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A Lifecycle Assessment (LCA) of cassava starch production in central Thailand

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Abstract

The LCA framework was used to conduct the environmental assessment of 2 cassava starch factories in central region of Thailand: Factories 1 and 2 were located in Kanchanaburi and Ratchaburi provinces respectively, with average production capacity of 150-200t starch/day/factory. The objectives of the study were (1) to assess the environmental benefits of using biogas for cassava starch production compared to fossil fuels; and (2) to compare the environmental performance of two biogas technologies. The system boundaries covered all cassava starch production processes from fresh cassava root till dry cassava starch. The input-output data are both from primary data collection (factory surveys) and literature data (agricultural production). This study uses Thailand Greenhouse Gas Management Organization (TGO) method to assess the carbon footprint impact. To produce 1 ton of starch, with biogas generation from the factory wastewater treatment system, the study indicated that factories 1 and 2generate 701 and 537kg CO_2-eq/t starch, respectively. The agricultural phase contributed 255kg CO_2-eq/t starch for both factories. The starch production phase contributed less impacts in factory 2 (267 versus 424kgCO_2-eq/t starch), due to lower use of chemicals and grid electricity, and higher production of biogas. Additionally, production of biogas at factory 1 had started recently and may increase in the future. Biogas had significant environmental benefits at both factories, enabling a reduction in CO_2 emissions in the range 110-350kgCO_2 eq/t starch compared to a scenario using only fuel oil instead of biogas.

Keywords: Cassava starch, life cycle assessment, biogas, energy use

1. Introduction

Thailand is the third largest world producer of cassava with about 27 million ton (Mt) of cassava roots processed per year, while Nigeria and Brazil rank first and second respectively (UNCTAD,TTTA,2012). Thailand is also the leading exporter of cassava starch in global terms.Its export in 2012 was 2.2million tons of starch(The customs department,2012).The export price of tapioca starch with super high -grade quality in the last five year (2008-2013), ranges from 283-455 US$ per Ton. The price was multiplied by almost 1.6 since 2008 (TTTA,2012). Cassava starch is produced from fresh cassava roots and has numerous applications in various industries such as food and beverages, textile, glue industry or even in cosmetic and pharmaceutical Industry. The agriculture of cassava consists of material preparation, soil preparation, farming, weed control and fertilization and harvest (Khongsiri S., 2009).

The production of cassava starch first starts with the weighting of starch percentage in fresh cassava root by using Reimann Balance to estimate the buying price at factory gate. Then the roots are fed to rotary screener to remove sand and impurities. After that , the root are fed to peeling and cleansing device, then to chopping out the root stem which is hard and stone-like in order to avoid breakage with the subsequent rasping process (M.R. GRACE, 1977). Then, the rasping operation crushes the root to a pulp in order to increase efficiency for starch extraction. Then, during the extraction operation, freshly rasped root slurry is pumped through a series of extractors, from coarse to fine extractor to remove cellulosic fibers. Then, during the starch separation stage, water is separated from the starch slurry using a separator. Then dewatering stage is done by a series of horizontal centrifuges and/or hydrocyclones in order to concentrate the starch slurry. The final cycle of dewatering discharges starch cake at 33-35% moisture content. Then, at the drying stage, the wet starch is blown with hot air in a flash dryer and dried to 12-13% moisture content. Then, the starch discharged out of the dryer is packed to a polyethylene bag or nylon jumbo size bag (Sriroth *et al*., 2000).

Cassava starch processing has a high rate of natural resource consumption such as fuel oil, electricity and water. It also produces large amounts of wastewater. Recent studies show that the production of 1 ton of cassava starch requires up to 2500 MJ of thermal energy (supplied by 35-40 L heavy fuel oil or 60m^3 biogas) for starch drying, 165 kWh/ton of electricity and produces 15-35 m^3 of wastewater, which carries several organic substances (BIOTEC factsheet, 2006).

Therefore a way for cassava starch factories to improve production efficiency is to improve environmental performance, for instance by using water recycled from the extraction operation for the washing process, or by adopting waste water treatment systems producing biogas as a renewable energy, which reduces the consumption of grid electricity and fuel oil. Currently, most cassava starch factories use biogas to substitute fuel oil for burners that generate hot air for drying moist starch. One cubic meter of biogas is equivalent to 0.45 L of heavy fuel oil (BIOTEC factsheet, 2006).The biogas technology installed in the factory is based on production capacity and factory size. Typically, the covered lagoon system is installed for small and middle size starch factories in order to obtain biogas from anaerobic ponds. Whereas larger factories implement a more complex system such as an up-flow anaerobic sludge blankets (UASB). Biogas production helps the factory to reduce the fuel cost by approximately 25 million baht/year (Chavalparit *et al*., 2009).

The purpose of this study is to assess the environmental benefits of using biogas for cassava starch production compared to fossil fuels at two starch factories; and to compare the environmental performance of two biogas technologies. The two factories in this study (factories 1 and 2) were located in Kanchanaburi and Ratchaburi provinces respectively in the central region of Thailand, with average production capacity of 150-200tstarch/day/factory. The life cycle assessment (LCA) framework was used to conduct the environmental assessment.

2. Methodology

According to ISO14040, LCA comprises 4 stages which are goal and scope definition, inventory analysis, impact assessment and interpretation.

2.1 Goal and scope definition

The goal is to evaluate environmental performance of cassava starch production from cassava root farming to the cassava starch processing, ending with dry cassava starch. The functional unit is 1 ton of starch with moisture content 13%, packaged in polyethylene or polypropylene bags. The system boundaries are shown in Figure1.

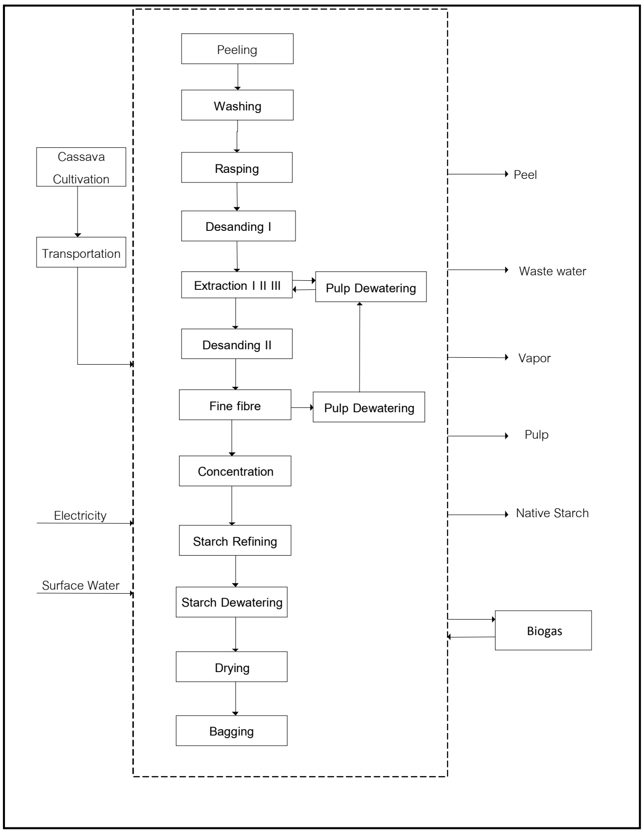

Figure 1 system boundary of the study.

2.2 Lifecycle Inventory

The life cycle inventory consists in collecting data for all the inputs and outputs of the system (figure 1) in the two selected factories, such as fertilizers, pesticides, chemicals, energy (diesel, fuel oil, biogas, electricity), water, co-products, solid waste, wastewater, etc. The input-output data were both from primary data collection (factory surveys) and literature data (agricultural production). Selected inventory data are presented in table 1. The two factories run 24/7 working day with maintenance downtime for 2 to 3 months during the low season (July-August). Factories 1 and 2 use covered lagoon and UASB technologies respectively to generate biogas from the process wastewater.

2.3 Impact assessment

Greenhouse gas emissions were assessed in terms of kg CO_2 equivalent per ton of cassava starch, using the Thailand Greenhouse Gas Management Organization (TGO) method. The method aims to promote the use of a carbon footprint on Thai products and also to support the Thai industrial sectors in implementing the low carbon trend in Thailand (Supappunt, 2011). The TGO method provides a database of emission factors (EF) for greenhouse gas emissions specific to Thailand. Other environmental impacts were calculated using the LCA ReCiPe method. When emissions factors (EF) were not available in the TGO database, the Ecoinvent database was used instead.

Table 1 The amount of raw materials and waste produced in the two selected factory

Input / Output*	Quantity	
Input	Factory 1	Factory2
▪ Cassava root (ton)	4.34	4.50
▪ Grid Electricity (kWh)	270	175
▪ Water (m^3)	21.22	23.49
▪ Heavy Fuel Oil (Liter)	-	0.19
▪ Sodium Metabisulphite(kg)	58.45	2.71
▪ Biogas produced(m^3)	180.37	231
Output		
▪ Cassava starch (ton)	1	1
▪ Peel fresh m/c 75%(ton)	0.05	0.15
▪ Pulp fresh m/c 85% (ton)	2.13	1.19
▪ COD (kg)	392.83	474.47
▪ Wastewater(m^3)	16.59	23.49

*The input and outputs are expressed per 1 ton of starch with moisture content 13%.

According to the study system boundary, the scope of assessment is business-to-business (B2B) which has 2 phases of product lifecycle: material procurement and manufacturing phase. The emissions of greenhouse gas were divided in three categories: cassava root agriculture, transportation of raw materials, cassava starch production.

In order to compare the emissions of greenhouse gas of the factories using biogas, with the situation before biogas technology was adopted and fuel oil was used instead, theoretical "no biogas" scenarios were calculated by replacing all the inputs and emissions related to biogas as follows: (1) Biogas used for starch drying was replaced with fuel oil, (2) electricity produced from biogas was replaced with grid electricity, and (3) the methane captured during biogas production was counted as emissions to atmosphere after fermentation in anaerobic open lagoons.

2.4 Interpretation

The purpose of this stage is to analyze results, to give references and to lead to conclusions and recommendations that allow taking future decisions.

3. Results

The greenhouse gas emissions of factories 1 and 2 under the "biogas from wastewater" and "no biogas" scenarios are shown on figures 2-5.

In the biogas scenario, the processing phase at the cassava starch factories had more environmental impacts than the agricultural phase and the material transportation phase, due to losses of methane to atmosphere during the production of biogas. The agriculture phase contributed 255kg CO_2-eq/t starch for both factories. However, different literature sources are available for emissions of greenhouse gas during cassava roots cultivation, with reported values up to 450kg CO_2eq/t starch(Nguyen *et al.*, 2007). The starch production phase contributed less impacts in factory 2 (267 versus 424 kg CO_2-eq/t starch), due to lower use of chemicals and grid electricity, and higher production of biogas.

Factory 1

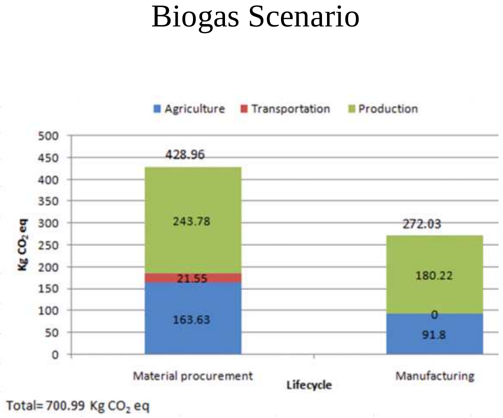

Figure 2 CO_2 emission of Factory 1 with biogas

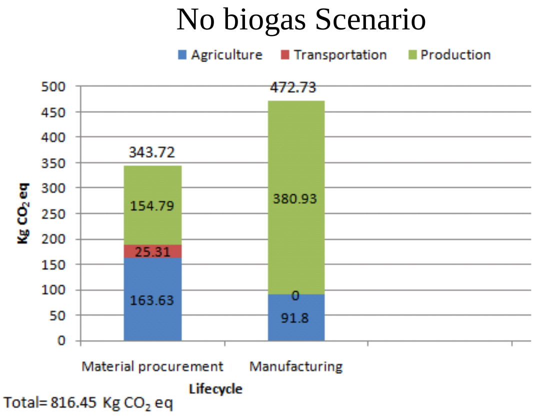

Figure 3 CO_2 emission of Factory 1 w/o biogas

Factory 2

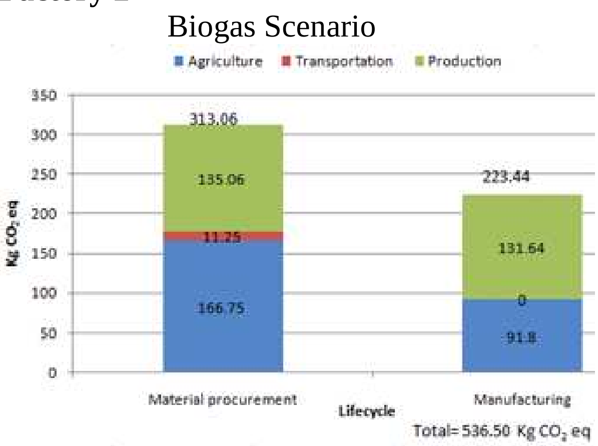

Figure 4 CO_2 emission of Factory 2 with biogas

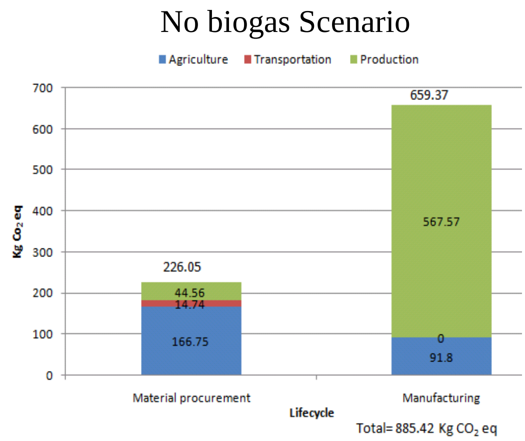

Figure 5 CO_2 emission of Factory2 w/o biogas

In the no biogas scenario, the environmental impacts of the processing phase at the cassava starch factories increased compared to the biogas scenario because of (1) the emissions of fossil CO_2 during combustion of fuel oil, (2) the higher use of grid electricity, and (3) the higher emissions of methane to atmosphere from the wastewater. The emissions from the procurement of raw materials for the factory stage decreased because fuel oil procurement emits less methane than biogas production. Variations in the emissions between the two factories were observed, due to different types of machinery, operation management and biogas technology, resulting in different levels of biogas production and of fuel oil and electricity use. Overall, implementing biogas technology significantly reduced the amount of CO_2 emissions, in the range of 110-350kg CO_2eq/t starch lower compared to a scenario using only fuel oil.

4. Conclusion

This study used LCA framework to assess the environmental performance of two cassava starch factories in term of CO_2 emissions, and to evaluate the environmental benefits of using biogas, by comparing the biogas scenario with a conventional scenario where fuel oil is used instead. Biogas enabled factories 1 & 2 to reduce CO_2 emission by 115 and 349 kg

CO_2eq/t starch, respectively. Biogas can substitute the use of fuel oil and grid electricity consumption. From the study of product lifecycle, both the cassava roots cultivation phase and the cassava starch production phase had significant greenhouse gas emissions. These emissions could be reduced by reducing methane losses during biogas production and improving energy efficiency of some factory operations (e.g. drying), so that more biogas could be used to generate electricity. For the cultivation phase, improved agricultural practices to limit fertilizer use while maintaining acceptable yields could reduce emissions of N_2O, a strong greenhouse gas.

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