Waste Management Option and Renewable Energy from Tofu Processing Waste in Banda Aceh City

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Abstract
This study discussed possible waste management option, renewable energy and material balance, from tofu processing waste in Banda Aceh City. There are 12 tofu processing industries in Banda Aceh with raw materials capacity ranging from 200-350 kg/day for each industry. Totally, about 66,000 kg of wastewater produced from 3,000 kg/day soybean in Banda Aceh. Currently, the waste has been disposed into the environment and river without any treatment, causing bad odours and pollution of the surface and ground water. The management of this waste with high water content represents an economic problem because of the high costs for disposal, treatment and/or use. Owing to its non-cellulosic nature with high carbohydrate and proteins, tofu processing wastewater has the potential to produce renewable energy such as methane, biohydrogen and ethanol. Depend on the process conditions, anaerobic digestion has been suggested as an alternative method of removing the high-concentration organic waste in tofu processing and at the same time can produce a clean renewable energy source of methane and hydrogen.

Keywords: Tofu waste, renewable energy, anaerobic digestion, organic compound, biogas.

Introduction
Biomass is a carbon-containing renewable energy resource but does not lead to the increment of green house CO₂ in a long term, and it is expected to be the resource of energy and chemicals in the future. To develop an appropriate technology which operates on a range of raw materials, the biomass chemical composition and other features should be taken into account.

Indonesia has been endowed with natural resources in areas such as forestry and agriculture. In agriculture sector, oil palm trees are widely planted in Indonesia, thus it is not surprising that it is the major biomass source and the world highest producer. The oil palm residue ranging from empty fruit bunches and fronds to the shell and mesocarp fibres can all be converted to energy sources via combustion, gasification and pyrolysis. The waste of oil palm processing has also been converted into methane gas by fermentation at a laboratory scale and know is developing for demonstration pilot scale. However, huge demand of oil palm and its application leads the competition of oil palm for food and energy. Therefore, alternative biomass source like crop residue is gaining popularity.

The unrestricted use of fossil fuels-based energy has severely hampered our environment, and caused global warming and greenhouse effect. Now, the decreasing availability of fossil fuels has drastically raised the prices of liquid and gaseous fuels worldwide. Therefore, developing renewable energy is indispensable. Anaerobic fermentation technology showed great potential for biogas (hydrogen and methane) and alcohol (bioethanol and biobutanol) production. These biofuels could be converted into energy through combustion engine or fuel cell [1,2]. Among all carriers of renewable energy, biogas (H₂ and CH₄) is an ideal and clean source of energy and its research is becoming more and more popular in recent years due to several benefits to its credit [1,3]. On the other hand, ethanol has remained the major commercial biofuel around the world.
and is blended with gasoline in several countries. In the past, using crops such as corn, sugarcane and sorghum as feedstock for producing bio H₂ and ethanol by dark fermentation was not cost-effective, and raised the food and fuel competition issue [1,3]. Therefore, organic wastewater is a potential feedstock for biogas and ethanol production [1,4].

Tofu is a very popular food among the Asian population, specifically in Japan and Indonesia, and is gaining popularity among Europeans as well, due to the associated health benefits and its acceptable price. Tofu is produce by grinding of soy bean, cooking (boiling), filtration, protein coagulation, preservation, and packaging. It has been reported that up to 30% of the soy bean is lost, becoming waste. However, only a small percentage of tofu waste is utilized as nutritious feed for livestock, the remainder being incinerated and/or reclaimed as industrial waste, thereby contributing to serious pollution problems.

The management of tofu processing waste represents an economic problem because of the high transportation costs for disposal, treatment and/or use. The concentration of tofu waste thus becomes a necessary first step for its waste management and recovery. In principle one could use evaporation as concentration process, but unfortunately this can cause damage to heat sensitive components or loss of volatile compounds, so that alternative concentration processes are needed [5]. Owing to its non-cellulosic nature with high carbohydrate and proteins, tofu processing wastewater has the potential to produce renewable energy such as methane, biohydrogen and ethanol. This paper discuss the way in managing of tofu processing waste in a small city (Banda Aceh) and renewable energy from the waste, the material balance of tofu processing is also discussed.

Materials and Methods
In this study, we conduct on site investigation for analyzing of material flow analysis of tofu production, since the process might differ from other countries. Waste management and the possibility of energy recovery were analyzed based on literatures.

Results and Discussion
The production of tofu requires large amounts of wastewaters, as it is a water intensive process. The wastewater is a serious environmental pollutant due to its high organic content (COD: 17,000–26,000 mg/L) comprising mainly of reducing sugars, sucrose, starch and volatile fatty acids [5]. Although the waste contains oligosaccharides, proteins and isoflavones, which can be isolated and used as ingredients for functional products, it is currently disposed as a waste stream. Unfortunately, when disposed directly to the environment tofu waste can cause bad odours and pollution of the surface and ground water [5-7].

Previous studies shown that the tofu waste produced biohydrogen through dark and photo fermentation methods [8-11]. They found that the method will not only provide the energy source but also solve the waste treatment problems. Therefore, dual benefits are obtained from fermentation of tofu-processing wastewater, thereby making the process more economical and valuable. Although tofu-processing wastewater to biohydrogen conversion is feasible through fermentation, the process however is still in its infancy and needs to be optimized and appropriate conditions for maximal recovery of biohydrogen should be developed. Process
factors such as temperature, pH, nutrient, toxic materials, hydraulic retention time and cell density generally affect the anaerobic fermentation pathway [5].

**Current Tofu Processing Waste Treatment in Banda Aceh**

There are 12 tofu processing industries in Banda Aceh with raw materials capacity ranging from 200-350 kg/day for each industry. Totally, about 66,000 kg of wastewater produced from 3,000 kg/day soybean in Banda Aceh. Figure 1 shows the materials balance of tofu production in Banda Aceh. Visit results shows that, the waste has been disposed into the environment and river without any treatment, causing bad odours and pollution of the surface and ground water. The industries do not treat their waste is due to the high cost of treatment processing.

![Figure 1. Materials balance of tofu production in Banda Aceh](#)

**Renewable Energy and Management of Tofu Processing Waste**

Tofu manufacturing is one of the traditional oriental food processes using soy bean as the raw material. A typical process consists of soy bean grinding, cooking (boiling), first filtering, protein coagulating, second filtering, preserving, washing, drying and packaging. The first filtration removes the residues of soy bean from the colloid solution with coarse cloth. In the coagulation step, usually a divalent cation is added to the milk as a coagulating agent, the protein along with the lipid is precipitated. The second filtration separates the liquid whey from the soy bean curd. Filter press with desired pressure is usually employed in this second filtration. The filtrate from this step is used as a nutritious drink for animals like cows and pigs. With the development of municipality, this traditional practice is no longer practical, simply because of the long distance that separates industry and agriculture. This filtrate thus becomes wastewater that requires further treatment before discharging. The wastewater from tofu processing is characterized by its high chemical oxygen demand (COD) and biological oxygen demand (BOD) values derived from the high protein content. The characteristic of tofu processing wastewater is shown in table 1.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>5.8</td>
</tr>
<tr>
<td>VSS (g/L)</td>
<td>1.1</td>
</tr>
<tr>
<td>Total COD (g/L)</td>
<td>36.4</td>
</tr>
</tbody>
</table>

Table 1. Characteristics of tofu-processing wastewater [1].
Soluble COD (g/L)  33.0  
Total carbohydrates (g/L)  12.8  
Soluble carbohydrates (g/L)  11.9  
Alkalinity (g/L as CaCO3)  NA  
NH4-N (mg/L)  81  
Protein (g/L)  1.9  
SO4 \(^2\) (g/L)  3.4  

VSS, volatile suspended solid; NA, not available.

Hence, the usual treatment method is biological degradation. It is, however, often prohibitively expensive in densely populated areas such as Hong Kong due to the high space requirement of this method. Chemical coagulation is an option to remove most of the organics from the water colloids [12]. The treatment of tofu waste using supersonic irradiation of the substrate suspension on the methane fermentation performance has been studied, and found that the supersonic wave irradiation is effective to enhancing the methane yield [13].

Anaerobic digestion of tofu waste producing methane and carbon dioxide, and at the same time reducing organic content in the waste. Several process have been developed for effective anaerobic digestion of tofu waste including the upflow anaerobic filter process (UAFP), upflow anaerobic sludge blanket (UASB), anaerobic attached film expanded bed reactor (AAFEB) and anaerobic fluidized bed reactor (AFBR) to improve cell retention, and the two-phase digestion process to optimize acidogenesis and methanogenesis. However, to enhance these processes, it is necessary to determine their applicability to other types of wastewater, such as those containing recalcitrant and toxic compounds, and high solid organic materials [14].

Lay, et al [1] have studied the bioenergy production from tofu-processing wastewater by anaerobic hydrogen fermentation for onsite energy recovery and significant amount of biogas could be produced. Theoretically, 1 kg of COD will produce 0.35 m\(^3\) methane, and this value might be used for engineering purposes in the designing & optimization stage of the biogas plant. It is found that the methane yield increases with the increasing substrate loading rate, reaches a maximum and then decreases with a further increasing loading rate. Methane gas are odorless, colorless and highly flammable. The biogas produce from anaerobic digestion is not a pure gas but, a mixing of methane (65%), carbon dioxide (30%), hydrogen disulfide and 1% other gases in very small quantities. Biogas, 1,000 ft\(^3\) (28.32 m\(^3\)) has a value equal to 6.4 gallons (1 U.S. gallon = 3.785 liters) butane, or 5.2 gallons gasoline (petrol) or 4.6 gallons of diesel oil. Generally, with 5-6 members of family in the household require about 200 ft\(^3\) per day of biogas.

As has been mention, there is no treatment processing in the tofu manufacturing in Banda Aceh city due to economic reason. In fact, the utilization of tofu waste can produce renewable energy that can use in their industry. The management of tofu waste is very important to be socialized for tofu manufacturing owner. Government involvement is also very necessary to encourage the owner to treat their waste and keep the environment clean. Figure 2 show possible option to manage the tofu waste in Banda Aceh City.
Conclusions
About 66,000 kg/day of wastewater produced from 3,000 kg soybean in Banda Aceh. This high amount of waste could disturb the environment and thus further treating process is required. Anaerobic digestion might be used for the treatment of tofu waste, since the process has advantage in producing a clean renewable energy source of methane. The Government involvement is also very necessary to encourage the owner to manage the tofu waste.

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References


