Development of Sago Starch Extractor with Stirrer Rotary Blade for Improving Extraction Performance

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Abstract— Although Indonesia has the largest potential of sago palm (*Metroxylon sagu*) in the world, up to the present time sago starch production and utilization has been very low compared with its potential. This is because of farmers in this area still use traditional method to process sago starch which are inefficient and ineffective. The objective of this study was to develop sago starch extractor in order to improve its extraction performance with the focus on the effect of rotating speed of stirrer rotary blades and number of stationary blades. In the experiment, three levels of rotating speed i.e.100 rpm, 150 rpm and 200 rpm, and four levels of stationary blade numbers i.e. no blade, 4 blades, 8 blades, and 12 blades were examined. The extractor performance test was carried out by measuring extraction rate, starch percentage, starch yield, and starch left in sago pith waste (*hampas*). Results showed that the higher the rotating speed the higher the extraction rate, starch percentage, and starch yield. Meanwhile, the higher the rotating speed the lower the starch left in *hampas*. Likewise, the greater the number of stationary blade the higher the extraction rate, starch percentage, and starch yield while the starch left in *hampas* was lower. The highest extraction rate of 491 kg/hour, starch percentage of 20.54 %, and starch yield of 101 kg/hour and not at all starch left in *hampas* was resulted at the condition of 12 stationary blades and rotating speed of 200 rpm. Therefore, the best condition to achieve highest extraction performance was 12 stationary blades and rotating speed of 200 rpm.

Keywords: sago starch extractor, stirrer rotary blade type, stationary blade, starch yield, extraction rate, starch in hampas

I. INTRODUCTION

The sago palm (*Metroxylon sagu*) has long been an important source of nutrition throughout the South East Asian archipelago [1], [2] and in some parts of Melanesia, certain islands of Micronesia, and various areas of tropical South America [3]. Starch from the stem of palms is an important product in those regions. At present time, this starch is an important food source among some native peoples in several parts of Indonesia, Papua New Guinea, Malaysia, and Philippines. Besides is used as staple food, complementary food, and animal feed, it is also used as raw material for agroindustry, bio-pesticide, bio-ethanol, bio-degradable plastic, cosmetic, and pharmaceutical industry [4], [5], [6], as well as raw material for sugars production [7]. The palm is able to thrive in swampy areas or peat soils and grows naturally without the need for pesticide and herbicide, and it is the highest starch producer compared with other starch producer crops [5], [8]. It will be recognized as an important crop for starch-based industries in the 21st century [9].

In Indonesia, sago palm can be found scattered in almost all part of the country except DKI Jakarta, Yogyakarta, West Nusa Tenggara and East Nusa Tenggara Province. In recent time, in some parts of Indonesia, the cultivation of rice, maize and cassava has gradually replaced sago. However, sago remains important as subsistence foodstuff in many parts of the country such as the Mentawai Islands, Bangka and Billiton Islands, Riau, Eastern Sumatra, Bali, Lombok, Kalimantan, Sulawesi, Molucca and West Papua. Within Indonesia, Molucca and West Papua is the area most strongly associated with dependence on sago for staple food for indigenous people [4], [10], [11].

Indonesia has the largest sago potential with the total area of sago palm stands about 1,398,000 ha [2]. Manan and Supangkat [10] estimated an even greater total sago area in Indonesia is around 4,000,000 ha. More than 50 % of the total world sago palm stands were grown in Indonesia and 95 % of it was located in West Papua Province. Reference [2] estimated a total of 1,200,000 ha wild stands (natural sago forest) and 14,000 ha stands of semi cultivated sago palm was located in West Papua. Meanwhile, Matanubun and Maturbong [12] stated that sago palm stand in West Papua is approximately 1,471,232 ha, which is mostly natural sago forest. By using the area of 1,471,232 ha, [12] predict the sago starch production potential in West Papua is about 12,035,555 tons/year. According to [5], the potential yield of natural sago forest is around 20-40 tons starch/ha/year. It means that the total potential yield of sago in this region is around 29,424,640-58,849,280 tons/year. The most recently research conducted by [13] concluded that in the natural sago forest in South Sorong, West Papua, dry starch yield potential was between 10-15 tons/ha/year. Therefore, the total dry starch yield potential was between 14,712,320-22,068,480 tons/year.

Although Indonesia has the largest potential of sago in the world, unfortunately, the sago starch production and utilization is very small comparing with its potential. Millions of tons of the starch is not harvested and disappear every year. According to [14], the utilization of sago palm resources in Indonesia is only about 0.1 % of its total potential. Matanubun and Maturbong [12] stated that utilization of sago resources in West Papua, which has over 95 % of Indonesia's sago palm, is less than 5 % of its existing potential. Up to the present time, farmers 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 West Papua. Unlike in Serawak, 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 [7], [15], [16]. The sago industry in Malaysia (in the State of Serawak) is well established and has become one of the important industries contributing to export revenue [16].

A traditional method of sago starch extraction is now 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 or sago starch extraction is almost the same for both traditional and mechanical production, but differs only in the equipment which is used and the scale of operation [17], [18], [16]. The purpose of the extraction 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 [15], [16]. Therefore, farmers in this area should change the traditional method with mechanical one in order to increase sago starch production. With regard to the mechanical processing, it is necessary to provide mechanical equipment that are suitable and easy to use by common farmers.

The most time consuming and labor intensive stages of sago starch extraction are pith disintegration and starch separation. For traditional method, the total time required to process one trunk is 41 hours (6 days of work) from which is 53.22 % and 38.92 % are respectively spent for pith disintegration and starch separation (92.14 % of the total time required) [19]. In the last five years, several studies have been done to increase sago starch production in the farmer level in West Papua by introducing sago raspers and extractors. In previous research, a prototype of sago starch processing equipment which consists of sago rasper and sago starch extractor was developed. Functionally, both worked properly but that still had some drawbacks, especially for sago extractor [20]. The objective of this research is to develop stirrer rotary blade type sago starch extractor in order to improve its performance. This research focuses on investigating the effect of rotary blades rotating speed and number of stationary blades on extraction performance.

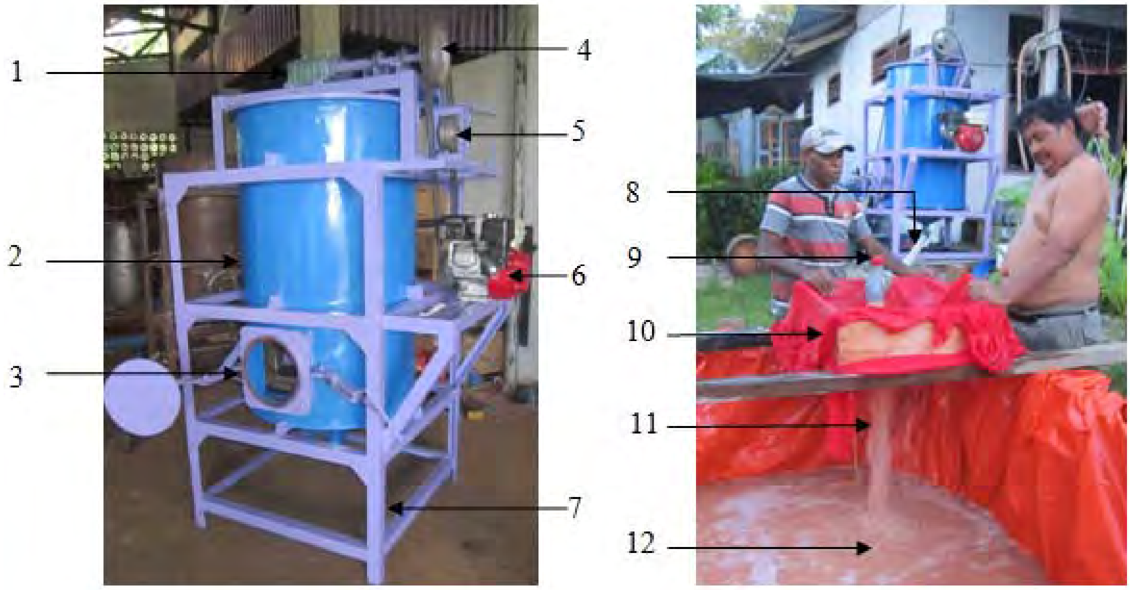
II. MATERIALS AND METHODS

A. Overall Structure and Operating Principles

The first stage in the extraction of starch is rasping or grating the pith. The rasped pith (disintegrated pith) is called *repos* [1], [21]. After pith disintegration, which aims to break down cellular structure and to rupture the cell walls, fiber and starch existed in the *repos* have not separated yet. The purpose of the extraction process is to separate the maximum amount of starch from the *repos*. The separation of the starch granules which exist in the cells, so far can only be removed by a washing process using water. Starch separation mechanism is that firstly *repos* is suspended in water and then stirred rigorously to release the starch. The suspended starch or starch slurry is then separated from the *repos* using a screen.

This sago starch extractor consists of several main components which are integrated in a single operational system (Fig. 1). The extractor has the following features: (1) Extraction cylinder, made of 2 mm thick steel. The cylinder's size was 74 cm in diameter and 120 cm in height (volume = 0,544 m^3). The lower end of the cylinder was a conical shape to prevent starch sedimentation incidence in the bottom of cylinder; (2) A screen, made of perforated stainless steel sheet with the holes size of 1.5 mm in diameter. The screen's diameter is slightly smaller than extraction cylinder and it is placed inside the extraction cylinder; (3) Stationary blades are made of

5 mm thick L-shape 50 mm x 50 mm steel bar. They are mounted vertically on the inner surface of screen; (4) Stirrer rotary blades, its function are to free starch granule from fiber and suspended into water; (5) Power transmission system, consists of v-belt, pulley and reduction gear box (WPX 80, ratio 10:1); (6) Power source, using a 6.5 HP gasoline engine; (7) Frame is made of 5 cm × 0.5 cm equal angle steel bar. In addition, it is equipped with a pipe (2 inch in diameter) to pass starch suspension from extraction cylinder to the sedimentation tank. At the end of the pipe, it is equipped with a stop tap (valve) to control starch suspension flowing.



Note: (1) Reduction gear box, (2) Extraction cylinder, (3) Gate, (4) Driven pulley, (5) Fastener pulley, (6) Engine, (7) Frame, (8) Flowing pipe, (9) Valve, (10) Fine cloth sieve, (11) Starch suspension, (12) Collecting tank.

Fig. 1. Overall structure of stirrer rotary blades sago starch extractor

B. Experimental Conditions

The processes of starch extraction which occur in the extractor involve stirring and filtering simultaneously. In order to hasten the filtering process, it is necessary to create turbulent current of starch suspension inside the extraction cylinder. For this purpose, the inner surface of the screener was equipped with stationary blades. During the stirring process, starch granules are suspended in the water and forced through the pores of the screener.

The functional parts of this extractor are the stirrer rotary blades and screener. Previous research has shown that, as stirrer blades rotation speed increases, extraction rate increases. The extraction performance was tested under experimental conditions as follows: (1) Rotating speed of stirrer rotary blades consisting of 3 levels i.e. 100 rpm, 150 rpm and 200 rpm. (2) Number of stationary blades consisting of 4 different numbers (four levels): no blades, 4 blades, 8 blades and 12 blades. Adjustment of stirrer rotary blades rotating speed is conducted by changing the ratio of the driver pulley (pulley on motor's shaft) to driven pulley (pulley on gear box input shaft). Three different ratios of driver to driven pulleys were used in this experiment, each corresponding to the intended rotation speed. The features of stationary blades and stirrer rotary blades are shown in Fig. 2.

C. Extraction Rates Test Determination

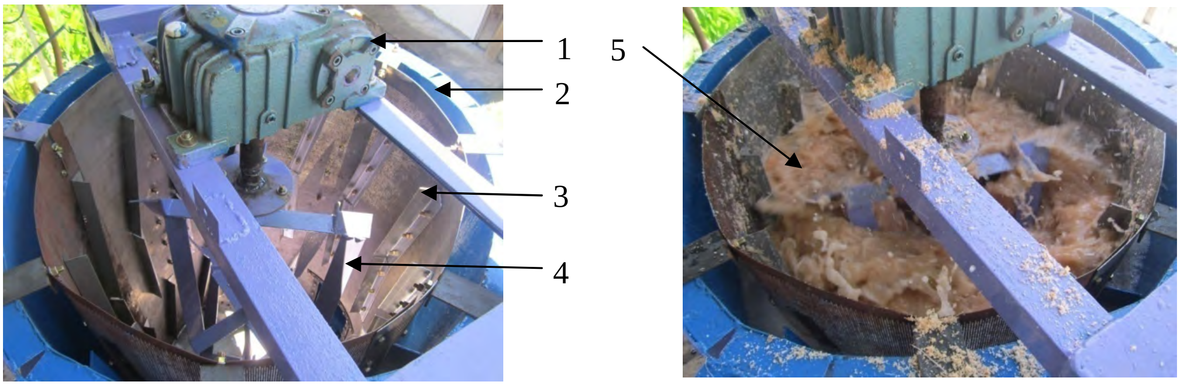
The flow chart of the extraction process in this research is shown in Fig. 3. It is necessary to rupture cell walls in order to release the starch granules. Unless the cells are ruptured in some way the starch can not be washed out in the extraction process. Rasping is the most commonly used method to break down the cellular structure of sago pith for mechanical processing. The sago rasper used in this study was cylinder type with sharp teeth [22].

The starch extraction starts by feeding the rasped pith (*repos*) manually into the extractor. As much as 90 kg of *repos* was fed into the extractor in each procedure. A lot of water was also being added and constantly supplied into the extractor while the extraction process is taking place to facilitate starch extraction. The stirrer rotary blade rotated at a fixed speed according to its designation speed as mentioned previously in experimental conditions (section 2.*B*). While the stirring process is taking place, starch granules are forced to pass through the pores of screener into the outer surface they then flowed to the sedimentation tank via pipe. This process was stopped when all starch had been washed out (no more starch in the repos), which was indicated by the slurry draining out from the extractor becoming clear. The time needed from the beginning to the end of extraction process was recorded.

Extraction rate was then determined according to equation (1):

$$E_r = \frac{w_R}{t} \quad (1)$$

Where E_r is extraction rate; w_R is weight of repos; t is time required.



Note: (1) Reduction gear box, (2) Screener/sieve, (3) Stationary blade, (4) Rotating blade, (5) Rasped pith (*repos*) with water in cylinder extraction

Fig. 2. Functional components of the extractor

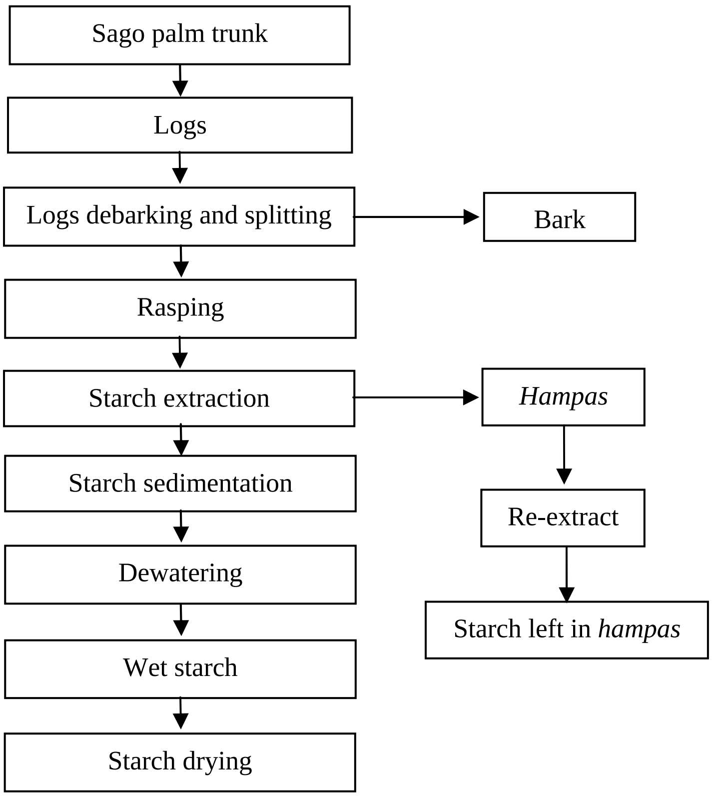


Fig. 3. Overall process flow chart of sago starch processing

D. Starch Percentage and Starch Yield Measurement

The resulting starch suspension in the collecting tank was left for sedimentation to allow starch particle to precipitate in the bottom of tank. Meanwhile, sago pith waste (*hampas*) which is retained in the extractor was discarded out at the extractor gate. After 2 hours, supernatant water was drained out and the fresh or wet starch was taken and weighed (Fig. 4a and Fig. 4b).

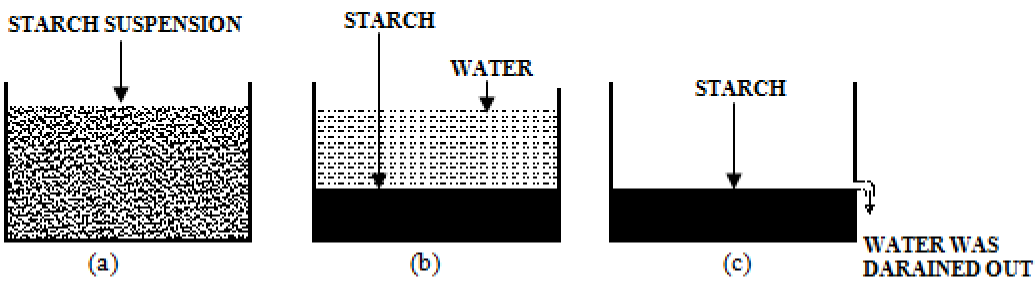


Fig. 4a. Starch suspensions in sedimentation tank (a), after 2 hours starch was settled on the bottom of the tank (b), then supernatant water was drained out and fresh starch ready to be taken out(c).

(a) (b)

Fig. 4b. Supernatant water was drained out (a) and fresh starch was taken out and then weighed (b)

The starch percentage (wet basis) was obtained using equation (2) and starch yield was obtained using equation (3) as follows:

$$\lambda = \frac{w_S}{w_R} \times 100\% \quad (2)$$

$$\omega = E_r \times \lambda \quad (3)$$

Where λ is starch percentage (%); w_S is weight of starch (kg); ω is starch yield (kg/hour)

E. Determination of un-extracted freed starch (loss in sago waste residue/hampas)

Sago pith waste residue is called *hampas* [1], [21], [23]. In order to investigate the amount of freed starch left in *hampas* which was not extracted during the extraction process (starch losses in *hampas*), 200 g samples of *hampas* in each process was taken and then further processed. The *hampas* then was re-processed further to extract starch which supposed not washed out in the former process. The starch is washed out from the *hampas* manually using a lot of water. The starch was separated from fibrous and cellular residue using a fine sieve (fine cloth). In this process, *hampas* was kneaded with water and the resulting slurry was then filtered using the fine cloth sieve and squeezed manually to obtain starch. The starch slurry passes trough the fine cloth sieve, and is then collected in a plastic bucket (Figure 5). This process is repeated several times until virtually no starch comes out from *hampas*. The *hampas* containing no starch is then discarded. Meanwhile, the starch is allowed to settle to the bottom of the bucket for 2 hours, and subsequently the supernatant water is drained off. The wet starch in the bucket is taken out and weighed.

The amount of starch losses in *hampas* was determined using equation (4):

$$\lambda_h = \frac{w_{Sh}}{w_H} \times 100\% \quad (4)$$

Where λ_h is the amount of starch loss in *hampas* (%); w_{Sh} is weight of re-extracted starch (g); w_H is weight of *hampas* (g).

Kneading squeezing

Fig. 5. Manually sago starch extraction to re-extract the starch left in *hampas*

III.RESULTS AND DISCUSSION

The performance of sago starch extractor developed was tested based on experimental conditions. The function of this extractor is to separate as much freed starch as possible from the *repos*. Separation is done in two stages of screening; a coarse screening operation which is placed in the extraction cylinder (Figure 2) removes/retain most of the *hampas* and fine screening operation, using fine cloth which is placed on a open wooden box (point No.10 as shown Figure 1) to separate the starch from fine *hampas*. 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 [1], [21], [23]. These soluble materials caused the color of starch suspension become brownish instead of white.

A. Extraction Rate

The efficiency of starch extraction depends on how carefully the operation is managed. The amount of starch obtained depends on the fineness of the rasping and the efficiency of washing the starch out of the rasped pith. The more finely the pith is rasped, the more starch can be extracted in the subsequent rinsing process. However, this makes it more difficult to separate the starch from the *hampas* [1], [24]. The relationship between stirrer blades rotating speed and extraction rate at four different numbers of stationary blades is shown in Fig. 6.

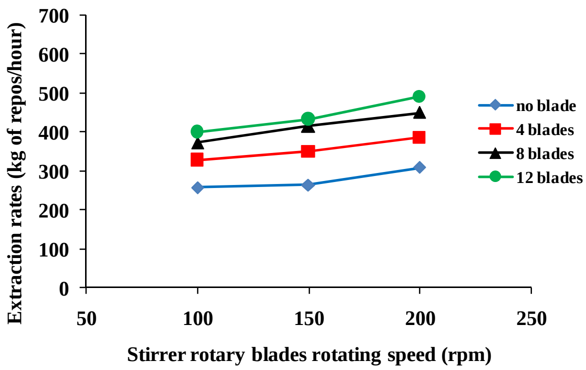


Fig. 6. Relationship between stirrer blades rotating speed and extraction rate

Fig. 6 shows that increases of stirrer blades rotating speed caused an increase of extraction rate. The higher the rotating speed the higher the extraction rate. It is also shown that the greater the number of stationary blades the higher the extraction rate. These imply that the extraction process is more effective at higher rotating speed than lower one. Moreover, the greater the number of stationary blades the more effective the extraction process is. The highest extraction rate (491 kg /hour) was obtained at the condition of 12 blades, 200 rpm and the lowest one (257 kg /hour) was at the condition of no blades, 100 rpm. These results are consistent with those of [20].

Principally, the working mechanism of this extractor is very similar with traditional method which is both involving kneading and screening. In traditional method, kneading is done by hand. On the other hand, this extractor uses stirrer rotary blades instead of hand to knead the repos. 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 sedimentation tank. To improve the separation process, the inner surface of screener is equipped with stationary blades. These stationary blades create turbulent flows/eddy currents of repos slurry (Fig. 7c) which more effective releases starch granules compared with steady state flow. In addition, at the condition of no stationary blades, beside the starch slurry flow is almost steady state, it is also created an empty space in the centre part of cylinder (Fig. 7b). Basically, increase of stirrer blades rotating speed as well as number of stationary blades results in the amount of turbulence, consequently it increases the starch separation effectiveness. This results in an increase in the extraction rate.

It should be noticed that during the extraction operation, sufficient water is needed to practically wash/release all of the freed starch out of the pulped pith. If too little water is used, freed starch will be left in the pulp and will be lost, but if too much water is used it will be more expensive to recover the starch from it [1]. Another 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.

(a) (b) (c)

Fig. 7. Flowing pattern of material in the cylinder extractor: (a) Turbulence flowing of water, (b) steady state flowing of repos slurry, (c) Turbulence flowing of repos slurry

A mechanical sago extractor that has been developed in Serawak, Malaysia consists of an open wooden frame supporting mosquito netting in the form of a horizontal open-ended cylinder about 30 cm in diameter and 3 m long. A solid wooden shaft, with deep longitudinal ribs rotates at about 100 rpm about a horizontal axis inside the mesh cylinder. Wash water is distributed along the top of the screen, and passes through the screen into the repos being agitated inside the washer [21]. Moreover, [1] reported that in rather larger factories, rotating screens are almost always used. Six rectangular frames holding the screen are joined together along their long side to form an open ended cylinder with a hexagonal cross-section. The frame is mounted on rollers which allow it to move. The assembly is mounted at a slight slope (about 5 %) so the repos which is introduced at higher end gradually moves down to the lower outlet end. The screen rotates around its long axis at 15 to 20 rpm. The water is sprayed onto the repos from a pipe inside the cylinder. Water is also sprayed onto and through the mesh at the top of cylinder to keep the screen clean. The starch and fine pulp is washed through the screen. Rajyalakshmi [15] and [18] reported that in large scale processing of sago starch, a series of centrifugal sieves are used to remove coarse fibers, and cyclone separator are used to extract the starch which is then dried using a rotary vacuum drier followed by hot air drying.

The Indonesia Technological Research and Applications Agency (ITRAA) [25] has also developed similar sago starch extractor which consists of a stirrer tank and horizontal open-ended rotating cylinder screen about 60 cm in diameter and 600 cm in length. The cylinder screen is mounted on rollers and driven by electric motor of 2.2kW. The assembly is mounted at a slope of 15 degrees. The rasped pith is fed at the higher end and gradually moves down to the lower outlet end during the screen rotate. Water is sprayed continuously onto the rasped pith (repos) from a pipe inside the cylinder. The starch slurry and fine pulp is washed through the screen. Before the repos are fed into rotating screen, it is first stirred in a stirrer tank. The stirrer is made of stainless steel and rotates around its vertical axis at 1500 rpm. Similarly, The Indonesia Agency for Agricultural Research and Development (IAARD) [26] has developed an integrated sago starch processing machine. This machine consists of three main components i.e. rasper, extractor and sediment tank unit. The extractor unit is similar to those of [25] but smaller in size.

Compared to the sago extractor that had been developed in Serawak as reported by [1]and.[21], and the sago extractor developed by [25] and [26], the extractor developed in this study was simpler, easier to move from one location to another (portable) and cheaper. The stirring and screening processes are carried out simultaneously in the same unit. Therefore, the extractor's overall construction is simpler and smaller in size. The former are suitable for medium and large scale extraction of sago starch, while the latter is more suitable for small scale one. Furthermore, this extractor is very easy to operate and can be owned by single farmer or a group of farmers.

B. Starch Percentage and Starch Yield

Fig. 8 shows the relationship between stirrer blades rotating speed and starch percentage at four different numbers of stationary blades, and the relationship between stirrer blades rotating speed and starch yield is shown in Fig. 9.

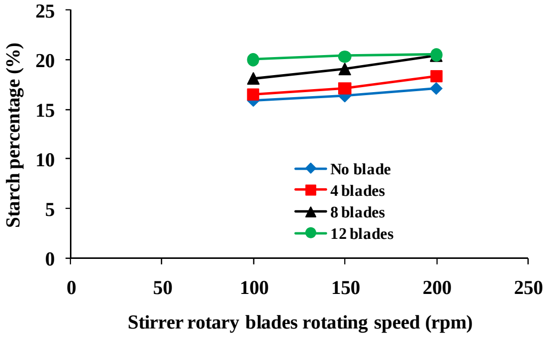


Fig. 8 Relationship between stirrer blades rotating speed and starch percentage

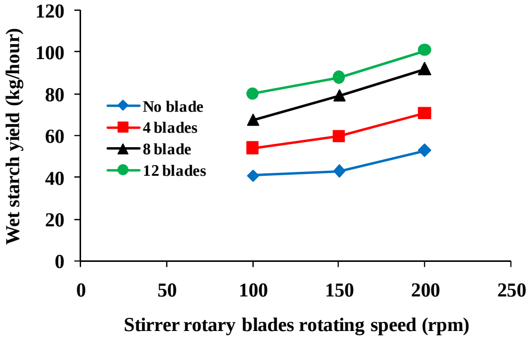


Fig. 9 Relationship between stirrer blades rotating speed and starch yield

Figure 8 shows that for the three different number of stationary blade (no blade, 4 blades, and 8 blades) starch percentage slightly increased with the increase of stirrer blades rotating speed. The higher the rotating speeds of stirrer blades the higher the starch percentage resulted. Meanwhile, for the condition of 12 blades, increases rotating speed of stirrer blades results in almost the same starch percentage for the three rotating speed. In general, an increased rotating speed of stirrer blades as well as an increased number of stationary blades results in a higher starch percentage. Therefore, the highest starch percentage (20.54 %) resulted from the condition of 12 blades, 200 rpm while the lowest one (15.9 %) was at the condition of no blade, 100 rpm. Based on the starch that left in *hampas* which varied from 0 % to 2 %, this indicates that more than 98 percent of freed/loosen starch was recovered. These results support the previous study [20] who tested the similar type of sago extractor. [17] had used two new techniques (laboratory-scale) to extract starch from sago pith and found that the starch percentage were respectively 13 % and 26 %.

Starch yield depends on both extraction rate and starch percentage. As shown in Fig. 9, the higher the stirrer blades rotating speed the higher the starch yield. Also the greater number of stationary blades the higher the starch yield resulted. These results indicate that higher rotating speed of stirrer blades as well as greater number of stationary blades the more effective the extraction process. As a result, higher starch yield was resulted at the condition of higher rotating speed of stirrer blades as well as greater numbers of stationary blades. The highest starch yield (101 kg/hour) resulted in the condition of 12 blades; 200 rpm while the lowest one (41 kg/hour) was at no blade, 100 rpm. The highest starch yield that resulted in this study was higher compared to the previous study [20] which resulted in starch yields of 33 kg/hour. This higher starch yield is due to the higher rate of starch extraction as a result of using a better screener system (not only at the bottom of the cylinder but also in the whole circumference of inner cylinder extractor). According to [1] starch yield depends greatly on the sophistication of the method employed. Recently, there have been extensive studies on starch extraction and many are focusing on improving and increasing the efficiency, and subsequently the starch yield [17].

C. Starch Left in Sago Pith Waste (loss in hampas)

The relationship between stirrer blades rotating speed and starch left in *hampas* at four different numbers of stationary blades is shown in Fig. 10.

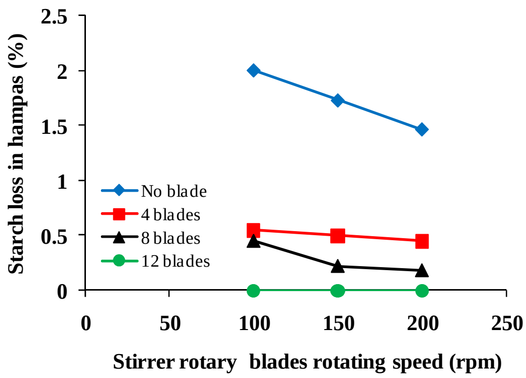


Fig. 10 Relationship between stirrer blades rotating speed and starch left in *hampas*

More starch left in *hampas* indicates that the extraction process is less effective. As shown in Fig. 10, for the three different numbers of stationary blades (no blades, 4 blades, and 8 blades), the starch left in *hampas* decrease with the increases of stirrer blades rotating speed. Meanwhile, for the condition of 12 blades, increases rotating speed of stirrer blades results the same amount of starch left in *hampas* i.e. 0 %. This is means that at the condition of 12 blades, practically 100 % of the freed starch is extracted in the extraction process. Therefore, no starch at all remains in *hampas*. In general, increased rotating speed of stirrer blade as well as increased number of stationary blades results a lower starch left in *hampas*. The highest amount of starch left in *hampas* (2 %) resulted from the condition of no blades, 100 rpm. This implies that the greater the number of stationary blades, the more effective the extraction process and vice versa. These results are consistent with those of [20]. It should be mentioned that in this study only the freed starch left in hampas was measured. Therefore, it does not mean that there is no starch at all left in *hampas*. Unfreed starch remains either trapped within the parenchyma cells or the sago fibres. This is because that not all of the cell walls were ruptured in the preceding process (rasping process). In the extraction process only freed starch can be extracted while the unfreed starch still remains in *hampas*.

The amount of starch loss in *hampas* that resulted in this study was lower than those of [26], which resulted in a starch loss in *hampas* of 2.4 % - 3.2 %. In similar study, [1] and [21] reported that the amount of starch losses in *hampas* at several sago starch factories in Serawak, Malaysia varied from 19.5 % to 29.4 %. This difference may be due to the different techniques that have been used to disintegrate the pith (different characteristics of sago pith rasper). [23] reported that the amount of starch disposed as sago residue in East Malaysia alone accounts for nearly 50 % of the total Malaysian imports of starch per year, which totals approximately 40,000 tons. It is well known that the efficiency of starch extraction depends largely on the degree and mode in which cell walls were ruptured. The more finely the pith is rasped, the more starch can be extracted in the subsequence rinsing process but more difficult to separate the starch from the hampas [1], [24].

IV. Conclusions

In this study, sago starch extractor with stirrer rotary blades was developed and the performance of the extractor was tested. Overall, all parts of the developed sago starch extractor work and function properly and has higher performance compared to previous ones. In the extraction experiment, three levels of stirrer blade rotating speed (i.e. 100 rpm, 150 rpm, and 200 rpm), and four levels of stationary blade number (i.e. no blade, 4 blades, 8 blades, and 12 blades) were tested. From this experiment the following can be concluded:

Extraction rate increased with the increase of both stirrer rotary blades rotating speed and the number of stationary blades. The higher the stirrer blades rotating speed the higher the extraction rate. Also, the greater the number of stationary blades the higher the extraction rate. The highest extraction rate (491 kg /hour) was found at the condition of 12 blades, 200 rpm, while the lowest one (257 kg of repos/hour) was at no blade, 100 rpm.

Starch percentage and starch yield increased with the increase of both stirrer rotary blade and number of stationary blades. The higher the stirrer blades rotating speed the higher the starch percentage and starch yield. Likewise, the greater the number of stationary blade the higher the starch percentage and starch yield. The highest starch percentage (20.54 %) and the highest starch yield (101 kg/hour) were resulted in the condition of 12 blades, 200 rpm.

The amount of freed starch left in pith waste (starch loss in *hampas*) decreased with the increase of stirrer rotary blades rotating speed as well as increase of number of stationary blades. The higher the stirrer blades rotating speed the lower the starch left in *hampas*. At the condition of 12 blades, 200 rpm practically no freed starch at all (0 %) was left in *hampas*.

Based on the results obtained in this study and using the equipment designed for this study, the best condition of extracting sago starch was 12 blades, 200 rpm in which resulted highest extraction rate, starch percentage, starch yield, and resulted the lowest starch left in *hampas*.

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