Biogas Production from Tofu Waste to Improve the Environmental Performance of Tofu Industry

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Abstract
The tofu industry produces solid waste and wastewater that still contain high protein which suitable as raw material for biogas. Conversion of waste into biogas will contribute to improving the environmental performance of small and medium scale industries to increase the added value for the industry. This research was aimed to develop biogas production process by utilizing wastewater and solid waste from tofu industry. There were three stages of process development: biogas production from wastewater (as control), biogas production from solid waste, and biogas production from a combination of solid waste and wastewater. The results of the production process were evaluated based on the volume and its added value on both financial and environmental performance. The output from this research was the model of solid waste and wastewater processing for small and medium scale tofu industry. The result showed that the addition of solid waste of tofu and the source of microorganisms from cow manure was able to produce much larger volume of biogas as much as 715 ml in shorter time of 7 days. Another result of this research was to make a better environment in tofu industry which is seen from the aspects of health and aesthetic.

Keywords: *biogas; environment; tofu; waste*

1. INTRODUCTION

The tofu industry is a small industry that show encouraging growth in both of production volume, product type and distribution of production centers. According to the Central Bureau of Statistics and National Socioeconomic Survey (2015), the level of tofu consumption in 2012 reached 0.134 kg / capita / year and became 0.136 kg / capita / year in 2014. Nevertheless, various obstacles are still faced both in conventional constraint such as capital, knowledge, technology, and new constraints which is a demand for small industries to play a role in protecting the environment.

With the current production technology, the tofu industry still produces large quantity of solid and wastewater. The technology uses a lot of water for milling, soaking, clotting, and sometimes know-how, and cleaning machines and equipment. The wastewaters knows to have a water content of 99.21%, 0.11% ash, 0.02% fat, 0.18% protein and 0.49% carbohydrate, whereas the tofu bag has 82% water content, 0.55% ash, fat 0.62% protein 2.42% and carbohydrates 13, 71% (Nining, 2012).

Direct waste disposal to the environment obviously has negative impacts such as odors, multiple disease mediators and disrupting aesthetics. Environmental pollution caused by the degradation of organic matter contained in wastewater with COD value of 5,000 - 8,000 mg / L (Wagiman, 2001). Some industries have begun to recognize the potential of waste to be developed into other products or reused. For example, the tofu wastewater is reused in the production process as a clotting starter and as a raw material of nata de soya. Then solid waste is used for food such as tempe or as animal feed.

The high content of organic matter makes the wastewater of tofu very suitable as raw material of biogas production. For each gram of COD potentially to produce 0.13 L biogas using Upflow Anaerobic Sludge Blanket (UASB) reactor (Wagiman, 2007).

In order to reduce the formulation of policies for the establishment of small and medium industries in saving the environment, especially for tofu and nata industry, a preliminary study on the opportunity to improve the environmental performance is needed. Investigation of alternative environmental impact mitigation by preventive as reactive methods proved to be ineffective. With the improvement of environmental aspects continuously then one day will be found a model of Green Small and Medium Industry (G-SMI).

2. MATERIAL AND METHODS

2.1 Raw materials: wastewater and solid waste of tofu

Wastewater (whey) and solid waste were obtained from the tofu industry located in Yogyakarta and then stored in the freezer. Before used, the solid materials from wastewater were removed by filtration and then the pH is neutralized. For solid waste, the size reduction was conducted after the material dried.

2.2 Characterization of raw materials

The proximate analysis was done to both ingredients to ensure the content of organic substances, especially proteins, carbohydrates and C / N ratios. The Chemical Oxygen Demand (COD) and pH also tested for wastewater, while the identification of cellulose and hemicellulose content was conducted for solid waste.

2.3 Experiment

The experimental scheme performed on a laboratory scale (volume 2 L) and divided base d on the materials used:

- Experiment 1: Production of biogas from w astewater (whey) as control
- Experiment 2: Production of biogas from so lid waste
- Experiment 3: Biogas production from wastewater and solid waste

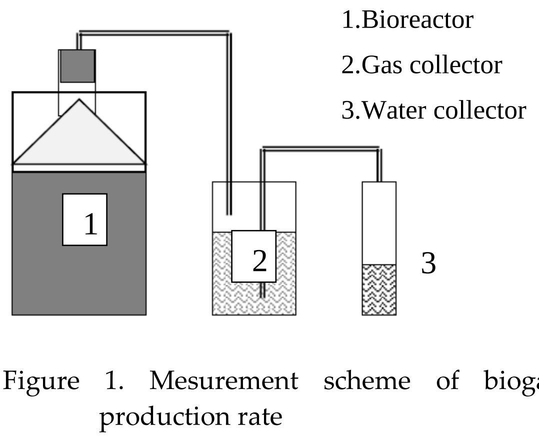


Figure 1. Mesurement scheme of biogas production rate

The experiments were performed at the same ambient temperature conditions (room temperature) and used the same starter from the extract of cow dung which firstly acclimatized for 7 days.

2.4 Parameters

Assessment of experimental results was based on biogas volume, decreased organic matter content (protein, carbohydrate and fat), and pH. The biogas volume was seen cummulatively during the 30-days trial period, while the decrease of organic matter content and pH were seen every 5 days. Environmental performance is determined using the Environmental Performance Indicator (EPI) parameter that reflects the environmental efficiency of the production process by involving the number of inputs and outputs.

3. RESULTS

3.1 Characteristics of tofu wastewater and solid waste Subsection

Industrial waste comprises solid waste and wastewater approximately as much as 2.06 kg/kg and 9.31 L/ kg of tofu. The waste comes from the process of soaking, washing, milling, precipitation and printing. Figure 2 shows the production process of tofu and sources of both wastewater and solid waste. In addition to the production process, wastewater also comes from the process of washing tools and production machines that require clean water as much as 140 L/batch and produce waste of 140 L/ batch. The process of washing equipment and machinery such as buckets, filter cloth, stirrer, molding equipment and milling machine by means of rinsing with water and wiping.

In addition to the large volume of wastewater, especially whey, still contain high organic material and easily decomposes by microorganisms in the environment. Therefore, the disposal of wastewater into the environment without prior processing will cause pollution to the environment. Anaerobic model for wastewater treatment technology was very appropriate for handling tofu industry wastewater because it can convert organic materials into biogas.

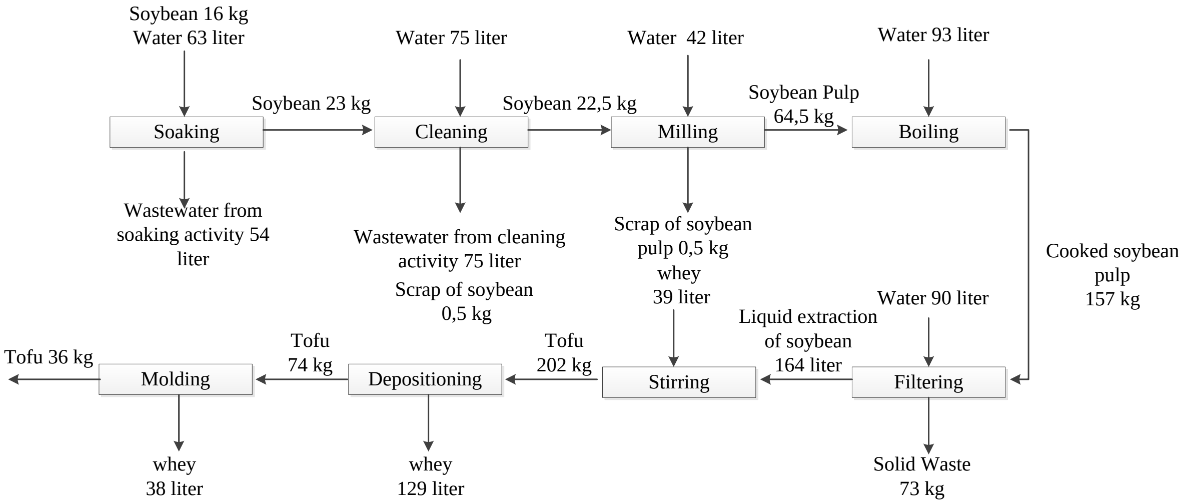


Figure 2. Production process of Tofu and source of wastewater and solid waste

The test results of several parameters (Table 2) indicate that the wastewater from the tofu industry had not yet complied with the D.I.Y. Governor Regulation. No 7 Year 2016 on the Standard of Tofu Wastewater. The pH value of tofu wastewater (whey) was 3.91 far below the standard of 6-9. Likewise, for Chemical Oxygen Demand (COD) value was 6,865,15 mg / L, while according to standard quality of 300 mg / L. For the value of Total Suspended Solid (TSS) of 3,708.67 mg / L above the standard quality of 200 mg / L and also the value of Total Dissolved Solid (TDS) of 10.416 mg / L above the standard value of 2000 mg / L.

Table 2. Characteristics of tofu wastewater (whey)

Parameter	Value
Fat (%)	0,11
Protein (%)	0,25
Carbohydrate by diff (%)	0,20
Reducing Sugar (mg/100 gr)	39,66
BOD_5 (mg/L)	592,10
COD (mg/L)	6818,95
TSS (mg/L)	3708,67
TDS (mg/L)	10.416
pH	3,91

3.2 The production of biogas from wastewater added with solid waste

Biogas production used 5 liters reactor and the ingredients were tofu whey and solid waste which were pakchoi, petsai, and cabbage. The addition of solid waste had two functions: enriching protein, fat and carbohydrate sources and the most important was as a source of decomposing microorganisms. Biogas product using whey only relatively small which was about 65 ml with 35 days process time. Thus the biogas production rate was 0.15 ml / day, relatively small compared to other biogas sources.

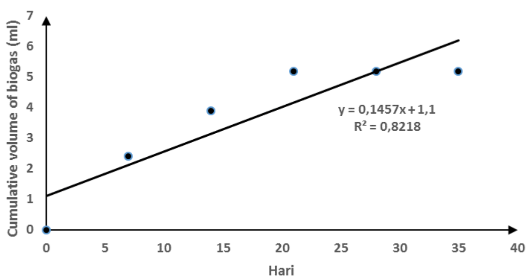


Figure 3. Biogas Production using tofu wastewater (control)

To increase the production of biogas it was necessary to add substrate and source of microorganisms that can convert organic materials into biogas. Whey was an ingredient that contains protein (0.25%) so the type of microorganism should be able to grow in protein-rich ingredients. Pakchoi, petsai and cabbage were solid waste containing relatively high protein of 2.67, 1.58 and 1.91, respectively. Naturally, solid waste will contain microorganisms that utilize substrate in vegetable waste. The content of microorganisms based on Total Plate Count (TPC) in solid waste materials as follows pakchoi (9.6 x 108 cfu / ml), pouch (5.75 x 108 cfu / ml) and cabbage (5.95 x 108 cfu / ml) . Thus, the addition of this waste provides an advantage because it increases the concentration of protein and at the same time can be a source of decomposing microorganisms.

After 35 days incubation period, biogas production volume yield was much greater than control (without co-feeding). The volume of biogas production at the end of the incubation period for co-feeding of pakchoi, cabbage and cabbage was 209 ml, 246 ml and 46 ml. Production of biogas by co-feeding petsai had a rate of 7.33 ml / day higher than the co-feeding of pakchoi and cabbage which had a respective rate of 5.81 ml / day and 2.07 ml / day. Nevertheless, the three co-feeding materials can increase the volume and production rate of biogas significantly compared to the control.

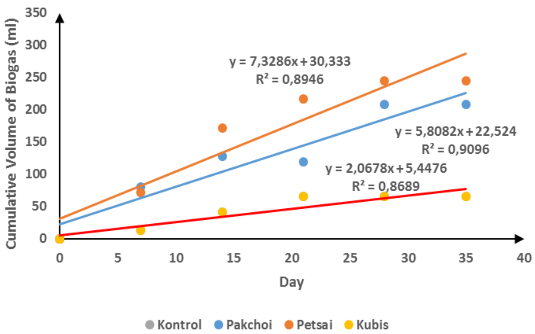


Figure 4. Biogas Production using whey and vegetables waste as raw materials

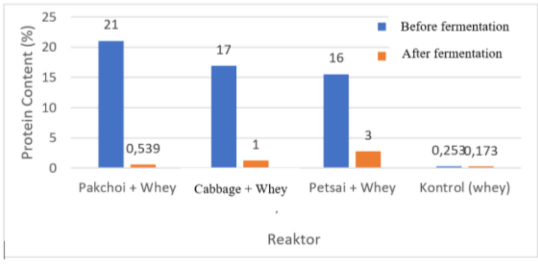
Methane gas in the three reactors only formed in the first week. The pakchoi reactor model produces methane gas of 5.14%, the petsai reactor model produces methane gas of 2.62% and the cabbage reactor model produces 2.05% methane gas. It can be seen from the three models of the reactor that the model pakchoi reactor had the largest methane levels. While for the control reactor does not produce methane even though there was a gas that comes out in small amounts. According to Schnürer and Jarvis (2010) that the absence of methane gas formed due to too low the content of organic matter in the substrate so that bacteria can not maximize its energy capacity to degrade the substrate into methane gas. In the reactor model there was co-substrate in the form of cabbage waste so that other reactor can produce methane gas.

Biogas was derived from the degradation of organic matter in the substrate, it can be known from the organic material content that remain in the material (Figure 5). The less organic residue the more optimal decomposition that occurs during the fermentation process.

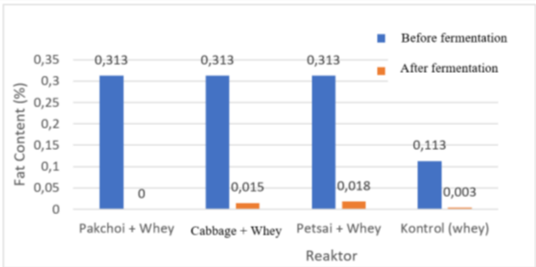
The content of pakchoi fat, round head cabbage and petsai was obtained based on literature study from USDA which then added with whey fat. The reducing sugar of Pakchoi, round head cabbage and pouchture were obtained by literature study which then converted into mg / 100 g (Appendix 6) Based on the above table for the pakchoi reactor, protein reduction of 97.44%, fat reduction 100%, reduction of reducing sugar levels of 86%. For round head cabbage reactor, protein reduction of 92.59%, fat reduction 95.208%, reduction of reducing sugar content of 83.03%. For petsai reactor, the protein reduction is 82,33%, fat reduction equal to 94,249%, reduction of sugar content equal to 77,816%. For control reactor or whey, the protein reduction is 31,62%, fat reduction equal to 97,345%, reduction of reducing sugar content equal to 87,55%.

Another strategy was the production of wastewater biogas that is enriched with solid waste of tofu. Considerations for the use of solid waste debris include among others, the remaining protein in the waste was 26.6% so that growing microorganisms were accustomed to convert protein into simple products such as biogas.

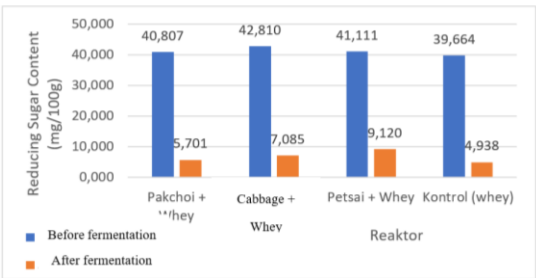
Based on Figure 5, biogas production using co-feeding of tofu's solid waste can produce a larger ammount of biogas compared to control or addition of solid waste. Experiments with 1 liter volume of reactor can produce biogas of 715 ml in 7 days incubation time so that biogas production rate can reach 97,95 ml / day. The high volume of biogas was due to good sources of ingredients from whey, tofu waste and cow dung waste.



(a)



(b)



(c)

Figure 5. Comparison graph of before and after fermentation (a) protein content; (b) fat content; (c) reducing sugar content

CONCLUSIONS

The addition of solid waste into the biogas production system can increase the volume of biogas and the resulting methane content. For vegetable solid waste, petsai was the best material for co-feeding with 246 ml biogas production and 2.62% methane content. While the addition of solid waste of tofu and the source of microorganisms from cow manure was able to produce a much larger volume of biogas as much 715 ml in a shorter time of 7 days.

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