Chapter 23

New Sago Palm Starch Resources and Starch Pith Waste Properties

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Abstract Generally, *Metroxylon sagu* Rottb. contains about 400 kg of dried starch in the pith of each tree. The starch stored in the pith exceeds 300 kg according to Ehara et al. (Environmental factors limiting sago production and genetic variation in *Metroxylon sagu* Rottb. In: Karafir YP, Jong FS, Fere VF (eds) Sago palm development and utilization: proceedings of the 8th international sago symposium. Universitas Negri Papua Press, Manokwari, pp 93–103, 2005). However, only 50% of starch from the deposits can be extracted using current methods, and one-half remains behind in the residue. In this chapter, the characteristics of sago pith residue and features of these unused resources are described. Specific utilization of starch residue by establishing a conversion method as a sweetener is proposed. The food security of sugar from sugarcane may be helped by a sweetener made from sago starch. The genus *Metroxylon* has two sections. One is *Metroxylon* and the other one is *Coelococcus*. Section *Coelococcus* is a relict crop. The starch content and physicochemical properties of section *Coelococcus* are presented. It is anticipated that section *Coelococcus* will be available as a future source of biomass.

The cellulose contained within sago palm trunks is a major carbohydrate resource. However, because of its crystallinity, which makes it very difficult to digest, it presents a challenge to process and use in other products. In contrast, sago starch is an important bioresource and can be eaten, is used as feed for animals and microorganisms, and has industrial applications.

Generally, *Metroxylon sagu* Rottb. contains approximately 400 kg of dried starch in the pith of a single tree. According to Ehara et al. (2005), more than 300 kg of starch is stored in the pith. However, only 50% of the starch from the deposits can be extracted with current methods, and the other half remains in the residual pith waste.

Starch in sago pith waste occurs in the parenchyma cells (Fig. 23.1). Therefore, it is difficult to extract all of the starch from the pith using mechanical processing,

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Fig. 23.1 Scanning electron microscope image of sago pith waste
 Acceleration voltage: 10 kV
 Note: Holes in the starch may be the result of microorganism digestion

such as a rasper. In this chapter, we propose specific utilization of the starch residue by establishing a conversion method to make it into a sweetener. We also hope that the food security of cane sugar may be improved by producing a sweetener made from sago starch derived from pith waste.

23.1 Starch in Sago Pith Waste

The sago palm has a large trunk and grows more quickly than many woody plants. The palm requires approximately 12 years to reach maturity when it is harvestable (Jong 1995). Sago palm has the potential to become an important carbohydrate provider.

From the perspective of industrial starch production, sago palm pith contains approximately 26% (dry weight) in pith waste (Fig. 23.2). When we measured the starch content using a rasper and also comparatively determined the true starch content using chemical extraction, the pith content was found to be 37 and 77% in dry weight, respectively (Fig. 23.3). This result confirms that approximately one-half the volume of starch is left in the pith waste. If we can develop a new extraction technique, it will be possible to use sago pith waste as a biorefinery raw material.

Fig. 23.2 Starch yield of each crop

■: Dry starch wet weight

■: Dry starch dry weight

Considering the actual processing, the sago palm, like grains, has less water content as compared to the potato

Source: Agriculture and Livestock Industries Corporation 2004, 2008; Jong 1995; Ministry of Agriculture, Forestry and Fisheries, Japan 2009

23.2 Pith Waste Starch as a Possible Biorefinery Material

Native starch has a strong crystalline structure that allows it to be stored for a long time. When sago starch is used in the food industry, it is usually treated with water and heat. The process of melting the crystalline structure to make starch is called *gelatinization*. Gelatinization is an important treatment. Liquefaction and saccharification are important treatments as well. Starch is a glucose polymer with α -1,4- and α -1,6-glycosidic bonds. After gelatinization, starch can be easily hydrolyzed by enzymes or acid. The products after liquefaction consist of glucose and maltooligosaccharides. Saccharification makes glucose from liquefaction products. Glucose is an important raw material for sweeteners, ethanols, polyols, organic acids, and amino acids (Whistler 2009).

Simple mechanical treatment of sago pith is an easy and low-cost method. However, the starch yield is quite low. Santoso et al. (2015) proposed a high-level milling treatment for sago pith waste to effectively recover the starch. Please see Chap. 19. This method allows recovery of additional starch from sago pith waste.

As a different method of recovering starch from sago pith waste, a direct liquefaction and saccharification method for sago pith waste is proposed. This method is useful for obtaining maltooligosaccharides and glucose from sago pith waste;

Fig. 23.3 Sago pith and the composition of the extracted substances

: Extracted starch
: Others

The starch content was measured and calculated by the solvent extraction method using perchloric acid extraction in order to measure the true starch content

Table 23.1 Viscosity properties of major starch sources

Sample	P.T. (°C)	Viscosity (RVU)				
		P.V.	F.V.	M.V.	B.D.	S.B.
Corn	76.1	114	78	41	72	36
Wheat	84.4	108	125	55	54	70
Sago	75.6	263	192	112	151	80
Potato	68.9	636	273	204	432	69

Viscosity measured by Rapid Visco Analyzer RVA-3D (FOSS)
The concentration of the sample was 6%
P.T., peak viscosity temperature; *P.V.*, peak viscosity; *F.V.*, final viscosity; *M.V.*, minimum viscosity; *B.D.*, breakdown (*P.V.*–*M.V.*); *S.B.*, setback (*F.V.*–*M.V.*)
Source: Kako (2004)

however, some problems must be resolved. Generally, cornstarch is used to make high-fructose corn syrup consisting of fructose and glucose.
The gelatinization process requires agitation, and viscosity is one effective parameter for it. Table 23.1 shows the viscosity of major starch sources. Cornstarch shows the lowest viscosity, and sago starch shows a viscosity twice that of cornstarch. When we directly gelatinize the sago pith waste, the viscosity is so high that we cannot agitate it. Therefore, we tried direct liquefaction, expecting that the

Table 23.2 Glucose yield treated with micro-powdering, heating, and the addition of Termamyl 120 L

	With micro-powdering treatment	Without micro-powdering treatment
Yield (%)	101	87

Source: Sakakura (2013)

viscosity would decrease by starch hydrolysis. However, our expectation was not realized because the gelatinization temperature, at approximately 75 °C, was lower than optimal enzyme temperature of approximately 95 °C. Therefore, we combined micro-powdering treatment, direct gelatinization, and direct liquefaction. The micro-powdering treatment of sago pith waste was done using a Super Masscolloider (Masuko Sangyo Co., Ltd., Japan) with tap water. After the treatment, the slurry was heated with Termamyl 120 L (Novozymes). Table 23.2 demonstrates that the combination of the three treatments makes glucose from the starch in the pith waste.

23.3 Properties of *Metroxylon* spp. Sago Palm Starch

The genus *Metroxylon* is divided into two sections: *Metroxylon* and *Coelococcus* (see Chap. 4). In this chapter, we explain the starch properties of three species of the *Coelococcus* section: *M. vitiense*, *M. warburgii*, and *M. amicarum*.

Scanning electron microscopy images of six sago starches are shown in Fig. 23.4. All starch shapes have a bell or oval form. The results of the starch size distribution show that *M. sagu* and *M. warburgii* are similar in size but that *M. vitiense* and *M. amicarum* are smaller than *M. sagu* (Table 23.3).

The crystalline types of these starches are similar, showing a C type and approximately 30% crystallinity (Table 23.3). These data indicate that all samples have similar properties.

The starch contents of four species are shown in Table 23.3. *Metroxylon sagu* shows the highest starch content, followed by *M. amicarum* and *M. warburgii*; the lowest starch content was found in *M. vitiense*. The gelatinization properties of these starches are also similar (Table 23.4).

These results demonstrate that the starch properties of palms of the *Coelococcus* section are similar to those of the *Metroxylon* section. However, the starch yields of the *Coelococcus* species are about one-half those in the *Metroxylon* section; interestingly, the *Coelococcus* palms reflect a different non-swampy natural habitat.

Fig. 23.4 Scanning electron microscopy image of sago starch
Acceleration voltage: 3 kV. (Source: Mamiya 2005)

Table 23.3 Physicochemical properties of sections of various sago starches

	Long diameter (μm)	Short diameter (mm)	Crystallinity (%)	Crystalline type	Starch content (%)
<i>Metroxylon vitiense</i>	21.6	15.7	29.4	C	27
<i>M. warburgii</i>	29.2	19.3	28.7	C	36
<i>M. amicarum</i>	19.0	15.5	N.T.	C	39
<i>M. sagu</i>	30.5	21.8	32.3	C	77

Source: Kako (2004)

Table 23.4 DSC properties of various sago starches

	To ($^{\circ}\text{C}$)	Tp ($^{\circ}\text{C}$)	Tc ($^{\circ}\text{C}$)	ΔH (mJ/mg)
<i>Metroxylon vitiense</i>	66.1	69.5	73.8	13.7
<i>M. warburgii</i>	65.4	69.2	73.7	13.7
<i>M. sagu</i>	66.6	71.7	76.9	15.4

Source: Kako (2004)

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