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The Assessment of Grated Sago Size Produced by Different Type of Grating Machine

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The native sago starch is stored inside the trunk pith. In order to extract the starch, the mechanical method is required to break the pith fibre producing grated sago. The more refined the grated sago, the more sago starch can be dissolved in water during the extraction process. A comparative study on the capabilities of existed and potential grating machine to produce grated sago was conducted to identify the best and most appropriate existed grater machine. A hand chainsaw, coconut husk decorticator, coconut grater and roller grater were types of machine used in producing grated sago in this study. A 100 mm^3 sago trunk block was prepared and grated using four different type machines as stated above. 100 g of dry grated sago were sieved with grade size of (2.80 mm, 2.00 mm, 1.00 mm, 0.85 mm and 0.425 mm) to give discrepancy in size distribution. Next, 1000 g of freshly grated sago were mixed with water with ratio (1:3) and squeezed using a muslin cloth to extract starch. The result shows that the hand chainsaw produced the highest quantity of finer grated sago (56.80% at X ≤0.85 mm) and starch recovery of 15.70%. The best-tested equipment to be used as a sago grater is a hand chainsaw, which has the highest efficiency and effectiveness to produce finely grated sago.

Keywords: sago; grating; starch; extraction; size distribution

I. INTRODUCTION

Sago palm (*Metroxylon* spp.) is a tropical tree that grows in wetlands such as peat swamps (Jong, F.S., 1995A). Sago palm is the source of the starch that has been processed into staple food or used as a raw material for the processing industry. In Sarawak, most of the land areas are swampy, which is naturally suitable for sago cultivation and growth. The sago industry in Sarawak was well established and become one of the important industries that contributed to export revenue (Karim *et al.*, 2008). Based on the report by the Malaysia Department of Statistic (2005), the export value was recorded at about RM40.4 million which is equivalent to 45,300 metric tons of food-grade sago starch. Due to the incensement of demand, about 184,163 metric tons of sago was produced in Malaysia (DOA, 2015) and estimated equivalent to RM 164.2 million per year.

Currently, the uses of starch relatively have a wide range in the food and manufacturing industries. Usually, starch was used as a staple food, now from the staple food to noodle and flour (Hirao K., 2015). In the food industry, starch is often used as an ingredient for food products or act as an additional texture in beverage products. Meanwhile, in the manufacturing industry, starch is usually used as a raw material for agro-industry, biopesticides, bio-ethanols, cosmetics, and pharmaceutical industry (Bintoro, 2011). In addition, starch has resistant to microbial and enzyme digestion, which is useful as additional material to the biodegradable product such as packaging material. However, it has low durability that requires blending with plastic resins to produce long-lasting durability composite material (Karim *et al.*, 2008).

Sago palm (*Metroxylon* spp.) is a kind of plant that store food (starch) inside the trunk between the pith fibre gap. In order to extract the native starch, the trunk needs to be

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crushed to release the starch. In traditional sago processing method, the sago trunk was first debarked and then split into several large pieces to facilitate the next handling process. Then, the pieces of the trunk were grated using a small hoe made from bamboo and placed on a wide end of a sheath made from sago palm leaf. Water was added to the grated sago and kneaded by hand to extract the starch. The grated sago remained on top of the sieve while the water carrying the sago starch solution run through the sieve and accumulated in an old dugout canoe. Sago starch settled down at the bottom of the canoe. After several hours, the excess water on the top layer inside the canoe was removed and the remainder was wet sago starch (Flach, 1983; Yamamoton, 2014). In total, 41 hours are required for traditional process. Most of the processing time was consumed in the disintegration of the trunk (53.22% of the total time), followed by washing and screening process (38.92% of the total processing time). This means that 92.14% of the total time is required for only these 2 steps (Darma, 2011; Darma, 2014). Nowadays, most sago production processes in a small-scale plant. After the sago palm is harvested, the trunk is cut into the length of 1 m and tied to a raft and transported to the processing area through the river path. The outer layer of sago trunk is debarked and then cut into small pieces. Base on observation in Sarawak, the trunks were grated using spinning nails board or roller type which is powered by a diesel engine. During the grating process, water is added to the grated sago in order to transfer to rotating mesh screener for sieve process. The sago starch solution is channelled to a small settling pond. After a few hours, the sago starch settled down at the bottom of the pond. Finally, the drying process of wet starch was completed mostly under the sun (Cecil, 2002; Oates C.G., 2002; Darma, 2017).

According to Vikineswary (1994), about 65.7% of sago starch remaining was recorded inside the grated sago trunk residue. Mostly, the residue was widely dumped into the river for disposal. Furthermore, one of the factors that contribute to this issue was due to the inefficiency of the grating process to produce finer grated sago. It is clear that the grating process intended to reduce the large structure size of grated sago. This is because the more refined of grated sago, the more sago starch can be extracted from the grated sago (Cecil J.E., 1992). It also was scientifically proven that the finer grated sago produced higher sago starch recovery during the extraction process (Wan Mohd Fariz W.A., 2018).

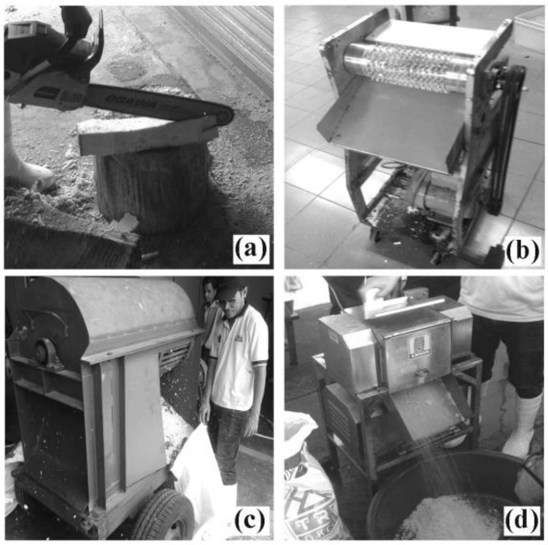

Figure 1. Grating machines; (a) Hand chainsaw, (b) Roller grater, (c) Coconut husk decorticator and (d) Coconut grinder

Currently, the technology or equipment that is used in sago processing industry especially grating machine is different depending on the region as reported by Nishimura (2018). Based on observations, which were conducted in Malaysia, it was found that the grating processes were carried out using hand chainsaw (Figure 1a) and Roller grater (Figure 1b) type. However, the potential to be used as sago graters like Coconut husk decorticator (Figure 1c) and Coconut grinder (Figure 1d). A comparative study on the capabilities of existed and potential grating machine to produce grated sago was conducted to identify the best and most appropriate existed grater machine. This study was done by comparing the sago grater size factor and starch recovery percentage during the extraction process.

II. MATERIALS AND METHODS

A. *Sago Trunk Selection*

The selection of sago palm tree for the test was based on the tree maturity which potentially produced maximum sago starch recovery. As reported by Jong F.S. (1995A), the maximum starch content was found inside a sago trunk between the growth and flowering stage maturity. Therefore, the characteristics of the sago palm tree as suggested in the literature has been identified and selected for this study. Herein, the sago palm sample was collected from Labu area (State of Negeri Sembilan). In order to transport the material to the lab, the sago palm trunk was cut into several sections with a length of 0.5 m.

B. Sago Trunk Preparation Procedure

The sago trunks were split into quarter sections using hand chainsaw (OG6816, Ogawa, Japan) as shown in Figure (2) and the outer layer was debarked. Each quarter trunks were label as A, B, C and D respectively. Next, each quarter trunks sections were cut into several square blocks of 100 mm^3. For additional information, during individual machine efficiency test, the same section of the trunk (A, B, C and D sago trunk block from the same section) were used. This is because each level of the trunk section has a different amount of starch content as reported by Jong F.S. (1995A).

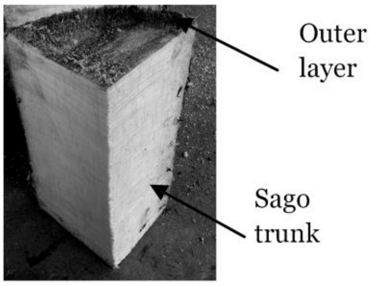

Figure 2. A quarter section of sago trunk

C. Sago Trunk Grating Process

Four types of grating machines were selected for this assessment: Hand Chainsaw (OG6816, Ogawa, Japan), Roller Grater (MARDI, Malaysia), Coconut Husk Decorticator (MARDI, Malaysia) and Coconut Grinder (1.5 HP, Anson, Indonesia) as shown in Figure 1. Each grater teeth were measured using Vernier Calipers to determine the size and spacing between centre positions of grater teeth (Figure 3).

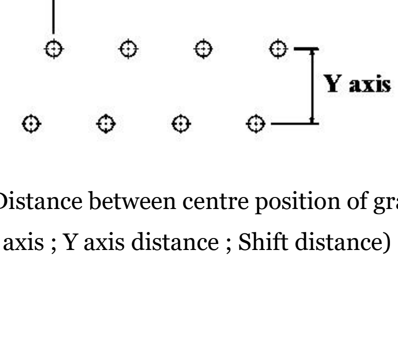

Figure 3. Distance between centre position of grater teeth (X axis ; Y axis distance ; Shift distance)

A sago trunk block (A) was grated using hand chainsaw, followed by Roller grater to grated sago block (B), Coconut husk decorticator used to grate sago block (C) and Coconut grinder used to grate sago block (D). Each sago grated sample was collected separately.

D. Grated Sago Size Distribution Measurement

The sieving process was conducted to assess the grated sago particle size distribution. The initial moisture content of each grated sago sample was recorded and then dried using a drying oven (FAC-100, Protech, Malaysia). Herein, the oven temperature was set at 65°C. It was reported that the sago starch started to gelatinize at the temperature of 69.4 to 70.1°C (Okazaki M., 2018). During the drying process, the moisture content of the sample was taken at every half an hour and the drying process was stopped until 3 stable readings. After the drying process is completed, the weight and moisture content of the samples were recorded. Furthermore, each sample (weight of 100 g) was sieved using test sieve shaker (Endecott, United Kingdom). At every 10 minutes of the sieving process, the weight of the sieve including the contents was taken and the sieving process was stopped after 3 readings showed a constant value (ASTM Standards: C136-01). Based on initial assessment, most of the dried grated sago particle size distribution was ranging between the range of $0.25 < X < 3.35$ mm, whereby X value refers to sieve grade size. Therefore, the selected sieved grade sizes set at 2.80 mm, 2.00 mm, 1.00 mm, 0.85 mm, 0.425 mm, and 0.3 mm (Wan Mohd Fariz W.A., 2018). These procedures were repeated for 5 times to get an average (μ). As a result, the final weight for each sieved product according to the sieve grade sizes was recorded. Next, the percentage ratio of weight (WPR%) for each sieve products were calculated using equation 1, which is the percentage ratio referred to the weight of sieves products to the total weight of grated sago.

$$WPR\% = \frac{Weight\ of\ the\ sieve\ products}{Total\ weight\ of\ grated\ sago\ sample} \times 100\% \quad (1)$$

E. Extraction Process and Starch Recovery

Herein, the extraction processing is a process to separate the native sago starch from the sago trunk fibre. The starch recovery was calculated using equation 2, which is referred to as the percentage of starch weight extracted from the total weight of the grated sago. Based on the initial assessment, the volume of 1 kg grated sago was equal to 3 kg of water volume (1:3). Thus, the mixture between 1 kg grated sago and 3 kg of clean water produce grated sago slurry and left for 5 minutes to allow the water to seep into the grated sago fibre. Then, the grated sago slurry was squeezed manually using a muslin cloth until all the droplets were extracted and collected inside the container. Next, the extracted liquids (a mixture of starch slurry and excess water) were left for 2 hours for the sedimentation process. Finally, the excess water on the top surface of the starch slurry was removed by tilting the container position and as a result, the remainder inside the container was the starch slurry. The initial weighed and moisture content of the starch slurry was taken. Furthermore, the starch slurry was dried using a drying oven (FAC-100, Protech, Malaysia) at 65ºC (Okazaki, M., 2018). At every half an hour the moisture content was measured, and the drying process was stopped after the moisture content showed a constant value. Once completed, the weight of the sample (dry starch) and moisture content were recorded. The process was repeated for all sample of grated sago (B, C and D). The percentage of starch recovery was calculated using equation 2 (Jong F.S., 1995A; Kamal, 2007; Wan Mohd Fariz W.A., 2018).

$$Starch\ recovery\% = \frac{Weight\ of\ dry\ starch}{Total\ weight\ of\ freash\ grated\ sago} \times 100\% \quad (2)$$

F. Statistical Analysis

All statistical analysis is calculated using IBM SPSS Statistics 25.0 software to test the main effects of independent and interaction parameters and including the average value (μ), standard deviation (±) and P-value.

III. RESULTS AND DISCUSSION

A. Grated Sago Size Distribution

The grated sago size distribution was conducted to identify the machine capability. The value of X<1 mm sieve mesh size refers to the finer grated sago and X≥ 1 mm sieve mesh size refers to the coarse or rougher grated sago. The grated sago size distribution determination was done at 5.33±0.07 % average moisture content of grated sago after drying process from the initial average moisture content of 53.38±0.01 %.

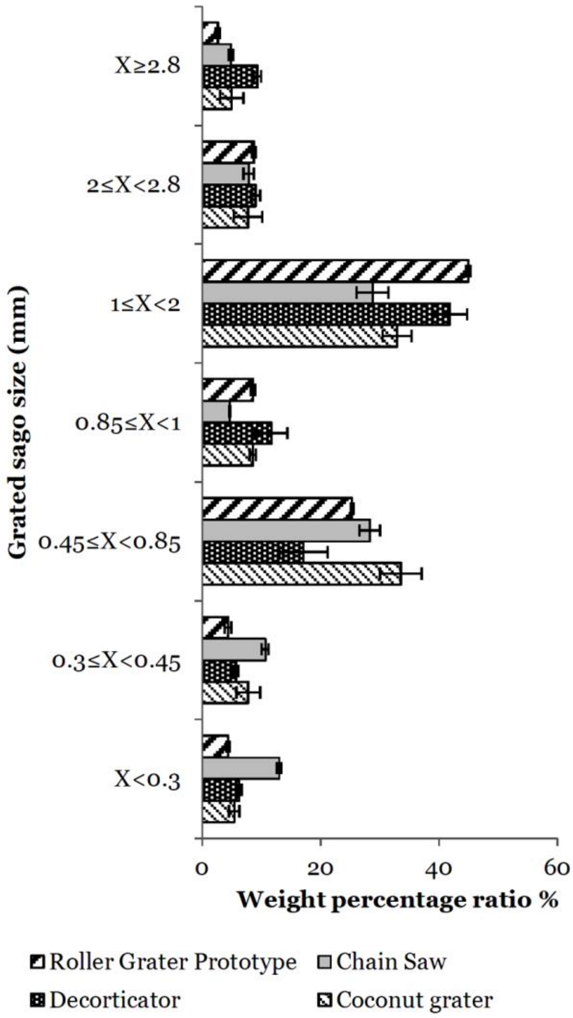

Figure 4. Weight percentage ratio (%) of grated sago at different grated sago size distribution according to grating machine (mm). Error bars were expressed as mean ± SD; n = 5

Figure (4) shows the weight percentage ratio (WPR %) of grated sago according to the grating machine at different mesh size (mm). The error bars refer to the standard deviation value for average data of weight percentage ratio (%). Overall, the bar graphs show the same pattern distribution of WPR % for grated sago produced by each machine. As per observation, the WPR % values of grated sago produce did not show a significant difference for each machine (P>0.01). Furthermore, at mesh size of X<0.3, 0.3 ≤ X< 0.45 mm, 0.85 ≤ X< 1 mm, 2 ≤ X <2.8 mm and X ≥ 2.8 mm the WPR % of grated sago for all machine which was approximately less than 13%. However, the grated sago produced by hand chainsaw at a mesh size of X<0.3 showed the highest value compare to others (P<0.01). In addition, at mesh size of 0.45 ≤ X< 0.85 mm resulted in WPR % ranging from 17 to 34 % (for all machines). Meanwhile, at a mesh size range of 1.00 ≤ X < 2.00 mm showed the highest WPR % of dry grated sago produced with percentage ratio ranging between 28 to 45% (for all machines). At grated sago size of X≥2.8 mm results on the highest value of rougher grated sago produced by decorticator (P<0.01) compare to other machines. This indicates that the uses of the decorticator machine as a sago grater is inappropriate. Furthermore, the grated sago size bar graph (Figure 4) shows the same pattern of grated sago size distribution when the sago block fibre grated at 90° direction to the roller grater teeth as reported by Wan Mohd Fariz W.A. (2018).

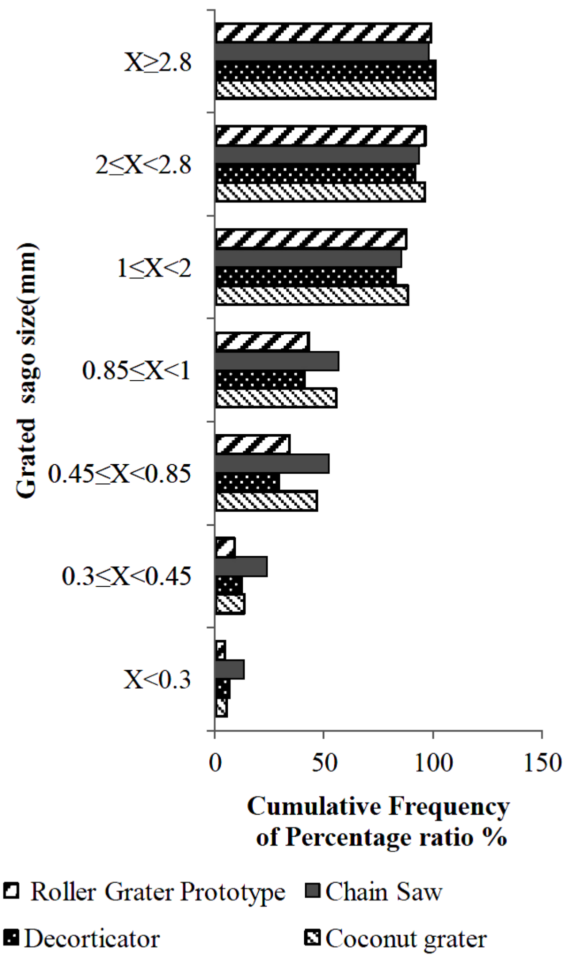

Figure 5. Cumulative Frequency Percentage ratio of grated sago (%) at different grated

Figure (5) shows the cumulative frequency of grated sago WPR % according to the grating machine at different grated sago size (mm). The results show that the number of finer grated sago produced by hand chainsaw and coconut grinder have the highest values with 56.80% and 55.45%, respectively at X ≤0.85 mm compare to others. Aside, the lowest numbers of finer grated sago were produced by decorticator and roller Grater with the value of 40.86% and 42.73%, respectively. Production of finer grated sago is vital since starch can be dissolved from the grated sago to produce higher native sago starch recovery during the extraction process (Colon, F.J. *et al.*, 1984). Cecil (1992) added that the efficiency of starch extraction is also depending on the proportion of starch cells that are ruptured during trunk grating process.

Table 1. Type of graters specification; capacity, teeth shape, contact surface area, grating speed, teeth spacing and WPR%

Grater type		Chainsaw	Decorticator	Coconut grater	Roller grater prototype
Capacity (Kg/min)		5	60	3	20
Teeth Shape					
Contact surfaces area (mm²)		4.0	2626.0	4.5	39.0
Grating speed (rpm)		2500	3600	1800	975
Teeth spacingX:Y:S (mm)		40:0:0	120:180:20	10:5:5	8:8:2
Total of WPR ago grated size (%)	X<1	56.80	40.85	55.45	42.73
	X≥ 1	43.20	59.14	44.55	57.27

Legend:

■ Contact surface area between grater teeth and sago trunk during grating process.

X:Y:S; X-axis distance : Y-axis distance : Shift distance

B. *Type and Size of Grater Teeth*

Respective machines have different types and sizes of grater teeth based on their main application. Table (1) shows the type of graters specification. A grater teeth type is the crucial key factor as it has contact with the tested material (sago trunk) during the grating process that derived the chip sizes (grated sago). Based on the model derived from the forces acting analysis of cutting blade by Wojtanowicz A.K. (1993), the cutting surface area was taking account in the theory as to calculate the chip size that was produced during the cutting process. Moreover, each machine has variance in total surface contact area during the grating process that depends on the teeth shape. Hand Chainsaw shows the lowest surface contact area (4 mm²), followed by coconut grater (4.5 mm²), roller grater (39 mm²) and the highest surface contact area is the decorticator (50 mm²). Therefore, the results show that the contact surface area between grater teeth and material during the grating process affect the quantity of finely grated sago produce ($P<0.01$). The higher the value of grater teeth surface contact area during the grating process, the rougher grated sago will be produced. Furthermore, there are also other factors that affect the size of the sago grater product such as grater teeth speed and arrangement as reported by Darma (2017). For the purpose of this study, grater teeth speed and teeth spacing used is 2250 rpm and X-axis distance 40mm; Y-axis distance 22mm; Shift distance 1mm, respectively (Darma, 2017).

C. Starch Recovery

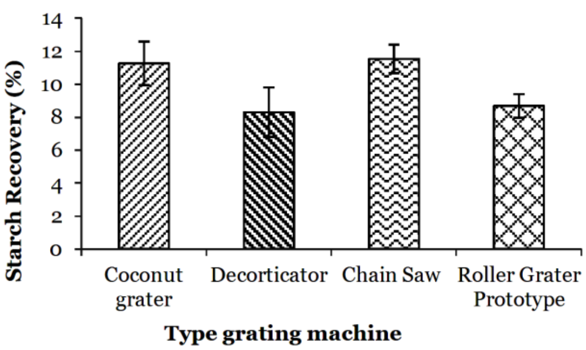

Figure 6. Sago starch recoveries produce according to difference type of grating machine used. Error bars were expressed as mean ± SD; n = 5

Herein, the total weight (g) of starch that is extracted from 1000 g of grated sago known as starch recovery percentage (equation 2). The average moisture content of starch slurry before drying process was 35.80 ± 0.43% and the moisture content value decreased to 10.33 ± 0.55% after drying process. The reduction of moisture content percentage was 25.47%. Figure 6 shows the result of starch recovery percentage that has been extracted from grated sago produce by difference type of grating machines. Based on the results, the dry starch recovery extracted from grated sago is ranging from 8.30 to 11.53%. The highest starch recovery extracted from grated sago is by chainsaw followed by Coconut grater with the percentage of 11.53% and 11.26%, respectively. The starch recovery percentage of Chainsaw and Coconut grater has a small percentage difference (equation 3) which is at 2.3%. It is due to the grated size effect, as both machines have the almost the same value of cumulative frequency of WPR% at X ≤0.85 (56.80%, 55.45%) and teeth surface contact area. The lowest starch recovery percentage was recorded by the product produced using Decorticator (8.30%). As stated above, Decorticator produced the highest quantity of coarse grated sago (X≥ 1 mm). This proved that the finer grated sago is more favourable as it results in higher starch recovery during the extraction process (Cecil, 1992). The result of starch recovery on the dry base sago is lower compared to a prior study conducted by Siti Mazlina M.K. (2007) with 25.76% recovery. The deviation might due to the wet grading process step before the extraction process that has been implemented in this study. This leads to the starch granules that present in the pith were dissolved in water and subsequently released when it is ruptured during the grinding process (Siti Mazlina M.K., 2007).

$$\frac{|\Delta V|}{\frac{\sum V}{2}} \times 100\% \quad (3)$$

$$M_n = \frac{W_w - W_d}{W_w} \times 100 \quad (4)$$

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

On most of the previous studies, the calculation of starch recovery (equation 2) mainly used wet base starch as an input value. Hence, for comparison purpose with the current study, the wet basis starch recovery (equation 4) at a moisture content of 35.80% (starch slurry before dried) for Chainsaw, Roller Grater, Coconut Husk Decorticator and Coconut Grinder are at 15.70%, 11.60%, 16.10% and 12.1% respectively. Therefore, the value of starch recovery at a wet basis is ranging between 11.50% up to 16.10%. Assuming that all previous studies used wet base as starch recovery calculation at moisture content of 35.80% since it is it not reported, the obtained value of present study shows a close agreement with Flach (1997) and Darma (2014) which obtained starch recovery ranging from 10 to 25% and 12.43 to 39.89% respectively. Meanwhile, Haryanto B. (1992), Cecil J.E. (1992), Yunus (1997) and Darma (2017) resulted with the starch recovery of 15 to 25%, 23 to 27%, 35.45% and 43 to 48%, respectively. As stated above, there is a difference in starch recovery obtained from this experiment with the other reports that might be because of different extraction method. While in this study, squeezed grated sago method (squeezed manually using a muslin cloth) is used for extraction process which was conducted without repetition of adding water to ensure optimal usage of water. The conventional method used repetition of adding water during the extraction process, that normally consumed a lot of water (Jong F.S., 1995A). Water addition during the extraction process is an important element since it helps to dissolve and release sago starch granules (Kamal S.M.M., 2007). Furthermore, it may due to the different maturity stage of sago palm used for the study. The usage of immature sago palm (not reaching full maturity stage) resulting in low starch recovery (Jong F.S., 1995B).

IV. CONCLUSION

The result from the study showed that the usage of chainsaw is the most appropriate compared to other types of grater machine (Roller Grater, Coconut Husk Decorticator and Coconut Grinder) in producing finer grated sago (56.80% at X ≤0.85 mm) and 11.53% of a dry base starch recovery after the extraction process. However, there are still leftover of roughly grated sago produced by hand chainsaw machine. In addition, the result showed that the finer grated sago facilitates the high release of native starch during the extraction process which is influent by the grating effect. Therefore, it is believed that further development of grater machine is needed to increase the quantity of finer grated sago in order to increase the starch recovery.

V. ACKNOWLEDGMENT

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VI. REFERENCES

Bintoro, MH 2011, 'Progress of Sago Research in Indonesia', in *Sago for food security, Bio-energy, and Industry from Research to Market: Proc. 10th Int. Sago Symposium,* Bogor, Indonesia, pp.16-34.

Cecil, JE 2002, 'The development of technology for the extraction of sago', eds K Kainuma, M Okazaki, Y Toyoda & JE Cecil, in *New frontiers of Sago palm studies: Proceedings of the International Symposium on Sago (Sago 2001),* Tokyo, Japan: Universal Academy Press Inc., pp. 83–91.

Cecil, JE 1992, *Small Medium and Large Scale Starch Processing*, FAO Agriculture Services Bulletin 98, Rome.

Colon, FJ & Annokke, GJ 1984, 'Survey of some processing route of sago', in *Proc. of the Expert Consultation of the Sago Palm and Palm Product,* Jakarta, Indonesia, pp. 1-17.

Darma, Santos, B & Reniana, 2017, 'Development of cylinder type sago rasping machine using pointed teeth', *International Journal of Engineering & Technology (IJET)-IJENS,* vol. 17, no. 1.

Darma, Wang, XL & Kito, K 2014, 'Development of sago starch extractor with stirrer rotary blade for improving extraction performance', *International Journal of Engineering and Technology (IJET)*, vol. 6, no. 5, pp. 2472-2481.

Darma, & Istalaksana, P 2011, 'Traditional processing of sago in Papua Province', in *Sago for food security, Bio-energy, and Industry from Research to Market: Proc. 10th Int. Sago Symposium,* Bogor, Indonesia, pp. 115-116.

DOA 2015, *Malaysia Industrial Crops Statistics*, Department of Agriculture, Putrajaya.

Flach, M 1997, *Sago Palm (Metroxylon sagu Rottb*), International Plant Genetic Resources Institute (IBPGR), Rome.

Flach, M 1983, *The sago palm*, *AGPC/MISC/80,* FAO plant production and protection paper 47*,* Food and Agriculture Organization, Rome, Italy.

Haryanto, B & Pangloli, P 1992, *Potency and utilization of sago palm*, Kanisius, Yogyakarta.

Hirao, K 2015, 'Use as food, starch properties and use, The sago palm', *The Society of Sago Palm Studies*, Kyoto Univ Press, pp 264–272.

Jong, FS 1995A, *Distribution and variation in the starch content of Sago palms (Metroxylon sagu Rottb.) at difference growth stages*, Sago Palm vol. 3, Agriculture Research Center, Department of Agriculture, Kuching, Sarawak, Malaysia.

Jong, FS 1995B, 'Research for the development of sago palm (Metroxylon sagu Rottb.) cultivation in Sarawak, Malaysia', PhD thesis, Wageningen Agriculture Univ., The Netherlands.

Kamal, SMM, Mahmud, SN, Hussain, SA & Ahmadun, FR 2007, 'Improvement on sago flour processing', *International Journal of Engineering and Technology*, vol. 4, no. 1, pp. 8-14.

Karim, AA, Pei-Lang Tie, Manan, DMA & Zaidul, ISM 2008, *Starch from the Sago (Metroxylon sagu) Palm Tree-properties, Prospect, and Challenges as a new Industries Source for Food and Other Uses*, Comprehensive Reviews in Food Science and Food Safety, Institute of Food Technology.

Malaysia Department of Statistic, 2005, *Sarawak export of sago starch*, *SITC Code*: 592-150-100, Department of Statistic, Kuala Lumpur, Malaysia.

Nishimura 2018, 'Sago Starch: Transformation of Extraction and Consumption Processes in Traditional Indonesian Societies', eds H Ehara, in Sago *Palm*, Chapter 16, pp. 221-229.

Oates, CG & Hicks, A 2002, 'Sago starch production in Asia and the Pacific problems and prospects', eds K Kainuma, M Okazaki, Y Toyoda & JE Cecil, in *New frontiers of Sago palm studies: Proceedings of the International Symposium on Sago (Sago 2001),* Tokyo, Japan: Universal Academy Press Inc., pp 27–36.

Okazaki, M 2018, 'The Structure and Characteristics of Sago Starch', eds H Ehara, in *Sago Palm*, Chapter 18, pp. 221-229.

Siti Mazlina, MK, Siti Norfadhillah, M, Siti Aslina, H & Fakrul Razi, A 2007, 'Improvement on Sago Flour Processing', *International Journal of Engineering & Technology,* vol. 4, no. 1, pp.8-14.

Vikineswary, S, Shim, YL, Thambirajah, JJ & Blakebrough, N 1994, 'Possible microbial utilization of sago processing wastes', *Resources, Conservation and Recyling*, vol. 11, pp. 289-296.

Wan Mohd Fariz, WA, Rosnah, S, Azman, H, Mohd Shahrir, A, Saiful Azwan, A, Asnawi, SH & Zainun, MS 2018, 'Effect of grater position on the size of grated sago (*Metroxylon* spp.)', *Food Research,* vol. 2, no. 6, pp. 572 – 577.

Wojtanowicz, AK & Kuru E 1993, 'Mathematical modeling of PDG bit drilling process based on a single cutter mechanics', *Journal of Energy Resources Technology, Transactions of the ASME*, vol. 115, no. 4, pp. 247-256.

Yamamoto 2014, *Sago as an Approach to Food and Nutritional Security*, The Global Food Security Forum, Kuala Lumpur.

Yunus, MR 1997, 'Improves V-tooth Blade Sago Grater', *Magazine of Chemistry, Indonesian Centre for Agricultural Library and Technology Dissemination (ICALTD)*, Bogor, no. 57, pp. 1-4.