The utilization of sago waste: prospect and challenges

T H Rasyid¹, Y Kusumawaty² and S Hadi¹

¹ Research and Development Agency of Riau Province, Pekanbaru, 28156, Indonesia
² Faculty of Agriculture, University of Riau, Pekanbaru, 28293, Indonesia

Email: thrasyid@gmail.com

Abstract. The utilization of sago waste has been the subject of research which has studied aspects of sago bark, including sago wastewater effluent and fibre waste. This paper presents a review of the types of waste generated from sago processing plants, prospects and challenges of its utilization based on prior studies. During sago starch extraction, a large amount of sago tree bark would be separated, and wastewater mixed with fibre waste would be discharged daily. Therefore, it is important to train sago farmers and mill owners to manage and utilize waste. The development of sustainable management of sago requires support from all relevant stakeholders. Waste utilization should be promoted and the added value to be explained to the stakeholders to gain their interest and willingness to participate in waste processing plants. Sago waste management is recommended to focus on: (1) efforts to increase the yield and efficiency to reduce waste (2) improvement of the processing layout and mechanism to facilitate its utilization; (3) selection of appropriate drying methods to reduce the volume of liquid waste and facilitate further storage and processing; (4) the implementation of appropriate technology that can provide additional income to farmers and smallholder sago refineries.

1. Introduction
Sago palm (Metroxylon sagu Rott.) is one of the few starch-bearing palm species found in the tropics which grows on peat soils and wetlands. A high concentration of starch deposit occurs in the trunk of the palm and it has been harvested to produce starch for human consumption and industrial purposes [1].

Sago stems have the potential to produce very high production compared to other food crops. In good environmental conditions, 15-25 tons/hectare of dried sago flour can be produced, when compared to other food-producing plants. Besides being efficient in producing carbohydrates, other advantages of sago plants are: 1) economically and culturally acceptable; 2) good growth on shallow peatlands and wet mineral soils without chemical-based production inputs and 3) forming stable agroforestry [2].

Sago is one of the non-wood forest products which support food security as an important source of starch in Southeast Asia [3]. The importance of Non-Timber Forest Product (NTFP) income to total household income is apparent across many regions, particularly in rural households. NTFP products may be critical to overall subsistence and can supply a high percentage of household cash income [4].

Indonesia has the largest sago area in the world, with an area of around 1,128 million hectares or 51.3% of the 2,201 million ha of the world sago, followed by Papua New Guinea (43.3%). However, in terms of utilization, Indonesia is still far behind compared to Malaysia and Thailand, each of which only has an area of 1.5% and 0.2%. Potential sago-producing areas in Indonesia include Riau, North Sulawesi, South Sulawesi, Southeast Sulawesi, Maluku and Papua [5].
Riau Province is one of the biggest sago starch producing regions in Indonesia. Based on data from the Riau Central Bureau of Statistics in 2013, the area of sago plantations in Riau is approximately 82,713 hectares and production of 281,784 tons/year. Of the total sago production, it is assumed that there is a potential of sago leaves of 25,360,560 stalks which result in 3,606,271,623 tons of sago leaves. The largest sago plantation area in Riau Province is Kepulauan Meranti Regency. Sago plantations in Kepulauan Meranti Regency cover 45,000 ha, and around 20,000 ha have been managed semi-culturally. So far, sago leaves are used to make woven walls as a building material and the sago pulp is still left to pile up around the refinery causing environmental problems [6].

The development of sago industrialization in the Kepulauan Meranti Regency in the future is very promising. The available and untreated land is around 70,091 ha while the existing sago plant area is 53,456 ha or 43% of the existing land (123,547 ha). Sago processing in Kepulauan Meranti Regency is still running conventionally and only produces half-finished material in the form of sago starch. The production of sago starch produced by sago refineries in 2011 was 144,927 tons is increasing with an average growth of 6% per year; the production of sago starch in 2017 was 205,051 tons [7].

Processing sago tree logs into sago starch is by an extraction process using water to separate the sago starch from the fiber. Therefore, the sago industry is generally built in areas close to water sources such as on the banks of rivers or creeks, because besides requiring water for extraction, sago logs from plantations or forests are also transported to production sites using water transportation. Large scale processing of sago can cause the accumulation of the remaining sago starch in rivers which can cause pollution [8].

This article identifies the types of waste generated from sago processing plants, prospects and challenges of its utilization based on prior studies and proposes recommendations for sago waste management to support a sustainable sago industry.

2. Materials and method
This study applied secondary research method (desk research) which involves using information that others have gathered through primary research. The secondary research process consists of four steps that can be repeated if needed: (1) identifying the subject domain and related information sources; (2) collecting data; (3) comparing data from various sources if possible; and (4) analysing data.

Material used in this desk research was external secondary data which includes sources from media and prior studies related to sago waste utilization. Hence this article identifies the types of waste generated from sago processing plants, prospects and challenges of its utilization based on prior studies and proposes recommendations for sago waste management to support a sustainable sago industry.

3. Results and discussion
3.1. Potential waste
In Riau, the current utilization of sago is still focused on sago starch as its main product. The development of downstream products is still relatively limited. The side products in the form of waste from sago pulp (repu) and sago tree bark (uyung) have not been utilized optimally. The owners of sago refineries generally dispose of sago pulp waste into the river and the sago bark has not been used much.

During sago starch extraction, sago trunks are washed, debarked, rasped prior to hammer milling or pulping process. During the entire production process, a large amount of water (20 liters of wastewater per kg of sago starch production) is discharged as sago wastewater effluent being rich in carbohydrates, fibers and dense suspended solids, unextracted starch, cellulose (fibrous residue from pith), nitrogenous compounds, cyanoglucosides and insoluble fibers. These effluents, containing a high concentration of organic matter (such as protein, lipids and carbohydrates) and reported to be acidic and emitting a foul smell thus causing pollution and deteriorating the environment quality globally [9].
Sago waste is usually mixed with wastewater and either discharged into streams or deposited in factory compounds. Each ton of extracted sago starch produces and dumps approximately one tone of sago waste into the nearby rivers. Data from the Malaysian Department of Statistics reveal that the country produced approximately 52,000 tons of sago starch in 2011. Nearly the same amount of sago waste was dumped in nearby rivers, thereby causing a serious environmental pollution problem. The high demand for biological oxygen (approximately 5820 mg/L) and chemical oxygen (approximately 10,220 mg/L) in the wastewater affects marine life and water quality via microbiological degradation by consuming the dissolved oxygen in the water [10].

From the perspective of industrial starch production, sago palm pith contains approximately 26% (dry weight) in pith waste. When the starch content was measured using a rasper and comparatively determined the true starch content using chemical extraction, the pith content was found to be 37 and 77% in dry weight, respectively. This result confirms that approximately one-half volume of starch is left in the pith waste [11].

Kepulauan Meranti Regency has an area of 45,000 ha of sago plantations where around 20,000 ha are managed semi-intensively. The potential for sago plantation waste has been underutilized so far. The sago processing process produces follow-up waste in the form of bark around 17-25% and sago pulp 75-83%. Sago pulp can be used as a mixture of biogas substrate because it contains a lot of organic material, especially carbon and animal feed if processed properly. So far, the sago pulp is wasted and pollutes the aquatic environment around Kepulauan Meranti Regency which is indicated by the murky waters around the area. Based on the data from the Ministry of Industry and Trade, there are 47 sago processing plants scattered in various locations in Kepulauan Meranti. Generally, the sago factories are located on river banks and most of the sago mills do not have a waste management plan. There is a tendency for the sago mills to just dump their waste into the river. The impact is a change in parameters in the water around the waste disposal area, both in terms of color and taste. This is an early indication of the occurrence of water pollution.

Waste is produced from the bark (uyung) of sago that has been peeled and sago solid waste (pulp or repu in local language) produced from the processing of sago. So far, tens of tons of solid waste have been thrown away by the sago industry [12].

Sago bark is used as a small supplement for fuel and partly as a machine foundation or as load restraint; it is unfortunate that most of the sago bark is burned to avoid buildup [7]. There are two types of sago bark waste, i) shredded and ii) peeled type. Most of the peeled barks are from the lower part of the sago tree are peeled using parang manually because of the uneven shape. Only the thicker peripheral, approximately from 2 cm to 3 cm thick, has the potential to produce processed sago wood. On the other hand, the debarking process using machines produces the shredded bark. The length of the shredded bark is 10 cm–15 cm. Only 15% of the shredded bark produced is used as fuel for drying flour in the sago mill. In the modern process of sago starch extraction, 0.5 tons of sago bark wastes and 3 tons of ground pith wastes are produced per ton of dried flour [13].

In Malaysia, approximately 90% of the sago starch is produced from the State of Sarawak. A recent development in sago starch research results in a total of over 60,000 hectares being cultivated with sago palm. Daily sago starch production is about 24 tons or equivalent to 20 kg (15%) of starch/log. In modern sago starch extraction, 0.5 tons of sago bark waste are produced per ton of dried flour. Normally, the bark is not fully utilized for higher value-added products and, until now, there has been no clear new technology that can be adapted for alternative sago bark utilization [14].

It is estimated that 0.75 tons of sago bark waste are generated for every ton of sago flour produced, which accounts for 32,250 tons of annual sago bark waste generation [15]. Sago bark waste is normally incinerated for power generation in sago mills, dumped directly into nearby rivers or left for natural degradation outside sago mills. More than 85% of sago bark is left unutilized in sago processing mill, giving an opportunity for utilization of the waste as useful products.

Regarding sago fiber waste (hampas/repu), ela sago is the waste of sago pith after processing its starch [16]. The waste is generally dumped at the river edge. For industrial-scale processing, the waste generated each day can reach 3 to 5 tons after processing between 8-12 logs. Utilization of sago waste
has been studied such as for animal feed, mushroom cultivation planting medium, and raw material for organic fertilizer (compost).

Some factories in Malaysia have started to burn these sago residues after realizing the negative effects of discharging these wastes into nearby streams. However, the combustion of sago can contribute to air pollution and wastage, considering the reuse potential of sago waste. Before reusing these materials, the moisture content of sago waste must be reduced by drying [10]. Drying is a well-known method that is used in many industries, such as in the food industry, to inhibit bacteria and microorganism growth. It is important to maintain product quality such as color, textural attributes, and residual polyphenol content. Several conventional drying methods are currently being applied, including solar and oven-drying. However, these methods consume much energy and may expose the dried waste to a dirty and dusty environment. The most famous practical method for drying solid particles is the use of a fluidized bed dryer (FBD), which offers several advantages over other dryers (i.e., spray and cabinet dryers), including the high mass and heat transfer between the gas and solid phase, good mixing of solids, lower capital costs, and ease of operation and maintenance.

3.2. Prospects for utilization
The development of the agricultural industry often leads to an increase in agricultural waste, which is largely a cellulose-rich waste including sago waste. The increase in sago production is directly proportional to the increase in the amount of waste produced. Processing of waste that is not maximal using conventional systems causes pollution in rivers. Therefore, it is necessary to understand integrated waste utilization and processing, so that the waste products generated from the sago industry have economic value and minimize environmental pollution. The management of liquid waste in sago extraction water can be minimized by using aeration techniques, metal ions and microorganisms [7].

Prior studies have shown the potential use of sago waste. Sago fiber waste is lignocellulosic biomass which contains a high percentage of starch (~ 65.7%). Thus, sago fiber can be converted into sugar and bioethanol. Besides, it also could be converted into biosorbents, biogas, animal feed and compost, and biodegradable composite material. On the other hand, sago wastewaster could be utilized as a substrate for algae cultivation, biomethane generation, and bio-hydrogen generation [17]. Several studies have utilized sago hampas as confectioners’ syrup, particleboard, and as a substrate for microbes to produce reducing sugars and enzymes [18]. Solid sago waste has also been utilized as livestock feed by processing through soaking pretreatment and fermentation with Trichoderma sp yields data of crude fiber content decrease from 33.37% to 17.36% and increase of crude protein content from 4% to 7.95% [19].

A study [18] was formulated to utilize sago hampas as an alternative substrate for glucose production, which will be used as feedstock for bioethanol production. The study concluded that the properties of sago hampas were affected by its structure, the characteristics of starch and lignocellulose compounds, thus the enzymatic hydrolysis process was difficult to carry out when a higher substrate load was used. The 7% (w/v) of sago hampas suspension was suitable for enzymatic hydrolysis using dextrozymes with respect to glucose production and conversion yield [20]. However, to increase glucose concentration (g/L), the strategy of conducting three cycles of sago hampas enzymatic hydrolysis was seen to be practical. A high proportion of glucose compared to other constituents in hydrolysate is another advantage as it can serve as a suitable substrate by most of the microorganisms to produce value-added products. The ability of this glucose for bioethanol production also proved that sago hampas can serve as an excellent raw material as well as representing an alternative and readily manageable option.

The use of sago as animal feed has been practiced for many years. Farmers cut the sago trunk to expose the starch and poultry can feed on the starch. The pith can also be harvested, dried and milled to produce sago pith meal which is a high energy feed that can be used to replace corn in poultry diets [1]. In the starch extracting, the sago pith is ground in wet form and the starch granules decanted and
collected. In doing so large quantities of sago waste, which still contain more than 20% starch is produced. This sago-waste is commonly used as feed for ruminants but needs to be in wet form.

Fermented sago waste can form a substitute feed for up to 75%, which is very beneficial for cattle farmers because it can reduce dependence on conventional feed [12]. In addition, 40% of sago pulp can be given as an alternative feed for goats [7]. The sago pulp in the form of fibers was obtained from the dissolution of the starch contents of the sago stems into sago starch. Sago pulp can be used as an alternative energy feed ingredient because it contains high extract ingredients without nitrogen (76.51%). However, it has a low crude protein content, so it needs to be fermented to improve nutritional value so that it can be given as a single feed or as a mixture of ingredients in complete feed [12].

Sago pulp has a low price and its contents also do no harm to livestock. Nutrients contained in sago pulp are generally very low because of low crude protein and high crude fiber. Although the nutrient content, especially low crude protein, ranges from 2.30 to 3.36%, starch in sago pulp was still quite high at 52.98%. This allows the pulp to be still useful as animal feed. To improve the quality of sago pulp, sago pulp can be fermented using Aspergillus niger [12].

The residual solid waste is the fibrous residue obtained after the starch has been washed out of the rasped pith of the sago palm. Due to the presence of the lignocellulosic fibrous material, this material is a strong pollutant with little industrial application except as an animal feed supplement and for chipboard production. However, dried fibrous sago waste has been found to contain about 60-70% dry weight of starch although this depends mostly on the quality of the extraction process [20]. Based on this characteristic, the starch present in the fibrous sago waste can be hydrolyzed into useful glucose to be used as a low-cost nutrient source in fermentation processes for the biotechnology industry.

In Malaysia, the sago bark (20% of the total trunk weight) normally is sun-dried and utilized as firewood or transformed into various valuable products such as bioethanol and decorative products [9]. Sago bark has been used for timber fuel, temporary walls, ceilings, and fences. More recent utilization includes processed bio-composites for sago plywood and particleboard, which have potential use as building materials. Interior products have been created from sago bark waste, where shredded sago bark is cured and rebounded in molds using resins and bio compounds to produce wall tiles [13]. The sago barks are technically suitable for making particle and fiberboard while sago flour can be used as an extended binder to minimize the use of resin. Products created for flooring exhibit a natural and unique texture of sago bark. It has a potential usage for the interior decoration, especially walls, furniture, flower pots/containers and decorative lighting. The texture can be implemented into a variety of tones and textures. The low technology and simple procedures involved in this process should allow small industries to pick up this idea for commercial production.

Another potential utilization of solid waste is to mix shredded bark and soft fibers, to produce paper for wrapping and packaging after kraft pulping [21]. The sago bark and fibers waste materials have been experimentally processed into eco-friendly kraft paper. Such paper was developed into various types. The cardboard type was found to be suitable for making gift boxes of various designs with uniform consistency and rigidity. Similarly, the paper was found to be suitable for making envelopes, notebook covers and good quality souvenir paper bags.

A study to produce lightweight concrete bricks made from sago waste [22] found that the bricks are more lightweight and economical. Authors concluded that by referring to the quality standard and minimum compressive strength of bricks required by SNI 03-0349-1989, light brick with a mixture of 1: 4.5: 1.5 with a composition of 75% sand and 25% sago pulp, waste has fulfilled the requirements of class III quality for bricks [22].

Other than building and interior products, sago bark can be used to support agriculture. Sago bark compost can support seed germination hence free of toxic substances [15]. Organic fence blocks can be created from the shredded sago bark which is designed as stackable L shaped blocks. Seeds of plants can germinate on the blocks. These bio-structures will create natural fences or garden decorations. It can also function as soil protection from erosion at the edge of the hills [13]. When the seed has grown, the organic frame will decay and transform into fertilizers. The process of
decomposition of sago fiber waste with Promi activator into organic fertilizer can increase corn productivity by 35% - 105% compared to the existing productivity of the farmers [23]. The possibility of using sago bark as renewable energy has been widely examined [14]. The authors suggested that in view of the underutilized resource of waste, sago bark has great potential for use as a co-firing fuel with coal to generate electricity in the processing mills.

3.3. Challenges

According to [24], some constraints for managing sago plants related to processing are (a) the low yields of processed sago productivity which result in a lack of efficiency in labor and production; (b) the method of processing sago logs into starch/wet flour is still carried out through the use of simple equipment, especially the storage and water containers which are considered unhygienic; (c) the condition of roads from the sago processing site to the market is still not favorable for four-wheeled vehicles, thus affecting transport costs to the markets.

The efficiency of starch processing and infrastructure constraints will also affect technical constraints for waste management and processing efforts. Among the technical constraints is the management of sago wastewater which requires microorganisms that are resistant to phenolic acids from the sago logs. Sago industrial wastewater contains large amounts of organic matter. In sago logs, there are phenolic acids which are toxic to the growth of microorganisms, so it is necessary to identify the microorganisms that can survive and degrade organic matter in sago industrial wastewater [25].

Processed sago waste product ingredients are more developed in Indonesia as animal feed. The constraints on the use of sago waste as animal feed are high levels of crude fiber and low levels of protein making the use of sago pulp more suitable for ruminants [26]. The use of sago pulp for livestock still requires a solution in the form of a fermentation process to be able to reduce amounts of crude fiber and increase protein levels because livestock has limited ability to digest crude fiber. In the utilization of sago waste into animal feed, the problems faced include: (1) limited technical knowledge of sago farmers in the rural areas regarding the potential economic value of sago pulp waste; (2) the need to supervise and transfer the technology of sago pulp waste process into animal feed that has economic value; and (3) the need for training in managing the business of processing sago waste as a basic ingredient for animal feed [27].

Market aspects must also be considered in waste processing projects. Without a clear market, production will stop, for example, processing sago bark waste into pellet biomass fuel. As [7] noted, the production of pellets produced by a company reached 3000 tons per month in 2014, but this was not maintained and stopped in April 2015.

3.4. Sustainability

The development of sustainable management of sago requires support from all relevant stakeholders, including the government, academics, entrepreneurs, farmers, financial institutions and non-governmental organizations (NGOs) in the form of policies needing direct assistance. The aim of this policy is to train sago farmers to be able to produce sago-based products that are more innovative and varied. Efforts to rehabilitate existing sago land need to be improved by establishing cooperation between various parties including the community, central and regional governments so that the potential of sago land can be conserved, developed effectively and integrated sustainably [7].

Inseparable from this sustainability concept is the management and processing of sago waste for value-added products that need support from related agencies for training and development of waste processing equipment/infrastructure. Sago plants have a natural character that is environmentally friendly but without proper waste management, the effects of pollution can be limiting. The dominant leverage in sustainable sago management is the ability to process and utilize waste, apart from other factors, including middlemen (ijon), availability, distribution, market segmentation, and water availability [7]. Therefore, the management and processing of by-products (waste) is a key factor in sustainable sago agroindustry.
4. Conclusion
Sago waste management is recommended to focus on: (1) efforts to increase the yield and efficiency of the wet sago production process to reduce the daily amount of sago waste generated; (2) improvement of the layout and mechanism of the sago log processing to facilitate the classification of sago waste types into sago pulp waste, wastewater and sago bark waste so as to facilitate its optimal utilization; (3) selection of appropriate drying methods to reduce the volume of sago liquid waste and facilitate further storage and processing (4) the implementation of appropriate technology that can provide additional income to farmers and smallholder sago refineries such as processing sago pulp into animal feed, paper from the sago bark, interior products and building materials because it is amenable to less complex technology.

To minimize technical problems, further research is required to identify the types of sago waste produced and how to optimize their processing for electricity, water, and transportation. Accordingly, waste utilization should be promoted and the ability to value add from sago processing needs to be explained to stakeholders to gain their interest and willingness to participate.

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