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Color characteristics of sago starch as they relate to the growth environment of the sago palm (*Metroxylon sagu* Robb)

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Studies were undertaken in Nakhom Si Thamarat Province in Southern Thailand, in an effort to correlate the color of sago starch to the characteristics of ecosystems from which the sago palm (*Metroxylon sagu* Robb) is harvested. Sago palms grown in fresh water swamp under acidic conditions and high soil sulphur concentrations (samples obtained from Kreng), yielded starch of a high ash content that was highly prone to phenolic oxidation, and was pink to brown in color. Sago palms grown under neutral soil conditions with comparably lower levels of sulphur (1/6 the sulphur content of soil in Kreng) and ash as in the case of samples obtained from Lansakar, were white in color. A mixture of sago palm varieties observed to grow in netural brackish conditions as occur in the Ronpioboon ecosystem.

Key words: Sago plam, *Metroxylon sagu*

Introduction

Growing concerns about feeding the world's population in the future has sparked interest in identifying alternative crops for food use. Underutilized plant resources are increasingly being investigated by scientists in an effort to explore their use as food. The sago palm (*Metroxylon sagu)* is on such crop that is increasingly gaining attention in this regard owing to its ability to thrive in harsh swampy peat soils and in submerged and saline soils where few other crops survive. It grows more slowly in peat soils than in mineral soils (Flach and Schuilling, 1989).

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The genus *Metroxylon* predominates in countries such as Thailand (South Thailand), peninsular Malaysia (Sabah, Serawak and West Malaysia), Indonesia (Papua, Maluku, Sulawesi, Riau Island, and Mentawai Island), the Philippines (Mindanao), Micronesia, Fiji, and Samoa and is found largely between 17°S and 15 – 16°N latitude, (Schuiling, 1995). Indonesia, Malaysia and Papua New Guinea, are the three leading producers of sago palm globally, and produce the crop on a commercial basis for the production of sago starch and/or conversion to animal food or to ethanol. Stems of the sago palm are thick and are either self supporting or grow with a somewhat climbing characteristic. The leaves are pinnate, not palmate. The palms generally take 7 – 10 years to reach maturity and are harvested before they flower. Starch can accumulate in the trunk of the sago palm until the flowering stage with maximum starch content occurring just before the onset of the palm flowers. At maturity, the trunk is fully saturated with starch almost to the crown. Sago palms only flower and fruit once before they die

When compared to other starches, sago starch has a low cost of production and is high yielding (Fasihuddin and Williams, 1996). Sago palms yield 2-3 tons of starch per hectare per year when compared to cassava which yields 2 tons per hectare and maize 1 ton (Stanton, 1993). Starch grains are mostly ovoid in shape, with some sub-spherical grains. Some kettledrum shaped grains are also present. Sago starch grains average 30 to 50 µm in diameter and are transparent and colorless (McCrone *et al.,* 1973). Compositionally, sago starch consists of 88 percent carbohydrate, 0.5 percent protein, minute amounts of fat. In terms of nutritional content, one hundred grams of dry sago starch contains 355 calories, including an average of 94 grams of carbohydrate, 0.2 grams of protein, 0.5 grams of dietary fiber, 10 mg of calcium, 1.2 mg of iron, and negligible amounts of fat, carotene, thiamine, and ascorbic acid. Sago starch is used as a staple food and as a food ingredient in poorer communities in many of the countries where the palm is grown.

The palms are of secondary importance to thousands who use them as a source of superior house thatch. Growing use of sago palm shingles as a form of roofing in the tourism industry, contributes greatly to income generation for women in Fiji. New and potential growth opportunities for the use of sago starch as food warrants a greater focus on assuring the quality of sago starch. The commercial acceptance and value of sago starch hinges greatly on its quality characteristics, and particularly its color. Starches extracted from different ecosystems vary in color from gray to pink to various shades of white. Ahmad *et al.* (1999) noted that the quality of sago logs as well as their post-harvest handling operations greatly impact on sago starch quality. In a recent review, Karim *et al.* (2008) highlighted among a number of issues, the need to correlate growth conditions of the sago palm, to the quality and yield of starch. We report here, studies undertaken in an effort to correlate the color of sago starch to the characteristics of ecosystems from which the sago logs are harvested.

Materials and methods

Samples of the sago trunks for starch extraction were obtained from 7-10 year old trees from three different ecosystems in Nakhom Si Thamarat Province in Southern Thailand - namely Ronpiboon (a costal site), Kreng (peat swamp) and Lansakar (a hill area) (Figure 1) .

Fig. 1. Habitat from which sago palm samples were collected in Ronpiboon - a coastal site (a); Kreng – fresh water peat swamp (b) and Lansakar – a hill area (c)

Soil Sampling and Analysis - Soil samples were taken from each of the three ecological systems in two layers: an upper layer (15 cm) and a lower layer (30 cm) using clean equipment and materials (hoe and spade, plastic bag, plastic can and plastic cloth, 1 x 1m) in accordance with the sampling plan illustrated in Figure 2. Samples from each respective ecosystem were combined, mixed and stored in Ziplock bags for analysis of pH and sulphur content.

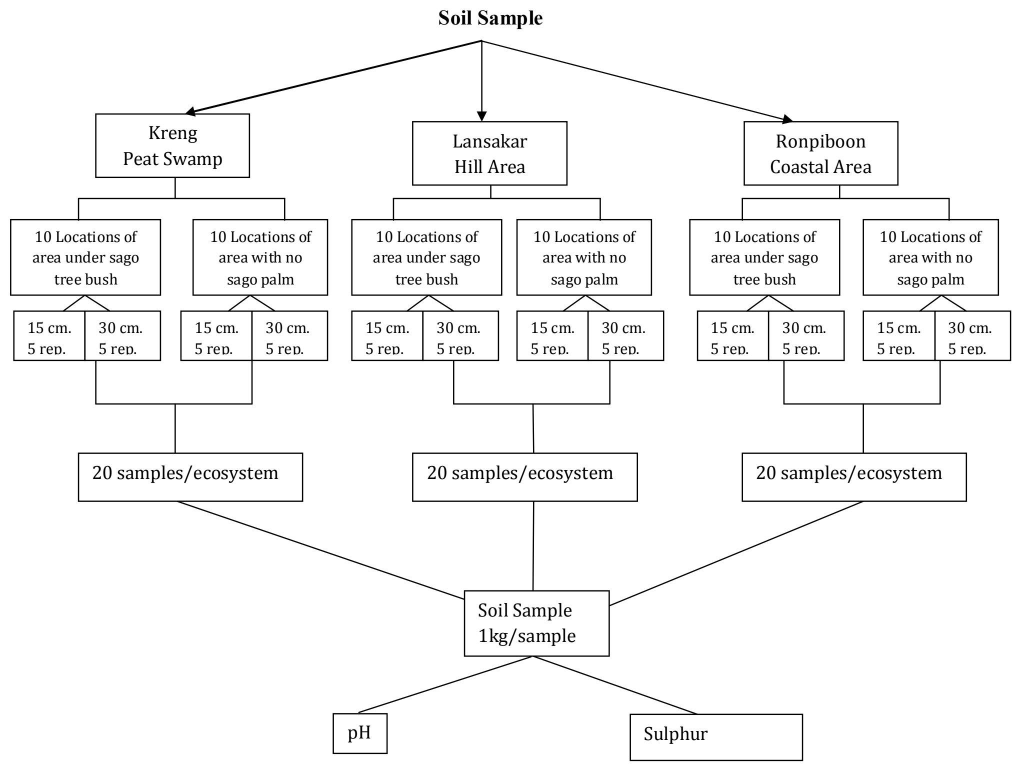

Fig. 2. Sampling plan for the collection of soil specimens for analysis.

Sampling of the sago-trunk – Sago trees were felled, following which the sago trunk was separated into lower, middle and upper portions according to the method of Srioroth *et al.* 1999 (Figure 3). A stainless steel axe was used to separate the bark from the sago pith for each portion of log (Figure 4).

Fig. 3. Measurement of the sago trunk into 1 meter portions for starch extraction (a); schematic identifying the categorization of samples of the sago trunk (b).

Fig. 4. Method used for separating the bark from the sago pith.

Extraction of sago starch – Sago starch was extracted from the pith according to the methodology of Cecil (1986), Flach (1981) and Fuji et al (1986). This involved grating the sago pith using a mechanized stainless coconut grater. Water adjusted to pH 4.5 with citric acid, was added to the grated starch. The starch slurry thus obtained was filtered through a clean cloth to separate any residual amounts of pith associated with the starch. The filtrate thus obtained was subsequently transferred to a plastic tank and allowed to precipitate over 1 day, under ambient conditions in the laboratory. The starch collected was subsequently sun dried and packaged in Ziploc bags for further study.

Physicochemical analysis of samples

The sulphur content of the soil samples was determined according to AOAC (2000). The ash content of extracted starch was also determined according to AOAC (2000).

Measurement of pH - One gram of the sample was ground and added to 25 ml distilled water at a temperature of 25^{o}C. The mixture was mechanical stirred for 5-10 minutes, following which the pH of the suspension thus obtained was measured using a pH meter (cyberscan 500 pH).

Measurement of particle size- 150-175 Mesh - The particle size of sago starch granules suspended in distilled water was measured using a laser Coulter LS 230 counter.

Color ("L value") - ColorFlex^{TM} - The degree of whiteness of starch samples (L value) was measured using a chroma meter (CR-300, MIN LTA, Japan).

Statistical Analysis - All data obtained was statistically analysed using an SPSS programme.

Results and discussion

Properties of soil samples

Sulphur content - The sulphur content of five replicates of soil samples taken from two layers (15 cm and 30 cm) of soil in each of the ecosystems where sago palms were growing as well as in areas where sago palms were not growing, was analyzed. The lower soil layer (30 cm) was found to have higher sulphur content when compared to the upper layer (15 cm) for soil samples obtained from Ronpiboon and Kreng (Table 1). Soil samples from Kreng (66.9680 mg/kg) had by far, the highest sulphur content of the three ecosystems, followed by those obtained from Ronpiboon (11.6130 mg/kg) and Lansakar (5.9300 mg/kg). Kreng is therefore, a high sulphur peat swamp environment, while Ronpiboon and Lansakar could be categorized as being comparably low sulphur coastal and hill environments respectively.

pH - The pH of the soil was found to range from acidic to almost netural in all three ecosystems Table 2. pH values for the three ecosystems varied significantly at $p<0.05$ (Table 3) . Soil samples obtained from Kreng were the most acidic (pH 4.91) while by those obtained from Lansakar (pH 5.96 were weakly acidic) and from Ronpiboon (pH 6.50) were almost neutral.

Table 1. Sulphur content (mg/kg) of soil samples from the three ecosystems studied

Ecosystems	soil_level	Mean (mg/kg)	Std. Deviation	N
Ronpiboon	upper soil	5.7440	.50713	5
	lower soil	6.1160	.97190	5
	Average	5.9300	.75667	10
Kreng	upper soil	49.2540	5.15973	5
	lower soil	84.6820	2.38388	5
	Average	66.9680	19.05279	10
Lansakar	upper soil	12.9340	3.79594	5
	lower soil	10.2920	.76195	5
	Average	11.6130	2.93275	10

Table 2. Average pH values for soil samples obtained from each of the three eco-systems

Ecosystem	soil_level	Mean	Std. Deviation	N
Ronpiboon	upper soil	6.2020	.30211	5
	lower soil	6.5200	.41599	5
	Average	6.3610	.38153	10
Kreng	upper soil	4.5600	.04690	5
	lower soil	4.5260	.05079	5
	Average	4.5430	.04945	10
Lansakar	upper soil	6.2020	.22698	5
	lower soil	6.2660	.15868	5
	Average	6.2340	.18769	10
Average	upper soil	5.6547	.82666	15
	lower soil	5.7707	.94806	15
	Overall Average	5.7127	.87595	30

Table 3. Homogeneous test (*Duncan*'s multiple range tests) for soil pH

Ecosystems	N	Subset	
		1	2
Lansakar	10	4.5430	
Ronpiboon	10		6.2340
Kreng	10		6.3610
Sig.		1.000	.248

Means for groups in homogeneous subsets are displayed.
Based on observed means.
4The error term is Mean Square(Error) = .058.

Physicochemical properties of sago starch

pH – pH values for starch samples from all three ecosystems, were similar (Table 4). These pH values are very much in line with the pH of aqueous extracts of industrial (4.0 minimum) and edible (4.0 minimum) grades of sago starch (Malaysian Standard Sepcifications 468 and 470 respectively, cited by Karim *et al.*, 2008).

Table 4. Descriptive statistical analysis for pH, and ash content (%) of sago starch obtained from the three ecosystems

Ecosystem	Trunk portion	Mean	Std. Deviation	N
Ronpiboon	lower	97.5973	1.12149	15
	middle	98.1167	1.31382	15
	upper	98.1787	0.87549	15
	Average	97.9642	1.12373	45
Kreng	lower	98.3620	1.06725	15
	middle	98.1460	1.08634	15
	upper	98.4053	0.71841	15
	Average	98.3044	0.95670	45
Lansakar	lower	98.1873	1.01569	15
	middle	98.4467	0.94095	15
	upper	97.9150	0.88913	12
	Average	98.2021	0.95539	42
Overall	lower	98.0489	1.09559	45
	middle	98.2364	1.10868	45
	upper	98.1843	0.83016	42
	Average	98.1559	1.01889	132

Ash - Sago starch samples obtained from Kreng had the highest ash content 5.76 %, followed by samples obtained from Lansakar which had an ash content of 3.81 % (Table 4). Samples obtained from Ronpiboon had the lowest ash content averaging at 2.55 %. Flores (2009) determined that the ash content of sago flour can go as high as 6 to 9 %. A recent draft regional FAO/WHO (2010) standard for sago flour N06-2007, however, recommends a maximum ash content of 2 % for optimum sensory properties of sago flour.

Particle size of sago starch – According to McCrone *et al*. (1973) sago starch grains average 30 to 50 µm in diameter. Starch samples obtained from Lansakar had the highest average particle size (34.49 µm) followed by those obtained from Kreng which had an average particle size of 33.59 µm (Table 5). Samples obtained from Ronpiboon had the lowest particle size; averaging at 31.54 µm. Average particle size showed a decreasing trend from the base to the higher end of the trunk, thus indicating that potential exists for enhancing the value added potential of starch by segmenting the sections of the trunk from which it is extracted. The upper part of the trunk had the smallest particle size average of 32.7510 µm (Table 5).

Table 5. Descriptive statistical analysis for particle size (□m) of sago starch from the three ecosystems.

Parameters	Ecosystems	Trunk portion	Mean	Std. Deviation	N
pH	Ronpiboon	Lower	4.5424	.72022	25
		Middle	4.6656	.59068	25
		Upper	4.4067	.52663	24
		Average	4.5400	.61958	74
	Kreng	Lower	4.6576	.42524	25
		Middle	5.0496	.40648	25
		Upper	4.5568	.42783	25
		Average	4.7547	.46626	75
	Lansakar	Lower	4.9062	.66477	21
		Middle	4.6888	.64500	25
		Upper	4.6495	.55478	20
		Average	4.7461	.62607	66
		Middle	43.4944	1.94752	25
		Upper	42.9388	2.30368	24
		Average	43.1827	1.93363	74
Ash (%)	Ronpiboon	Lower	1.6956	2.21843	25
		Middle	2.5212	3.10968	25
		Upper	3.4821	2.78610	24
		Average	2.5539	2.78905	74
	Kreng	Lower	6.6004	2.35031	25
		Middle	5.7976	2.46819	25
		Upper	4.8840	2.55730	25
		Average	5.7607	2.52719	75
	Lansakar	Lower	4.1990	2.82217	21
		Middle	3.2820	2.52215	25
		Upper	4.0615	2.83660	20
		Average	3.8100	2.70684	66

Nozaki *et al.* (2004) observed that starch derived from palms grown in acid sulphate (peat) soils, had larger granules than starch obtained from palms grown in mineral soil. Findings reported here are somewhat different given that starch samples obtained from acid sulphate peat soils conditions as occur in the Kreng ecosystems had a lower average particle size, than those obtained from Lansaker, where soils are of the mineral type.

Color - The L value gives an indication of the level of whiteness of the starch. An L value that is close to 100 indicates a more reflecting diffuser indicating a whiter color. Starch samples obtained from Lansakar showed the highest L value reading (L = 89.45), indicating that starch samples obtained from that ecosystem were comparably whiter than samples obtained from Ronpiboon (L = 88.81) and Kreng (L = 86.10) (Table 6). Samples obtained from Ronpiboon were visually pale pink in color, when compared to those obtained from Lansakar (Figure 5) which were whiter in color. The low L value obtained for the sample from Kreng, showed good correlation to brown color of the wash water after extraction of sago starch from the pith (Figure 6), and indicates the presence of a very high level of polyphenoloxidase activity in starch samples obtained from the Kreng ecosystem, when compared to samples obtained from the other ecosystems. The color difference between starch from Kreng and that obtained from Lansakar was also very easily visually discernible (Figure 7).

Starch samples obtained from different trees in the Ronpiboon, showed differences in color (Figure 8) suggesting some differences among the varieties of sago palm grown in that ecosystem.

Fig. 5. Starch cake samples extracted from Ronpiboon (top) and Lansakar (bottom) during processing

Fig. 6. Wash water obtained during extraction of sago starch from the pith of samples obtained from Kreng (top) and Ronpiboon (bottom).

Fig. 7. Dried starch samples obtained from Kreng (left) and Lansakar (right)

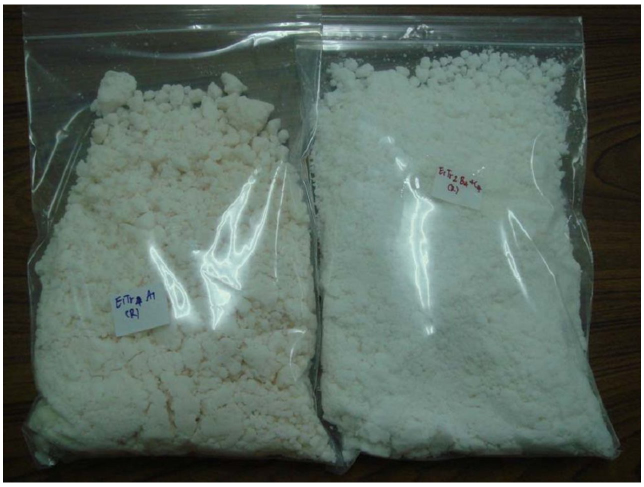

Fig. 8. Starch samples obtained from two different trees in Ronpiboon

Statistical analyses were conducted to ascertain the correlation between the L value and available suphur in the soil. Results of these analyses (Tables 7-10) show that an increase in the independent variable (available S) was associated with a decrease in the dependent variable (L value). The reverse was found to be true where a decrease in S value was associated to an increase in L-value. Since a higher L-value indicates a whiter color of starch, the results indicate that the higher the level of sulphur in the soil, the lower the L-value and the darker color of the starch as was observed in Kreng.

Table 6. Descriptive statistical analysis for the L - value of sago starch extracted from the three ecosystems

Ecosystems	Trunk portion	Mean (µm)	Std. Deviation	N
Ronpiboon	Lower	31.8728	2.64728	25
	Middle	31.7408	2.52791	25
	Upper	30.9912	2.98389	24
	Average	31.5423	2.71310	74
Kreng	Lower	34.3356	2.21149	25
	Middle	33.3840	1.67307	25
	Upper	33.0628	1.05171	25
	Average	33.5941	1.77448	75
Lansakar	Lower	35.2038	3.96817	21
	Middle	33.9164	3.38393	25
	Upper	34.4730	1.52234	20
	Average	34.4947	3.16887	66
Average	Lower	33.7252	3.25469	71
	Middle	33.0137	2.75013	75
	Upper	32.7510	2.45973	69
	Average	33.1644	2.85836	215

Table 7. Regression analysis of the effects of available soil sulphur on the L value of sago starch samples from the three ecosystems

Ecosystems	Trunk portion	Mean	Std. Deviation	N
Ronpiboon	Lower	88.3712	2.35550	25
	Middle	88.8364	1.04371	25
	Upper	89.2442	1.82213	24
	Average	88.8115	1.83208	74
Kreng	Lower	84.6260	1.93496	25
	Middle	86.5584	2.34788	25
	Upper	87.1168	1.03812	25
	Average	86.1004	2.12272	75
Lansakar	Lower	89.4686	1.69452	21
	Middle	90.3640	1.22496	25
	Upper	88.2890	4.88798	20
	Average	89.4503	3.02616	66

Table 8. Correlation of the available soil sulphur and L-values (independent variable S) for sago starch samples from the three ecosystems

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	222.665	1	222.665	191.871	.000[a]
	Residual	30.173	26	1.160		
	Total	252.838	27			

a. Predictors: (Constant), available_S b. Dependent Variable: L_value

Table 9. Correlation of available sulphur and L-value (dependent variable L) for sago starch samples from the three ecosystems

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.938[a]	.881	.876	1.07726

a. Predictors: (Constant), available_S
b. Dependent Variable: L_value

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	91.332	.282		323.510	.000
	available_S	-.093	.007	-.938	-13.852	.000

a. Dependent Variable: L_value

Conclusion

The result of the sago starch analysis show that sago palms grown in fresh water swamp under acidic conditions and high soil sulphur concentrations (Kreng), yield starch of a high ash content that is highly prone to phenolic oxidation, and is pink to brown in color on extraction. On the other hand, palms grown under neutral soil conditions with a comparably lower levels of sulphur (1/6 the sulphur content of soil in Kreng) and ash as in the case of Lansakar, were white in color. A mixture of sago palm was varieties observed to grow in netural brackish conditions as occur in the Ronpioboon ecosystem.

Starch granules from the low sulphur netural environment (Lansakar) had a comparably larger average particle size (34.49 µm) than those obtained from the high sulphur acidic peat swamp environment (33.59 µm). These findings highlight the fact the quality characteristics of sago starch, and particularly the color are greatly influenced by the conditions under which the palm is grown. Further studies are required in order to better correlate sago starch quality to the conditions under which the sago palm is grown.

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References

Ahamad, F.B., Williams, P.A., Doublier, J-L., Durand, S., Buleon, A. (1999). Physico-chemical characterization of sago starch. Carobohydr. Polym 38: 361-70.

AOAC. (2000). Official Methods of Analysis of AOAC International, 17th. William Horwitz, Ed. AOAC International (2000)

Cecile, J.E. (1986). Increasing profits from sago processing. In: The Development of the Sago Palm and its Products. Report of the FAO/BPPT consultation, Jakarta Indonesia, 16-21 January 1984. FAO Rome, pp. 112-120.

FAO/WHO (2010). FAO\WHO Food Standards Programme FAO/WHO Coordinating Committee for Asia. Draft Regional Standard for Edible Sago Flour (No 6- 2007). Comments at Step 6, August 2010. ftp://ftp.fao.org/codex/ccasia17/as17_03e.pdf

Fasihuddin, B. A., & Williams, P. A. (1996). Studies on the properties of sago starch. In B. A. Fasihuddin & P. A. Williams (Eds.), Sago: The future source of food and feed. Sixth International Sago Symposium. pp.219–224.

Flach, M. (1981). Sago palm resources in the northeastern part of the Sepik River flood plain basin: Report of a survey. Department of Minerals and Energy. Rep. No. 3. Konedobu, Papua New Guinea.

Flach, M., and Schuilling, D.L. (1989). Revival of an ancient starch crop: a review of the agronomy of the sago palm. Agroforestry Systems,7: 259 -281.

Flores, D.M. (2009). From the sago log to the table: an alternative method of sago flour processing. Keynote paper presented at the First ASEAN Sago Society Symposium, 29-31 October 2009, Sarawak, Malaysia.

Fujii, S., Kishibara, H., Tamaki and M. Komoto. (1986). Studies on the improvement of sago starch quality: Effect of manufacturing conditions on the quality of sago starch. In: Science Reports of the Faculty of Agriculture. Kobe University, Japan.

Karim, A.A., Pei-Lang Tie, A., Manan, D.M.A. and Zaidul, I.S.M. (2008). Starch from the Sago (*Metroxylon sagu*) Palm Tree – Properties, Prospects and Challenges as a New Industrial Source for Food and Other Uses. Comprehensive Reviews in Food Science and Food Safety. 7: 215 – 228.

McCrone, Walter C. and Delly, John Gustav. (1973). The Particle Atlas. Edition Two, Volumes I-IV. Ann Arbor Science Publishers, Ann Arbor, Michigan. Volume V.

Nozaki, K., Nuyim, T., Shinano, T., Hamada, S., Ito, H., Matsui, H., and Osaki, M. (2004). Starch properties of sago palm (*Metroxylon sagu* Rottb.) in different soils. Plant Foods Human Nutr 59: 85-92.

Schuiling, D.L. (1995). The variability of the sago palm and the need and possibilities for its conservation. In: S. Subhadrabandhu, and S. Sdoodee, eds., Proceedings of the Fifth International Sago Symposium. Songkhla: International Society for Horticultural Science. pp. 41–66.

Sriroth, K., Piyachomkwan, K., Chotineeranat, S., Chollakup, R., Hicks, A., and Oates, C.G. (1999). Structural and functional properties of Thai sago (*Metroxylon* spp.) starch extracted from different trunk portions.

Stanton, R. (1993). Have your trees and eat them. Food Science and Technology Today 7 2, pp. 89–94.

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