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ASSESSMENT OF TOFU CARBON FOOTPRINT IN BANYUMAS, INDONESIA - TOWARDS 'GREENER' TOFU

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Abstract

Tofu is famous as an alternate protein source. Comparing to Beef and Chicken based products; Tofu is indeed one of those promising foods which using less energy. Nevertheless it takes a lot of energy to turn fresh soy beans into tofu. It includes energy used for draining, grinding, cooking, extracting the soymilk, pressing the curd, cutting and wrapping the final products. To increase the love of tofu, consumers in the era full with environment awareness need to be convinced that switching from others to bean curd does help cutting back greenhouse gas emissions. The question is: how significant are those numbers? Is it possible to reduce energy usage in tofu production without interfering its quality? This research, conducted in one of tofu central productions in Indonesia, attempts to answer those questions. Kalisari village, Banyumas is also known as tofu village, since producing tofu in traditional ways is the main occupation of its residents. The objectives of the study are: (1) to investigate the overall energy consumption and emission produced by tofu production process in Kalisari village, Banyumas, Indonesia, (2) to compare those numbers with other soybean products as well as other protein sources and (3) to come up with process improvements to reduce the tofu carbon footprint. Life Cycle Assessment methodology (LCA) – a method commonly used to identify and calculate energy usage, natural resources usage and amount of emissions to the environment - is applied to reach those objectives. This paper depicts preliminary results of this on-going research.

Keywords: Tofu, LCA, Indonesia, Energy consumption, Carbon footprint

INTRODUCTION

Tofu – a soy-based product - is on high demand, especially in Asia. This inexpensive product is healthy, characterized by its high protein, low fat, and very low saturated fat content. Previous researches suggest that soy can lower cholesterol levels, and the best way to consume it is in the form of processed products such as tofu or tempeh. Additionally, tofu itself is cholesterol free. One of tofu production centers in Indonesia is located in Kalisari, Banyumas. In the village covering 204,355 ha area there are 312 tofu craftsmen involving about 1,400 workers who transform soybean into the bean curd product every day in their houses. On average the production volume is about 7.5 – 8 tons soy bean each day. Clearly, tofu production gives a positive impact on the community's economy by providing jobs for most of the villagers (Source: Village Kalisari, 2012).

The production process in Kalisari village is carried out in traditional ways, in which approximately 25 liters of water is added for each kg soybean processed. As other production processes, tofu production not only produce the final output, but also waste-products such as solid and liquid waste. Soybean as the main raw material contains 34.9 percent protein, 34.8 percent carbohydrate and 18.1 percent fat. Consequently, its wastewater contains high organic material also. High organic material in wastewater may lead to the death of aquatic organisms, inhibiting growth of aquatic plants and cause unpleasant odor.

Fortunately, in recent years, Kalisari industrial center's wastewater problem has received a lot of attention from various research groups. As one of the results, the center has already equipped with three wastewater plants built from the contribution of the Ministry of Research and Technology. Biogas generated from the Waste Water Treatment Plants (WWTP) is then provided to the community for domestic purposes. Unfortunately, the existing WWTP has not been able to accommodate all wastewater generated by tofu industrial centers. It is also discovered that the WWTP effluent back into society was not entirely meet the standard output established by Indonesian Government. However, the problem with solid wastewater is resolved by transforming it into a side product called tofu crackers.

Aside from wastewater problem, tofu production suffers from its high energy usage. It requires a great deal of energy for each production processes: draining, grinding, cooking, extracting the soymilk, pressing the curd, cutting and wrapping the final products. The energy is consumed in the form of electricity, fuel usages as well as human energy. Obviously, the higher the energy consumed, the higher the emissions also.

Hence, to increase the love of tofu, consumers in the era full with environment awareness need to be convinced that switching from others to bean curd does help cutting back emissions and environmentally friendly. Therefore, the objectives of this on-going study are: (1) to investigate the overall energy consumption and emission produced by tofu production process in Kalisari village, Banyumas, Indonesia, (2) to compare those numbers with other soybean products as well as other protein sources and (3) to come up with process improvements to reduce the tofu carbon footprint.

METHODOLOGY

The subject of this research is tofu production centers in Kalisari Village, Banyumas. Life Cycle Assessment methodology (LCA) – a method commonly used to identify and calculate energy usage, natural resources usage and amount of emissions to the environment - is applied to reach research objectives. Four main components of LCA are as follows: (1). Goal and Scoping, (2). Inventory Analysis, (3). Impact Assessment, (4). Improvement Analysis (ISO14040, 2007).

Required data for LCA include environment impact, wastewater produced, energy consumption and inputs used in each step of the production. To conduct a credible LCA, it is critical to use good quality, current data on all raw materials, energy, and processing aids used as well as the environmental outputs associated with producing a product because this information becomes the platform for performing the life cycle inventories (LCIs) which are the basis for the LCA (OmiTech International, 2010). The limitation of this study is it only measures the impact of air emissions and water emissions. Air emissions will be limited to the measurement of CO2 levels, while the water emissions will be based on measurements of pH, BOD and COD.

For this study, both primary and secondary sources of information are utilized for LCA data collection. Primary data, including monthly gas, electricity, and soybean use, from production centers in Kalisari village is used to calculate energy use per tofu unit (kilogram). Secondary data from recent tofu LCA is utilized to gather tofu production information including energy and water usage. Selected academic papers and online sources are used to find energy content as well as emission factor information for various energy sources, as summarized in Table 1 and Table 2. Energy usage and emission calculation is depicted in Figure 1.

Table 1. Energy Conversion Factor

Energy Source	Energy Content
Diesel	38,68 MJ/l
Manpower	0.725 (MJ/hr. person)
Firewood	16 MJ/kg
Electricity	1kWh = 3.6MJ

Table 2. Emission Factors

Energy Source	Emission Factors	Reference
Diesel	22.37 kg CO2e / l	US EIA, 2009
Petroleum	19.54 kg CO2e / l	US EIA, 2009
Diesel	74,100 kg/TJ	IPCC Guidelines, 2006
Firewood	112,000 kg/TJ	IPCC Guidelines, 2006
Electricity (Hydro)	28 t CO2e / GWh	BC Hydro.com

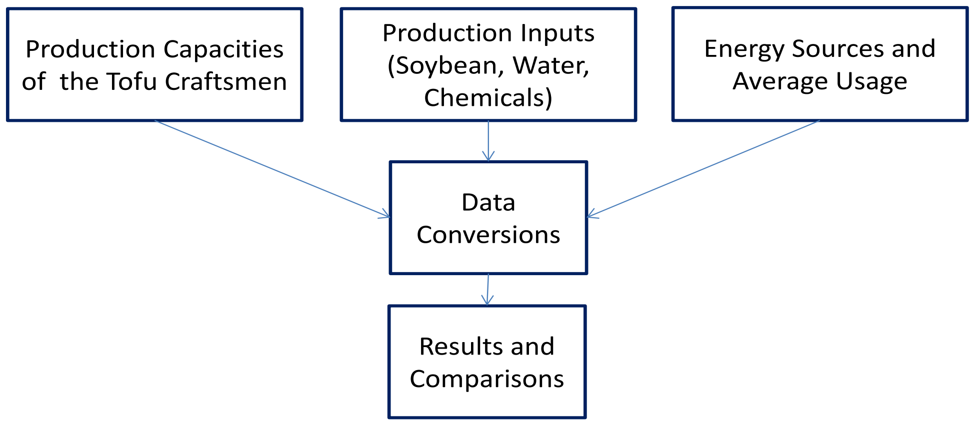

Figure 1. Energy usage and emission calculations

RESULT AND DISCUSSION

Tofu production process which carried traditionally in Kalisari Village, Banyumas is illustrated in Figure 2. The average waste-water produced is 7.8 liter/kg soybean. The main energy sources for production process are firewood and diesel. Electricity is only used for waste water treatment plant's pumps and some lighting.

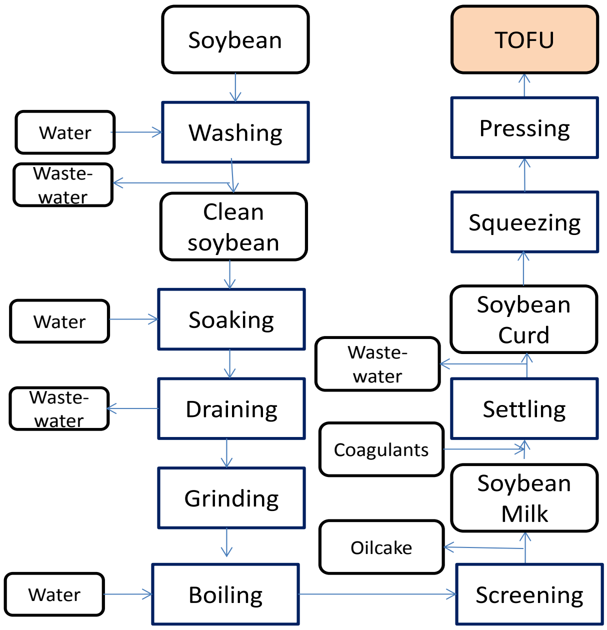

Figure 2. Tofu Production Process in Kalisari, Banyumas

Currently there are 256 active production centers in the village varying from very small industries to medium ones. The production capacity of each tofu production center is between 10 kg soybeans to 200 kg soybeans daily. Sixty seven of them have already equipped with waste-water processing plants producing biogas for 91 households. The biogas is plentiful enough for daily usage of those households, but not for tofu production activities. The remaining production centers – mainly small production centers – still have to work with the waste-water problems, as portrayed in Figure 3.

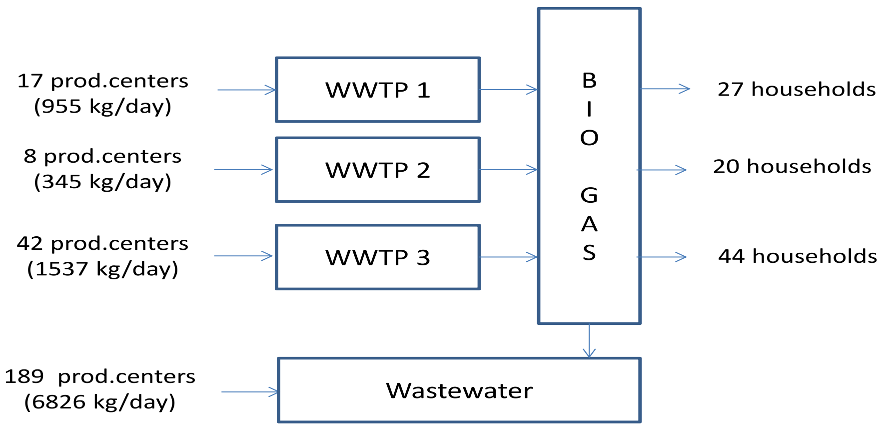

Figure 3. Current Wastewater Treatment Plans
(Sources of data: Primary Data, Musfiqoh (2013), Prihantoro (2012))

On average, each kilogram tofu requires 3 liters of water, 0.62 kg of firewood as the main energy source and 0.04 l of diesels as the additional energy source. Typically, each kilogram tofu produces 3.53 l wastewater and 0.35 tofu oilcake. The latter is not considered waste by the villagers; the tofu craftsmen have fully utilized it to create side products, by transform it into tofu crackers. The main inputs and output of the tofu production process are summarized in Table 3.

Table 3. Inputs and Outputs of Tofu Production Centers *)

		Unit	Quantity
INPUTS	Soybean	kg	0.45
	Water	l	11.29
	Firewood	kg	0.62
	Diesel	l	0.04
OUTPUT	Fresh Tofu	kg	1
EMISSIONS TO WWTP	Wastewater	l	3.52
SOLID WASTE	Residues	kg	0.35

*)Based on average of 25 production centers

Table 4 shows the energy usage as well as the emission for each kilogram of Kalisari tofu produced. Approximately 11.44 MJ energy is required to produce one kilogram tofu. The data collected from 25 production centers shows that fuel energy is the most significant energy source used, which account for 87.75 % of energy usage, followed by human power energy and diesel energy, which have share of 12.89% and 0.66% respectively.

Table 4. Energy Usage and Emission Produced

	Energy (MJ/kg tofu)	Emission (CO2e gr/kg tofu)
Diesel	1.46	107.13
Firewood	9.93	1,591.99
Workforce	0.07	
Electricity	0.05	0.40
Gasoline	0.07	5.26
	11.44	**1,699.52**

Carbon footprints for soybeans as well as tofu varies based on different farming systems, energy sources, processing steps, efficiency of the processes, and other factors. Huo et al, (2009) reported that the total energy used in conventional soybean production is estimated to be 22,084 Btu/bu: 64% diesel, 18% gasoline, 8% LPG, 7% natural gas, and 3% electricity. It results in 57.29 gram CO^2e/kg soybean produced (Omni Tech International, 2010). While one kilogram of soybean in Netherland produces 642 gram carbon dioxide equivalents. Whereas a kilogram tofu sold in Rotterdam produces about two kilogram carbon dioxide equivalents from farm to supermarket (Daalgard et al., 2008), Kalisari tofu creates about 1.70 kilogram carbon dioxide equivalents from the production process only. Assuming the craftsmen use Netherland soybean, tofu from farm to market generates about 2.4 kilogram carbon dioxide equivalents.

Table 5. Carbon Footprints

Product	**CO_2 e/kg product**	**System Boundary**	**Reference**
Kalisari Tofu	1.70 kg	Prod to Market	-
Netherland Tofu	2.00 kg	Farm to Market	Daalgard et al., 2008
Chicken Meat	3.00 kg	Farm to Market	Daalgard et al., 2008
US Beef	15.00 kg	Farm to Market	Capper, 2011
Soybean Oil	2.96 kg	Farm and Prod.	Omni Tech Int., 2010
Crude Soy Oil	2.82 kg	Farm and Prod.	Omni Tech Int, 2010
Netherland Soybean	642 gr	Farm to Gate	Daalgard, 2008
Conventional Soybean	620 gr	Farm to Gate	LCA Food Dbase

Hence the total carbon foot print of the tofu produced in Kalisari village is better compared to other soy-based products, such as soybean oil. It is also significantly better than other protein source products such as chicken meat and beef. However, compared to tofu produced in Netherland it yields more emissions. Clearly, more detail analysis need to be done to study the differences and come-up with improvement plants to reach the goal of producing a 'greener' tofu. Detail analysis on volume of air and land emissions is currently being performed. The research should be completed in few months. Complete findings along with discussion on possible improvements in energy-usage and volume of emissions will be presented in the next paper once the study is wrapped-up.

CONCLUSION

Energy for tofu production in Kalisari Village, Banyumas, Indonesia is mainly from fuel energy which account for 87.75% of total energy required to transform soybeans into tofu, transporting it to the consumer as well as for waste-water processing plants. This main source of energy might be the one accountable for relatively high CO2 emissions of Kalisari tofu production. In terms of carbon foot prints, compared to other protein-source products, such as chicken meat and beef, tofu is significantly offering lower emissions. However, more extensive study is needed to picture the overall impacts of tofu production to the environments.

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