

THE BIOGAS PRODUCTION FROM SHRIMP FARMING WASTE

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Abstract

Biochemical methane potential has been widely studied to treat waste organic matters and turn them into alternative energy. In this study we have shown the possibilities for using shrimp farming waste as the main substrate in co-digestion with rice straw and food waste by batch anaerobic digestion at room temperature. The experimental test was conducted for 30 days. Co-digestion was used to compare the methane production from shrimp waste at the inoculum to substrate volatile solids ratios (r_{IS}) of 3, 2, and 1. The progress of the reaction from a solid substrate to a gaseous product was counted by water replacement and the gas composition by gas chromatography. A maximum methane yield of 53.71 mL/g volatile solids was obtained at the ratio of 15W:15 rice straw. The methane content up to 48.52% was obtained from this fraction whereas shrimp waste alone produced a maximum up to 16.51%. Co-digestion can improve the methane production compared with digestion of shrimp waste alone.

Keywords: Shrimp farming waste, anaerobic digestion, biogas production potential

Introduction

Due to the insufficiency of petroleum and coal throughout the world, mankind is seeking new energy sources for living in the future which are friendly to the environment. The marsh gas methane was discovered by Alessandro Volta in the 1770s and appears to be an alternative to petroleum-based energy. This gas occurs naturally in some soils and in lake and oceanic basin sediments where it is referred to as anaerobic digestion. Since Volta's discovery,

anaerobic digestion has been studied. The process is by fermentation from disposal in the absence of oxygen and is mainly by conversion of products to methane and carbon dioxide gases. Methane gas has been studied for many years and has been used as renewable energy. This renewable energy is distinct from others because it is simple to use and can be applied to households or industrial factories (Dechruga *et al.*, 2013).

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Since 1991, Thailand has been the world leader for shrimp production and the export of frozen shrimp, for which the volume totals more than 100,000,000,000 Thai baht per year (Thai Frozen Food Association, 2011). However, problems have been discovered in the environment near to shrimp ponds and in the sea. For shrimp culture, most shrimp producers are still using an open water system in which the discharged water is drained from the ponds into the sea and is replaced with natural seawater; this causes vast problems. The effects on the environment are increases in the pH value, salinity, shrimp disposals, nitrogen chemical compounds, hydrogen sulfide, and even methane gas all of which are left over from shrimp feeding. According to the biogas occurrence, one was found out from disposal soils. Therefore, shrimp farming waste was used as the main substrate to produce a biogas.

Most anaerobic digestion is made by energy crops such as sugar cane, maize, and rice straw. Those crops are easy to find, clean, have a low capital cost, and also give a high percentage of methane gas under anaerobic digestion. In this case, rice straw was chosen as the co-substrate because of its wide availability as a crop by-product in Thailand. The feasibility of co-digesting shrimp manure and rice straw is one way to approach biogas manufacturing. Due to the carbon to nitrogen ratio of the shrimp waste being too low, the carbon to nitrogen ratio of the rice straw was mixed to approach the optimum ratio. Owing to the different characteristics of both substrates, the consequences of using this rice straw need to be known.

Materials and Methods

Substrate

Three different types of samples were used in this study. Raw shrimp farming waste (SW) was used as the main substrate for biogas production and was collected from Bangkla sub-district, Chasengsao province, Thailand. A coarse-cut folder rice straw (MS) was used as a co-substrate. This was finely cut and dried at 105°C before being ground until it passed through a 2 mm sieve. Food waste (FW) from the Suranaree University of Technology

canteen (Nakhon Ratchasima, Thailand) was also used as a co-substrate. The non-biodegradable contaminants in the food waste, such as bones, plastic bags, egg shells, and tissue paper were removed by hand; the food waste was then crushed using an electrical kitchen blender and stored at 4°C until it was used in the biogas production (Angelidaki *et al.*, 2009).

Inoculum

Sludge from a starch plant (Sa-nguan Wongse Industries, Nakhon Ratchasima, Thailand) was used as the inoculum.

Biochemical Methane Potential (BMP) Assays

As there is no protocol for BMP assays, the most common conditions used in the literature, according to Raposo *et al.*, 2006 and Esposito *et al.*, 2012, were applied. The amounts of the inoculum to substrate ratio expressed in g of VS l⁻¹ for the r_{VS} of 3, 2, and 1 were: 15 and 5 g VS l⁻¹, 15 and 7.5 g VS l⁻¹, and 15 and 15 g VS l⁻¹, respectively. The inoculum to substrate mixtures were supplemented with 20% (v/v) of a medium containing macro- and micro-elements (Raposo *et al.*, 2006). The composition of this nutrient and trace element solution is set out as follows:

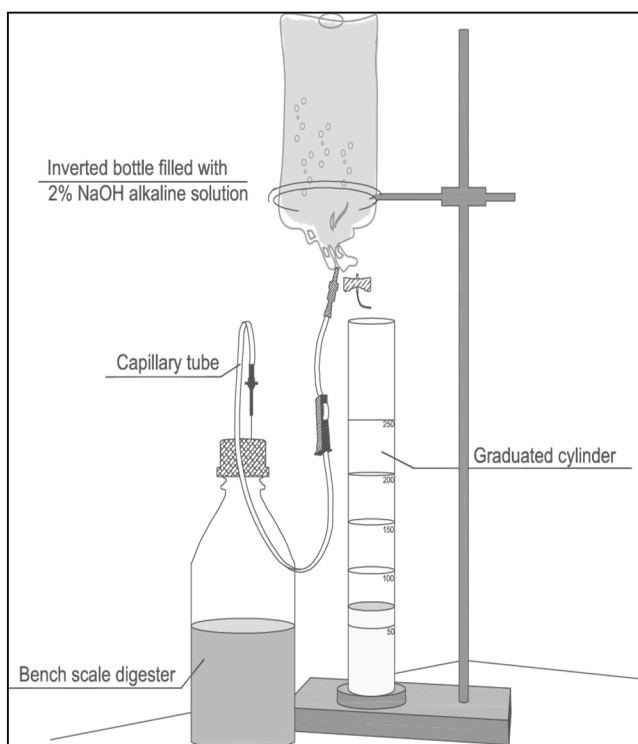
- *Stock nutrient solution:* NH₄Cl, 1.4 g l⁻¹; K₂HPO₄, 1.25 g l⁻¹; MgSO₄·H₂O, 0.5 g l⁻¹; CaCl₂·2H₂O, 0.05 g l⁻¹; yeast extract, 0.5 g l⁻¹; trace element solution, 5 ml l⁻¹.

- *Trace element solution:* FeCl₂·4H₂O, 2000 mg l⁻¹; H₃BO₃, 50 mg/l; ZnCl₂, 50 mg l⁻¹; CuCl₂·2H₂O, mg l⁻¹; MnCl₂·4H₂O, 500 mg l⁻¹; (NH₄)₆Mo₇O₂₄·4H₂O, 50 mg l⁻¹; AlCl₃·6H₂O, 90 mg/l; CoCl₂·6H₂O, 2,000 mg l⁻¹.

In order to obtain the r_{VS} values of 3, 2, and 1, the amounts of substrate that were used are shown in Table 1. A total of 20 assays, including duplicates and controls, were run at room temperature (28±3°C). Each BMP assay was performed in a 300 ml glass bottle with a butyl rubber stopper used as a batch digester. All digesters were flushed with N₂ for 3 minutes in order to remove oxygen from the headspace and maintain the anaerobic condition. All digesters were shaken by hand for 1 minute per day.

Table 1. Characteristics and properties of the substrates

I/F* Ratio (g VS/L)	Substrate loading (g)			Inoculum loading (g)
	Shrimp wastes only (SW)	Shrimp wastes (SW) and Rice straw (MS)	Shrimp wastes (SW) and Food wastes (FW)	
15:15	139	70:2.8	70:6	190
15:7.5	70	35:1.4	35:3	190
15:5	46.3	23.2:0.93	23.2:2	190

**Figure1. Experimental equipment used to measure the daily biogas (ml) (Modified after Esposito *et al.*, 2012)**

Each bottle was connected by a capillary tube to an inverted 1000 ml plastic bottle containing an alkaline solution (2% NaOH), as shown in Figure 1. Gases such as CO₂ and H₂S were removed by chemical reactions and CH₄ was the only gas that passed through. To enable the gas transfer through the 2 connected bottles, the capillary tube was equipped on both ends with a needle which was sharp enough to pierce the silicone disc (Esposito *et al.*, 2012). The methane volume was equivalent to the alkaline solution

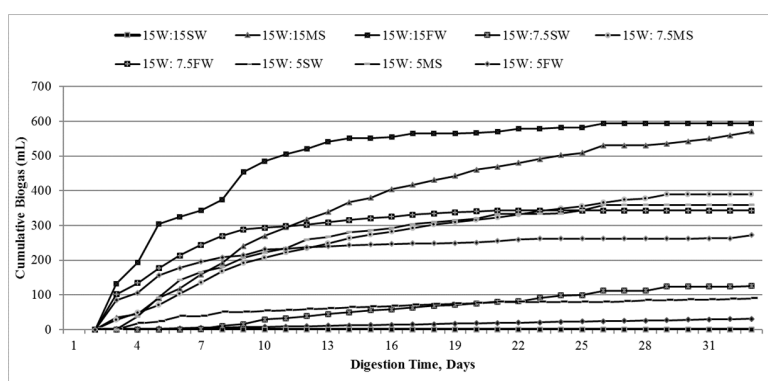
displacement in the gas collecting bottle (Liu G. *et al.*, 2009).

Analytical Methods

The biogas composition was determined using a gas chromatograph equipped with a thermal conductivity detector and packed column. The oven, detector, and inlet temperatures were 100, 250, and 200°C, respectively. The compounds detected were methane and carbon dioxide. The volume of biogas was collected in gas-tight aluminum

Table 2. Properties and characterization of the substrates

Parameter	Shrimp farming wastes (SW)	Rice straw (MS)	Food wastes (FW)	Inoculum
TS (g VS/l)	234	887	330	33.51
VS (g VS/l)	27	671	312	19.756
VS/TS (%)	11.53	76	94.5	59
pH	7.5	6.7	5.1	6.77
C/N ratio	8	57.8	15	-

**Figure 2. Cumulative biogas production curve**

bags. In all the experiments, the methane yield, total solids (TS), volatile solids (VS), and pH were determined by the American Public Health Association standard methods.

Results and Discussion

Feed Stock

Table 2 shows the analyzed properties and characterization of the substrates.

Biogas Production

The accumulative biogas production through the co-digestion of different feedstocks is presented in Figure 2. It indicates that co-digestion with rice straw and food waste produced a volume of biogas greater than digestion only with shrimp waste. For the measurement of the biogas quality by methane gas percentage, the results showed the highest percentage at 48.52% from co-digestion with rice straw, while co-digestion with food waste gave a highest methane production estimated

at 39.18%; finally, single waste alone gave a highest methane production estimated at 16.51%.

Ratio Effect on Biogas Production Using a Co-Digester Reactor

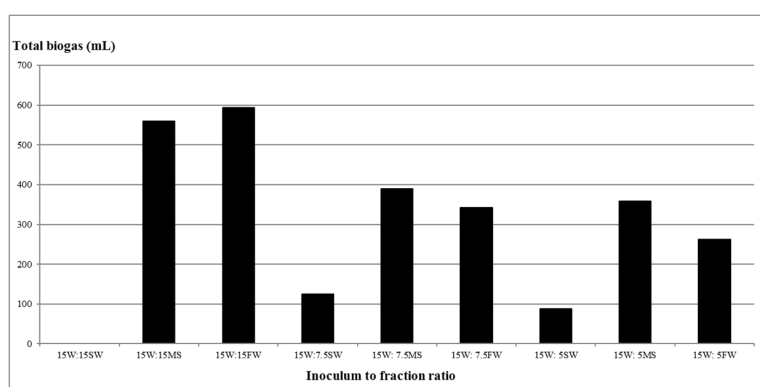
In this study different fractions of the inoculum to the substrate were used to determine the biogas production in batch assays. Figure 3 shows the total biogas production volume using the different inoculum to substrate ratios; 3, 2, and 1. It shows that the maximum biogas occurs at the ratio of 1:1, whereas the ratios of 2:1 and 3:1 produced quite the same volume. The single waste at the ratio of 1, does not produce any biogas due to the inhibitory initial material that is difficult to be digested.

Volatile Solids Reduction

The VS reduction for the various co-digesters leads to the reduction of organic matter that is measured through the VS reduction. Figure 3 shows the results of all

Table 3. Results of 30-day BMP anaerobic digestion of shrimp farming waste (SW), rice straw (MS), and food waste (FW)

Ratio	Initial loading (g VS/L)	VS reduction (%)	CH ₄ content (%)	Biogas yield (mL/g VS)	CH ₄ yield (mL/g VS)
15W:5SW	20	77.18	14.19	0.21	2.92
15W:5MS	20	98.48	31.01	0.29	8.95
15W:5FW	20	97.41	30.65	0.31	9.59
15W:7.5SW	22.5	69.05	16.51	0.34	5.54
15W:7.5MS	22.5	96.29	37	0.67	24.95
15W:7.5FW	22.5	93.70	35.67	1.01	36.12
15W:15SW	30	99.62	0	0.00	0.00
15W:15MS	30	97.17	48.52	1.09	53.71
15W:15FW	30	99.67	39.18	0.69	27.01

**Figure 3. Effect of different ratios on biogas production**

experiments for 30 days of batch operation. The increasing of the VS reduction decreases the amount of the substrate. The high VS reductions show that organic matter can be digested. The VS reductions are high in the co-digestion substrate whereas there are low VS reductions in the shrimp waste as the main feedstock.

Table 3 summarizes the results of the BMP anaerobic digestion of SW, MS, and FW for the experiment which lasted for 30 days. During the experimental period, the methane content was about 30-48 %, except for the digestion from the single waste. Co-digestion of MS and FW can improve the methane production and methane yield compared to SW alone. After being digested, all the digesters

became acidic except the single waste. The results indicate that SW mixed with MS gave the highest total biogas and methane percentage.

Conclusions

The present study produced feasible biogas from anaerobic digestion in batch scale with co-digestion of rice straw. Rice straw as the co-digester produced the maximum methane content up to 48.52% and increased total biogas production compared with digestion using shrimp waste alone and co-digestion with food waste. The optimum ratio from this

anaerobic digester is 1:1 of co-digester with rice straw and with food waste. Furthermore, this biogas production can be used to diminish the expenses in households or in pig farms in closed systems.

Acknowledgements

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