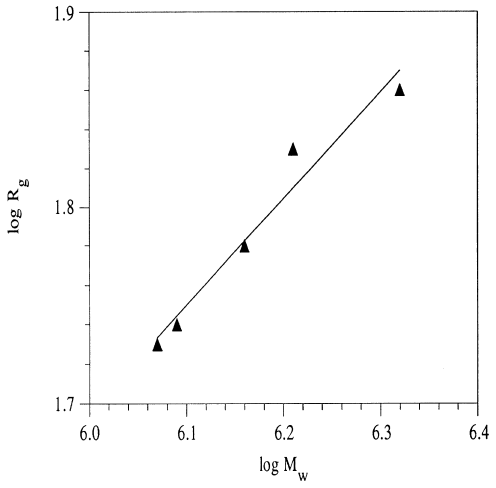

Fig. 4. Plot of log R_g against log M_w for amylose from sago starch

1994; Vorwerg & Rodosta, 1995). For example, Everett & Foster (1959) reported the M_w value for amylose obtained from potato in 1 M KOH as 2.34×10^6 while Ong et al. (1994) reported a value of 1.3×10^6 for amyloses from wheat, potato, cassava and sweet potato. For amylopectin the M_w was much higher and Biliaderis et al., (1979) reported M_w for amylopectin as 2×10^7 while Colonna & Mercier (1984) reported M_w for amylopectin in the order of 1.9×10^7 and 8×10^7. Fig. 3 is a plot of log intrinsic viscosity against log molecular weight for amylose from sago starch and it is linear. The slope of the line gives the Mark–Houwink exponent and was found to be 0.80 which agrees well with the published value (Cowie, 1961; Roger & Colonna, 1996). The radius of gyration, R_g is related to M_w according to the equation $R_g = kM^{\alpha}$. α has values of 0.33, 0.60 and 1.0 for spheres, random coils and rigid rods, respectively (Burchard, 1994) and can be obtained from the slope of the plot of log R_g versus log M_w. The plots of log R_g agaisnt log M_w for amylose and amylopectin respectively are shown in Figs. 4 and 5 and are linear. The values

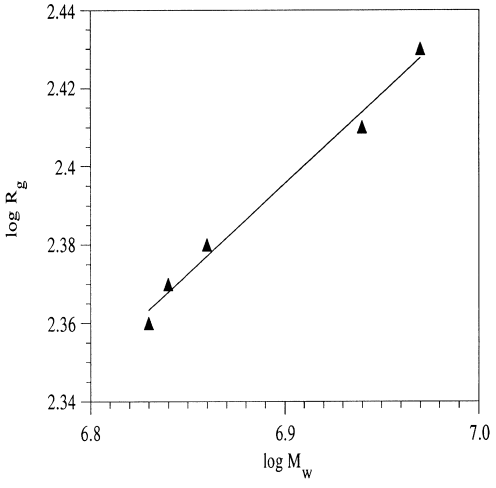

Fig. 5. Plot of log R_g against log M_w for amylopectin from sago starch

Table 4
Gelatinisation temperature and enthalpy for starchs amples

Starch samples	Endothermic peak temperature, °C	Enthalpy, J/g
Sago 1	69.4	15.8
Sago 2	70.1	16.3
Sago 3	69.5	15.7
Sago 4	69.5	15.2
Sago 5	69.3	16.1
Sago 6	69.4	15.1
Sago 7	69.7	16.0
Sago 8	70.1	16.7
Sago 9	69.7	16.1
Sago 10	70.1	16.3
Sago 11	69.7	15.1
Corn	67.4	12.4
Waxy corn	68.1	13.9
Tapioca	66.3	15.1
Potato	63.1	17.8
Pea	56.1	9.5

of α were found to be 0.58 and 0.45 for amylose and amylopectin, respectively, consistent with their random coil and highly branched structures.

3.6. Differential scanning colorimetry

DSC results obtained for the various starch samples are given in Table 4 and representative curves are shown in Fig. 6. The results show that the gelatinisation temperature for sago starches ranged from 69.4°C to 70.1°C. The gelatinisation temperature for sago starches are high compared to corn, pea and potato but low compared to starch from sweet potato, tania and yam (Tian et al., 1991; Veletudie et al., 1995). No significant differences in the gelatinisation enthalpy between sago starch samples were observed. The gelatinisation temperature and enthalpy of the starches depends on the microstructure and degree of crystallinity within the granule and also on granule size and the amylose

Table 5
Gel strength of starch samples

Sago starch	Gel strength for sago starch, g cm^{-2}				
	6 h	1 day	2 days	4 days	7 days
Sago 1	97	98	97	98	99
Sago 2	185	178	179	179	179
Sago 3	77	72	72	74	74
Sago 4	69	65	65	66	66
Sago 5	86	83	83	83	84
Sago 6	57	51	51	51	52
Sago 7	78	70	70	nd	71
Sago 8	122	122	123	123	125
Sago 9	93	94	94	95	96
Sago 10	41	41	42	43	45
Sago 11	64	65	65	65	67
Pea	210	210	211	210	212
Corn	162	164	164	163	164
Potato	25	26	25	27	27

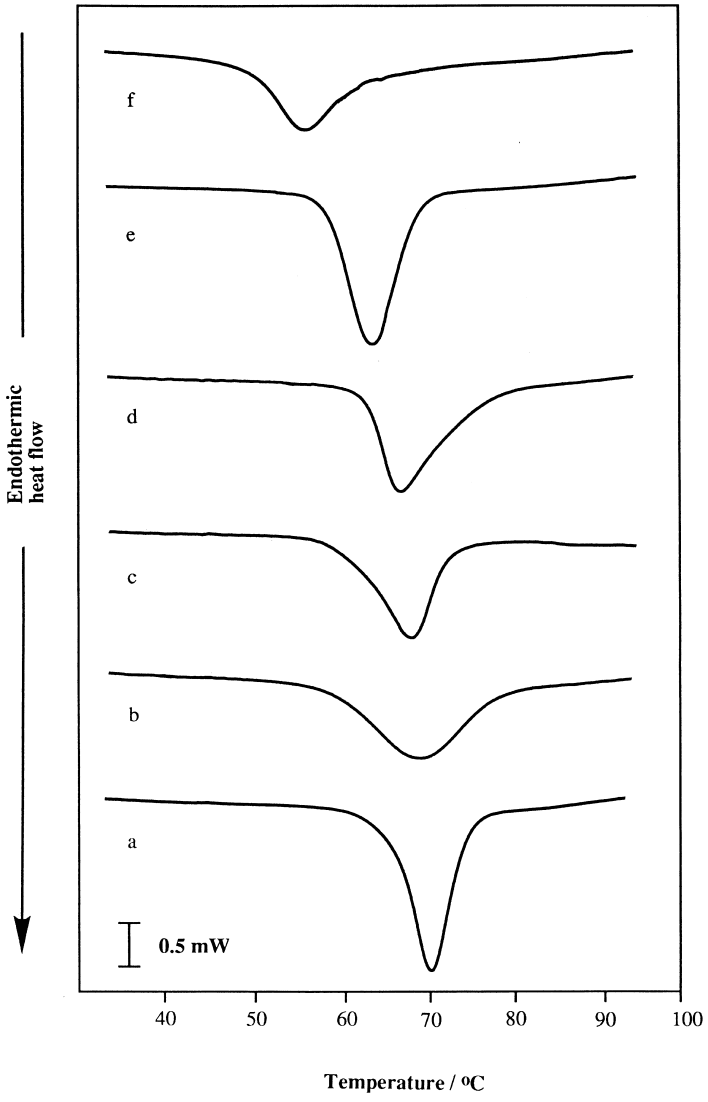

Fig. 6. DSC heating curves for various starches: (a) sago; (b) waxy corn; (c) corn; (d) tapioca; (e) potato; and (f) pea

Table 6
Pasting behaviour of sago starches

Sample	Pasting temperature (°C)	Maximum consistency (cmg)	Temperature at maximum consistency (°C)
Sago 1	72.5	157.4	76.5
Sago 3	73.0	177.0	96.0
Sago 4	72.5	172.0	80.0
Sago 5	72.5	233.8	85.0
Sago 6	72.5	172.8	85.0
Sago 7	74.0	181.2	84.0
Sago 9	72.5	201.5	88.0
Sago 10	73.0	148.3	77.0
Sago 11	73.0	169.3	77.5

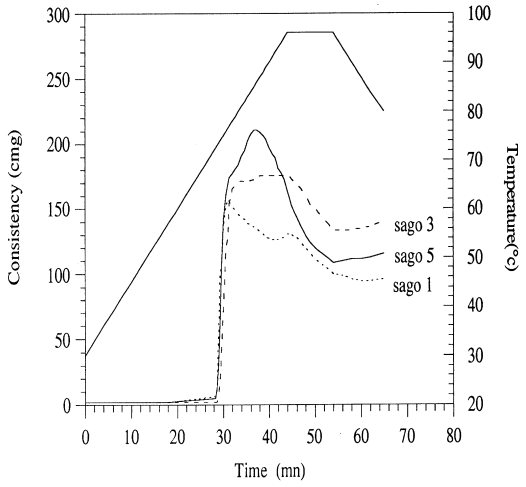

Fig. 7. Pasting properties for sago 1, 3 and 5

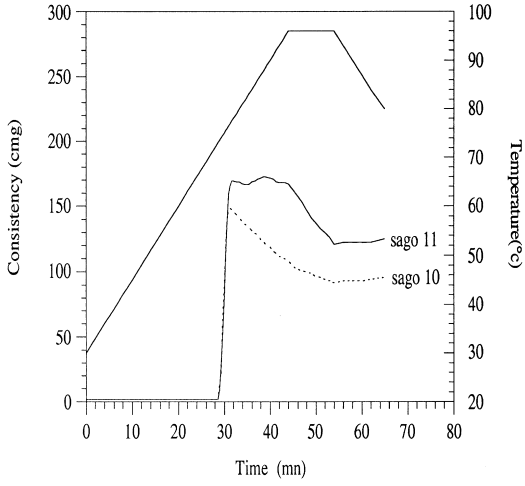

Fig. 9. Pasting properties for sago 10 and 11

to amylopectin ratio. Normally the smaller the granule the higher will be the gelatinisation temperature (Cowburn, 1989).

3.7. Gel strengths

Gel strengths for the starch samples are given in Table 5. The gel strength for 6% sago starches varied considerably for the sago starches and agreed well with the amylose content and also molecular weight. Sago starch 2 gave the highest gel strength compared to that of corn starch possibly because of its higher amylose content. The gel strength did not change significantly over a 7 day period. The sago starch gels were moderately clear compared to the gels from corn and pea which were more opaque. However the clarity decreased on standing especially for sago starch 2 and sago starch 8 and the gels became more turbid. The gel strength for sago starch was higher than potato but lower than pea (Table 5).

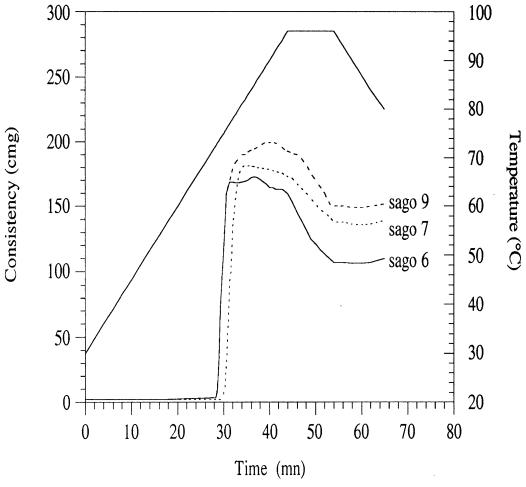

Fig. 8. Pasting properties for sago 6, 7 and 9

3.8. Viscograms

Results for the viscograms are shown in Figs. 7, 8 and 9. Based on the shape of the viscograms, sago starch can be separated into two categories that is type 1 (for sago 1, 5 and 10) and type 2 (for sago 3, 4, 6, 7 and 9). Type 1 sago starches are characterised by a maximum consistency at 75°C (sago 1 and 10) or at 85°C (sago 5) immediately followed by a sharp decrease. However, starch 5 differs quite significantly from the two others. This latter sample seems to yield a viscogram with a shape that is quite similar to that of potato starch. Type 2 sago starches are characterised by a plateau when the maximum consistency is reached. This category appears more homogeneous than type 1. The overall results are given in Table 6.

4. Conclusions

The proximate composition and other physicochemical properties of sago starches from different origin did not vary significantly except for the molecular weight for the amylose fraction and also the amylose content. The difference in the amylose content most probably arises as a result of harvesting the sago palm at different stages of its growth while the differences in the molecular weight are most probably as a result of processing conditions in the factory, notably the pH of the water used. The physicochemical properties of sago starch are quite similar to other commonly used starches but intermediate to those of cereal and potato starches. The amylose content and gelatinisation temperatures are very similar to corn starches while the hot paste properties are similar to the potato starch. Moreover, sago starch exhibits a C-type (i.e. a mixture of A and B crystalline types) diffraction pattern consisting of about 65% A-type and 35% B-type as some faba bean starches. Based on the data presented and its high yield/hectare sago palm could be useful source for starch if properly exploited.

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