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Small Scale Mechanical Processing of Sago in District Momi Waren South Manokwari Regency West Papua Province

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Abstract: Small scale processing of sago both mechanically and semi-mechanically are now common practicing by sago farmer in West Papua and Papua Province. The objective of this research was to apply small scale mechanical sago processing equipment in order to transform the traditional processing method to mechanical one. In this research the sago processing machinery have been employed were cylinder type sago rasping machine and sago starch extraction machine, both were made in workshop of Agricultural Technology Faculty, University of Papua Manokwari. The performance of employed processing machinery in District Momi Waren were evaluated in terms of rasping capacity, extraction capacity, starch yield, fuel consumption and starch left in sago pith waste. Results showed that sago farmer in District of Momi Waran can operate the sago processing machineries easily without any difficulties. The performance of the machines were (a) rasping capacity 650 kg/hour, (b) extraction capacity 315 kg/hour, (c) starch yield 33.75 %, (d) starch losses in sago pith waste 2.5 % and (e) fuel consumption for rasping and extraction machine were 1.4 litre/hour and 1.23 litre/hour respectively.

Keywords: Extraction capacity, Mechanical processing, Rasping capacity, Sago processing, Small scale

Introduction

The production and utilization of sago palm resources (*Metroxylon sago* Rottb.) in Papua and West Papua Province is still very low compared to its existing potential. The potential of sago in Papua and West Papua Province are estimated 4.7 million ha and 510,000 ha respectively, most of which are natural sago forests (Djoefrie at al., 2014). The sago palm distribution in Indonesia consisting of 85 % of the sago worldwide, is 5.5 million ha. Most of these Indonesia's sago area, is about 95 % (5.2 million ha) are located in Papua and West Papua (Djoefrie at al., 2014). According to Matanubun and Maturbong (2006), utilization of sago palm resources in Papua and West Papua Province is less than 5 % of its existing potential. Up to the present time, sago owner in this region cut sago trees and process mainly for subsistence use and sell locally but they exploit only a very small amount compared with its potential. Consequently, a large number of mature sago palm are not harvested and lost every year. Meanwhile the current demand for sago starch, both for local and global markets, increases continuously. There has been no significant increase in sago starch production in these areas. Unlike in Sarawak, Malaysia, even though the sago potential was small, it was the world biggest exporter of sago starch with total export of 44,700 tons in 2007 (Bujang, 2011; Singhal et al., 2008; Karim et al., 2008). The sago industry in Malaysia (in the State of Sarawak) is well established and has become one of the important industries contributing to export revenue (Karim et al., 2008)

A traditional method of sago starch processing is now still being used in most parts of West Papua and is mainly for subsistence. It is well known that traditional method of sago starch processing was a time and labor intensive process. Consequently, sago starch production is very low, both in quantity and quality. Farmers in this area continue to use traditional systems to process sago starch because the lack of mechanical equipment. The industrial technology of processing starch and its derivatives from potato, cassava, maize, rice and wheat has developed very well. However, this is not the case with sago starch technology. There are only a few simple technologies besides traditional method.

The principles and methods of sago starch processing is almost the same for both traditional and mechanical production, but different only in the equipment which is used and the scale of operation (Kamal et al., 2007; Rajyalakshmi, 2004, Karim et al., 2008). The purpose of the sago processing is to separate starch from the cellulosic cell walls of the trunk. This procedure is: (1) palms are selected and felled, (2) clearing, debarking and splitting the logs, (3) disintegration or breaking down the pith of log, (4) starch extraction/separation of starch, (5) starch sedimentation and dewatering, (6) starch drying and packaging. The traditional method of sago starch extraction not only ineffective and inefficient but also the starch quality produced is low. In contrast, mechanical processing of sago palm, beside much more effective and efficient, the starch produced has higher quality and is more hygienic (Karim et al. 2008; Singhal et al., 2008). Therefore, farmers in this area should change the traditional method to mechanical one in order to increase sago starch production. With regard to the mechanical processing, it is necessary to provide mechanical equipment that is suitable and easy to use by common farmers. Mechanical processing of sago will transform the traditional agricultural system into a developed and commercial agriculture and as a result is increase of farmers' income.

The application of mechanical technology in the form of appropriate machinery and equipment (appropriate technology) to the farmers in West Papua is suitable to be applied (Darma, 2018). The characteristics of the technology are simple, low cost, small scale and labor intensive. In addition, a region should have to develop its mechanical equipment suitable for local conditions thus its application does not meet any constraints. Application of mechanical equipment in some areas should pay attention to the various aspects of socio-cultural of local community otherwise applications will be unsuccessful.

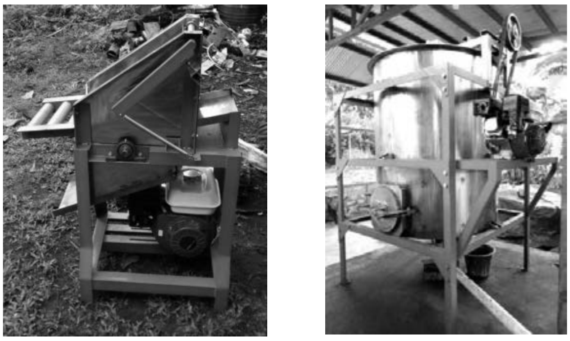
In West Papua province, sago palm can be found mainly in the regency of Sorong, South Sorong, Manokwari, Teluk Wondama, Teluk Bintuni, Fak-Fak and South Manokwari. This time, there are two large and modern sago industries operating in Sorong Selatan namely Perum Perhutani sago factory and PT. ANJAP with a natural sago forest concession area of 16,000 ha and 40,000 ha respectively. The two factory only process sago within their concession area, while the sago area is widespread in almost all regency. To overcome this constrain, small-scale mechanical processing of sago is suitable to be applied widely in this province because of its low price and can be operated easily by farmer. The objective of this research was to apply small-scale mechanical sago processing in district Momi Waren, South Manokwari Regency, West Papua Province. The small-scale sago processing machine that had been employed in this research consists of cylinder type sago rasping machine variant-02 and vertical stirrer rotary blade sago starch extractor, both produced in workshop of Agricultural Technology Faculty, University of Papua.

Materials and Methods

Description and specification of sago processing machine employed

The small-scale sago processing machine had been applied in this study were cylinder type sago rasper variant-02 (Darma et al., 2020a; Alua et al., 2021)

(Fig. 1a) and vertical stirrer rotary blade sago starch extractor (Darma et al., 2020b) (Fig. 1b). These machines were produced in the workshop of Faculty of Agricultural Technology, University of Papua. The technical specifications of these machines were presented respectively in Table 1. and 2.



(a) (b)

Fig. 1. Cylinder type sago rasper variant-02 (a) and vertical stirrer rotary blade sago starch extractor.

Tab. 1. Technical specification of cylinder type sago rasper

Name	Cylinder type sago rasper variant-02
Dimension (l×w×h)	56 cm × 36 cm × 103 cm)
Rasping system	Without debarking the sago log
Rasper component	Cylindrycal with stainless steel teeth
Power transmision	Pulley and V – Belt A-40 (2 pieces)
Silinder rotation	2.000 – 2.700 rpm
Rasping capacity	600 – 900 kg/h
Power source	Gasoline engine GX 200, 6.5 HP
Total weight	67 kg

Tab. 2. Technical specification of vertical stirrer rotary blade sago starch extractor.

Name	Vertical stirrer rotary blade sago starch extractor
Dimension (l×w×h)	118 cm x 90 cm x 170 cm
Tube dimension,ø×h)	76 cm × 120 cm (volume: 0.544 m^3)
Tube material	Stainless steel SS 304, 2 mm thick
Extraction system	Stirring and sieving
Transmission	Pulley and V-belt (A-83, 2 pieces)
Stirrer rotation	100 rpm
Extraction capacity	100 kg/process (3 batch/h)
Power source	Gasoline engine GX 200, 6.5 HP

Small-scale sago processing procedure in Momi Waren District

Once the sago processing machines had been produced, then they are transported to the processing site located in District of Momi waren, South Manokwari Regency. In the processing site, the machines were installed near the water source, is small river because sago processing process require a lot of water (Fig. 2). In addition, starch sedimentation tank was also prepared as it is an integral component of the sago processing machines (Fig.3). Until recent

Fig. 2. Small scale sago processing machine were ready to be operated

Fig. 3. Starch sedimentation tank made of wooden box covered with water proof plastic sheet.

time, the only way to separate starch from the fiber (starch extraction) is by using of water. The freed starch which is contained in the rasped pith (repos) is washed out using plenty of water. The principles of starch extraction are to suspend or to dissolve the rasped pith in water and then stir it vigorously to release the starch. The suspended starch or starch slurry is then separated from the fiber using a screen. A good screening operation should wash as much starch as possible through the screen with as little water as possible.

In this study, the machines were fully operated by sago farmers after being previously were trained. The sago processing procedures conducted in this study was shown in Fig. 4. As it is shown in Fig. 3 the sago

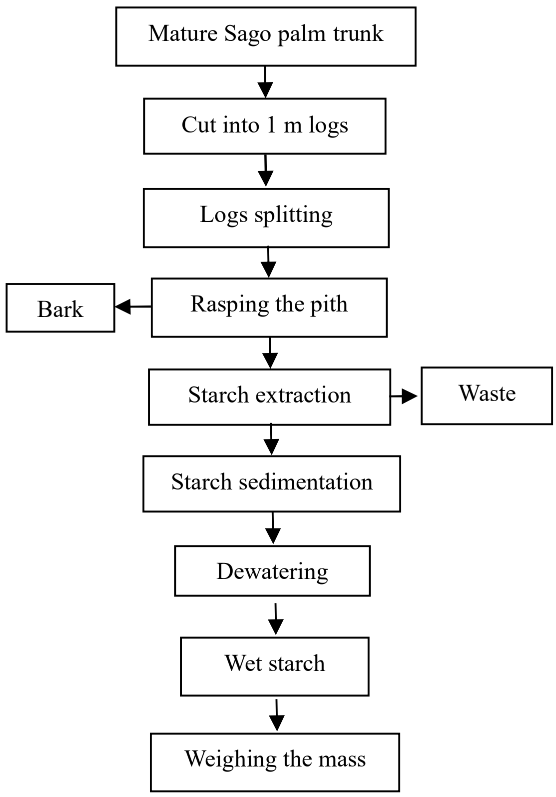


Fig. 4. Process flow diagram of sago starch processing conducted in this study.

rasping machine and sago starch extraction machine is independently unit (not integrated one to another). During the sago process, firstly sago pith was rasped and then followed by starch extraction. The rasped pith called repos was put into the extractor manually.

The performances of the machines were evaluated in term of (a) rasping capacity, (b) extraction capacity, (c) starch yield, (d) starch losses in sago pith waste and (e) fuel consumption for both sago rasping machine and extraction machine.

Results and Discussion

Rasping capacity

Rasping the pith of the sago trunk using a sago rasping machine is the most common method used to disintegrate sago pith both in small scale, and big one production. It is one of the important stages in the sago starch extraction process which is purposed to disintegrate the cellular structure of the pith thus starch granules contained within can be released and separated in the subsequent process.

Rasping capacity is the ability of the machine to disintegrate sago pith per unit of time in (kg/hour). Mature sago palm trees were felled down and then cut into 1 m length logs. The logs are then split into pieces suitable to feed onto the rasping machine. The rasping process was carried out manually by putting the pieces onto the hopper and pushing gently to the rotating cylinder (Fig. 5a). The result was rasped pith called repos is then collected in plastic bag and weighed (Fig. 5b) for calculating the rasping capacity. The rasping capacity is presented in Table 3.

Tab. 3. Rasping capacity of various time periods

Rasping time duration (min.)	Rasped pith produced (kg)	Rasping capacity (kg/hr)
5	43	516
5	46	912
5	76	552
10	89	543
10	72	432
10	76	456
15	199	769
14	217	868
15	197	788
Average		650

(a) (b)

Fig. 5. Sago rasping process (a) and rasped pith produced is collected for further process (b)

Table 1 show that rasping capacity was 650 kg/hr in average. This result was lower compared to those of Darma et al., (2020b) and Alua et al., (2021) in which resulting rasping capacity were respectively 1,065 kg/hr and 928 kg/hr, both tested the same type of sago rasper in different location. The lower rasping capacity obtained in this study because of the low skill of operator. As it has mentioned previously that the machine were fully operated by sago farmer which have no experienced previously in operating the machine. Unlike with those of Darma et al., (2020b) and Alua et al., (2021), the machine was operated by experienced skillful operator. However, by time pass the farmer would improve their skill in operating the machine. According to Thoriq and Suteja (2017) and Darma et al., (2014a; 2019), operator's skill is one of the factors affecting rasping capacity. In addition, other factors affecting rasping capacity were characteristics of teeth, cylinder size, hopper angle, cylinder rotation speed and power source of the machine.

Extraction capacity

The function of sago starch extraction machine is to separate starch from fiber (pith waste). In the process, the rasped pith (disintegrated pith) and water are fed into the extraction cylinder and then stirred vigorously. The separation of the starch granules from the fiber can thus far only be achieved by a water-washing process. The starch separation mechanism is a combination of stirring and screening. First, rasped pith (*repos*) is suspended in water and then stirred vigorously to release the starch. The suspended starch or starch slurry is separated from the fiber using a screen. Starch in suspension that passes through the screen then flows into the settling tank through a pipe.

Starch separation is done in two stages of screening; a coarse screening operation which is placed in the bottom of extraction cylinder removes most of the waste and fine screening operation, using fine screen (100 mesh stainless steel wire) which is placed on an open wooden box to separate the starch from fine waste. The fine screen is handled manually by an operator. Soluble components that are also exist in the sago pith such as sugars, proteins and many of the other constituents are dissolved and pass through the screens along with starch. These soluble materials caused the color of starch suspension become brownish instead of white (Cecil, 1992; Manan et al., 2001). A good screening operation should wash starch as much as possible through the screen without clogged.

Extraction capacity is the amount of rasped pith which is processed per unit of time (hour). The extraction capacity depends on how much of rasped pith is being processed and time duration per batch/process. The longer the extraction time required, the lower the extraction capacity and vice versa. Meanwhile, the more amount of rasped pith, the larger the extraction capacity. The average extraction capacity at several batches is shown in table 4.

Tab. 4. Extraction capacity of stirrer rotary blade sago starch extraction machine

Mass of rasped pith (kg)	Time required per bath (hr)	Extraction capacity (kg/hr)
107	0.37	289
100	0.33	303
102	0.37	276
100	0.32	313
101	0.25	404
124	0.37	335
113	0.43	263
133	0.45	296
Average		310

Table 4 shows that average extraction capacity was 310 kg of rasped pith/hr or equivalent to 3 batches per hour. This result was consistent with those of Darma et al., (2020b) and Alua et al., (2021). It is also support with those of Darma et al. (2014b; 2017 and 2020a). However, the result was lower compared to those of Darma et al., (2020c).

The stirrer rotary blade sago starch extractor is using batch system instead of continuous one. The total time that was required per batch consists of (a) input rasped pith into extractor (average 1 minute), (b) starch extraction (average 7.5 minutes) and (c) waste removal from inside the extractor (average 13.4 minutes). During the extraction process, water is continuously discharge using a pump into extraction cylinder and in the mean time starch slurry was flowed to sedimentation tank. An important factor that has to be controlled carefully is that the amount of water supplied into the cylinder extractor and the water (starch slurry) flowing out should be balanced. If the amount of added water is less than water that is flows out, the slurry in the cylinder extractor will be quite dense and become difficult to stir. In the extreme condition it could overload the engine or even caused serious damage to the extractor's components. On the other hand, if supplied water is more than that is allowed to flow out, it will spill out from the upper side of cylinder extractor.

Principally, the working mechanism of this extractor is similar with traditional method which is both involving kneading/squeezing and screening. However, unlike traditional method which use hand or leg, this extractor uses stirrer rotary blades instead of hand to knead the rasped pith. During the stirring process, freed starch as well as others substances that were present in repos were suspended into water. The suspended starch is then forced to pass through the screen. After passing through the screen, the starch suspension flowed to the secondary screen and then to the sedimentation tank.

Starch yield

Starch yield is the ratio of starch's mass and rasped pith's mass. The starch suspension in the sedimentation tank (Fig. 3) was left for sedimentation to allow starch particle to precipitate in the bottom of tank. After 3 hours or more, supernatant water was drained out and the fresh or wet starch was taken and weighed (Fig.6).

Fig. 6. Sago starch collecting from sedimentation tank

As it was shown in Table 4, the total mass of rasped pith had been processed was 880 kg and the total mass of fresh starch resulted was 297 kg, therefore the starch yield was 33.75 %. This result was consistent with those of Alua et al., (2021), Darma et al., (2014b) and Darma et al., (2017) who tested the same type of sago extractor in which resulted starch yield respectively 32.12 %, 35 % and 31.6 %. However, it is lower compared to Darma et al., (2020a; 2020b and 2020c) which obtained starch yield 38.26 %, 39.98 % and 36 %.

The amount of starch that is obtained in a processing plant depends greatly on the effectiveness of the methods employed as well as starch content in the pith of sago palm. According to Flach (1997), starch content of sago is around 10 % to 25 %. Meanwhile, according to Haryanto et al., (2015), starch content in the sago pith is around 15 % to 25 %. Cecil (1992) also reported almost the same values i.e. 23 % to 27 %. Darma (2011) reported that starch content of sago in Papua province varies from 12.43 % to 39.89 %. Singhal et al., (2008) reported that starch content of the pith obtained from ready harvested sago palm varies from 18.8 % and 38.8 % (fresh weight). Yamamoto (2011) reported that starch percentage of sago at around Sentani lake, Jayapura, Papua is around 22.1 %-75.4 %. Jong and Ho (2011) reported that dry starch content of sago (natural sago forest) in South Sorong Regency, West Papua is average 12.5 %. Therefore, the different results of starch percentage or starch yield among researchers indicate that not only the methods employed but also varieties of sago affect starch yield.

Starch losses in sago pith waste

At the end of each process/batch, sago pith waste retained in the extractor tube was discarded out (Fig.7a) and 1 kg sample was taken for further processed using manually screener to extract the starch left within (Fig.7b). The starch is washed out from the waste manually clean water. The starch was separated from fibrous and cellular residue using a

(a) (b)

Fig. 7. Sago pith waste was discarded from the extractor tube (a) and manually extraction of 1 kg of waste sample (b).

fine sieve (fine cloth). In this process, waste was kneaded with water and the resulting slurry was then filtered using the fine cloth sieve and squeezed manually to obtain starch. This process is repeated several times until virtually no starch comes out from waste. The waste containing no starch is then discarded. Meanwhile, the starch is allowed to settle to the bottom of the bucket for 3 hours, and subsequently the supernatant water is drained off. The resulted starch are then collected and weighed to determine the amount of starch losses in waste. The amount of starch losses in sago pith waste in each batch is shown in Table 5.

Tab. 5. The amount of starch losses in sago pith waste

Batch/process	Starch losses in sago pith waste (%)
1	1.65
2	2.82
3	2.00
4	3.10
5	2.18
6	1.80
7	1.97
8	1.45
Average	2.12

As shown in Table 5 the average starch losses in sago pith waste was 2.12 %. This result support with those of Darma et al., (2014b; 2020a; 2020b; 2020c) in which resulting starch losses in waste were 2 %, 1.03 %, 1.80 % and 2.6 %. This result is also consistent with that of Alua et al., (2021) which resulted in the starch in sago pith waste of 1.07 %.

It should be mentioned here that in this study only the freed starch left in waste that was measured and considered, while un-freed starch remains either trapped permanently within the parenchyma cells or the sago fibers. This was due to not the entire cell walls were ruptured in the preceding process (rasping process).

Fuel consumption

Fuel consumption (gasoline) for sago rasping machine and sago starch extractor are presented in Table 6.

Tab. 6. Fuel consumption of sago rasping machine and sago starch extractor.

Replication	Fuel consumption (litre/hour)	
	Sago rasper	Sago extractor
1	1.81	1.11
2	1.45	0.98
3	1.93	0.84
4	1.17	1.29
5	1.08	0.97
6	1.50	0.87
7	1.62	0.89
8	1.46	1.24
Average	1.50	1.02

Average fuel consumption of sago rasper and sago starch extractor are respectively 1.5 l/hr and 1.02 l/hr. These results were consistent with that of Darma et al., (2020b) in which resulted fuel consumption 1.46 l/hr for sago rasper and 0.97 l/hr for sago starch extractor. This is also consistent with that of Alua et al., (2021) which resulted in fuel consumption of sago rasper and sago extractor were respectively 1.7 l/hr and 0.6 l/hr.

Fuel consumption of the machines greatly depend on the rotation speed of the engine's shaft. The higher the shaft rotation the more fuel is consumed. The engine's shaft speed was controlled via throttle of the engine.

As the mass of sago pith had been processed (1 trunk) was 880 kg and average rasping capacity was 650 kg/hr, thus it was required 2.03 l of fuel to rasp 1 trunk of sago palm. Meanwhile, the required fuel of sago extractor for the same mass of rasped pith was 2.89 l.

Conclusions

Small scale mechanical sago processing machines applied in District Momi Waren, South Manokwari Regency, West Papua Province work properly without any technical constrains. Sago farmer were able to operate the machines easily. The performances of the machines were (a) rasping capacity 650 kg/hr, (b) extraction capacity 310 kg/hr, (c) starch yield 33.75 %, (d) starch losses in sago pith waste 2.12 % and (e) fuel consumption 1.5 l/hr for sago rasper and 1.02 l/hr for sago starch extractor. Compared to the traditional method, application of the machines were able to increase sago production capacity from 1 to 6 trunks per week.

References

Alua, I., Darma dan Lisangan, M. M. 2021. Field Test and Economic Feasibility Analysis of Sago Rasping and Extraction Machines Produced by Agroindustry Workshop of Fateta Unipa. *Jurnal Igya Ser Hanjop*. 3(1): 25-35.

Bintoro, M. H., Nurulhaq M. I., Pratama A. J., Ahmad F. and Ayulia L. 2018. Growing Area of Sago Palm and Its Environment in: SAGO PALM: Multiple Contribution to Food Security and Sustainable Livelihoods (Eds: Ehara, H., Y. Toyoda and D.V. Johnson). Springer. Singapore.

Bujang, K. B. 2011. Potential of sago for commercial production of sugars," in *Proc. 10th Int.Sago Symposium, Sago for food security, Bio-energy, and Industry From Research to Market*, 36-41. Bogor, Indonesia, Oct. 29-31.

Cecil, J. E. 1992. Small, Medium and Large Scale Starch Processing. Rome: FAO Agricultural Services Bulletin, 98

Darma. 2011. Traditional processing of sago in Papua in: Proceedings of the 10th International Sago Symposium: Sago for food security, Bio-energy, and Industry From Research to Market, Bogor: 29-31 October 2011. p. 115.

Darma, Wang X. and Kito K. 2014a. Development of cylinder type sago rasper for improving rasping performance. *International Agricultural Engineering Journal* (IAEJ). 23 (1): 31-40.

Darma, Wang X, and Kito K. 2014b. Development of Sago Starch Extractor with Stirrer Rotary Blade for Improving Extraction Performance. International Journal of Engineering and Technology (IJET). 6(5): 2472-2481.

Darma, Santoso B. and Reniana. 2017. Development of cylinder type sago rasping machine using sharp teeth. *International Journal of Engineering and Technology (IJET-IJENS)*. 17(1): 1-7.

Darma. 2018. Improvement of sago processing machinery. in: *SAGO PALM: Multiple Contribution to Food Security and Sustainable Livelihoods* (Eds: Ehara, H., Y. Toyoda and D.V. Johnson). Springer. Singapore

Darma, Faisol, A. dan Selano, M.M. 2019. Uji Lapang Mesin Parut Sagu Tipe Silinder Bertenaga Motor Bakar Bensin. Jurnal Agritechnology, 2(2), 41-52.

Darma, Reniana and Arbianto, M A. 2020a. Field Test of Sago Processing Machines Produced by Agroindustry Workshop of Papua University. *Jurnal Teknik Pertanian Lampung*. 9(3): 191-200.

Darma, Santoso B, Reniana dan Arbianto M A. 2020b. Performance of Small-scale Sago Processing Machinery in Supiori Regency, Papua Province. *Jurnal Pengkajian dan Pengembangan Teknologi Pertanian*. 23(2): 163-176.

Darma, Santoso, B. and Reniana. 2020c. Development and Performance Test of Vertical Stirrer Rotary Blade Type of Sago Starch Extraction Machine. International Journal of Engineering and Technology (IJET-IJENS) Vol. 20, No.03: 01-10.

Djoprie, M. H. B, S. Herodian dan Ngadiono. 2014. Sagu untuk Kesejahteraan Masyarakat Papua: suatu kajian dalam upaya pengembangan sagu sebagai komoditas unggulan di Provinsi Papua dan Papua Barat. Laporan Penelitian Unit Percepatan Pembangunan Papua dan Papua Barat. Jakarta

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

Haryanto B, Mubekti dan Putranto A. T. 2015. Potensi dan Pemanfaatan Pati Sagu dalam Mendukung Ketahanan Pangan di Kabupaten Sorong Selatan Papua Barat. *Jurnal Pangan*.(24)2: 97-106.

Jong, F. S. C.J. Hoo, C.J. 2011. Growth and Yields of Natural Sago Forests for commercial operations. In *Proc. 10thInt.Sago Symposium, Sago for food security, Bio-energy, and Industry from Research to Market*, 43-45. Bogor, Indonesia, Oct. 29-31.

Kamal, S. M. M., S. N. Mahmud, S. A. Hussain, and F. R. Ahmadun. 2007. Improvement on sago flour processing. *International Journal of Engineering and Technology*, 4(1): 8-14.

Karim, A.A, Pei-Lang Tie, D.M.A. Manan, and I.S.M. Zaidul. 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 7 (3):215-228

Manan, D. M. A., M.N. Islam, and B. M. Noor. 2001. Enzymatic Extraction of Native Starch from Sago (*Metroxylon sagu*) Waste Residue. *Starch-starke*, 53(12): 639-643.

Matanubun, H and L. Maturbongs, "Sago Palm Potential, Biodiversity and Sociocultural Consideration for Industrial Sago Development in Papua, Indonesia," in *Proc. 8thInt.Sago Symposium: Sago Palm Development and Utilization*, Jayapura, Indonesia, August.4-6,2006, pp.41-54.

Singhal, R.S., J. F. Kennedy, S. M. Gopalakrishnan, A. Kaczmarek, C. J. Knill, and P. F. Akmar. 2008. Industrial production-processing, and utilization of sago palm-derived products. *Science Direct Carbohydrate Polymers, 72: 1-20. Elsevier*.

Thoriq, A. dan Sutejo, A. 2017. Desain dan Uji Kinerja Mesin Pemarut Sagu Tipe TPB 01. Jurnal Teknik Pertanian Lampung, 37(4), 453-461.

Yamamoto. Y. 2011. Starch Productivity of Sago Palm and Related Factors in Proc. *10thInt.Sago Symposium: Sago for food security, Bio-energy, and Industry From Research to Market*, 93-95. Bogor 29-31 October.