Implementation of Life Cycle Assessment on Tempeh Production at "Tempe Ibu Sujati", Yogyakarta

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Abstract

Tempeh is one of Indonesian traditional food that have been favored by the locals for centuries. Tempeh has a life cycle from the supply of raw materials, production processes, packaging and transportation that have a potential impact on the environment. In this study Life Cycle Assessment (LCA) is used as a tool to evaluate the environmental impact on Global Warming Potential (GMP). The LCA study will be conducted in tempeh industry "Ibu Sujati" located at Pandean Street, Umbulharjo, Yogyakarta. The LCA study will be focused on the energy consumption in production process, including the raw material transportation . The result showed the boiling process which part of production process has the largest GWP value that equals to 0.488388 kg CO_2-eq which contributes 78.79% of the total GWP in the system boundaries.

Keywords: *energy consumption, global warming potential, life cycle assessment, tempeh*

1. INTRODUCTION

Tempeh is one of Indonesian traditional food that have been favored by the locals for centuries. According to the data gathered by Statistics Indonesia (BPS), average consumption of tempeh in Indonesia reached 0,146 kg/capita/week in 2018 (Anonymous, 2019). The high demand of tempeh has to be balanced by the production rate. Tempeh is made from soybean. Arief (2019) reported that according to Gabungan Koperasi Produsen Tempe Indonesia (Gakoptindo) production of tempeh in Indonesia in 2018 is 2.6 million tons with 120,000-unit producer in total. Tempeh has various selling prices depends on the place. In traditional market tempeh sells at Rp 12,000 – Rp 15,000 per kilogram. In the shopping mall or supermarket tempeh sells at Rp 18,000 – Rp 25,000 per kilogram. For exports, tempeh sells at Rp 30,000 – Rp 40,000 per kilogram.

Tempeh industries face few serious issues on its daily production such as raw material (soybean) availability, environmental impacts, energy consumption, quality inconsistency, etc. This paper will further discuss about the energy consumption of a tempeh industry and the environmental impacts of it. Tempeh has high production rate and a large number of industries. Tempeh industries use various sources of energy according to its capabilities and preferences. Energy sources that usually used in the production process are firewood, gas, and electricity (Insusanty et al., 2016). In the distribution process, petrol is needed to run the vehicle used. The usage of those energy sources contribute to greenhouse gases production such as carbon dioxide (CO2), carbon monoxide (CO), and others. The majority of tempeh industries run in small- scale home industries. Most of them are not aware of the urgency in minimizing greenhouse gases nor have the capabilities to improve their production and distribution process into a more environmentally friendly one.

One of the early stages to form an environmentally friendly industry is Life Cycle Assessment (LCA). According to ISO 14040:2006, LCA addresses the environmental aspects and potential environmental impacts (e.g. use of resources and the environmental consequences of releases) throughout a product's life cycle from raw material acquisition through production, use, end-of-life treatment, recycling and final disposal (i.e. cradle-to-grave) (Anonymous, 2007). There are four phases in an LCA study including goal and scope definition, inventory analysis, impact

assessment, and interpretation (Anonymous, 2007). The result of LCA study will be used by the stakeholder to create a product and production process that is sustainable and have minimal impact to the environment.

LCA study will be conducted in tempeh industry "Ibu Sujati" located at Pandean Street, Umbulharjo, Yogyakarta. The LCA study will be focused in energy consumption of the specific industry in the production and transportation of the final goods. The outcome of the study is the environmental impact measure of the specific energy consumption in tempeh industry "Ibu Sujati".

2. MATERIAL AND METHODS

2.1 Goal and Scope Definition

Goal and scope definition is the starting point of the whole method of LCA that must be defined as the reference and becomes the boundary to answer the purpose of the research. Goal of this LCA is to calculate the Life Cycle Impact Assessment (LCIA) to determine the hotspot especially for the Global Warming Potential (GWP). Scope of the life cycle in this research is tempeh industry, especially in the scope of Gate to Gate that includes tempeh production and product transportation which focused at energy and fuel uses burden. This LCIA study was done at "Rumah Produksi Tempe", where the product is the tempeh that is ready to sold. LCIA study scheme in this research is shown in Figure 1. Life cycle of tempeh product as shown in Figure 1 below is the boundary of this LCIA research, that start from tempeh production process until end at end product transportation.

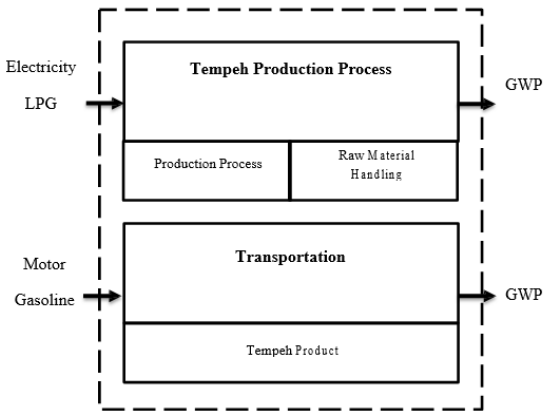

Figure 1. Life Cycle Scheme of Tempeh Product from Tempe Ibu Sujati

2.2. Functional Unit

Functional unit used in this research is 1 kg tempeh. The industry produces bar-shaped tempeh, as well as thinner shape of tempeh and the longer shape. There is no fixed form of the product.

2.3 System Boundaries

The system boundaries of this research is from the input material which is soybean is come into the industry from the soybean supplier. The boundaries end at the transportation of product, which uses motorcycle as the vehicle to transport them. The subsystem is divided at each process in the industry, started from soybean cleaning, followed by soybean soaking, and then soybean husk removal, followed by rinsing, soybean boiling, cooling, yeast sowing, packaging, fermentation, and end at transportation.

3. RESULTS

3.1 Life Cycle Inventory

Inventory analysis is done by taking an inventory of all input and output flows involved in mass and energy units per kg of tempeh products. Inventory data used includes secondary data obtained from the company, and various previous research publications. Some other data are primary data and data from the results of their own calculations using several assumptions.

The life cycle inventory analysis of tempeh products in this study was conducted in the process of production and transportation of products to consumers. In this LCA study, the input that will be calculated as an inventory analysis in the transportation system is only from the fuel consumed because it has a direct impact on the environment. As fuel consumption increases the GHGs it generates also increases. Inputs in the production system are soybean, LPG gas, tempeh yeast, drums, plastic packaging, water for production, and electricity while the output of the material from the system is hygienic tempeh, soybean husk mixture and wastewater production. Inventory of the stages of the production process that can have an impact on the environment is every use of LPG gas and electricity. LPG gas is used in the process of boiling soybeans and boiling water. Electricity is used as a driving source for

washing machines (mixers), soybean crushing machines, sample storage freezers, and pumping machines for the supply of production water. LPG gas can have a direct impact during its use while electricity that is calculated for its impact comes from the procurement of the electricity source used (IPCC, 2014).

3.2 Life Cycle Impact Assessment

The impact assessment became the next step to evaluate the impact that comes from making the product (Ifdholy, 2018). The impact category that commonly used is GWP (Global Warming Potential), AP (Acidification Potential), and EP (Eutrophication Potential), but the category that we observed is only GWP (Global Warming Potential) due to the restriction of time and resources that used in this research. The normalization factor is based on Table of Default Net Calorific Values (NCVs) and Lower and Upper Limits of the 95% Confidence Intervals and Table of Default Emission Factors for Stationary Combustion in Manufacturing Industries and Construction. In Table 1 the amount of Green House Gases (GHG) emitted by some sources are shown, following where the process are them at. Most part of the GWP is determined by the amount of GHG that emitted to environment, because the main component of GHG are carbon. Carbon is an organic compound, and has high environmental burden, especially in the contribution of the high GWP. The burning process in the industry produces some carbon in it, and can causing global warming if there is high amount of it emitted to the atmosphere.

After the amount of gases is acquired, the amount should be converted into kg CO_2-eq unit. To convert that, the amount of each gases multiplied by the conversion factor of each GHG. The conversion is as shown on Table 2 and Table 3.

GWP values is calculated for each process in the system boundary, that is soybean boiling and transportation. Figure 2 shows the results of GWP impact categories in each process. Soybean boiling has the largest GWP value, which is 0.488388 kg equivalent CO_2, followed by Transportation which has the GWP value of 0.131478 kg CO_2-eq. This GWP are affected by the emissions of fuel that used in each process. The largest GWP is the soybean boiling, which is using LPG as the fuel. Although by direct observation the transportation emitted some smoke from the motorcycle used by the worker, but the GWP value of transportation is smaller than soybean boiling. This caused by the amount of LPG used by Ibu Sujati Tempeh Industry is quite much, reaching 12 kg per day.

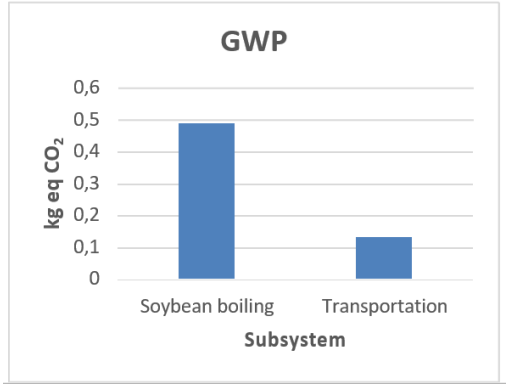

Figure 2. GWP Values on Each Subsystem

Table 1. Amount of GHG Emission to Environment per 1 kg Tempeh

Process	Source	Ai (Gg)	NCV (TJ/Gg)	EF	EF Unit	GHG Emission
Soybean boiling	Liquified Petroleum Gas (LPG)	0.15 kg x 10^{-6}	47.3	63100	Kg CO_2/TJ	0.448 kg CO_2/TJ
		0.15 kg x 10^{-6}	47.3	1	Kg CH_4/TJ	7.095 x 10^{-6} kg CH_4/TJ
		0.15 kg x 10^{-6}	47.3	0.1	Kg N_2O /TJ	7.095 x 10^{-7} kg CO_2/TJ
Transporta-tion	Motor Gasoline	0.0425 kg x 10^{-6}	44.3	69300	Kg CO_2/TJ	0.131 kg N_2O /TJ
		0.0425 kg x 10^{-6}	44.3	3	Kg CH_4/TJ	5.648 x 10^{-6} kg CH4/TJ
		0.0425 kg x 10^{-6}	44.3	0.6	Kg N_2O /TJ	1.130 x 10^{-6} kg N_2O /TJ

Table 2. Life Cycle Impact Assessment of Each GHG Emission for 1 kg Tempeh in Soybean Boiling Subsystem

LCI	Impact Categories	Factors	LCIA	Total LCIA
Emissions to air				
0.448 kg CO_2	GWP	1	0.448 kg eq CO_2	0.488388 kg eq CO_2
7.095×10^{-6} kg CH_4	GWP	25	1.77×10^{-4} kg eq CO_2	
7.095 x 10-7 kg N_2O	GWP	298	2.11 x 10-4 kg eq CO_2	

Table 3. Life Cycle Impact Assessment of Each GHG Emission for 1 kg Tempeh in Transportation Subsystem

LCI	Impact Categories	Factors	LCIA	Total LCIA
Emissions to air				
0.131 kg CO_2	GWP	1	0.131 kg eq CO_2	0.488388 kg eq CO_2
5.648×10^{-6} kg CH_4	GWP	25	1.41×10^{-4} kg eq CO_2	
1.130×10^{-6} kg N_2O	GWP	298	3.37 x 10-4 kg eq CO_2	

3.3 Interpretation

As shown in Figure 3, based on the Life Cycle Impact Assessment, soybean boiling has the greatest GWP value which is contributes around 78.79% of the total GWP value in this system boundaries. This is because soybean boiling uses quite much amount of the LPG that emitted GHG like CO_2, CH_4, and N_2O to the atmosphere, especially the CO_2 gas that contributes mostly to the GWP, thus increasing the potential of global warming. The hotspot in this system boundaries is the soybean boiling process.

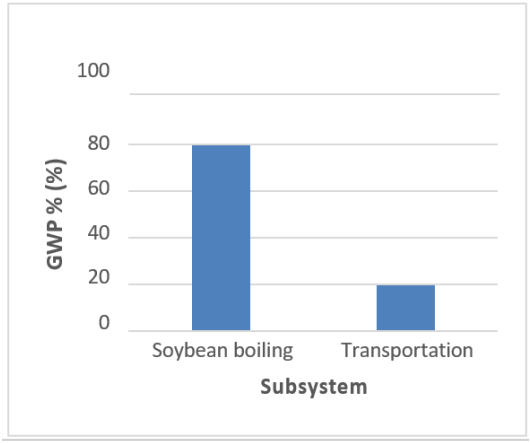

Figure 3. Contribution to Total GWP in the System Boundary for Each Subsystem

CONCLUSIONS

Based on data result and discussion, it could be concluded that:

1. Energy usage of Ibu Sujati Tempeh Industry production per 1 kg of tempeh product on boundaries gate to gate are 0,15 kg LPG for the soybean boiling process, and 0,0425 kg motor gasoline for the transportation. All the source of energy was converted in the unit of kg CO_2-eq for measuring the Global Warming Potential (GWP).
2. Based on the result of impact categories, the soybean boiling process has the largest GWP value that equals to 0.488388 kg CO_2-eq, followed by transportation that the GWP value equals to 0.131478 kg CO_2-eq.
3. The hotspot of this system boundaries is soybean boiling process, which is contributed around 78.79% of the total GWP in the system boundaries.

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