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Biogas Production from Anaerobic Co-Digestion of Food Waste Mixed with Domestic Wastewater

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Abstract: This research was to investigate the potential of biogas production from the co- digestion of canteen wastewater and food waste. Batch experiments were carried out under various substrate ratios1 : 1 : 0, 1 : 1 : 1, 1 : 1 : 2, 1 : 2 : 1, 2 : 1 : 1, 2 : 2 : 1, 3 : 2 : 1, 4 : 2 : 1, 6 : 5 : 1, 8 : 5 : 1, 10 : 3 : 1, 10 : 4 : 1 and 10 : 5 : 1 (canteen wastewater : swine manure : food residue waste) at room temperature. The biogas production was carried for a retention period of 7 days to investigate suitable mixing ratio. The suitable ratio was tested in a plastic container 200 liter with bath and fed-batch experiment for a retention period of 45 days. The results revealed that fermentation slurry mixing ratio of 1 : 2 : 1 was found to be optimum, which gave the methane production with composition 47.34-61 %CH_4. The biogas yield and thermal energy were 88.86 L/day and 69 kcal respectively.These primary results indicated the significance of co-digestion of canteen wastewater with food waste for biodegradation and biogas production.

Introduction

The economic growth has led rapidly increasing energy consumption [1], with increasing prices of oil and gas the world looks towards alternative and green energy resources[2]. There is an ongoing search to develop sustainable, affordable, environmentally friendly energy from renewable sources [3,4]. The dependence on fossil fuel as primary energy source has led to global climate change, environment degradation and human health problems [5]. Untreated wastewater generally contains high levels of organic materials with numerous pathogenic microorganisms, trace heavy metals, nutrients and toxic compounds. Therefore, the ultimate goal of domestic wastewater treatment is to protect the environment that has impact on protection of the environment with public health and socio-economic matters [6]. Co-digestion is the simultaneous digestion of more than one type of waste in the same unit. Advantages include better digestibility, enhanced biogas production/methane yield arising from availability of additional nutrients, as well as a more efficient utilization of equipment and cost sharing [7].To improve the potential of biogas production, co-digestion of organic wastes could have the potential to improve the efficiency of anaerobic digestion process[8]. The aim of this study was to investigate the potential of canteen wastewater and food waste for the methane production in laboratory scale. The effect of the feed mixing ratio on the system performance was tested in a batch experiment according to at various ratios of co-substrates and to evaluate its process performance.

Materials and Methods

1. Sample collection

Swine manure was collected from a local pig farm in Lablae district, Uttaradit province. Wastewater and food residue waste were obtained from canteen of Uttaradit Rajabhat University. The collected food wastes were considered impurities such as plastic, bone and fish bone. These are classified and remove by collector.

2. Materials/Instruments

The materials/instruments used for the purpose of this research are as follows: weighing balance, gas chromatography, pH meter, thermometer, Gas analyzer, desiccators, crucibles, oven, gas collectors and biogas burner fabricated locally for checking gas flammability.

3. Experimental procedure

The biogas production potentials of co-digestion in this study were determined in batch and fed-batch experiment. In the first experiment, laboratory batch reactors were set up in glass vessels to sealed anaerobic digesters. A schematic diagram of biogas unit is shown in Fig. 1. All experiments were conducted with 10 conditions. The ratios of co-substrates between canteen wastewater with swine manure mixing were 1:1:0, 1:1:1, 1:1:2, 1:2:1, 2:1:1, 6:5:1, 8:5:1, 10:3:1, 10:4:1 and 10:5:1 respectively to determine the optimum ratio of biogas production. After filling, all digesters were closed with a rubber cap. Each biodigester is connected to a means of connecting tube. A stand holds all the gas collectors. The experiment was performed for 7 days. During the experiments, all digesters were operated at room temperature (27–32°C). The volume of biogas production and gas composition were analysed until the biogas accumulation was constant. Biogas evolved is collected by downward water displacement.The biogas composition was measured by a gas chromatography (GC).The second experiment, was conducted based on the optimal mixing ratio for the biogas production selected from the results of the first experiment.The batch and fed-batch experiment was tested in a 200 liter plastic container. Co-digestion was carried for a retention period of 45 days. The effect of the feed mixing ratio to evaluate the methane production performances and its process.

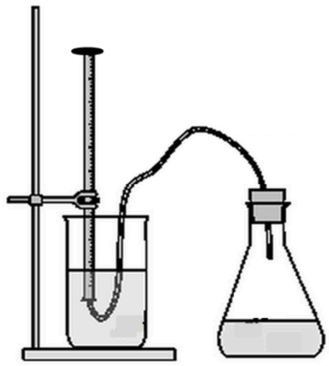

Figure 1. Schematic diagram of the digester

4. Analytical analysis

The samples were taken from each container before and after the experiments. The following parameters were analyzed: pH was measured using a glass electrode pH meter to monitor the pH of the sample. Analysis of the chemical oxygen demand (COD), total solid (TS), total suspended solid (TSS), total dissolved solid (TDS), volatile fatty acids (VFA) and Alkalinity(mg/l) were performed according to the Standard Methods for the Examination of Water and Wastewater [9]. The biogas volume and composition were measured by the displacement of water and analyzed by gas chromatography (GC-8A Shimadzu). Thermal energy was calculated based on the equation $Q = mc\Delta T$. The synergistic effect was calculated from the best condition.

Results and Discussion

Some substrates have limitations and appear to be low-efficient when they are degraded anaerobically. In this study, food wastes were used to avoid interferences from the minority compounds, and to analyse the viability of the co-digestion between substrates. The characteristics of the wastewater as compared to the literature reports. Domestics wastewater in this study had high COD concentration (1400 mg/L) compared to the literature reports (Bodkhe, 2009). The characteristics of wastewater in this study were shown in Table 1

Table 1. The characteristics of the wastewater as compared to the literature reports

Parameters	Unit	Current study	[8]	[10]
Temp.	°C	29.57	-	-
pH	-	5.75	6.87	7.5-8.2
TSS	mg/L	81.00	13	300-450
TDS	mg/L	4,123.11	311	-
TS	mg/L	4,655.33	324	-
COD	mg/L	1,400.89	516	350-450

1. Fermentation slurry

The quantity of cumulative biogas production with time for all the substrate ratios shown in Fig. 2, substrate ratio 1:2:1 and 10:5:1 commenced biogas production and evolved flammable biogas. While substrate ratio 1:1:1 and 2:1:1 which serves as blank. The highest biogas yield was for ratio 1:2:1 (235 ml/day). This performance could be because of optimum balance between the ratio.

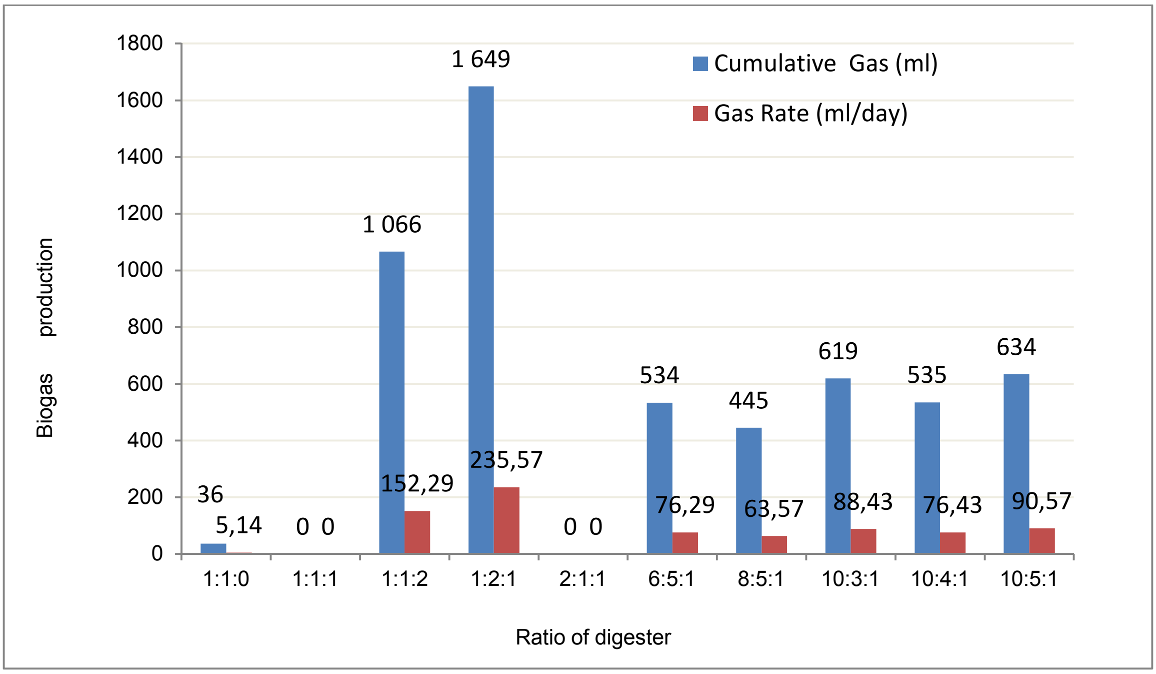

Figure 2. The quantity of cumulative biogas production for 7 days of each ratios

2. Anaerobic co-digestion

The batch and fed-batch experiment was tested in a plastic container 200 liter. Co-digestion was carried for a retention period of 45 days. The anaerobic process were observed of gas production. The data illustrated in Table 2 showed that the co-digester of 1 : 2 : 1 with fed-batch generated 88,864L/day of biogas which was the highest amount of gas recorded throughout the study. Compare the biogas production from anaerobic co-digestion of night soil with food waste. The biogas production was 2,184 l and 56.5 % of methane fraction has obtained within 31 days of experimentation [11]

Table 2. Gas production for 45 days in a large plastic container

Co-digestion ratio	Anaerobic process	Cumulative gas (cm^3)	Gas rate (L/day)	%CH_4	
1 : 2 : 1	Batch	694,216	46,281	0	Non-flammable
10 : 5 : 1	Batch	178,723	11,914	0	Non-flammable
1 : 2 : 1	Fed-batch every 3 days	820,750	54,716	22.00	Non-flammable
	Fed-batch everyday	3,998,882	88,864	47.34	flammable

Table 3. The characteristics of the fermentation slurry after digestion

Parameters	**Start up**	**15 days**	**45 days**
pH	8.23±0.05	6.67±0.02	7.29±0.04
Temp. (°C)	30.50±0.17	30.17±0.06	30.97±0.12
VFA (mg/l)	-	2,325.00±75.00	366.67±76.38
Alkalinity (mg/l)	-	2,133.33±10.08	1,233.33±76.38
COD (mg/l)	26,666.67±12,220.20	34,666.67±24,440.40	6,186.67±184.75
TS (mg/l)	7,880.00±423.00	14,098.00±716.59	7,519.33±80.16

Conclusion

The fermentation slurry mixing ratio of 1 : 2 : 1 was found to be optimum, which gave the methane production with composition 47 - 61 %CH_4. The biogas yield and thermal energy were 88.86 L/day and 69 kcal respectively. The co-digestion of canteen wastewater with food waste by fed-batch everyday that had significant improvement on biogas production.

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