

Effect of grater position on the size of grated sago (*Metroxylon* spp.)

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Abstract

The natural arrangement of sago palm's fiber orientation is parallel to the vertical axis of the trunk. Extraction of the sago starch requires breaking of the trunk into fine sizes. The sago size is affected by the grater position which affects the of starch recovery. This study was conducted to evaluate grating efficiency through sago size produced at the different direction of grating (0° and 90° to roller teeth rotation). Sago palm trunks without outer layer were cut into square blocks of 100 mm^3 . Each trunk block was placed on roller grater platform at a different position where the cutting spike was parallel to the vertical axis of sago trunk fiber orientation (grating at 0° direction) and perpendicular (grating at 90° direction). 100 g of dry grated sago was sifted to determine the size distribution with different sieve sizes i.e. 2.80 mm, 2.00 mm, 1.00 mm, 0.85 mm and 0.425 mm. A total weight of 1 kg of grated sago was mixed with water and squeezed to be extracted. The starch recovery produced by the grating process at 0° directions was 10.30% higher than 90° directions. The present study showed that the direction of grating at 0° was able to produce finer grated sago with maximum starch recovery.

1. Introduction

Sago (*Metroxylon* spp.) is one of the tropical trees that can grow in wet conditions including peat swamps (Jong, 1995a). In Sarawak, sago-based products such as 'kuih sago mata ikan', sago cake, sago pudding and others are the traditional food consumed by the local people. The state has a wide area of swampy land which is suitable for the cultivation of sago palm. The sago industry in Sarawak, Malaysia is very well established, and it is one of the important industries that contributed to export the state revenue (Kamal *et al.*, 2007; Karim *et al.*, 2008). Based on a report by Malaysia Department of Statistic (2005), the export value was recorded about 45,300 metric tons of food grade sago starch that equivalent to RM 40.4 million. In 2015, about 184,163 metric tons of sago was production in Malaysia (DOA, 2015) and estimated to be equivalent to RM 164.2 million.

Based on a study by Vikineswary *et al.* (1994), 65.7% sago starch remained inside the grated trunk residue. Mostly, the trunk residue was widely dumped into the river. Referring to the Department of Statistic (2005), the export value of sago starch was 45,300

tonnes approximately equal to 34.3% of total sago production and the loss rate was estimated 65.7% which was equivalent to 86,770 metric tonnes of food grade sago starch or RM 61.3 million. While based on DOA (2015) report, 184,163 metric tons of sago was produced and the total loss rate was estimated equivalent to 352,755 metric tonnes. The loss was due to grater inefficiency during sago extraction process. One of the factors that affected the efficiency of starch extraction was depended on the proportion of starch cells that are ruptured during trunk grating process (Cecil, 1992). Therefore, the grater efficiency to produce finer grated sago is an important factor affecting sago starch recovery.

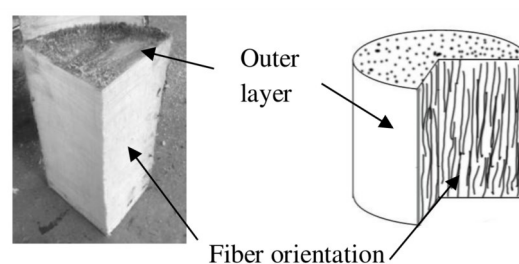


Figure 1. Sago trunk fiber orientation.

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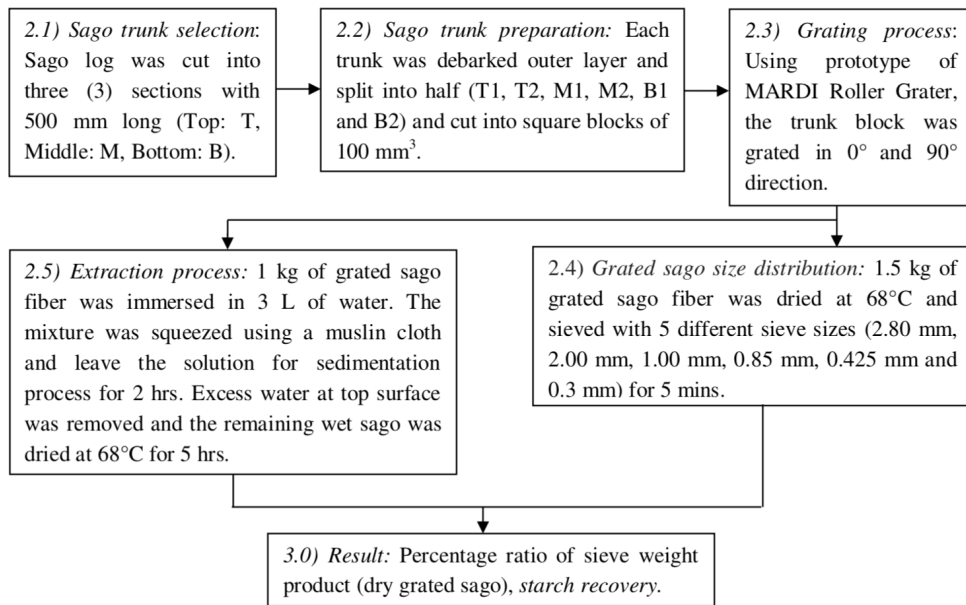


Figure 2. Flowchart of methodology

The grating efficiency depends on many factors such as the operation method or machine feeding handling. This study is aimed to determine the effect of difference sago trunk fiber orientation (Figure 1) during the grating process and to evaluate the starch and yield recovery during the extraction process.

2. Materials and methods

2.1 Sago trunk selection

Figure 2 shows the overview of methodology which includes sago trunk selection, sago trunk preparation, grating, extraction and grated sago size distribution. The selections of sago palm depend on the maturity of the trees which can produce maximum sago starch yield. According to a study by Jong (1995a), the maximum starch yield was reported found between growth and flowering stage. The sago palm material for this experiment was taken from Labu area (State of Negeri Sembilan).

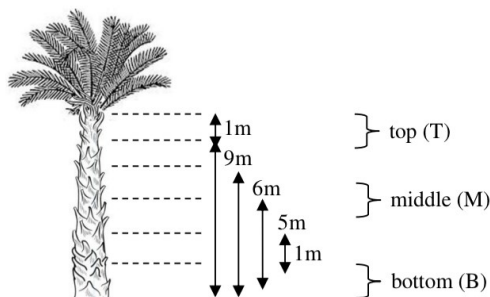


Figure 3. Sago palm trees section

The sago trees were divided into three parts: the top section (trunk section in between 1 m from the top leaf), the middle section (trunk section in between 5 m to 6 m from the ground) and the bottom section (trunks section between ground up to 1 meter) as shown in Figure 3. The sago trunks were cut into several parts in the length of

500 mm. Each selected trunk was marked as top (T), middle (M) and bottom (B) with permanent paint.

2.2 Sago trunk preparation

Each trunk's (T, M and B) outer layer were peeled off and then split into half section using handheld chainsaws (OG6816, Ogawa, Japan) as shown in Figure 4. Each half trunks section was marked as (T1 and T2) for top trunks section, (M1 and M2) for middle trunks section and (B1 and B2) for bottom trunks section. Then, each halved trunks section was cut into several square blocks of 100 mm³ and marked at the fibre orientation direction. The arrangement of sago palm's fiber orientation is parallel to the vertical axis of the trunk and used it as a reference for grating process.

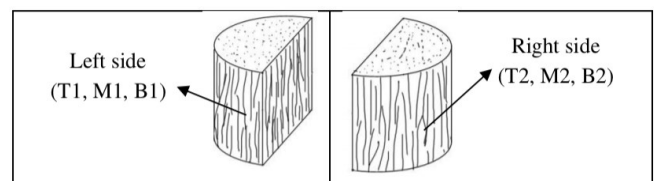


Figure 4. Half section of sago trunk

2.3 Sago trunk grating process

The grating process breaking the trunk structure into fine sizes. The grating process was done using a prototype of MARDI Roller Grater as shown in Figure 5. The trunk block T1 was placed on the platform whereby the position of the cutting spike was parallel to the vertical axis of sago trunk fiber orientation (Figure 6a) and then grated (T1 trunks block known as T0° after grated). The process was repeated with trunk block M1 and B1 (known as M0° and B0° after grated). Next, the sago block T2 was placed on the platform with the position the cutting spike was perpendicular to the vertical axis of sago trunk fiber orientation (Figure 6b)

and then grated (T2 trunks block known as T90° after grated). The process was repeated with sago trunk block M1, M2, B1, and B2 (M1, M2, B1 and B2 known as M0°, M90°, B0° and B90° after grated). Each sample was collected separately.

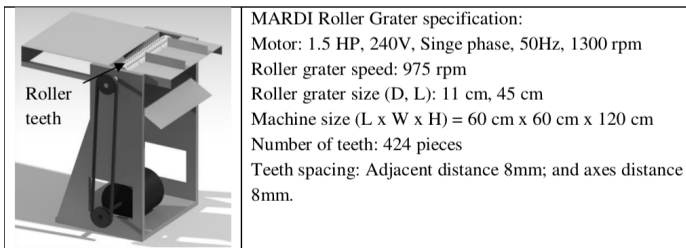


Figure 5. MARDI Roller Grater machine (specification)

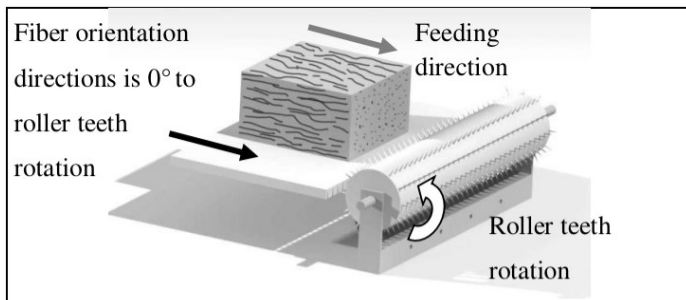


Figure 6a. Sago trunk block (T1, M1, B1) grating at direction (0°)

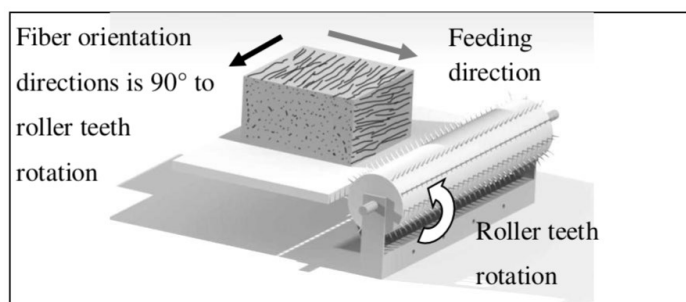


Figure 6b. Sago trunk block (T2, M2, B2) grating at direction (90°)

2.4 Grated sago size distribution

The sieving process for dried grated sago fiber was to assess the particle size distribution. The initial moisture content of each grated sago fiber sample was recorded before the sieving process. The grated sago was dried using a drying oven (FAC-100, Protech, Malaysia). The oven temperature was set at 68°C (Jong, 1995a). During the drying process, the moisture content of the sample was taken at every half an hour and the drying process was stopped when the readings didn't show any difference after 3 samples. After the drying process completed, the weight and moisture content of the sample was recorded. Each sample (weight of 100 g) was sieved using a test sieve shaker (Endecott, United Kingdom). During the sieving process, at every 10 mins (ASTM Standards: C136-01) the weight of the sieve and the contents were taken, and the sieve process was stopped when the readings showed constant value after 3

readings. Based on the initial assessment, the dried grated sago particle size distribution was in the range of $0.25 < X < 3.35$, where X value refers to sieve grade size. Therefore, the selected sieved grade sizes were (2.80 mm, 2.00 mm, 1.00 mm, 0.85 mm, 0.425 mm and 0.3 mm). These procedures were repeated 3 times to get an average (μ) and standard deviation values using Equation 1 (Everitt, 1998). The final weight for each sieved product based on the sieve grade sizes was recorded. Then the percentage ratios (Equation 2) of weight for each sieve products were calculated where the percentage ratio referred to the percentage of the weight of the sieves products from the total weight of grated sago sample. The process was repeated once for all the sample of grated sago fiber (T0°, T90°, M0°, M90°, B0° and B90°).

$$\text{Standard Deviation (SD)} = \sqrt{\frac{\sum(x - \mu)^2}{n - 1}} \quad (1)$$

$$\text{Weight percentage ratio (\%)} = \frac{\text{Weight of the sieves products}}{\text{Total weight of grated sago sample}} \times 100\% \quad (2)$$

2.5 Extraction of grated trunk and starch recovery

The extraction process is a process to extract the starch from the fiber. The starch recovery referred to the percentage of starch weight which has been extracted from the total weight of the grated sago. Based on the initial study, the volume of 1 kg of grated sago was equal to the volume of 3 kg of water. Therefore, 1 kg of grated sago fiber was mixed with 3 L of clean water to produce grated sago fiber slurry. The manual mixing was left for 5 mins to allow the water to seep into the grated sago fiber. Then, the material was squeezed manually using a muslin cloth until all the droplets were extracted out and the extracted liquids (mixture of starch slurry and excess water) were left for 2 hrs for the sedimentation process inside the container. Next, the excess water on the top surface of the starch slurry was removed by tilting the container position and then the starch slurry was weighed. The moisture content of the starch slurry was recorded and then dried using a drying oven (FAC-100, Protech, Malaysia) at 68°C (Jong, 1995a). During the drying process, the moisture content of the sample was taken at every half an hour, and the drying process was stopped when the readings of the sample moisture content showed a constant value after 3 readings. Once completed, the weight of the sample (starch recovery) and moisture content were recorded. The process was repeated for all sample of grated sago fiber (T0°, T90°, M0°, M90°, B0° and B90°). The percentage of starch recovery was calculated (Equation 3) (Jong, 1995b; Kamal *et al.*, 2007).

$$\text{Starch Recovery (\%)} = \frac{\text{Weight of dry starch}}{\text{Total weight of fresh grated sago}} \times 100\% \quad (3)$$

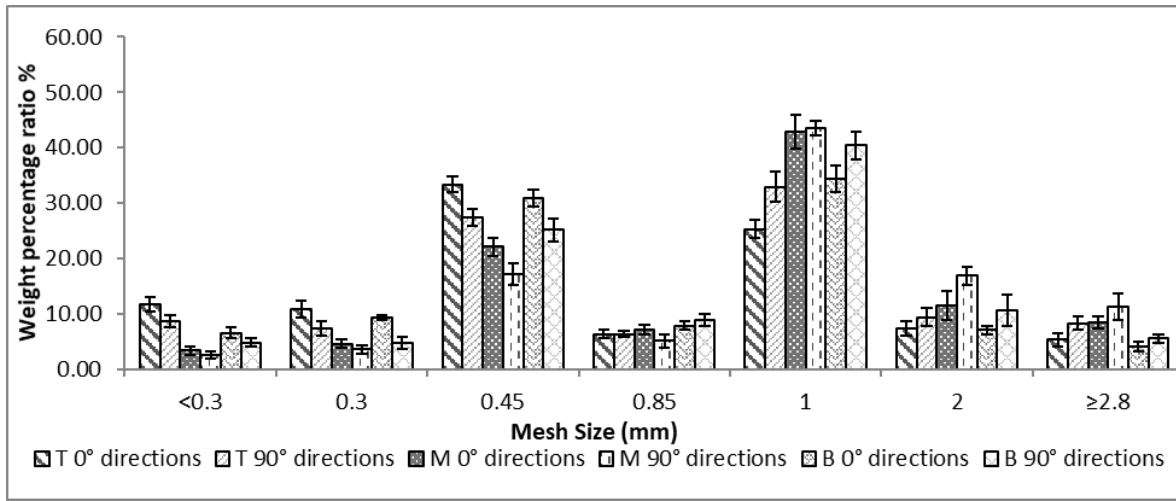


Figure 7. Weight percentage ratio (%) of grated sago at different mesh size (mm). (T, M and B represent top, middle and bottom section of sago trunk)

3. Results and discussion

3.1 Grated sago size distribution

The particle size distribution determination was done at $5.15 \pm 0.37\%$ average moisture content of grated sago after drying process from the initial average moisture content of $61.57 \pm 0.72\%$. Figure 7 shows the weight percentage ratio (%) of grated sago at different sieve mesh size (mm). The value of $X < 1$ mm sieve mesh size referred to the finer grated sago and $X \geq 1$ mm sieve mesh size refers to coarser or rougher grated sago. The error bars refer to the standard deviation value for average data of weight percentage ratio (%). At the mesh size of $X < 0.3$, $0.3 \leq X < 0.45$ mm, $0.85 \text{ mm} \leq X < 1$ mm, $2 \leq X < 2.8$ and $X \geq 2.8$ mm the weight percentage ratio (%) of grated sago at all section of sago trunks for both grating position of 0° and 90° was less than 17%. The mesh size of $0.45 \text{ mm} \leq X < 0.85$ mm resulted with weight percentage ratio ranging from 17 to 33 % (at all sections of sago trunk). The highest weight percentage ratio of dry grated sago produced at mesh size range of $1.00 \text{ mm} \leq X < 2.00$ mm with percentage ratio ranging from 25 to 44% (at all sections of sago trunk). Overall, the data show the capability of MARDI Roller Grater machine produce more grated sago at the size of $0.45 \leq X < 0.85$ and $1 \leq X < 2$ mm. Up to date, no reported studies were available on the effect of mesh size on the weight percentage ratio of grated sago.

Figure 7 also shows that the total weight percentage ratio of dried grated sago (Equation 4) produced by a grating process with 0° directions for mesh size range $X < 1$ mm was 153.69%. The value was higher than grating process at 90° directions (121.19%), with a percentage difference (Equation 5) of 21.15%. However, at size range $X \geq 1$ mm the grating process at 0° directions, the total weight percentage ratio (Equation 6) was lower (146.05%) than processing at 90° directions (178.81%) with a percentage difference value of 18.32% (Equation 5). This showed that grating process at 0°

directions produced finer grated sago than grating 90° directions. Producing finer grated sago is important since it will produce more sago starch that can be dissolved from the grated sago during the extraction process (Colon and Anokke, 1986). Cecil (1992) added that the efficiency of starch extraction was depending on the proportion of starch cells that are ruptured during trunk grating process also. There were also other factors that affect the size of the sago grater produced such as grater teeth speed and arrangement as reported by Darma (2017). The present study used grater teeth speed and teeth spacing of 2250 rpm and adjacent distance 40 mm; axes distance 22 mm respectively (Darma *et al.*, 2017).

$$\sum_{X < 1} W = \sum_{X < 1} TW_x + \sum_{X < 1} MW_x + \sum_{X < 1} BW_x \quad (4)$$

$$\frac{|\Delta V|}{\frac{\sum V}{2}} \times 100\% \quad (5)$$

$$\sum_{X \geq 1} W = \sum_{X \geq 1} TW_x + \sum_{X \geq 1} MW_x + \sum_{X \geq 1} BW_x \quad (6)$$

Where W is weight percentage ratio (%); T is trunk top section; M is trunk middle section; B is trunk bottom section; X is the mesh size; V is the input value.

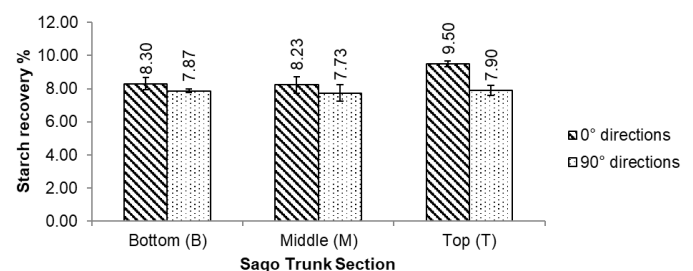


Figure 8. Starch recovery versus sago trunk section.

The total amount weight of starch that can be extracted from the 1 kg of grated sago sample was called as starch recovery. The average moisture content of starch slurry before drying process was $35.80 \pm 0.43\%$ and after the drying process the moisture content value decreased to $10.33 \pm 0.55\%$. The moisture content percentage reduction was 25.47%. Figure 8 shows that at 0° directions the starch recovery was higher than 90°

directions for all sago trunk sections. The top section of sago trunk resulted with the highest starch recovery, followed by the bottom and middle section. The starch recovery pattern distribution depends on palm trees maturity and it shows that the palm trees maturity was at stage 7 which was equal to 11.5 years old according to the starch distribution in the trunk as reported by Jong (1995b). The usage of immature sago palm (not reach full maturity stage) resulted with low starch recovery (Jong, 1995b). The total average starch recovery for all trunks section grated at 0° and 90° directions was 8.68±0.71 g and 7.83±0.09 g respectively. The percentage difference of total average starch recovery (Equation 7) at all trunk sections produced was 10.30% higher at 0° directions as compared to 90° directions. This proves that the grated sago produced from the grating process at 0° directions was more efficient than 90° directions during extraction process due to the effect of finer size of grated sago. Finer grated sago was more desirable as it resulted with higher starch recovery during extraction process (Cecil, 1992). Based on sago starch price reported by Malaysia Department of Statistic (2005) and starch recovery reported by Vikineswary *et al.* (1994), 10.30% of sago starch production in 2015 (DOA, 2015) at the weight of 55,302 metric tonnes which was equivalent to RM 49.3 million.

$$\frac{|\Delta\mu V|}{\frac{\Sigma\mu V}{2}} \times 100\% \quad (7)$$

From Figure 8, the starch recovery percentage difference (Equation 7) produce by grated sago at 0° directions and 90° directions for the top, the middle and the bottom section trunk was 18.39%, 6.26% and 5.36% respectively. Based on the experimental results (Figure 8), about 7.73% to 9.5% of dry base starch recovery has been extracted from grated sago. The present result obtained on the dry base starch recovery was lowered as compared to the prior study by Kamal *et al.* (2007) with 25.76% recovery. The deviation might be due to the wet grading process before the extraction process. The starch granules present in the pith were dissolved in water and subsequently released when it was ruptured during the grinding process (Kamal *et al.*, 2007).

Previously, the calculation of starch recovery mainly used wet base starch as an input. Therefore, for the current study, the value of starch recovery as wet basis (Equation 8) ranging from 10.80% up to 13.27% at moisture content of 35.80% (starch slurry before dried). The obtained value of the present study was in close agreement with Flach (1997) and Darma (2010) which obtained starch recovery ranges from 10 to 25% and 12.43 to 39.89%, respectively. Meanwhile, Haryanto (1992), Cecil (1992), Yunus (1997) and Darma *et al.* (2017) resulted with the starch recovery of 15 to 25%, 23

to 27%, 35.45% and 43 to 48% respectively. The variation of starch recovery obtained from this experiment with the reported studies by others might be due to the effect of the difference extraction method. The present study used squeezed grated sago method for extraction process which conducted without repetition to ensure optimal use of water and to produce good quality of sago. The conventional method of sago extraction involved with repetition of adding water to grated sago as extraction process of sago normally used a lot of water (Jong, 1995 A). Water addition during the extraction process was an important element since it helps to dissolve and release the sago starch granules (Kamal *et al.*, 2007).

$$M_n = \frac{W_w - W_d}{W_w} \times 100 \quad (8)$$

Where M_n is a moisture content (%) of material, W_w is a wet weight of the sample, and W_d is a weight of the sample after drying.

4. Conclusion

As a conclusion, the direction of the grating affected the grated sago size produced which is related to starch recovery. The grating process at 0° directions was more efficient than 90° directions in terms of producing finer grated sago and produced 10.30% higher of starch recovery during the extraction process. It was scientifically proven that finer grated sago produced higher sago starch recovery during the extraction process. It is recommended for the grating process at 0° directions to ensure the maximum output starch recovery.

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