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Life cycle assessment of raw and fried *tette* chips production

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KEYWORDS

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Environmental impacts

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ABSTRACT

Madura has typical cassava-based food products including cassava chips, raw tette chips and fried tette chips produced by Small and Medium-sized Enterprises (SMEs). The production process of the three products varies and produces different environmental impacts. This study aims to evaluate and compare environmental impact assessments in the production of raw tette chips and fried tette chips using Life Cycle Assessment (LCA) approach. This study evaluates the product life cycle from the procurement of raw materials until the product is consumed. The results showed that fried tette chips had a lower environmental impact than raw tette chips per 500 g basis. Climate change, photochemical oxidation and eutrophication are environmental impacts identified in this study. The results of this study are expected to get a comprehensive environmental footprint of the product system with respect to sustainable production and consumption.

Introduction

Cassava (*Manihot esculenta* Crantz) is a one of the tubers that widely grow on the Madura island. Cassava crops are processed into various types of food products to increase their economic value. Some cassava-based food products include raw *tette* chips and fried *tett*e chips produced by Small and Medium-sized Enterprises (SMEs) which are usually located within the cultivating area. *Tette* chips are processed cassava products which are only found in Madura and become one of the unique souvenir products (Tamami, 2013). Raw *tette* chips and fried *tette* chips are mostly produced in Pamekasan district. There are 15 producers of raw *tette* chips and fried *tette* chips (BPS Pamekasan, 2014). The large number of industries also results in a large number of environmental impacts from the production of cassava-based food products.

The food industry especially SMEs is one of the largest industrial sectors in Indonesia. They use a large of energy. Food production, preservation and distribution consume a large amount of energy, which contributes to total CO_2 emission (Roy et al., 2009). Currently, consumers in developed countries want safe food, high quality and environmental friendly (Boer, 2002). There is increased awareness that the environmentally concious consumer of the future will consider ecological and ethical criteria in selecting food products (Andersson et al., 1994). Therefore, it is important to evaluate the environmental impact and the utilization of resources in cassava-based food products for sustainable production and consumption. This is expected to support the 12th goal in the Sustainable Development Goals (SDGs) namely responsible consumption and production (Albino, 2009). One way to achieve this goal is to produce green food products. Green product is a product designed to minimize environmental impacts throughout its life cycle by minimizing non renewable resources, not using toxic materials, and using renewable resources as needed according to the rate of regeneration (ISO, 2006).

Life Cycle Assessment (LCA) is a tool for evaluating environmental impact of a product, process, or activity throughout its life cycle (Roy et al., 2009). Several studies about LCA on food products have been carried out including LCA on local tomatoes and imports (Payen et al., 2014) LCA of bread production (Braschkat et al., 2003; Rosing and Nielsen, 2003), LCA of beer production (Takamoto et al., 2004) LCA of tomato ketchup production (Andersson et al., 1998; Andersson and Ohlsson, 1999), and LCA studies on potatoes (Mattsson and Wallén et al., 2003; Williams et al., 2006). Research on LCA in food products cassava-based has never been studied.

This study aimed to evaluate environmental impact of twocassava-based food products: raw

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tette chips and fried *tette* chips. It was expected to determine what environmental impacts produced in the production of raw *tette* chips and fried *tette* chips. This study also aimed to compare the environmental impact between the two products. The results of this study can be developed as a basis for developing green production of cassava-based food products.

Research Methods

Geographycal context and industry samples

In Madura, most raw and fried *tette* chips producers are located in Pamekasan district. This study used purposive sampling to choose a sample of industry. Two industries were chosen are raw *tette* chips by 'Tomina' and fried *tette chips* by 'Chalista'. All two industries used groundwater in the production process and used firewood as fuel in the frying process. The use of fuel wood produced large CO_2 emissions and it was not environmental friendly (WLPGA, 2018).

LCA methodology

LCA method is rapidly developing into an important tool for authorities, industries, and individuals in environmental sciences. Figure 1 shows the stages of an LCA method (ISO, 1997). LCA can be used to: (1) compare some alternative products, processes or services; (2) compare alternative life cycles for a certain product or service; and (3) identify parts of the life cycle where the greatest improvements can be made (Roy et al., 2009).

LCA goal and scope

The purpose of the study was to evaluate environmental impact of raw and fried *tette* chips production in Pamekasan district. This research defined the functional unit as 500 g of raw *tette* chips and fried *tette* chips. The system boundaries were from material procurement until the distribution of final products to the market (from cradle to market). This study included all direct inputs for raw and fried *tette* production, packaging and distribution to the market, but excluded calculation of human energy inputs.

The study used primary data for the consumption of material input, electricity, fuel, and water from industry samples. Secondary data such as fuel consumption for transportation and production, emission factor for fuel and electricity, were obtained from the literature. Detailed analysis of mass and energy balance of raw and fried *tette* chips production can be seen in Figure 2. The LCA modelling was performed with OpenLCA 1.6.3 software, while for the database used is *open_lca_methods_1_5_6.zolca*.

***Life Cycle Inventory Analysis* (LCIA)**

The analysis aims to collect supporting data for LCA such as amount of materials, production process, amount of supporting materials, amount of fuel, electricity, and water, waste and emission which produced from raw and fried *tette* chips manufacturing. Supporting data for LCIA of raw and fried *tette* chips can be seen in Table 1 and Table 2.

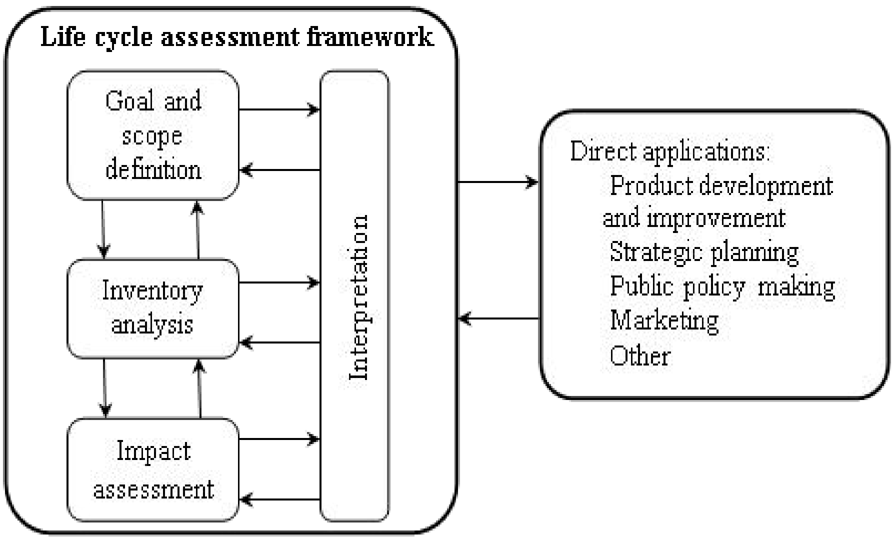

Figure 1. Stages of an LCA method (William et al., 2006)

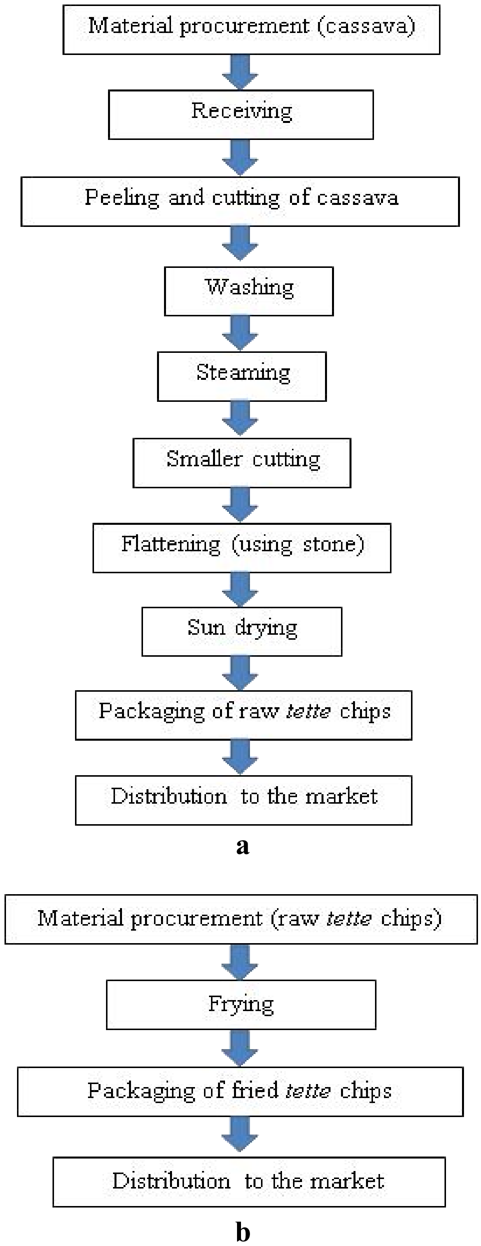

Figure 2. Flow diagram for production of raw *tette* chips (a) and fried *tette* chips (b)

Impact Assessment

Assessment and classification of environmental impacts caused by waste (liquid, solid and gas) from the production of raw and fried *tette* chips.

Interpretation

The interpretation is the stage of improvement, completion and conclusion of the solution aspects and impacts analyzed from the data obtained

Results and Discussion

Three categories of environmental impact of raw and fried *tette* chips production are climate change, photochemical oxidation dan eutrophication. Environmental impact assessment of raw and fried *tette* chips production can be seen in Table 3.

Climate change

Climate change is caused by global warming due to gradual deviations or anomalies in the earth's temperature increase over the years (Hairiyah et al., 2016). There are 3 main greenhouse gases (GHGs),carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) (Intergovernmental Panel on Climate Change, 2007). In the production of raw *tette* chips, material procurement, steaming and distribution stage were the main contributor to the climate change. Material procurement using gasoline as fuel, steaming process using firewood, and product distribution using gasoline as fuel. The three processes produce CO_2, CH_4 and N_2O which cause climate change impacts. Calculation of emissions from gasoline and LPG (Liquefied Petroleum Gas) is determined from the calculation of the amount of consumption, the heating value of gasoline and LPG and greenhouse gas emission factors. The amount of gas calculated in kg (inventory result) is multiplied by the impact factor in the OpenLCA software database. In the production of fried *tette* chips, material procurement and frying stage was the main contributor to the climate change. Material procurement using gasoline as fuel and frying process using LPG. Both of these processes produce CO_2, CH_4 and N_2O which cause climate change impacts.

Table 3 showed that raw *tette* chips production contribute to climate change bigger than fried *tette chips* production per 500 g basis. Raw *tette* production used woodfuels for steaming process. Woodfuel was dramatically less carbon-efficient than LPG. Wood consists of 50% fuel. LPG, by contrast, is 100% fuel. Per unit of delivered cooking heat, burning wood generates about five times the carbon of LPG (Nautiyal, 2013). Replacing fuel wood with LPG has a positive impact because it can reduce diseases caused by air pollution in the production room (Widodo et al., 2013).

Photochemical oxidation

The steaming process and product distribution in the production of raw *tette* greatly contributes to the photochemical oxidation. The steaming process uses fuelwood to produce methane gas emissions. Methane gas has the properties of asphyxia which can replace oxygen (Widodo et al., 2013). Thus, humans exposed to methane gas at certain concentrations may experience symptoms of oxygen deficiency such as nausea, dizziness, tightness, and etc. According to the 4.4 version CML baseline impact assessment method, methane gas has an impact factor of 0.006 kg ethylene eq/kg, thus methane gas has an impact of photochemical oxidation 0.006 times lower than of the ethylene gas. Open LCA software calculates by calculating inventory result with impact factor to find out the impact result.

Table 1. Input and output of raw *tette* production ("Chalista" SMEs, Pamekasan district)

Process and materials	Input	Output
Material procurement		
- Cassava (kg)	100	100
Receiving		
- Cassava (kg)	100	100
Peeling and Cutting		
- Cassava (kg)	100	
- Peel and waste		10
- Cassava		90
Washing		
- Cassava (kg)	90	90
- Ground water (L)	80	80
Steaming		
- Ground water (L)	10	10
- Wood (kg)	50	
- CO_2		
- NH_4		
- N_2O		
Smaller cutting		
- Cassava (kg)	90	90
Flattening		
Sun drying		
Packaging		
Product distribution		
- Gasoline (L)	1	
- CO_2 (kg)		2.05821
- CH_4 (kg)		0.0009801
- N_2O (kg)		0.0000891

Note: 100 kg cassava produced raw *tette* 50 unit (@500 g)

Table 2. Input and output of fried *tette* production ("Chalista" SMEs, Pamekasan district)

Process and materials	Input	Output
Material procurement		
- Gasoline (L)	1	
- CO2 (kg)		2.05821
- CH4 (kg)		0.0009801
- N2O (kg)		0.0000891
Frying		
- Raw *tette* chips (kg)		10
- Palm oil	10 L	90 kg
- LPG (kg)	3	
- CO_2 (kg)		0.1199
- NH_4 (kg)		0.00001
- N_2O		0.0001
Packaging		
- Electricity (kwh)	0,45	
- CO_2 (kg)		0.33
Distribution		

Note: 5 kg material input (raw tette chips) *tette* chips produced fried *tette* chips 10 unit @ 500 kg

Table 3. Environmental impact assessment of raw and fried *tette* chips production (500 g)

Process	Climate change (kg CO_2 eq.)	Photochemical oxidation (kg ethylene eq.)	Eutrophication (kg PO_4 eq.)
Raw *tette* chips			
- Steaming	1.32E+01	7.22E-05	5.8080E-03
- Distribution	1.32E+01	7.21E-05	5.8032E-03
TOTAL	2.64E+01	14.43E-05	11.6112E-03
Fried *tette* chips			
- Material procurement	2.35E+00	5.35E-05	2.6463E-03
- Frying	1.50E-01	6.00E-06	2.7000E-03
TOTAL	1.735E-01	6.535E-06	5.3463E-03

The calculation results (Table 3) showed that one unit fried *tette* chips produces a photochemical oxidation effect lower than *tette* chips production in the same functional unit (500 g). This is due to the use of fuelwood in steaming process which produces more methane gas emissions than raw *tette* production. In the raw *tette* production, the use of gasoline was higher than fried *tette* production.

Eutrophication

Eutrophication is one of the impact categories calculated based on emissions equivalent to kg PO_4 eq. In raw *tette* production, the steaming and product distribution process produces N_2O emissions which can be equivalent to PO_4. N_2O results from burning fuelwood in the steaming and gasoline burning processes in the product distribution. In relation to eutrophication, the use of fuels such as fuel wood and gasoline has large contribution. Replacing fuel wood into LPG as fuel is recommended to reduce environmental impacts (Nautiyal, 2013). Table 3 showed that raw *tette* chips have en eutrophication effect greater than fried *tette* chips, because they use fuel wood and use more gasoline.

Interpretation

The stage discusses solutions to minimize the impacts produced by the manufacture of raw and fried *tette* chips. The most effective way to reduce the impact produced is not in the waste treatment, but in the efficiency and improvement of the production process. To reduce climate change, industry can plant trees around the production site. Tree planting efforts around the location of sources of emissions can increase carbon stocks and reduce the impact of greenhouse gas emission (Hairiyah et al., 2016). In general, to reduce the impact of climate change, photochemical oxidation, and eutrophication by replacing fuel wood into LPG (Nautiyal, 2013) and using gasoline more efficient.

Conclusions

In conclusion, there were 3 categories of environmental impact of raw and fried *tette* chips production: climate change, photochemical oxidation dan eutrophication.The raw *tette chips* production has a lower impact than fried *tette* chips production in the same functional unit (500 g). Every 500 g of raw *tette* chips produce 2.64E+01 kg CO_2 eq, 14.43E-05 kg ethylene eq and 11.2116E-03 kg PO_4 eq. While every 500 g of fried *tette* chips produce 1.735E+01 kg CO_2 eq, 6.535E-06 kg ethylene eq and 5.3463E-03 kg PO_4 eq.

Various recommended strategies for the industry include to plant trees around the production site, to replace fuel wood into LPG, and to efficiently use gasoline for reducing the environmental impacts.

Conflict of interest

Authors declare that there is no conflict of interest.

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