Mitigation of Green House Gases Emission in Cassava Mill: Case Study in Lampung, Indonesia

By Udin Hasanudin; Agus Haryanto; Erdi Suroso

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Udin Hasanudin[1)]*, Agus Haryanto[2)], Erdi Suroso[1)]

[1)] Dept. Agroindustrial Technology, University of Lampung, Bandar Lampung, INDONEISA
[2)] Dept. Agricultural Engineering, University of Lampung, Bandar Lampung, INDONEISA
* Corresponding author. Tel: +62-721-700682, Fax: +62-721-700682
E-mail: udinha@unila.ac.id

Abstract

Lampung is the biggest contributor for cassava production in Indonesia. Recently, Lampung produced 7.57 million ton of cassava tubers annually and contributed about 34.4% of the national cassava production. Therefore, Lampung is the home for cassava-based industries. There were 76 industries are in operation in Lampung, including four small scale tapioca industries called ITTARA. These industries wasted huge of water having potential to generate biogas through anaerobic digestion process. The objective of this paper was to study greenhouse gas (GHG) emission mitigation of cassava mills in Lampung by using biogas fuel resulted from wastewater treatment. The study evaluated GHG emission from the existing conditions and then calculate GHG emission reduction potential in the processing step by utilization of waste. General life cycle methodology was applied for the evaluation of GHG reduction. Results showed that 2.82 to 4.5 m3 of waste water were produced for every ton of cassava being processed. The waste water was characterized by high organic matter with an average COD of 18,000 mg/L. During waste water treatment, biogas was estimated at around 26 m3 per ton cassava with methane content of 56.2 vol.%. The study also revealed that utilization of biogas may replace a part of diesel fuel used in the cassava mills and therefore potentially reduces GHG emission. Assuming that 80% of cassava production was processed directly in cassava mill, it can be showed that total biogas energy potential throughout Lampung Province was equivalent to 87.4 million liters diesel fuel per year. This quantity will reduce GHG emission about 1.32 million tons of CO2 equivalent per year.

Keywords: Biogas, Greenhouse gas, Emission, Cassava mill, Mitigation.

1. Introduction

Lampung is the biggest contributor for cassava production in Indonesia. Recently, Lampung produced 7.885 million ton of cassava tubers annually and contributed about 36% of the national cassava production (Table 1).

Table 1. Harvesting area, production and yield of cassava in Lampung as compared to Indonesia

Year	LAMPUNG[a)]			INDONESIA[b)]		
	Area (Ha)	**Yield (Ku/Ha)**	**Production (Ton)**	**Area (Ha)**	**Yield (Ku/Ha)**	**Production (Ton)**
2005	252 984	190.00	4 806 254	1 213 460	159.00	19 321 183
2006	283 430	194.00	5 499 403	1 227 459	163.00	19 986 640
2007	316 806	201.86	6 394 906	1 201 481	166.36	19 988 058
2008	318 969	242.09	7 721 882	1 204 933	180.57	21 756 991
2009	320 344	246.15	7 885 116	1 205 440	182.43	21 990 381

Source: a) Lampung Dalam Angka (2010)
b) BPS (2010)

Therefore, Lampung is the home for cassava-based industries. Most industries, both big industries and some people-managed small industries known as ITTARA (IndustriTepungTapioka Rakyat), directly processed cassava tubers into cassava starch (tapioca). Few industries converted cassava into ethanol. Other industries requiring cassava in a significant amount are feed industries.

The tapioca industries release huge amount of waste water characterized by high organic matter and high COD (chemically oxygen demand). Anaerobic decomposition of organic matter produces biogas with composition of 50 – 70% CH4; 25 – 45% CO2; and trace of nitrogen, hydrogen, hydrogen sulfide. For a complete reaction, the decomposition can be presented as:

$$C_nH_aO_b + \left[n - \frac{a}{4} - \frac{b}{2}\right]H_2O \rightarrow \left[\frac{n}{2} - \frac{a}{8} + \frac{b}{4}\right]CO_2 + \left[\frac{n}{2} + \frac{a}{8} - \frac{b}{4}\right]CH_4 \qquad (1)$$

From equation (1), it can be demonstrated that 0.35 m3 of CH4 can be produced for every kg of COD (chemically oxygen demand). If methane is released to the atmosphere it will contribute significantly to global warming since CH4 having high green house effect (21 times of CO2) so that its existence should be reduced (Rodhe, A.L., 1990). The CH4, however, is combustible and, therefore, can be utilized as fuel to replace diesel fuel used in the factory given that gas is produced and collected appropriately.

The purpose of this study is to estimate potential for GHG mitigation by using biogas fuels resulted from waste water treatment.

2. Methodology

The method used in this research included literature study, field survey, field measurement, and laboratory testing. Literature from other researches, industries, and government institutions will be used to dig important information related to the study. Field survey was explored to locate cassava-based industries throughout Lampung Province and to get information on the material balance, waste (type and amount), and waste treatment. Global Positioning System (GPS)tool (GPSMAP 60CSx, Garmin International Inc., USA) was used to geographically locate each industry.

Field measurement was conducted at five industries sampled based on their capacity to determine the amount of raw material flow, waste flow rate, and CH4 emitted from waste water. The amount of waste water was calculated by using mass balance in the processing steps. Methane emission was captured using floating material made from plastic box of 24 cm width by 60 cm length as depicted by Figure 1. Gas flowrate was measured using wet gas flow meter (WK-NK-0.5B, Shinagawa Corporation, Japan).

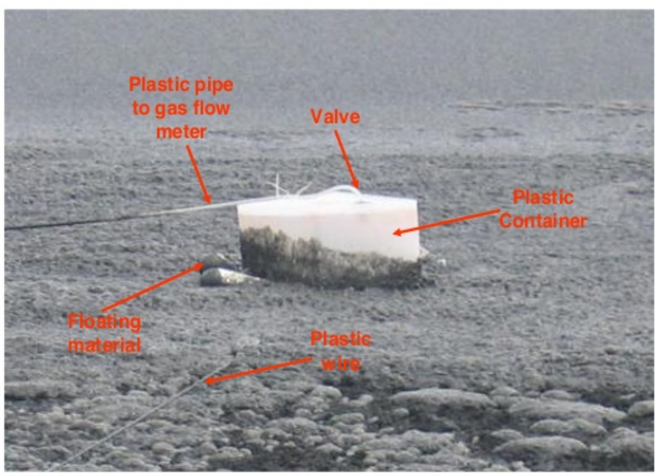

Figure 1.Gas trapping device used to measure CH_4 emission from the water treatment pond in a cassava mill

Laboratory measurement was carried out to characterize waste water and biogas composition. Wastewater properties will be represented by COD, TSS, VSS, pH, temperature values. COD was measured by spectrophotometer (HACH DR4000). Biogas composition was determined using gas chromatograph (GC 2014, Shimadzu).

Biogas production (FBio) was estimated using the following relation:

$$F_{Bio} = \frac{COL \times \eta_{CODr} \times c_f}{\% CH_4} \qquad (Nm^3/ton) \qquad (2)$$

Where COL is COD load (kg/ton of cassava tuber), ηCODr is COD removal efficiency, % CH4 is methane fraction in the biogas (vol.%), and cf is conversion of COD to CH4 (Nm^3/kg COD removed). Theoretically, 0.35 Nm3 of methane can be produced for every kg of COD removed. In this case, however, we used 0.3 as a realistic value.

GHG emission reduction potential (GER) was calculated using the following relation:

$$\mathbf{GER = GER_{CH4} + GER_{fuel or el}} \quad (3)$$

where GERCH4 is GHG emission reduction due to CH4 combustion and GERfuel or el is GHG emission reduction due to replacement of fuel or electricity by biogas utilization.

3. Results and Discussion

Our study revealed that there were 71 units cassava-based industries are in operation throughout Lampung Province with a total capacity of 5.2 million ton cassava root annually. Most them (70 units) process cassava into tapioca starch and one unit produces ethanol. Three units of tapioca industries also produced citric acid from their waste. In addition, there were four small scale tapioca industries (called ITTARA) managed by community also run with each processing capacity up to 80 ton cassava per day. Feed industries also demanded cassava in a significant amount (3.5 million tons cassava per annum). Figure 2 shows distribution of cassava-based industries within Lampung Province.

Processing capacity of those industries greatly varied from around 50 tons to 1800 tons cassava tuber per day. Our study at five tapioca industries (Table 2) revealed that tapioca starch yield varied from 23.8 to 25.6 percent of the raw material (cassava root). Cassava variety and machine capacity were amongst other factors affecting the tapioca yield. Presently, there are two varieties of cassava being popular for farmers, namely Kasertsat and Thailand with starch content of 18.15% and 16.99%, respectively. The cassava processing into starch is depicted schematically by Figure 3.

Table 2. Characteristic for selected tapioca industries

	Tapioca Industry Scale				
	small	Big	Big	Big	big
Cassava root consumption (ton/day)	80	600	750	800	1800
Tapioca production (ton/day)	20.5	150	187.5	190	450
Water consumption (m^3/day)	400	2,640	3,750	3,420	7,713
Water Index (m^3/ton tapioca)	19.5	17.6	20.0	19.7	17.1
Energy source	Grid	Grid and self	Grid and self	Grid and self	Grid and self
Energy consumption per ton tapioca:					
Electricity (kWh)	NA	193.5	207.4	197.1	NA
Diesel fuel (L)	NA	NA	37.05	36.98	34.47
Wastewater production (m^3/day)	395.4	1,690.0	2,112.5	3,629.5	5,713.9
(m^3/ton raw material)	4.94	2.82	2.82	4.54	3.17

It can be seen from Table 2 that in average 199.3 kWh electricity and 36.2 liters of diesel fuel was required to produce one ton tapioca starch. It can also be showed that tapioca yield varied slightly from 23.8 to 25.6 weight percent with an average value of 24.9%.

Cassava processing consumed huge amount of water (4.3 to 5 m3 per ton of cassava root). As a result, the process also produces a lot of wastewater (2.82 to 4.94 m^3/ton). The wastewater was high in organic matter as characterized by high COD content (Table 3). The pH value of wastewater from separator section in this research (6.0) was high enough compared to our previous study which was 3.8 – 4.5 (Hasanudin *et al*., 2007). This difference implied that location influenced the pH of wastewater exited from cassava mills.

Figure 2. Distribution of cassava mills (yellowed square with number inside) in Lampung Province. (Sampling location was indicated by red star)

Table 3. Characteristic of wastewater produced from tapioca industries in Lampung

Wastewater source	pH	Temperature (°C)	DO (mg/L)	COD (mg/L)	BOD_5 (mg/L)
Wastewater from separator	6.0	29.6	6.62	20,433	11,466
Wastewater from washing	7.7	30.4	2.36	2.015	1.132

Based on the results, we have calculated the potential of GHG mitigation in the cassava industries due to utilization of biogas. The results showed that the amount of biogas potentially generated from waste water treatment was 28.83 m3 per ton of cassava roots being processed. Biogas sampled from five cassava mills indicated methane fraction of 56.2% (by volume) as presented in Table 4. With this value, it meant that biogas had energy value of 20.08 MJ/Nm3which was equivalent to 0.52 L of diesel fuel. Every ton of cassava was able to generate biogas energy equivalent to 15.0L of diesel fuel. With average tapioca yield of 24.9 % (by weight), this meant that biogas was able to replace all of diesel fuel (166%) or all electric power (113%) used in the mill assuming that efficiency for biogas fired power plant was 35% (Eurelectric, 2003). The calculation used data and factors presented in Table 5.

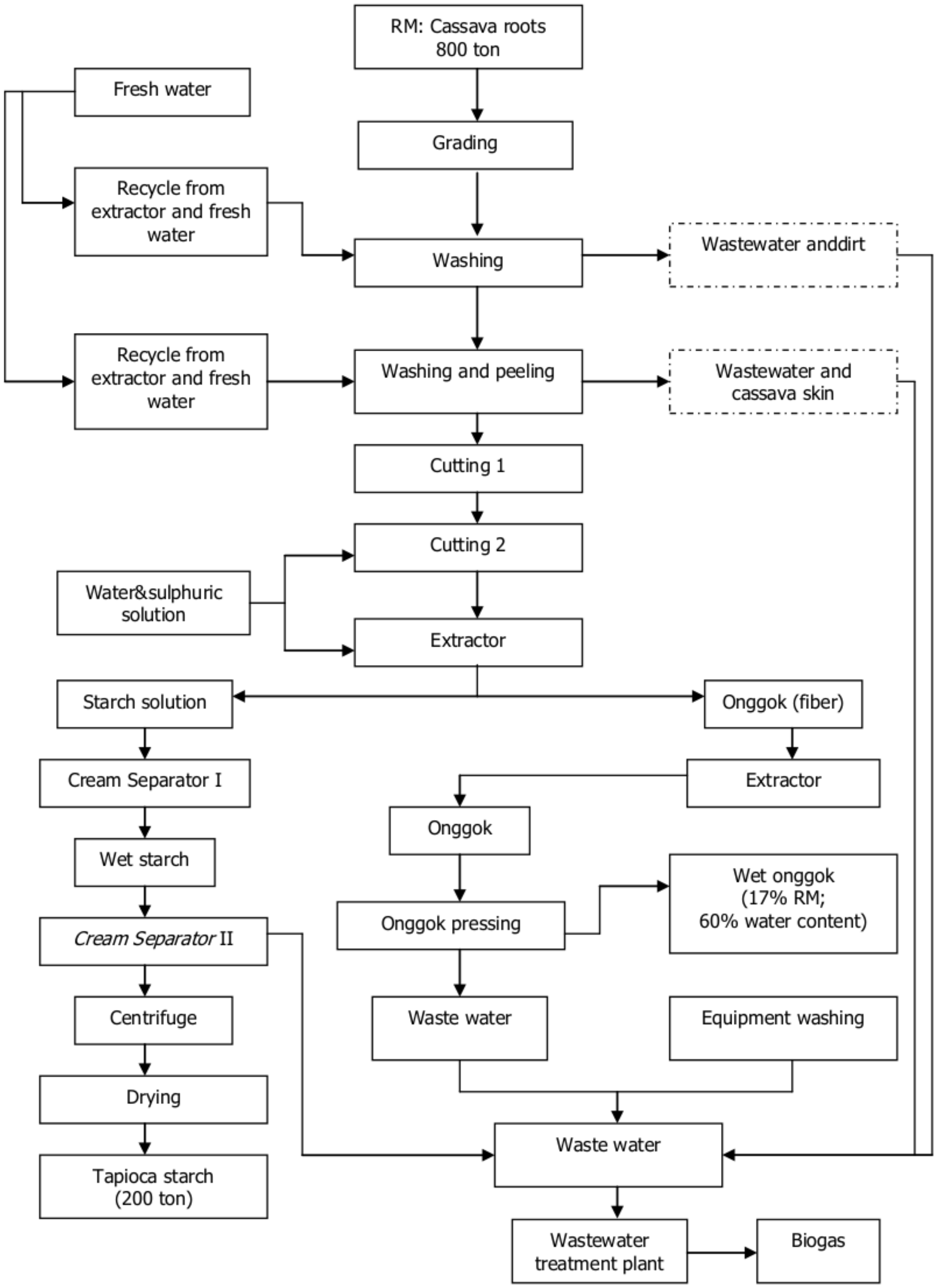

Figure 3. Flow chart for typical cassava processing to produce tapioca starch

Table 4.Biogas composition (% volume) produced from wastewater treatment in tapioca industries

Biogas Composition	Tapioca Industry Scale					
	small	Big	Big	Big	big	Average
Methane (CH_4)	54.36	60.47	55.97	52.38	57.89	56.21
Carbon dioxide (CO_2)	35.64	33.63	42.08	42.62	37.89	38.37
Nitrogen (N_2) and others*	10.00	5.90	1.95	5.00	4.22	5.41

*) by difference

Tabel 5. GHG emission reduction potential in cassava-based industries in Lampung Province

Data, factor, calculation	Unit	Quantity	Remark
DATA			
Cassava production	ton/year	7,569,178	
Total capacity of entire mills in Lampung	ton/year	5,200,000	
Wastewater (average)	m^3/ton cassava	3.66	
Fuel consumption in cassava mill	L/ton	36.62	
Electric consumption in cassava mill	kWhe/ton	199.3	
COD value of wastewater	kg/m^3	20.43	
COD removal efficiency	%	82	
FACTOR			
GHG factor for diesel fuel combustion	kg-CO_2e/L	2.92	Lal (2004)
GHG factor for coal power plant	kg-CO_2e/kWh_e	1.03	West,T.O. andMarland, G. (2002)
GHG factor for petroleum power plant	kg-CO_2e/kWh_e	0.96	West,T.O. andMarland, G. (2002)
Coal power plant efficiency	%	35.2	Graus*et al.*(2007)
Petroleum power plant efficiency	%	38 – 44	Eurelectric(2003)
Biogas power plant efficiency	%	30 – 40	Eurelectric(2003)
Energy value of methane	MJ/m^3	35.7	Calculated from www.chemeurope.com
CALCULATION			
Biogas production	m^3/ton cassava	28.83	
Biogas production throughout Lampung	m^3/year	149,926,518	
Methane (CH_4) component in the biogas	% volume	56.21	
Energy value of biogas	MJ/m^3	20.07	
Biogas equivalent to diesel fuel	L/m^3	0.52	
Total diesel fuel equivalent from biogas	L/year	77,976,847	
Potential GHG reduction due to CH_4 combustion	ton-CO_2e/year	1,264,105	
Potential GHG reduction due to fuel replacement	ton-CO_2e/year	227,613	
Potential GHG reduction due to electricity replacement	ton-CO_2e/year	302,566	
Total potential GHG emission reduction	ton-CO_2e/year	1,491,718 to 1,566,671	

With a total capacity 5.2 million ton of cassava tubers for entire mills in Lampung, it can be demonstrated that biogas energy potential generated from wastewater in cassava-based industries throughout Lampung Province was 150 million m3, equivalent to 78 million liter of diesel fuel, per year. Combustion of biogas will save CH_4 emission to the atmosphere at amount of 1.264.165 ton of CO_2 equivalent per year. In addition, the use of biogas may replace 78 million liter diesel fuel per annum. If the biogas is used to replace a part of diesel fuel, it will eliminate another GHG emission of 227,613 ton CO_2 equivalent per year. In case that biogas is used to replace electricity purchased from coal fired power plant, then it will remove 302,566 ton CO_2per year. In total, generating and utilizing biogas at cassava mills throughout Lampung Province potentially reduces GHG emission by 1,491,718 to 1,566,671ton CO_2 equivalent per year.

4. Conclusions

The main conclusion of the study is in the following:

1. Anaerobic digestion of wastewater in cassava mills potentially produce biogas energy equivalent to 78 million liter diesel fuel per annum.
2. Biogas produced from wastewater treatment in cassava mills may replace entire diesel fuel (166%) or entire electric power (113%) used in the mills.
3. The potential reduction of GHG emission due to biogas utilization in cassava mills 1,491,718 to 1,566,671ton CO_2 equivalent per year.

5. Acknowledgement

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