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Short communications

Sago starch and composition of associated components in palms of different growth stages

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Abstract

Sago (*Metroxylon sagu*) starch accumulates in the pith of the sago palm stem from the base upwards. At maturity, the trunk is fully saturated with starch almost to the crown. Apart from sago starch granules, the pith also contained other associated components. The starch content and composition of associated components at five different growth stages of sago palm have been investigated. The starch content was found to increase as the palms matured from plawei (mature vegetative growth) to angau muda (flowering) stage and decrease from angau tua (fruiting) to late angau tua stage. The composition of associated components in all the different growth stages showed that the amount of phenolic compounds was less than 1% whereas the lignin content ranged from 9 to 22%. The total and insoluble non-starch polysaccharides decreased as the palms matured to angau muda and angau tua stages and increased as the palms aged into late angau tua stage. The soluble non-starch polysaccharides did not show much difference except for plawei and late angau tua stages.

Keywords: Sago starch; Phenolic; Lignin; Non-starch polysaccharides

1. Introduction

Sago palm (*Metroxylon* spp.) is one of the few tropical crops with the ability to thrive in the harsh swampy peat environment (Johnson, 1977; Ruddle, 1977) which covers an area of 1.5 million ha i.e. 12% of Sarawak's total land area (Tie & Lim, 1977). Sago starch accumulates in the pith core of the stem of the sago palm (Cecil, Lau, Heng, & Ku, 1982). Trunk formation starts during the third and forth year growth of the palm (Kueh, 1977). The vegetative phase in the sago palm lasts 7–15 years during which time, the pith is saturated with starch from the base of the stem upwards (Kraalingen, 1986).

The sago palm produces an erect trunk that may reach 7–15 m in length and attain an average girth of 120 cm at the base of the palm (Flach & Schuiling, 1989). Most of the starch is found in the pith of the palm. The pith typically contains about 250 kg of starch, 425 kg of water and 175 kg of other material (Flach, 1983). The vegetative phase in sago palms lasts 7–15 years during which time, excess photosynthate from the leaves is transported to the trunk and stored as starch. In Sarawak, the local farmers classified the mature sago palms into different physiological growth stages (Table 1) namely, plawei (palms at maximum vegetative growth), plawei manit (inflorescence emerging), bubul (inflorescence developing), angau muda (flowering) and angau tua (fruiting) (Lim, 1991). After the matured fruits fall off, the palm will soon die (Dransfield, 1977).

Apart from sago granules, the pith of sago trunk also contained other associated components. Cecil et al. (1982) reported that the chemical analysis of pith showed about 6–12% of soluble solids (dry substance) and 1–3% of ash, apart from 79 to 88% of apparent starch plus sugar content. The sago pith also contained most of the constituents in any other plant materials namely fibre, hemicelluloses, other cell structural materials, soluble solids and unidentified traces of other substances.

The inconsistency of raw materials (sago logs) was known to cause the low quality of sago starch produced, while post harvest handling and processing contribute to the variation of starch extracted (Ahmad, Williams, Doublier, Durand, & Buleon, 1999). The purpose of this study was to determine the total starch content and composition of associated components namely, phenolic compounds, lignin and non-starch polysaccharides in the sago pith at two heights of five different

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Table 1
Different physiological growth stages of sago palm (Jong, 1995; Lim, 1991)

Growth stage	Estimated age from planting (year)	Palm description
Plawei	10	Palm have reached maximum vegetative growth; 75% trunk growth (6–8 m in length)
Plawei manit	11.5	Inflorescence emerging; full trunk growth (7–14 m in length
Bubul	6.5	Inflorescence developing; bolting
Angau muda	12.5–13	Flowering; reached maximum starch yield per trunk (Lim et al., 1991; Tie, 2004)
Angau tua	14	Fruiting; senescent stage

growth stages. In addition, it is hoped that the information obtained would aid in understanding the mechanism of starch release and the role played by the other components in the various stages of growth.

2. Materials and methods

Sago palms from five different growth stages, namely plawei (P), bubul (B), angau muda (AM), angau tua (AT) and late angau tua (LAT) were chosen from the spacing trial research plot of the Sg. Talau Peat Research Station, Mukah, Sarawak. Each palm was felled at 1 m above ground and sago log sections were obtained from two heights, i.e. 1 m above ground and 5 m above ground. After removing the bark at the point of drilling, core pith samples were drilled from the log sections using the increment borer. After drying, the pith samples were milled to fine powder and sieved through a 250 μm sieve.

The determination of total starch content in sago pith samples was carried out according to the method of Brunt, Sanders and Rozama (1998). The quantification of glucose was done following the hexokinase method using the D-glucose test kit (Boehringer Mannheim). The total starch content was then calculated using the formula as follows:

$$\%\ \text{Starch}(\text{g}/100\ \text{g}) = \frac{C \times 0.9 \times 100}{W}$$

where

C concentration of D-glucose (g/l sample solution)
0.9 conversion factor for glucose to starch
W weight of sample in g/l sample solution

Phenolic compounds was extracted from sago pith samples (0.3 g) by Soxhlet extraction using 125 ml of methanol:acetone solvent (Me:Ac 20:80) at 35–40 °C for 4 days. The phenolic extracts was concentrated by rotavap at 50 °C and transferred to 10 ml volumetric flasks using distilled water. An aliquot of 1 ml of extract was used for the determination of phenolic compounds using Folin–Denis reagent as described in Swain & Hillis (1959).

The determination of lignin content was based on the method used by Zadražil and Brunnert (1980) with a slight modification in the filtration process whereby ashless filter paper (Whatman No. 541) was used instead of glass filter. The organic matter lost at 450 °C was regarded as ash-free lignin and calculated using the formula:

$$\%\ \text{Lignin} = \frac{\text{Weight of dried residue} - \text{Weight of ash}}{\text{Initial weight of sample used}} \times 100$$

The non-starch polysaccharides of sago pith were determined according to the method of Englyst, Quigley, Hudson and Cummings (1992). The gas chromatography measurement of neutral sugars was carried out using a Supelco SP-2330 capillary column (30 m × 0.32 mm × 0.2 μm film thickness) and a flame ionization detector, the injector and detector were kept at 275 °C with helium as carrier gas, flow rate at 3 ml min^{-1}. The oven was set to start run at 150 °C, held for 4 min and then ramped at 25 °C min^{-1} to 230 °C, held for 8 min. The separation of alditol acetates were obtained within 15.2 min.

3. Results and discussion

The starch content was found to increase as the palms matured from plawei to angau muda stage with angau muda stage having the highest starch content of 41.3 and 41.4% at base and mid height, respectively (Table 2). Statistically, there is no significant difference ($P > 0.05$) observed in the starch content between the different growth stages. Nevertheless, a trend can be observed whereby angau muda stage showed the highest starch content at both base and mid heights. Within each stage, the difference in mean starch content at base and mid heights is least in angau muda stage as well. The slightly higher starch content at base height of plawei stage than mid height indicated accumulation of starch from base upward whereas the sharp drop in starch content at upper part of trunk in angau tua stage probably indicates the initiation of an upward mobilisation of starch from the base to the upper portion of the trunk (Kraalingen, 1984) for the conversion of starch to other forms of energy for flower and fruits development (Kraalingen, 1984; Sim & Ahmed, 1978).

The general trend of total starch content from plawei to late angau tua stages changes with the physiological development of the palms (Table 2) and is in agreement with that observed by Lim (1991); Jong (1995) although both studied the extractable starch content rather than the total starch content.

The phenolic compound extracted using acetone:methanol solvent encompasses a wide range of polar and non-polar

Table 2
Comparison of phenolic compounds, and total lignin contents with total starch content in the sago pith from base and mid heights of the different growth stages

Stage	*n*	Height[a]	Component (%)[b]		
			Starch	Phenolic compounds	Lignin
Plawei	1	B	24.9±1.0	0.6±0.0	21.6±0.4
		M	20.1±0.7	0.8±0.0	22.1±0.3
Bubul	3	B	33.4±3.0	0.6±0.2	15.4±2.1
		M	35.2±9.2	0.3±0.1	13.3±3.9
Angau Muda	3	B	41.3±8.0	0.3±0.0	11.2±2.3
		M	41.4±10.1	0.2±0.1	9.6±3.6
Angau Tua	3	B	39.4±6.0	0.3±0.1	11.5±1.4
		M	31.4±6.2	0.2±00	12.1±1.3
Late angau tua	3	B	31.6±9.5	0.6±0.4	14.0±2.5
		M	21.8±11.7	0.9±0.9	16.6±6.6

[a] B, base height; M, midheight.
[b] Values are means of percentage on dry weight basis ± SD ($n=3$) except for plawei stage. Means within a column related to a particular parameter with the same superscript letter are not significantly different at $\alpha=0.05$ confidence level.

substances which includes the polyphenols, flavanols and probably polyphenol oxidases in the pith tissues and cell walls. The browning of sago starch has been attributed to the presence of phenolic compounds and polyphenol oxidases in the pith. The primary phenolic compounds related to browning are DL-epicatechin and D-catechin (Ozawa & Arai, 1986). As a whole, the percentage phenolic compound extracted is low (less than 1%) (Table 2).

From Table 2, the lignin content in the pith from plawei to late angau tua stages showed an opposite trend to that of starch content. The younger palms (plawei) has a high and evenly distributed lignin content at base and mid heights which decreased as the palms matured to angau muda stage. This could be due to the palm's concentrate activity at the crown where the inflorescence is developing for flowering. After flowering, the lignin content was observed to increase slightly perhaps due to the mobilization of starch where lignin is needed to support the weight of the palm and to prevent the compression of vascular tissue that would collapse the cell walls. Statistically, no significant difference was observed at $\alpha=0.05$ confidence level.

The non-starch polysaccharides (NSP) were determined based on the amount of neutral sugars and uronic acid in combination to obtain total non-starch polysaccharides (TNSP), insoluble non-starch polysaccharides (INSP) and soluble non-starch polysaccharides (SNSP) and the results are presented in Table 3. The major sugars obtained in this study were arabinose, xylose and glucose. The TNSP, INSP and SNSP decreased in value from plawei, bubul to angau muda stage and increased again as the palms matured to late angau tua stage. Within each stage, the mean TNSP and INSP at base height were higher than mid height for bubul and angau muda stages. In the angau tua stage, the TNSP and INSP are evenly distributed throughout the palms since both the values are almost the same for both heights. It would seem that the mobilization of starch in preparation for fruiting stage involved the TNSP and INSP in the pith. Finally, at late angau tua stage, the TNSP and INSP showed an increase at both heights. On the other hand, the SNSP showed a different pattern of distribution in the trunk of the different growth stages. Unlike TNSP and INSP, SNSP is evenly distributed in bubul, angau muda and angau tua stages where both base and mid heights having almost the same amount in a decreasing trend.

Table 3
Total, insoluble and soluble non-starch polysaccharides in sago pith of base and mid heights at different growth stage

Stages	*n*	Height[a]	(g/100g)[b] TNSP	INSP	SNSP
Plawei	1	B	105	84 1	21.3
		M	98.8	86.4	12.4
Bubul	3	B	88.8±7.7[a]	65.8±8.7[a]	22.9±2.0[a]
		M	83.0±18.8[a]	59.0±8.9[a]	23.9±12.5[a]
Angau muda	3	B	62.9±14.9[a]	50.1±5.8[b]	12.8±9.6[a]
		M	57.5±20.0[a]	43.5±8.8[b]	14.0±11.2[a]
Angau tua	3	B	69.8±16.3[a]	51.5±12.5[c]	18.3±3.8[a]
		M	69.2±7.7[a]	52.5±5.7[c]	16.8±2.4[a]
Late angau tua	3	B	77.9±18.8[a]	61.3±15.2[d]	16.6±3.7[a]
		M	86.7±21.4[a]	65.0±16.5[d]	21.7±7.0[a]

[a] B, base height; M, midheight.
[b] Values are means of percentage on dry weight basis ± SD ($n=3$) except for plawei stage. Means within a column related to a particular parameter with the same superscript letter are not significantly different at $\alpha=0.05$ confidence level.

4. Conclusion

The starch content and composition of associated components in sago palm at different growth stages changes with the physiological growth of the palm. The starch content was found to increase as the palms matured from plawei to angau muda stage with angau muda stage having the highest starch content of 41.3 and 41.4% at base and mid height respectively. Then, the starch content decreased from angau tua to late angau tua stage. On the other hand, the phenolic compound was very low in quantity (<1%) in all the different growth stages whereas the lignin content showed the opposite trend to that of starch content. Generally, the total and insoluble non-starch polysaccharides at mid height decreased from plawei to angau muda stage and increased as the palms matured to late angau tua stage. At base height, the TNSP and INSP is lowest at angau tua stage. The soluble non-starch polysaccharides (SNSP) did not showed much difference in the value at base and mid height except for the plawei and late angau tua stage.

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