

An Environmental Impact Analysis of Semi-Mechanical Extraction Process of Sago Starch: Life Cycle Assessment (LCA) Perspective

M A Yusuf^{1,2}, M Romli¹, Suprihatin¹ and E I Wiloso³

¹ Department of Agroindustrial Technology, Bogor Agricultural University, Bogor, Indonesia

² Department of Agricultural Engineering, Musamus University, Merauke, Indonesia

³ Research Center of Chemistry, Indonesian Institute of Science (LIPI), Serpong, Indonesia

E-mail: megaayu.yusuf@gmail.com

Abstract. Industrial activities use material, energy and water resources and generate greenhouse gas (GHG). Currently, various regulations require industry to measure and quantify the emissions generated from its process activity. LCA is a method that can be used to analyze and report the environmental impact of an activity that uses resources and generates waste by an industrial activity. In this work, LCA is used to determine the environmental impact of a semi-mechanical extraction process of sago industry. The data was collected through the sago industry in Cimahpar, Bogor. The extraction of sago starch consists of stem cutting, rasping, mixing, filtration, starch sedimentation, washing, and drying. The scope of LCA study covers the harvesting of sago stem, transportation to extraction site, and the starch extraction process. With the assumption that the average transportation distance of sago stem to extraction site is 200 km, the GHG emission is estimated to be 325 kg CO₂ eq /ton of sundried sago starch. This figure is lower than that reported for maize starch (1120 kg CO₂ eq), potato starch (2232 kg CO₂ eq) and cassava starch (4310 kg CO₂ eq). This is most likely due to the uncounted impact from the use of electrical energy on the extraction process, which is currently being conducted. A follow-up study is also underway to formulate several process improvement scenarios to derive the design of sago starch processing that generates the minimum emissions.

1. Introduction

Sago (sago palm) plants grow naturally in humid tropic regions, such as in Southeast Asia including Indonesia, Thailand, Malaysia, The Philippines, Vietnam, and Papua New Guinea. Starch contained in a sago stalk is a source of carbohydrates. [1] reported a rapid increase in sago starch production in recent years. Sago has advantages over other carbohydrate source plants, namely its high productivity that reaches 25-30 tons/hectare.year [2]. Compared to other carbohydrate sources such as rice and wheat flour, sago has also higher carbohydrate content, namely 84.7%. Sago starch is an intermediate product that can be processed further into various food and industrial products, such as liquid sugar for beverage industry [3] and bioethanol [4]. The by-products of sago processing in the forms of solid and liquid can be converted into value-added products [5].

Life Cycle Assessment (LCA) is a method to analyze resource issues across the life cycle of a product. It can systematically identify key areas to improve environmental performance, and can be



applied to agroindustrial systems especially in sago industry. A standardized LCA methodology for agroindustries will help practitioners undertake LCA studies and greatly increase their value by providing results that are comparable between product and industries.

Increased production of sago starch causes an increase in sago processing wastes, both liquid and solid. Handling of sago processing waste is still very limited, generally, waste is discharged directly into the river without treatment. Phang et al. [6] stated that each plant produces between 10-22 tons of wastewater containing carbon and nitrogen at a ratio of 105: 0.12.

This study analyses the environmental impact of sago processing by using a Life Cycle Assessment (LCA) method. The environmental impact of each stage of sago starch production process is analyzed by calculating the environmental loads based on inventory analysis of resource, energy, water, fuel and other materials.

2. Methodology

This study uses the LCA methodology to evaluate the inputs, outputs, and the potential environmental impacts of a product system throughout the sago starch's life cycle (ISO 14040:2006). The LCA methodology consists of four stages: goal and scope determination, inventory analysis, impact analysis and interpretation.

2.1. Determine the purpose and scope (Goal Definition and Scoping)

In this work, LCA is used to determine the environmental impact of a semi-mechanical extraction process of sago industry. Goal and scope definition is the first step in conducting LCA analysis. At this stage the objectives of the LCA study and the limits or scope of LCA analysis are determined. The parameters associated with the analysis include a functional unit

2.2. Inventory analysis (Life Cycle Inventory/LCI)

The LCA method is used to explore the sources that used to obtain the required data. Process flowchart of semi-mechanical sago processing that displays the sources of waste generation and emissions is depicted in figure 1.

2.3. Impact analysis (Life Cycle Impact Analysis / LCIA)

The impact analysis aims to determine the likely impacts that may occur during the life cycle of a product. Impact estimates are intended as a careful and in-depth study of the quality of the environment, indicated by their magnitude of impact and importance. In this study, a mathematical model is a formal method commonly used to estimate the magnitude of impacts on environmental components due to the calculated data. In this study, the data is calculated by using SIMAPRO software.

2.4. Interpretation (Interpretation / Life Cycle Improvement Analysis)

This step is the last step in doing the LCA, namely by interpreting the results, evaluating, and then analyzing the things that can be done in order to improve the products, processes or services related to environmental impact reduction. The results of analyzes that have been carried out in the inventory and impact assessment stage are manifested in actions that will benefit industry and the environment.

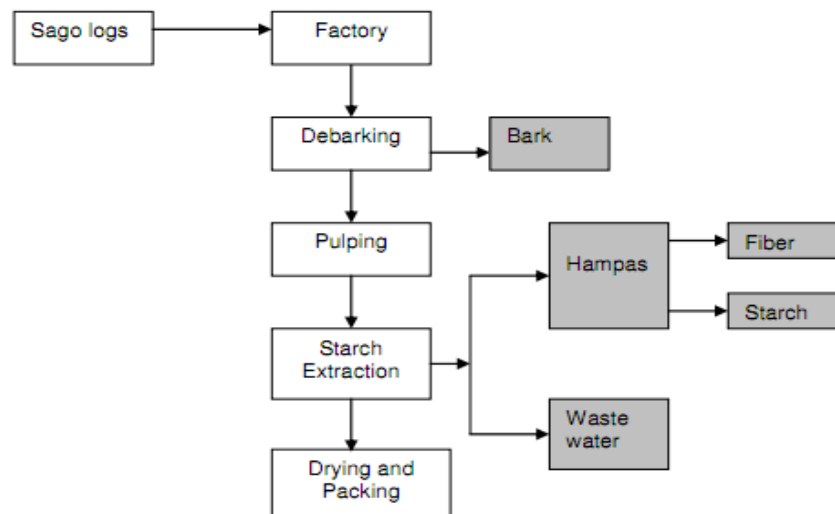


Figure 1. Process diagram and the formation of waste in sago starch agroindustry

3. Result and discussion

3.1. Semi-Mechanical Sago Starch Extraction

Semi-mechanical type of sago starch production is in principle the same process as the traditional one, except that tools or machines are involved in some process steps. For example, the use of the rasping machine in the process of pith destruction; the use of tank equipped with a mechanical stirrer in the process of dissolving sago starch; and the use of pumping system in the filtering process of sago starch separation. This semi-mechanical process is chosen in this study because most of the production of sago in Indonesia (especially in Riau, West Java, and South Sulawesi) uses this type of technology.

The process begins with cutting stems of sago plants after the trees are felled in length of 0.5-1 meter. These pieces are then peeled, split, and shredded. The grated materials are collected in a wooden tub equipped with a mechanical agitator. Agitation is usually done in two stages to make sure that all starch is extracted from the fibers. Afterwards, a mixture consisting of fibers, starch, and water is pumped to a series of filters. The slurry of the starch solution is collected in other wooden tubs for the process of starch deposition. The starch deposition is then washed in a tub or tank equipped with a stirrer and deposited further. The wet sago starch is then sun dried and ground with a grinder. Finally, the milled starch is stuffed into burlap sacks, and ready to be marketed.

3.2. Boundary System of Semi-Mechanical Extraction Process

The purposes of this LCA study are to identify sago starch production process, to determine the emission hotspots, and to calculate the environmental impact of the sago starch processing. Sago industry that being studied is just one sago industry in Cimahpar, Bogor as the case study. The scope of LCA study covers the harvesting of sago stem, transportation to extraction site, and the starch extraction process. The functional unit used is 1 ton of sundried sago starch. Functional unit is the value or services provided from a sago starch production system. The system boundary of sago starch production is defined in figure 2. The type of environmental impact category used in this study is global warming potential by quantifying the emission generated from the entire sago starch life cycle in the form of specific CO₂ eq.

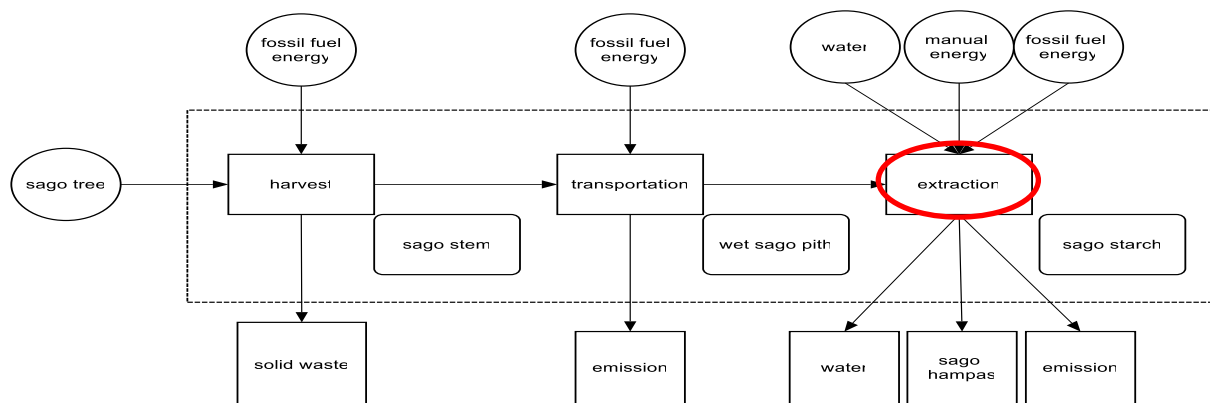


Figure 2. Boundary system scenario of semi-mechanical sago starch agroindustry

3.3. Life Cycle Inventory

For the inventory analysis, the data related to the extraction process is obtained from direct measurement in the industry, while for harvesting and transportation the secondary data is obtained from the Ecoinvent LCA database. The data collected by directly counting on the field and make a calculation through it. In this study, it is assumed that the distance of sago trunk transport to the extraction site is 200 km. Data used for inventory analysis is in accordance with pre-determined LCA goals and scopes. Inventory analysis consists of data collection and data calculation. In the data collection, each process unit will be described by the flow diagram of input and output. Process flowchart of sago starch extraction is given in figure 3. Mass balance calculation of each extraction process is presented in table 1. These figures combined with the secondary data from the Ecoinvent LCA database form the basis for the estimation of the environmental impact.

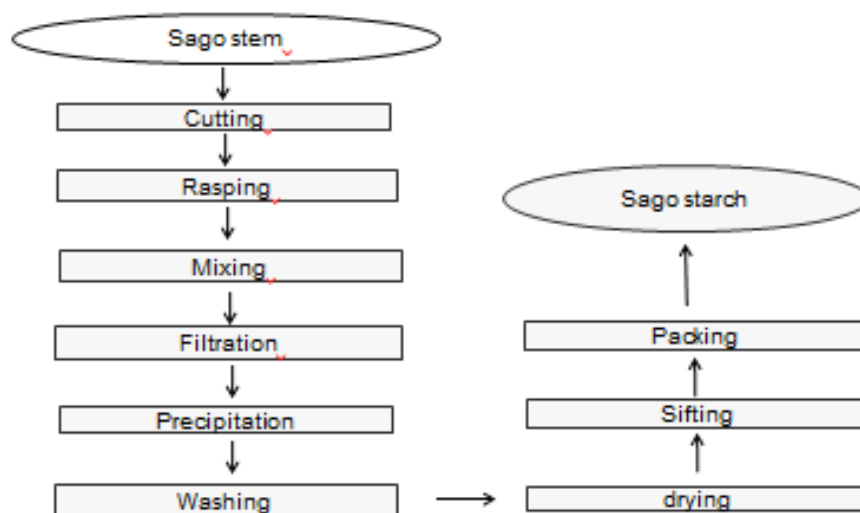


Figure 3. Flowchart of sago starch processing

Table 1. Mass balance calculation of each extraction process

Process	Input		Output	
	Material	Quantity (kg)	Material	Quantity (kg)
Cutting	Sago tree	7000	Sago stem	6965
			Solid waste	35
Sifting	Sago stem	6965	Sago powder	8
Mixing	Water	118430	Mixed with sago powder and water	125395
Filtration	Mixed with sago powder and water	125395	Wet hampas sago and water	17250
			Starch liquid	108145
Sedimentation	Starch liquid	108145	Water	106595
			Wet sago starch	1550
Washing	Wet sago starch	1550	Waste water	142316
	Water 132316	132316	Wet sago starch	1450
Drying	Wet sago starch	1450	Evaporate water	245
				1200

*this study has not accounted for the energy balance in the extraction process

With the assumption that the average transportation distance of sago stem to extraction site is 200 km, the GHG emission is estimated to be 325 kg CO₂ eq /ton of sundried sago starch. This lower figure for sago starch from this study is most likely due to the uncounted impact from the use of electrical energy on the extraction process, which is currently being conducted. A follow-up study is also underway to formulate several process improvement scenarios to derive the design of sago starch processing that generates the smallest emissions.

4. Conclusions

In this research work, LCA is used to determine the environmental impact of a semi-mechanical extraction process of sago industry. Using data from direct measurement of the extraction process and the secondary data obtained from the Ecoinvent LCA database for harvesting and transportation, and assuming the distance of sago trunk transport to the extraction site is 200 km, the GHG emission is estimated to be 325 kg CO₂ eq /ton of sundried sago starch. This figure is lower than that reported for maize starch (1120 kg CO₂ eq), potato starch (2232 kg CO₂ eq) and cassava starch (4310 kg CO₂ eq). This is due to the uncounted impact from the use of electrical energy on the extraction process. A follow-up study is underway to formulate several process improvement scenarios to get the design of sago starch processing that generates minimum emissions.

References

- [1] Singhal R S, Kennedy J F, Gopalakrishnan S M, Kaczmarek A, Knill C J and Akmar P F 2008 Industrial production, processing, and utilization of sago palm-derived products *Carbohydrate Polymers* **72** 1-20
- [2] Bintoro H M H, Asmona D and Erwin 2009 Some efforts to rehabilitate sago palm plantation at Meranti District Riau Province Indonesia *1st ASEAN Sago Symposium* 2009 pp 1-4
- [3] Purwaningsih I W 2016 *Life cycle assesment of PG. Subang Sugar Cane, West Java* Magister thesis (Bogor: Bogor Agricultural University)
- [4] Jong F S and Widjono 2007 The sustainability of sago palm (*Metroxylon spp.*) cultivation on deep peat in Sarawak *Sago Palm Studies* **3** 13-20
- [5] Adeni D S, Abd-Aziz S, Bujang K and Hassan M A 2010 Bioconversion of sago residue into value added products *African Journal of Biotechnology* **9**(14) 2016-21
- [6] Phang S M, Miah M S and Yeoh B G 2000 Spirulina cultivation in digestes sago starch factory wastewater *Journal of Applied Phycology* **12** 395-400