Chapter 17

Improvement of Sago Processing Machinery

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Abstract The traditional method of sago starch extraction is a time- and labor-intensive process. The most laborious stage is pith disintegration which is done by using a hammer-like tool called a pounder followed by washing and screening the starch. However, the use of mechanical processing equipment is saving time and energy. Consequently, sago starch production increased, both in quantity and quality. With regard to the mechanical processing, it is necessary to provide mechanical equipment which is suitable and easy to use by ordinary farmers. This paper provides an overview of improvement of small-scale sago processing machinery in order to improve the performance. It consists of two separate operation units, namely, the cylinder-type sago rasping machine and the stirrer blade-type sago starch extractor. The performance of the improved sago rasping machine is characterized by (a) rasping capacity 730–1009 kg/h, (b) starch percentage 47.2%, and (c) starch loss in sago pith waste of only 4%. Meanwhile, the performance of improved sago extraction machine is (a) extraction capacity 1007 kg of rasped pith per hour, (b) starch percentage was 24%, and (c) starch loss in waste is 2.1%. The machines are intended for small-scale (household) processing of sago and are suitable for adoption in most sago-producing areas, such as those in Papua and Papua New Guinea.

17.1 Introduction

Indonesia has the largest potential of sago in the world, but the sago starch production and utilization are very small compared with its potential. According to Samad (2002), the utilization of sago palm resources in Indonesia is only about 0.1% of its total potential. Matanubun and Maturbongs (2006) stated that utilization of sago resources in West Papua, which has over 95% of Indonesia's sago palms, represents less than 5% of its existing potential. Up to the present time, farmers in this region cut sago palms and process starch mainly for subsistence use and to sell starch locally, but they exploit only a very small amount compared with its potential. Consequently, a large number of mature sago palm go unharvested and are lost

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every year. Meanwhile the current demand for sago starch, both for local and global markets, continues to increase. There has been no significant increase in sago starch production in West Papua. Unlike in Sarawak, Malaysia, even though the sago potential is small, it was the world's largest exporter of sago starch with total exports of 44,700 mt in 2007 (Karim et al. 2008; Singhal et al. 2008; Bujang 2011). The sago industry in Malaysia (State of Sarawak) is well established and has become one of the important industries contributing to export revenue (Karim et al. 2008).

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

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

Mechanization in agriculture plays an important role because of its contribution in improving efficiency and productivity of agricultural resources. The application of technology in the form of appropriate machinery and equipment (appropriate technology) to the farmers in developing countries, such as Indonesia, is suitable to be applied. The characteristics of the technology should be simple, low in cost, small in scale, and labor-intensive. In addition, a region should have developed for it mechanical equipment suited to local conditions; consequently its application should not encounter any constraints. The application of mechanical equipment in some areas should pay attention to the various sociocultural aspects of the local community; otherwise mechanization will be unsuccessful. For instance, Sembiring et al. (1998) stated that the failure of agricultural mechanization in Sri Lanka was

due to the application of imported agricultural machinery directly, unlike the Japanese who make modifications according to local conditions and then produce their own for use by their farmers. The sago processing equipment/machines to be improved and discussed in this paper are intended for small-scale (household) processing of sago starch because it was considered suitable for application in most sago-producing areas such as in Papua and Papua New Guinea. The mechanization consists of two separate operational units, cylinder-type sago rasper and a stirrer blade-type sago starch extractor.

17.2 Sago Processing

The main edible food product obtained from sago palm is starch, which is stored in large quantities in its trunk as a prelude to flowering. The objective of sago processing is to extract starch from the sago logs. Sago palm is reported to be one of the cheapest and most readily available sources of food starch, with the highest productivity per land area among other starch crops (Bintoro 2011). There are several ways to extract the starch from the sago pith, but the principles and methods are similar. Traditionally, the starch extraction is performed manually by individual farmers or at domestic-scale sago processing plants. In contrast, modern processing is fully mechanized, has a relatively short processing time, and is more hygienic, as compared to traditional processing (Karim et al. 2008; Singhal et al. 2008). Principally, manual or traditional starch extraction is similar to the modern one, differing only in the scale of operation and the equipment used. In general, ready-to-harvest palms are selected and felled. The bark-like layer is stripped from the trunk, and it is cut into sections or floated whole to a central processing facility. There, it is, if necessary, cut into sections and reduced to battens and rasped either manually or mechanically to pulverize the pith and loosen starch particles within the fiber. The starch is removed from the fiber by kneading by hand or trampling by foot using water or by a spray of water. Starch-laden water or starch in suspension runs into a settling container, where the starch is precipitated out and the water overflows. The starch is then removed and dried.

17.2.1 *Traditional Method of Sago Processing*

In most of the main sago areas throughout Southeast Asia and New Guinea, starch is extracted using the traditional method. This method is still commonly used in Papua New Guinea (Greenhill 2006), West Papua (Darma and Istalaksana 2011; Darma and Sarunggallo 2010, Darma and Kito 2014a, b), the Molucca Islands (Rumalutur 1992; Girsang 2014), and Seram (Ellen 2004). The traditional method is very labor-intensive and time-consuming, usually involving the cooperation of a small group of people or a family.

Traditional sago starch processing involves cutting the trunk with an ax, and then the bark is either stripped back or split into two sections to expose the pith of the palm. In some locations, chainsaws are now used for cutting the trunk. The pith is disintegrated or pulverized using a pounder, an adze-like tool. Close human contact with pulverized/chopped pith is common during this stage of the process. The pulverized pith is then collected and carried manually to the extraction site. Starch is extracted from the pulverized pith by pouring water over it and kneading it in a trough made of the large sheath base of the sago leaves. The mixture of pulverized pith and water is then forced or pressed through a filter made of fine cloth. The suspended starch passing through the filter is collected into a larger trough, also made of sheath base of the sago leaf, where the starch separates out through sedimentation. It is then ready for packing into a container, also made of sago leaves sheaths.

The traditional method of extraction of sago starch can be classified into two levels: domestic and small-scale processing plant levels (Karim et al. 2008). The domestic level is practiced by individual farmers, where sago palms are felled and processed in the garden, without the need to transport the heavy trunks. After felling the trunk with an ax, it is split lengthwise. The pith is pulverized by means of a chopper or pounder. The pulverized mixture of fiber and pith is placed at the wide end of a leaf sheath of the sago palm, where a sieve is positioned at its lowest end. Water is added to the mixture and then the mixture is kneaded by hand. The fibers are trapped by the sieve, while the water carrying the starch granules in suspension passes through the sieve and collects in an old dugout canoe or any suitable container. The starch settles on the bottom, while the excess water flows over the sides. After kneading, the fibrous remnants are discarded, and the wet starch is removed from the canoe/container (Ruddle et al. 1978; Flach 1983, 1997).

In a small-scale processing plant, sago trunks are cut into shorter lengths of 1–1.2 m and tied into rafts and transported by flotation to the plant via rivers or man-made canals. Rasping is done using a board with nails in it. Some processors use engine-powered rasps with which the pith is dug out of the split trunk and then rasped. The rasped pith is trampled by foot on a platform. In some operations, a rotating mesh washer made of metal, wood, or screen washers is used to separate the starch and coarse fiber. The starch slurry is channeled to a small settling pond made of boards. Finally, wet starch is mostly dried in the sun (Ruddle et al. 1978; Cecil et al. 1982; Karim et al. 2008). Some small cottage mills produce only *lamentak* (wet processed sago starch) or second-grade-quality flour, which is sun-dried and unsieved wet sago starch.

17.2.2 Mechanical Method of Sago Processing

Malaysia, Indonesia, and Papua New Guinea are the main world producers where sago is a commercial palm for the production of starch and/or conversion to animal feed or to ethanol. Indonesia has the largest forest stands of wild sago palms, in which some factories have been established in Halmahera Island and in West Papua

Province to process sago starch and by-products. However, at present, Malaysia is the world's largest sago starch exporter. The most extensive sago-growing areas in Malaysia are outside the Peninsula, in Sarawak, which is the leading exporter of sago starch, annually exporting about 25,000–40,000 mt of sago products to Peninsular Malaysia, Japan, Taiwan, Singapore, and other countries (Bujang and Ahmad 2000; Singhal et al. 2008).

Currently, there are eight sago factories operating in Sarawak, seven of them in the Mukah-Dalat areas and one in the Igan-Sibu area (Manan et al. 2001). Modern methods of extraction involve some modifications from that of the small processing plant. New technologies for extracting starch are being adopted by the large-scale factories. These factories are fully mechanized; that level of technology is mostly found in Sarawak (Karim et al. 2008; Bujang 2011).

The commercial process is either partially (semi-mechanized) or fully mechanized, involving a sequence as presented in Fig. 17.1. Palm logs are rafted to the mill or factory and stored in the river to reduce deterioration. In the mill yard, the bark-like layer is stripped from each log with an ax or bush knife, and the logs are split into six to eight battens which are then rasped by a diesel-powered, homemade rasping wheel which rotates at high speed. The wheel is mounted on a platform to permit the rasped pith to drop into one end of a cylindrical washing reel that rotates on a central shaft. A perforated water pipe sprays water into the body of the reel and flushes the rasped pith as it is passed along the inside by perpendicular splines arranged in a spiral pattern along the central shaft of the reel. This loosens starch grains from the stem fiber and washes them out in suspension. Waste fibers drop from the lower end of the washing cylinder. Starch-laden water then flows through

Fig. 17.1 Flow diagram of modern sago starch processing

the coarse wire screen that encases the reel and is led off by a conduit through a coarse sieve which removes most of the fiber prior to sedimentation in cement tanks or wooden troughs. The starch may be separated using cyclone separators and dried on a rotary vacuum drum drier, followed by hot-air drying. When dry, it is known as *chong hoon*. The mill extracts wet starch mechanically and produces three grades of dry starch, from low to high, known as *chong hoon*, *thai hoon*, and *siong hoon*. To produce *thai hoon*, the middle grade, it is sieved after drying. Crude dry starch can be rewashed, dried again, and then sieved to produce the highest grade of starch, *siong hoon* (Singhal et al. 2008).

In some factories, the 30-cm-long log sections from the storage pond are first split lengthwise into about eight segments. These segments are fed into slicers that cut the pith from the bark. In certain other factories, the bark is first removed from sections of the logs. Each of the debarked sections, about 80–100 cm long, is fed into the mechanical rasper (with chrome nails mounted on one face of a disc or a drum). This rasps the pith into finer pieces, which are fed into the hammer mill via a conveyor belt. The resulting starch slurry is passed through a series of centrifugal sieves to separate the coarse fibers. Further purification is achieved by separation in a nozzle separator through sieve bends. A series of cyclone separators have also been used to obtain very pure starch. Dewatering of starch is carried out using a rotary vacuum drum dryer followed by hot-air drying (Singhal et al. 2008; Manan 2011).

17.3 Small-Scale Sago Processing Machine Improvement

17.3.1 Cylinder-Type Sago Rasping Machine Improvement

Rasping is the most frequently useful method to disintegrate or to break down the cellular structure of sago pith for mechanical processing. Sago palms produce starch inside pith cells. In the sago starch processing under traditional or mechanical methods, washing is the only method that is used to extract or to separate out the starch. Unless a cell is ruptured in some way, the starch cannot be washed. Therefore, the efficiency of subsequent processes (starch extraction) depends on the proportion of the starch cells that are ruptured. The amount of starch obtained depends on how fine the level of rasping is and the efficiency of starch washed out from the rasped pulp. The more finely the pith is rasped, the more starch can be extracted in the subsequent rinsing process. In other words, in order to free as much starch as possible, the pith must be disintegrated as fine as possible. However, the rinsing process becomes more complicated in separating the starch from the pith residue (*hampas*) (Colon and Annokke 1984; Cecil 1992).

A small increase in starch yield (perhaps 3–5%) can be obtained with secondary rasping, but this is not practical in small operations. Further rasping gives little fur-

ther increase in yield and makes separation of the starch and fiber very difficult. In addition, in large factories, hammer mills are used (Cecil 1992).

As previously mentioned, rasping is aimed at disintegrating or breaking down the cellular structure of the pith. There are other terms commonly used synonymously with pith disintegration such as *pith macerating* (Greenhill 2006) and *pith pulverizing* (Ellen 2004). Meanwhile, rasping is synonymous with grating. By doing so, the starch granules which exist in the cells are freed or loosened and thus suspended in the water during the extraction process.

Rasping is the third step in sago starch processing after the trunk is felled and debarked. Once the bark is removed, the pith is split into pieces up to 10 cm square called batons or billets. The pieces are fed onto the rasper end-on direction, the correct direction for optimal rasping (Cecil 1992). Whatever type of rasper is used, it is important not to press the pith too forcefully onto the rasping surface, as this will seriously reduce the efficiency of the rasper. In extreme cases, it could overload the motor or the engine. Furthermore, forcing material onto the rasper will result in coarser *repos* (rasped pith), fewer cells will be ruptured, and as a result more starch will be lost in the sago pith waste.

There are two types of raspers commonly used in sago starch processing: cylindrical and disc raspers. The functional component of a cylindrical rasper is a rotating cylinder/drum with an abrasive surface, while the disc rasper is a rotating disc with an abrasive surface. Because of its high rotational speed in the rasping process, it can cause a very nasty wound; thus for safety the raspers must be enclosed so that operator cannot be injured. The pith should be fed through an opening that should be the entire width of the rasper, but it should be made difficult for anyone to injure a hand or foot, either accidentally or in trying to push the pith into the cylinder or disc. Lumps of unrasped pith will always find their way through gaps between the rotating cylinder/disc and the housing. It is therefore important that these gaps should be kept as narrow as possible.

There are some different types of rasping surfaces for both cylindrical and disc raspers. The simplest form is made from a sheet of metal perforated with nails, which has been wrapped around a wooden cylinder or fastened on a wooden disc. It is very easy to make, and nothing more than a nail and sheet of tin plate is needed for a new rasping surface, but they are inefficient. They only process a small quantity per hour and do not last very long.

Another type of rasper that is widely used and can be made locally is the nail rasper. There are various designs. Nails are held in a wooden or metal cylinder. The more nails there are, the better the rasper will work, but it is impractical to set them closer than 5 mm apart (Cecil 1992). The nails must be embedded in the cylinder so that they do not fly out under the considerable centrifugal force that is produced by the high-speed rotation. This type of rasper, even one with a wooden cylinder, will last a long time if it is properly made. As the nails get worn down, the wood also wears down, often at about the same rate. Every effort should be made to use the full width of the cylinder so that wear is even along its entire length.

A better nail rasper is a modification of a design widely used in larger factories. Two curved plates are made from 4-mm steel plate, each covering half the circum-

ference of a steel or wooden cylinder 25 cm in diameter and 30 cm in length. Holes just large enough for the shafts of 15-mm-long nails (preferably masonry nails) are drilled in the plates on a slightly skewed square pattern; thus the nails which protrude through the plate do not exactly follow one another as the cylinder rotates. The nails are put in from the inner side and cannot go through the plate because their heads are too large to pass through the holes in the plate. The curved plates are bolted to the outside of the cylinder, which holds the nails securely in place. This rasper can be driven at 1500 rpm (Cecil 1992).

The best type of rasper is the Jahn rasper, but these are too expensive for small-scale operation. It consists of a rotating cylinder on which replaceable serrated flat blades, similar to saw blades, are mounted. The individual blades are made of steel about 1 mm thick and are available in different lengths such as 10, 20, and 30 cm. They are about 2 cm wide with teeth along each long side. The saw teeth may be 2–3 mm deep with the tips 1.5–2.5 mm apart. The blades are mounted in the plane of the axis of the cylinder. The length of the blade is parallel to the axis, and the length of the working part of the cylinder is thus the same as the length of the blades. The blades are separated by wooden or metal blocks so that they are parallel and about 10 mm apart. The blocks are cut so that the teeth protrude from the surface of the blocks by 2–3 mm. The blocks have to be narrower on the inside (nearer the center of the drum) than on the outside. A 30-cm-diameter cylinder having a circumference of about 100 cm will need between 70 and 100 blades, depending on the thickness of the wooden blocks. End plates with strong lips are necessary to hold the locks and saw blades against the strong centrifugal forces that occur in the high-speed rotating cylinder.

When the cylinder rotates, the saw teeth are dragged sideways through any material held against them. A 30-cm-diameter cylinder can be driven at 1500 rpm, and a 50-cm-diameter cylinder can be driven at 1200 rpm (Cecil 1992). Modern imported rasping machines can be driven considerably faster, depending on the manufacturer's specifications. The manufacturers claim that the high speed makes them substantially more efficient, but maximum efficiency is accompanied by problems in starch separation.

In addition to the various sago rasping machines (sago rasper/grater) mentioned, another cylinder-type sago rasping machine, recently used widely for small-scale operations in West Papua Province, Indonesia, is similar to the nail rasper (Fig. 17.2). The processing system of this rasper is a hard wooden cylinder 15 cm in diameter and 20 cm in length. The teeth are made of stainless steel rods 4 mm in diameter and 2 cm in height. This rasping machine is driven by a gasoline engine, 5.5 hp (4.103 kW) at 3000 rpm (Darma and Reniana 2009; Darma and Worabai 2010). The performance of the rasper is (a) rasping capacity 500–700 kg/h, (b) starch percentage 46%, and (c) starch loss in waste/hampas 4.6%.

The most recently improved sago rasping machine is similar to the previous one, differing only in the power source and the characteristics of the cylinder. Unlike the previous prototype, the improved one is driven by a more powerful 6.5-hp gasoline

Fig. 17.2 Overall structure of cylinder-type sago rasping machine. (1) Cylinder cover, (2) rasping cylinder, (3) input hopper, (4) main frame, (5) gasoline engine, (6) cylinder pulley/driven, (7) V-belt, (8) engine pulley/driver, (9) output hopper

engine. Meanwhile, the cylinder is made of stainless steel covered with pointed teeth.

The rasper consists of four main components: (a) a rotating rasping cylinder covered with pointed teeth on its circumference surface enclosed in a housing made of plat 2-mm-thick stainless steel plate. The size of the cylinder is 16.8 cm in diameter and 22 cm in length. (b) A four-stroke gasoline engine (6.5 hp, maximum shaft rotation 3600 rpm) as power driver. (c) Power is transmitted by a pulley and V-belt. (d) The main frame is made of 5×0.5 -cm equal angle steel bar. In addition, it is equipped with a cylinder cover and feeding component both made of plat steel, 2 mm in thickness. The overall structure of the improved sago rasper is shown in Fig. 17.3.

The performance of the rasper is (a) rasping capacity 730–1009 kg/h, (b) starch percentage 47.2%, and (c) starch loss in waste/hampas 4%.

17.3.2 Stirrer Rotary Blade Sago Starch Extraction Machine Improvement

To free the sago starch, pith must be disintegrated or pulverized, mostly using a rasper. It is well known that the more completely the pith is disintegrated, the higher the yield of starch. On the other hand, at a high degree of disintegration, fiber also is disintegrated to an appreciable extent which gives rise to trouble in subsequent fiber-starch separation (starch extraction) (Colon and Annokke 1984; Cecil 1992). After rasping, starch and fiber are in a free state and are able to be separated in the extraction process.

Fig. 17.3 Overall structure of improved cylinder-type sago rasping machine

The objective of the extraction process is to remove the maximum amount possible of fiber from the starch and to obtain the maximum amount of starch. The efficiency of the extraction depends on how carefully the operation is managed.

Up to the present time, the only way to separate starch from the fiber (starch extraction) is by using water. The freed starch which is contained in the rasped pith (*repos*) is washed out using an abundant amount 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.

Screening is the main operation in starch separation. Its purpose is to separate starch from fiber and other constituents. The fractions are separated by size by washing the rasped pith on a screen or a series of screens. Screening is often done in two stages, a coarse screening operation to remove most of the fiber and to thoroughly wash the starch out of it and a fine screening operation to separate the fine fiber from the starch. Soluble materials such as sugars, some of the protein, and many of the other constituents are dissolved and pass through the screen along with the fine insoluble materials (starch granules and fine fiber) (Cecil 1992).

An effective screening operation should wash as much starch as possible through the screen using as little water as possible. A screen with large apertures will have a high capacity, but it will allow the passage of too much oversized material. On the other hand, a screen with small apertures will give a better result, but its capacity will be less. The use of a screen with apertures of mixed sizes gives the worst result. In this case, the largest apertures will largely determine the quality of what passes through, but the smaller apertures may contribute to the capacity of the screen. It is best if all apertures are the same size. Fine cloth is commonly used as screening material in the traditional method of starch extraction, and sometimes it is made from the fibrous leaf sheath of either the coconut or sago palm.

Another important physical aspect of a screen is the total open area of the holes. Both solids and liquids can only pass between the strands; thus the more bulky the

strands are, the less open area there can be for the product to pass through. Natural fibers are relatively short, and in order to make a long strong thread, they have to be twisted together in a bundle. This makes the strands comparatively bulky, and there are always loose hairs that restrict the passage of particles through nearby apertures. Synthetics can be made in strong single strands which are fine and smooth and cause the least possible restriction to the passage of starch and water. It is also much easier to keep synthetic cloth clean than it is natural fibers. The screens work best if the cloth is tight. Synthetic cloth expands when it is wet; thus before putting it on the screen frames, the cloth should be soaked in water.

The choice of screening technology to be used in a starch processing plant depends on a number of factors, including availability of water and labor and settling tanks. At the present time, there are two suitable designs for the screening operation: a rotating screen and a flat vibrating (shaking) screen. A rotating screen is much more expensive and more difficult to install, but it is much easier to operate once installed. In a small-scale operation, a coarse mesh flat screen is recommended (Cecil 1992).

In addition to the rotating and shaking screens, Darma and Gani (2010), Darma and Kito (2014b) developed a new type of sago starch separation called a *stirrer rotary blade sago starch extractor*. It consists of a cylinder with a screen at the bottom of the cylinder. To release the starch granules from the fiber, the pulp is stirred vigorously using a stirrer blade. Unlike the rotating screening in which the screen is rotated as it operates, the screen of this extractor is neither rotating nor shaking. It is mounted and fixed at the bottom of the cylinder.

In principle, this extractor is similar to the traditional one, but instead of using either hands or feet to knead or trample the pulp, it is kneaded mechanically using a stirrer. After pith disintegration, which aims to break down the cellular structure and rupture the cell walls, the fiber and starch existing in the *repos* have not yet been separated. The function of this extractor is to separate starch from fiber (pith waste). In doing so, 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 kneading 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.

Overall, this sago starch extractor consists of several main components which are integrated into a single operating system (Fig. 17.4). The extractor has the following features:

1. Extraction cylinder, made of 2-mm-thick steel. The cylinder is 74 cm in diameter and 120 cm in height (volume = 0544 m³). The lower end of the cylinder has a conical shape to prevent starch sedimentation in the bottom of cylinder.

Fig. 17.4 Overall structure of stirrer rotary blade sago starch extraction machine

2. A screen, made of perforated stainless steel sheet with a hole size of 1.5 mm in diameter. The screen diameter is slightly smaller than the extraction cylinder into which it is placed.
3. Stationary blades are made of 5-mm-thick L-shape 50 × 50-mm steel bar. These are mounted vertically on the inner surface of cylinder.
4. The stirrer rotary blades are suspended in water and function to free starch granules from the fiber.
5. The power transmission system consists of a V-belt, pulley, and reduction gear box (WPX 80, ratio 10:1).
6. The power source is a 6.5-hp gasoline engine.
7. The frame is made of 5 × 0.5-cm equal angle steel bar. In addition, it is equipped with a pipe (5 cm in diameter) to carry the starch suspension from the extraction cylinder to the sedimentation tank. The end of the pipe is fitted with a stop tap (valve) to control starch suspension flow. Moreover, because some fine fiber also passes through the screen along with the starch, further screening is necessary to remove the fine fiber. For these purposes, a second screen made of fine cloth is used, and it is placed at the end of flowing pipe. Starch suspension from the extraction cylinder is passed through this second screen before flowing into the sedimentation tank.

The performance of the extractor is (a) extraction capacity 185–211 kg of rasped pith per hour, (b) starch percentage 28–32%, and (c) starch loss in waste 2.75–4.56%.

Recently, a new variant of the extractor was introduced by Darma and Kito (2014b). Overall, its components and construction are similar to the previous one, except for the screening system used. Unlike with the previous prototype in which the screen was mounted and fixed at the bottom of cylinder, an open-ended cylinder with a circular cross section is employed.

Fig. 17.5 Overall structure of improved stirrer rotary blade sago starch extraction machine

Similar to the previous prototype, this sago starch extractor consists of seven main components which are integrated into a single operational system (Fig. 17.5). They are:

1. Extraction cylinder, made of 2-mm-thick steel. The cylinder is 103 cm in diameter and 100 cm in height (volume = 0785 m³). The lower end of the cylinder has a conical shape to prevent starch sedimentation in the bottom of cylinder.
2. A screen, made of perforated stainless steel sheet with a hole size of 0.7 mm in diameter. The screen diameter is slightly smaller (92 cm in diameter) than the extraction cylinder, and it is placed inside the extraction cylinder.
3. Stationary blades are made of 5-mm-thick L-shape 50 × 50-mm steel bar. They are mounted vertically on the inner surface of screen.
4. Stirrer rotary blades function to free starch granule from fiber and are suspended in water.
5. The power transmission system consists of a V-belt, pulley, and reduction gear box (WPX 80, ratio 10:1).
6. The power source is a 6.5-hp gasoline engine.
7. The frame is made of 5 × 0.5-cm equal angle steel bar. In addition, it is equipped with a pipe (5 cm in diameter) to carry the starch suspension from the extraction cylinder to the sedimentation tank. The end of the pipe is equipped with a stop tap (valve) to control starch suspension flow. In addition, because some fine fibers also pass through the screen along with starch and water, further screening is necessary to remove the fine fiber. For this purpose, a second stage screen, of 100 mesh stainless steel strainers, is used, and it is placed at the end of flowing pipe.

The performance of this extractor is much higher compared to the previous prototype, i.e., (a) extraction capacity 1007 kg of rasped pith per hour, (b) starch percentage 24%, and (c) starch loss in waste 2.1%.

17.4 Conclusion

The improved sago processing machinery which consists of two separate operational units, namely, the cylinder-type sago rasping machine and the stirrer blade-type sago starch extraction machine, working properly gives high performance. The performance of the improved sago rasping machine is (a) rasping capacity 730–1009 kg per hour, (b) starch percentage 47.2%, and (c) starch loss in waste 4%. Meanwhile, the performance of improved sago extraction machine is (a) extraction capacity 1007 kg of rasped pith per hour, (b) starch percentage 24%, and (c) starch loss in waste 2.1%. The machines are intended for small-scale (household) processing of sago and are suitable for adoption in most sago-producing areas, such as those in Papua and Papua New Guinea.

References

- Bintoro MH (2011) Progress of sago research in Indonesia. In: Proc 10th int sago symposium: sago for food security, bio-energy, and industry from research to market. Bogor, p 16–34
- Bujang KB (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. Bogor, p 36–41. Oct. 29–31
- Bujang KB, Ahmad FB (2000) Country report of Malaysia: production and utilization of sago starch in Malaysia. In: Proceedings of the international sago seminar. IPB, Bogor, p 1–8
- Cecil JE (1992) Small-, medium-and large-scale starch processing, vol 98. FAO Agric Serv Bull, Rome
- Cecil JE, Lau G, Heng H, Ku CK (1982) The sago starch industry; a technical profile, based on a preliminary study made in Sarawak. Tropical Product Institute, London
- Colan FJ, Annokke GJ (1984) Survey of some processing route of sago. In: Proc. the expert consultation of the sago palm and palm products. Jakarta. January 16–21
- Darma R (2009) Prototype of cylinder type sago rasper powered by 5.5 hp gasoline engine. Agrotek J 1(6):49–56
- Darma WT (2010) Variant-1 of cylinder type sago rasper powered by 5.5 hp gasoline engine. Agrotek J 2(3):82–90
- Darma IP, Gani A (2010) Prototype of stirrer rotary blades type sago starch extractor. Agritech J 30(4):204–211
- Darma, Istalaksana P (2011) Traditional processing of sago in Papua Province. In: Proceedings 10th international sago symposium: sago for food security, bioenergy, and industry from research to market. Bogor, p 115–116. 29–31 October
- Darma WX, Kito K (2014a) Development of cylinder type sago rasper for improving rasping performance. Int Agric Eng J 23(3):31–40
- Darma WX, Kito K (2014b) Development of sago starch extractor with stirrer rotary blade for improving extraction performance. Int Agric Eng J 6(5):2472–2481
- Darma IP, Sarunggallo ZL (2010) Starch content and production potency of natural sago palm (*Metroxylon sagu* Rottb). Agrotek J 2(2):7–14
- Ellen R (2004) Processing *Metroxylon sagu* Rottboel (Arecaceae) as a technological complex: a case study from South Central Seram, Indonesia. Econ Bot 58(4):601–625
- Flach M (1983) The sago palm, domestication and product. FAO, Rome
- Flach M (1997) Sago palm. *Metroxylon sagu* Rottb. International Plant Genetic Resources Institute, Rome

- Girsang W (2014) Socio-economic factors that have influenced the decline of sago consumption in rural Maluku, Indonesia. *S Pac Stud* 34(2):99–116
- Greenhill AR (2006) Food safety and security of sago starch in Rural Papua New Guinea. James Cook University, Townsville
- Kamal SMM, Mahmud SN, Hussain SA, Ahmadun FR (2007) Improvement on sago flour processing. *Int Eng Tech* 4(1):8–14
- Karim AA, Tie PL, 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. *Comp Rev Food Sci Food Safe* 7(3):215–228
- Manan DMA (2011) Optimization of sago starch extraction using drum rasper in Proc. 10th int sago symposium: sago for food security, bio-energy, and industry from research to market. Bogor, p 93–95
- Manan DMA, Islam MN, Noor BM (2001) Enzymatic extraction of native starch from sago (*Metroxylon sagu*) waste residue. *Starch* 53(12):639–643
- Matanubun H, Maturbongs L (2006) Sago palm potential, biodiversity and socio-cultural consideration for industrial sago development in Papua, Indonesia. In: Proc. 8th Int. sago symposium: sago palm development and utilization. Jayapura, p 41–54
- Rajyalakshmi P (2004) Caryota palm sago, a potential yet underutilized natural resource for modern starch industry. *Nat Prod Rad* 3(3):144–149
- Ruddle K, Johnson D, Townsend PK, Rees JD (1978) Palm sago a tropical starch from marginal lands. University Press of Hawaii, Honolulu
- Rumalatu FJ (1992) Sago in Maluku: past, present, and future prospects. *Cakalele* 3:63–68
- Samad MY (2002) Application of semi mechanical technology to improve production of small scale sago industry. *Indon J Sci Tech* 4(5):11–17
- Sembiring EN, Radite PAS, Suastawa IN (1998) Development of agricultural mechanization in supporting self-sufficient of food. *Agric Eng J* 12(3):1–6
- Singhal RS, Kennedy JF, Gopalakrishnan SM et al (2008) Industrial production-processing, and utilization of sago palm-derived products. *Sci Direct Carbohydr Polym* 72:1–20

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