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Upgrading of Biogas Yield from The Liquid Waste of Tofu by Variation Types of Co-digestions

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Abstract. Accumulation of liquid waste of tofu can lead to environmental pollution due to the difficulty decomposition by microorganisms. Converting liquid waste of tofu into biogas is the right choice to overcome environmental problems and reduce the usage of fossil fuels. Biogas is produced through the anaerobic digestion (AD) process by microorganisms. The addition of co-digestion can improve the efficiency of microorganisms. Therefore, this study aims to compare biogas yields from various types of co-digestion (tomato wastes, food wastes, and cow rumen), determine the optimal concentration of co-digestion (10%, 20%, and 30%), and measure the content of volatile solids (VS) before and after the anaerobic digestion process. The methods were the preparation of feedstock, the production of biogas, and analysis of initial and final VS. The results showed that co-digestion of cow rumen produced the highest biogas yield of 376.24 mL/g VS. Cow rumen of 20% is an optimum co-digestion for biogas production from the liquid waste of tofu. VS reduction is directly proportional to biogas yield.

INTRODUCTION

The world's energy consumption is currently increasing every day [1]. On the other hand, fossil fuel sources are decreasing. Therefore, one of the main problems to overcome the energy lack is to provide energy needs in the future [2]. The use of fossil fuels harms environmental conditions such as greenhouse gas emissions and the accumulation of carbon dioxide [3].

Renewable energy has been developed to reduce the consumption of fossil fuels such as biogas [4]. The biogas production process is carried out by the decomposition of organic material into methane by microorganisms [5]. This process is known as anaerobic digestion (AD). The AD process also helps to reduce greenhouse gas emissions, carbon dioxide, and eutrophication [6].

The main composition of biogas consists of methane, carbon dioxide, and small amounts of other gases [7]. The raw material of biogas derives from various organic wastes, such as the liquid waste of tofu. The washing and boiling process of soybeans generates liquid waste. The liquid waste of tofu contains organic compounds, such as proteins, carbohydrates, fats, and oils. If tofu liquid waste increases and stagnates for a long time, the microbes will degrade tofu waste difficulty [8]. Liquid waste of tofu of 283.8 m3/day can convert into biogas of 442.65 m3/day.

The biogas production process takes a relatively long time because the microbes only digest the decaying organic matter. Increasing microbial efficiency can be done by adding co-digestion. Type of co-digestion derives from food waste, livestock waste, fruit waste, and vegetable waste. Several studies on biogas production from tofu waste have been reported by the previous research. However, no study investigated the effect of co-digestion types on biogas production from liquid waste. Therefore, this study aims to compare the effect of co-digestion types on biogas production of liquid waste of tofu. The volatile solids (VS) content before and after biogas production was also measured in this study.

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MATERIALS AND METHOD

Feedstock Preparation

Liquid waste of tofu as raw material was obtained from the home industry of tofu in Yogyakarta. Cow manure, tomato waste, and food waste are roled as co-digestion. Cow rumen was obtained from a slaughterhouse in Yogyakarta. Tomato waste was obtained from Giwangan Traditional Market, Yogyakarta, and food waste was obtained from canteens around campus. Tomato waste was cut into ± 1 cm in size and food waste was blended before use

Biogas Production

Liquid waste of tofu and co-digestion were mixed and stirred, then put into a 2 L digester with co-digestion concentrations of 10%, 20%, and 30%. The initial pH in the digester was 7. The experiment was carried out at room temperature. The volume of biogas was measured every 2 days by the water-displacement method.

RESULTS AND DISCUSSION

Effect of Co-digestion Types on Biogas Production

Biogas production is presented in daily and cumulative biogas yield. Biogas production is carried out for 45 days until no more biogas production. Liquid waste of tofu was mixed with co-digestion, namely tomato waste, food waste, and cow rumen fluid. The results of biogas production in types of co-digestion can be seen in Figure 1. Biogas production started on day 2 for all co-digestion with biogas yields of 4 mL/g VS, 3.55 mL/g VS, 6.0 mL/g VS, and 8.0 mL/g VS, respectively, for tofu liquid waste, without co-digestion, tomato waste, food waste, and cow rumen fluid.

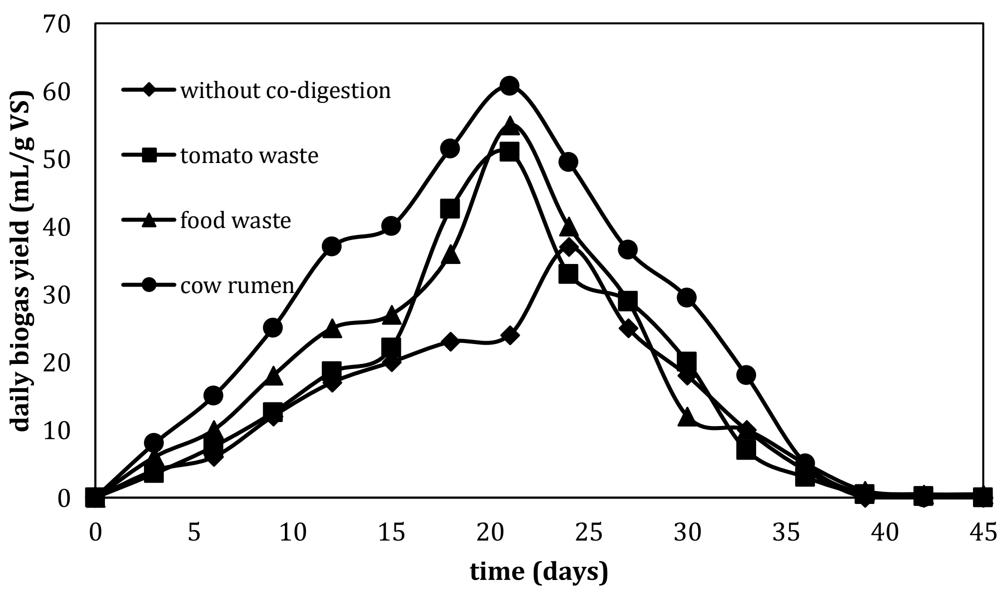


FIGURE 1. Daily biogas yield on variation types of co-digestion

Furthermore, biogas production increased and reached a peak on day 21 with peak yields of 50.96 mL/g VS (tomato waste), 55 mL/g VS (food waste), and 60.7 mL/g VS (cow rumen). Liquid waste of tofu without co-digestion reached its peak on the 24th day. This delay is due to an imbalance of nutrients. Consequently, nutrient transfer and methanogens rate become slowly in converting organic matter into biogas. After reaching the peak point, biogas production decreased dramatically until the constant value on day 45.

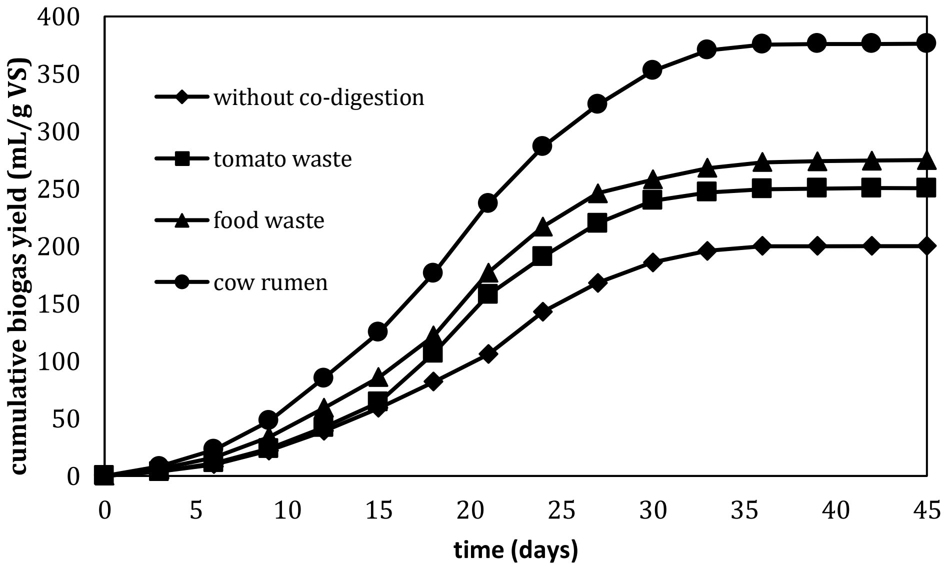


FIGURE 2. Cumulative biogas yield on variation types of co-digestion

Figure 2 shows the cumulative biogas yield. Co-digestion of cow rumen produced biogas of 376.24 mL/g VS, followed by liquid waste (275 mL/g VS), tomato waste (250, 48) mL/g VS), and liquid waste of tofu without co-digestion (200.02 mL/g VS).

The addition of co-digestion can increase biogas yield. Kenasa and Ken [9] stated that the appropriate type and amount of co-digestion selection is beneficial to build a nutritious environment in the digester. Consequently, microorganisms can digest more organic materials into biogas. Co-digestion plays a role in increasing the buffering capacity to help to maintain optimal pH for methanogenic bacteria and provides a better C/N ratio in raw materials. Co-digestion can also reduce the inhibitory effect of mono-digestion and increase productivity efficiency [10]. The optimal type of co-digestion for biogas production from the liquid waste of tofu is cow rumen fluid because it produces the highest biogas yield.

Volatile Solid Reduction

Figure 3 shows a comparison of the initial and final volatile solid (VS) content. The initial VS content without co-digestion and co-digestion of tomato waste, food waste, and cow rumen fluid were 58%, 87.50%, 90.50%, and 84.75%, respectively. After the biogas production was completed, the final VS content was also measured. Cow rumen generated the lowest final VS content of 11.21%, followed by co-digestion of tomato waste, food waste, and without co-digestion with final VS content of 42.75%, 39.23%, and 31.03%, respectively.

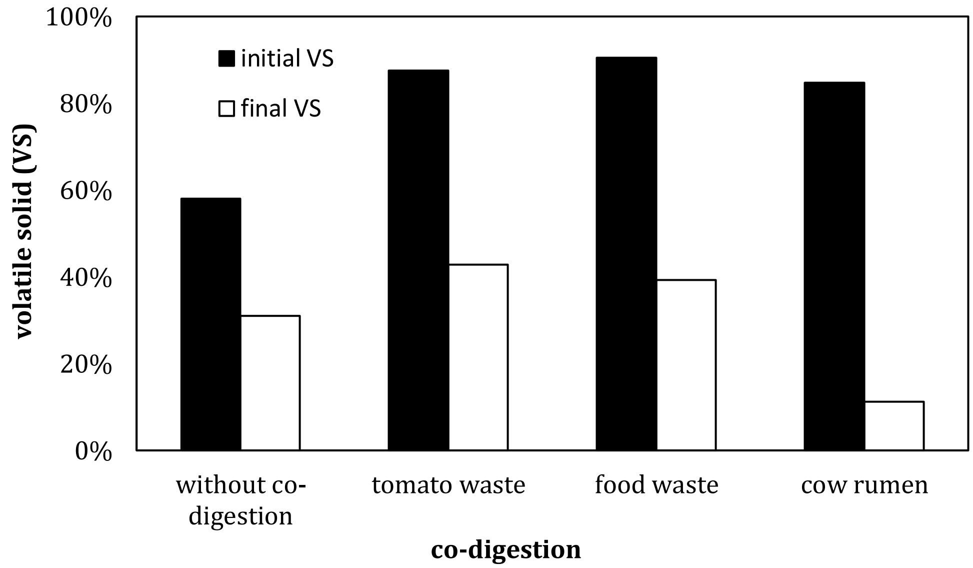


FIGURE 3. Comparison of initial and final VS on biogas production

Figure 4 illustrates initial and final VS. The highest VS reduction of 73.54% was obtained by co-digestion of cow rumen, followed by tomato waste (44.75%), food waste (51.27%), and without co-digestion (26.97%).

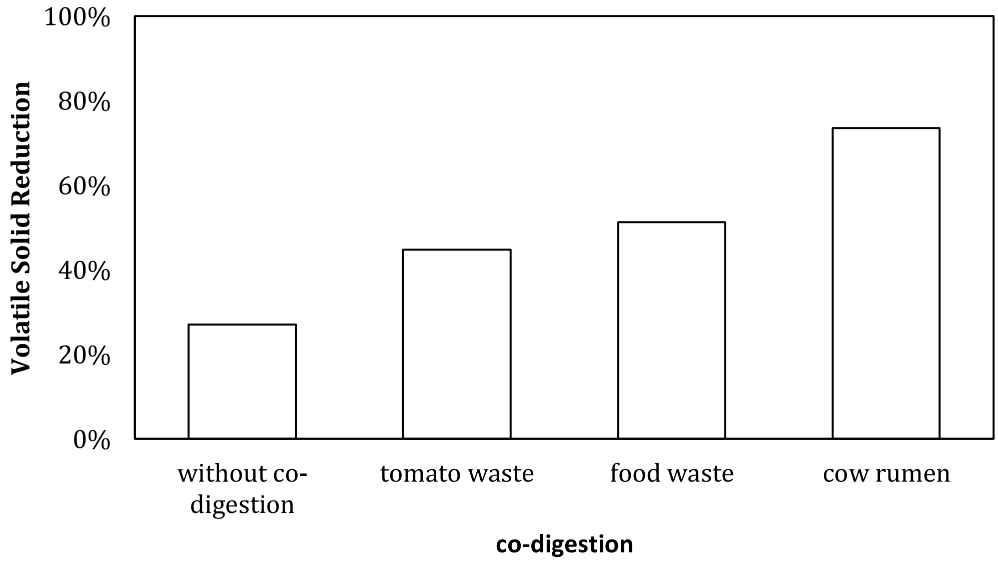
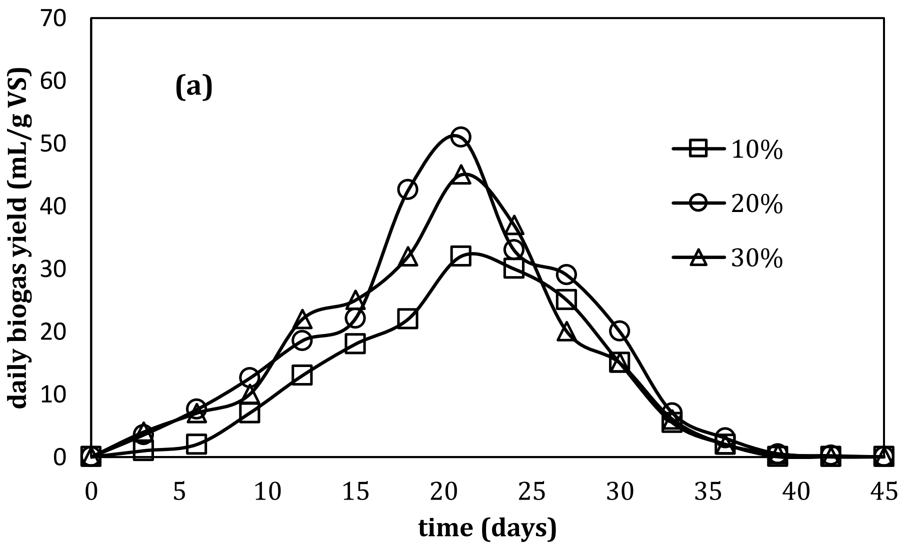


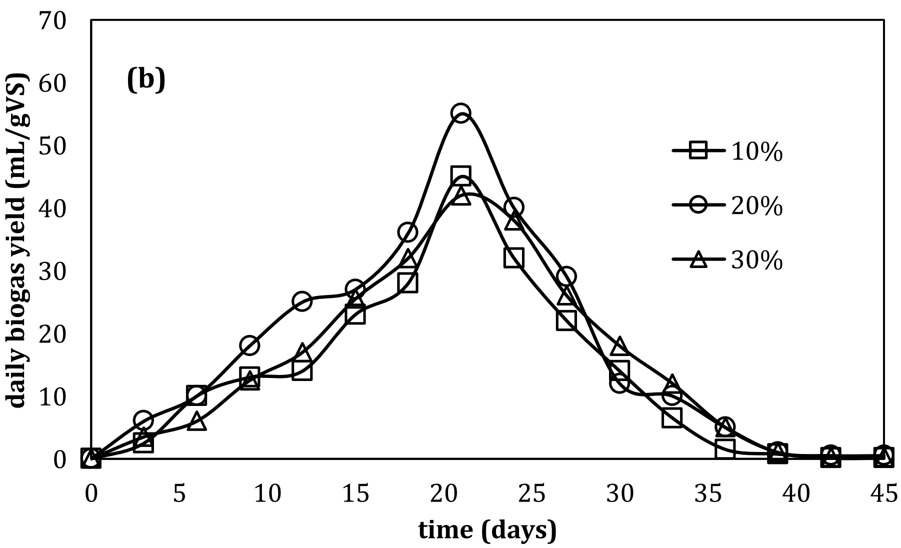
FIGURE 4. VS reduction on biogas production

The results indicated that the reduction of VS is proportional to the biogas yield. At the highest biogas yield, the VS reduction is also high. A high VS reduction indicates that methanogens convert higher organic matter into biogas.

Effect of Co-Digestion Concentration on Biogas Production

Variations in co-digestion concentrations of tomato waste, food waste, and cow rumen fluid were 10%, 20%, and 30%. The biogas production yield is shown as daily biogas yield and cumulative biogas yield. Daily biogas yield can be seen in Figure 5.





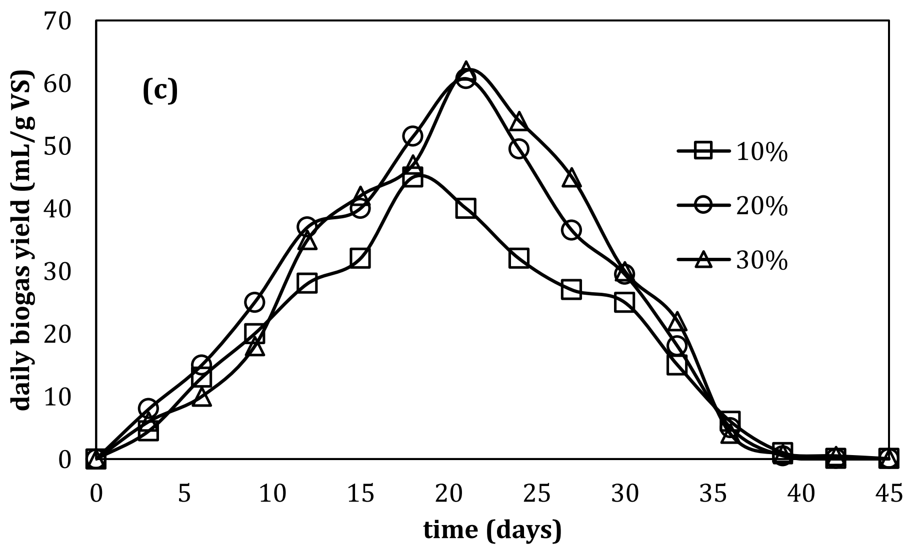
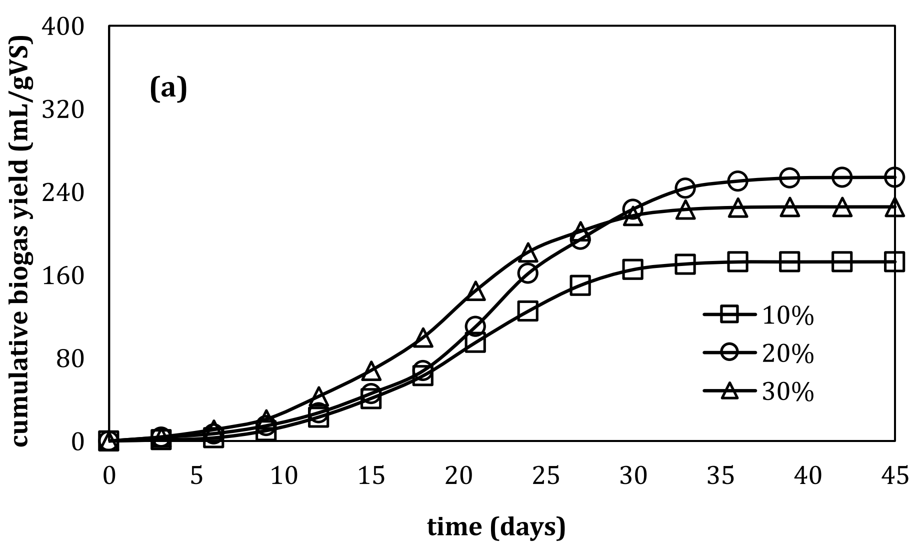
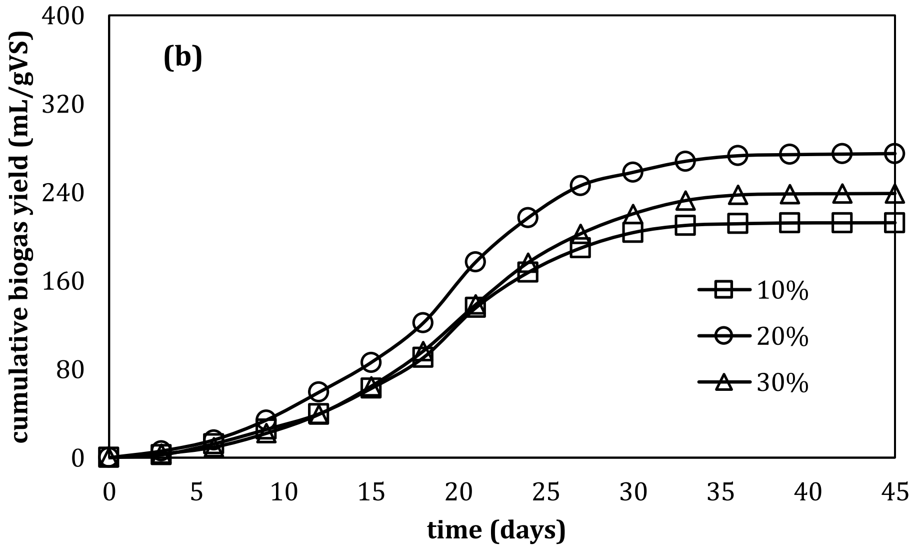


FIGURE 5. Daily biogas yield on biogas production with various co-digestion concentrations: (a) tomato waste; (b) food waste; (c) cow rumen

Figures 5(a), 5(b), and 5(c) show that the daily biogas yield increased from 10% to 20% for the co-digestion of tomato waste, food waste, and cow rumen. However, at 30% of tomato waste and 30% of food waste, the daily biogas yield was lower than the 10% and 20%, while at 30% of cow rumen, the daily biogas yield increased. Cumulative biogas yield can be seen in Figure 6.





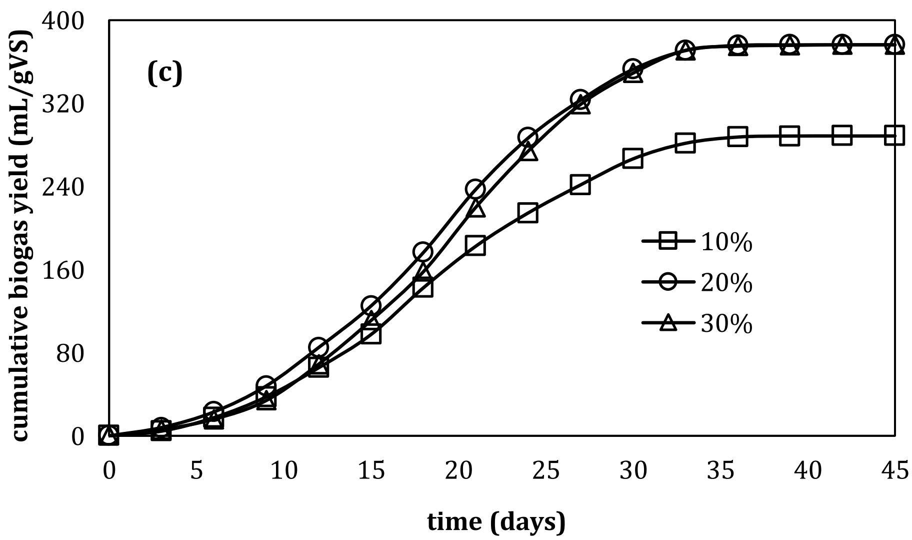


FIGURE 6. Cumulative biogas yield on biogas production with various co-digestion concentrations : (a) tomato waste; (b) food waste; (c) cow rumen

Co-digestion of tomato waste and food waste produced the highest cumulative biogas yield of 275 mL/g VS and 288.56 mL/g VS at a concentration of 20%. Co-digestion of cow rumen 20% and 30% produced the same relative cumulative biogas yields of 376.24 mL/g VS and 376.35 mL/g VS, respectively. The results indicate that the ideal concentration of co-digestion of tomato waste, food waste, and cow rumen fluid on biogas production from the liquid waste of tofu is 20%.

CONCLUSION

The suitable co-digestion for biogas production of liquid waste of tofu is cow rumen. Co-digestion of cow rumen produced the highest biogas yield of 376.24 mL/g VS. Cow rumen of 20% is an optimum co-digestion for biogas production from the liquid waste of tofu. VS reduction is directly proportional to biogas yield. Cow rumen generates the highest VS reduction.

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