CHEMICAL ENGINEERING TRANSACTIONS
VOL. 80, 2020

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.cetjournal.it

Guest Editors: Eliseo Maria Ranzi, Rubens Maciel Filho

**ISBN** 978-88-95608-78-5; **ISSN** 2283-9216
DOI: 10.3303/CET2080012

# Biogas Production from Beverage Industry Wastes by Co-Digestion

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This research investigated biogas production from Co-Digestion of beverage industry waste. The optimum ratio of four beverage wastes were analysed. The anaerobic fermentations were done in 300 mL volumetric flask by batch shaking at normal ambient temperature with controlled of dry substrate at 3 g. The biogas production was collected and measured by water replacement and its composition was evaluated by gas chromatography. The results revealed that the highest amount of biogas was occurred at 750 mL at milk : coffee : beer : energy drink 2:1:1:1 and the ratio 1:1:1:1, 1:2:1:1, 1:1:1:2 and 1:1:2:1 could produce biogas at 709, 577, 467 and 302 mL, respectively and at ratio 2:1:1:1 occurred COD removal from degradation efficiency of organic substances at 69.30 % which was the highest value. Whereas, the ratio 1:1:1:1, 1:2:1:1, 1:1:1:2 and 1:1:2:1 occurred at 46.80, 35.20 and 17.20%, respectively. The result of biogas production was consistency with the result of COD removal in every ratio. It could be summarized that the best ratio of 4 beverage waste was 2:1:1:1 which shown the best in amount of biogas production and degradation efficiency. It could use this ratio to apply in industrial waste application and the production of renewable energy which could help environment.

## 1. Introduction

In present, the domestic industry is rapidly expanding in order to sufficient for the increasing of the consumer. In the manufacturing process, large amounts of waste and waste water are generated at the end of the production process from these industries. These wastewater contains microbes that affects to the environment. This brings to biological treatment in various stages which has a lot of waste water sediment. The final methods of sludge disposal that are commonly used are landfill and incineration. These two methods are costly and affect the environment. The beverage production process causes large amounts of waste water. For example, the amount of wastewater from the beer industry is 65-70 percent, with COD and BOD up to 32,000-75,000 mL/g and 124,630-182,200 mg, respectively (TEI, 2012). In addition, there have a lot of sludge volume of waste water in many treatment ponds. The way to get rid of these sewage sludge is landfill which can cause methane ($CH_4$) and carbon dioxide gas ($CO_2$) nitrogen gas ($N_2$) and other gases which cause greenhouse effect (Yechiel and Shevah, 2016) and it is found that these sludge still have high potential for utilization. The amount of methane in 1 ton of garbage can be converted into energy at approximately 0.78 MW which can generate 6,500-10,000 MWh of electricity.
The study of the research on the fermentation of waste from the beverage industry and organic fertilizer factory is found that waste from milk industry can cause the maximum amount of methane gas compared to coffee, beer and energy drinks (Toomthong**,** 2016) The researchers found that the beverage industry still has the potential to be utilized to produce renewable energy by various methods, such as fermentation without oxygen to produce biogas. Therefore, studies on increasing the efficiency of biogas production from the fermentation of waste from 4 beverages are milk : coffee : beer : energy drink in different ratios. Microorganisms can be started from the wastewater treatment ponds of pig farms to find a suitable ratio for the production of biogas from different kinds of beverage waste. According to the research studies reported, it is found that the combined fermentation of more than 1 species of organic substances can increase the

Paper Received: 20 December 2019; Revised: 10 March 2020; Accepted: 7 April 2020
Please cite this article as: Wiwatwongwana F., Suihirun R., Vivanpatarakij S., 2020, Biogas Production from Beverages Industry Waste by Co-digestion, Chemical Engineering Transactions, 80, 67-72 DOI:10.3303/CET2080012

amount of biogas (Wiwatwongwana et al, 2019). Moreover, there have a study of efficiency of bio co-digestion from beverage industry waste (xW) and organic fertilizer raw material (OFM). It is found that the ratio of the maximum biogas volume is occurred at OFM:xW of 75:25. The dairy has the highest biogas volume at 272 mL, followed by coffee, beer and energy drink with the accumulated biogas volume at 162, 139 and 128 mL, respectively. The heating value from the experiments shows that when mixing industrial waste with OFM, the heat value is increased by adding industrial waste which gives higher value of biogas compared to ferment with only fertilizer raw material (Wiwatwongwana et al, 2019). The biogas digestion for the energetic valorization of the sewage produced in swine farms shows that the models base on physical chemical parameters and the model base on quantity of growing pigs which are coherent with results provided by lab-scale bioreactor (Leite et al., 2018). The anaerobic co-digestion (co-AD) of the pre-hydrolysed Organic Fraction of Municipal Solid Waste (hOFMSW) and Maize Cob Waste (MCW) are studied in lab scale anaerobic digester. The results show that the pretreatment is recommended before submitting MCW to co-AD and the chemical pre-treatment of MCW with $H_2O_2$ at room temperature is a promising low-cost way to valorise MCW through co-AD (Surra et al., 2018). There have the research about dry fermentation of food waste for carboxylate production. The result showed maximum soluble COD <60% of food waste with residual food waste 13.6–16.3% and also disused for the operating cost which was low price as 1.7 $/ton FW. It could help for the economic benefit (Saha et al., 2020). The biofuel production has been studied and developed by utilizing duckweed as feedstock for bio hydrogen production using dark fermentation and fermentative waste to produce microalgae lipids. The results revealed that the best condition of acid hydrolysis was 1% suitable for the pretreatment of duckweed biomass. The maximum microalgae biomass and the lipid productions were 2.8 and 33 times higher respected to the autotrophic growth. It could provide green strategy for biofuel production. (Mu et al., 2020).

Therefore, the researchers chose industrial waste from beverage production from 4 factories because it was an industrial waste that had a high COD value [3] which was the value indicating the concentration of organic substances that could be used to produce biogas. Therefore, this research aimed to study the optimum ratio of the fermentation from 4 industrial waste beverage production plants resulting in the highest amount of biogas and methane gas.

## 2. Research Experiment

This research studied the production of biogas from the fermentation of waste from the beverage industry in different mix ratios by using microorganisms from the pig farm. This experiment was done at the laboratory scale by batch experiment design. This was done by adding the mixture only once, the experiment would be a fermentation between waste from the beverage industry at the same time, for 4 samples, including milk : coffee : beer : energy drink in order to find the optimum ratio of methane production. Study by comparing the biogas generation and the percentage of methane that was a component in biogas.

Waste from the beverage industry used in the experiment was from 4 factories, consisting of waste from the dairy, coffee, beer and energy drink industry. All 4 beverage industry samples were collected by loading from the sludge suction truck as shown in Figure 1. It was sucked into the waste water treatment pond at the plant collecting sludge before dispatching (Wiwatwongwana et al, 2019) by storing in a closed container and storing at a temperature of 0-2 $^{o}$C. The characteristics of all 4 waste samples were shown in Figure 2.

*Figure 1: The sludge from wastewater treatment system.*

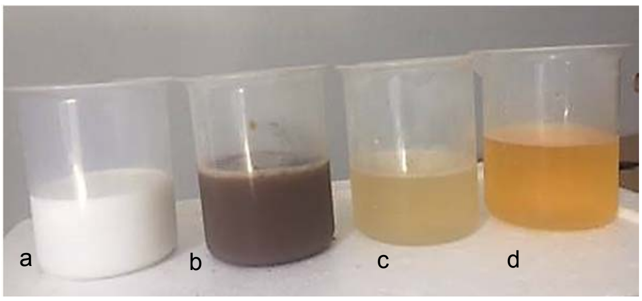


*Figure 2: Wastes from the production plant of all 4 samples which were a) milk, b) coffee, c) beer, and d) energy drink, respectively.*

### 2.1 Starter microbes

Inoculated microorganisms used in this research were taken from a pig farm in Sam Phran District, Nakhon Pathom Province. This farm had 1 active bio-fermentation tank which was UASB (solids-Up flow Anaerobic Sludge Blanket).

### 2.2 Batch Biogas Fermentation

The experiment would be divided into two main parts. There was a mixture fermentation set consisting of 500 mL of colored glass bottles used for fermentation of the mixture. The fermentation amount was 300 mL. Cover the bottle with rubber stopper with two puncture type to fit the top of the bottle to prevent air entering the fermenter bottle. Drill hole in the rubber stopper and insert the thermometer to measure the temperature inside the fermenter. Put a gas pipe to bring gas into the gas storage set and measure the amount of gas from the water replacement of the biogas that occurred. The fermenter was placed on an automatic shaker for 12 hours.

### 2.3 Biogas storage set

It contained 2,000 mL of glass bottles. Fill the bottle with water and close the bottle with punctured rubber stopper. Two compartments to fit the mouth of the bottle to prevent the biogas stored in the leaky bottle. The puncture hole in the 2 rubber stoppers, one was a gas pipe formed by the fermentation set into a 2,000 mL. Gas storage bottle which had water was full of bottles. According to the principle of water replacement, when the gas entered the bottle, the gas would push the water out of the other pipe into the beaker. The amount of water released at the beaker was a measure of the amount of biogas that was produced each day. The biogas storage set was shown in Figure 3 (Wiwatwongwana et al, 2019).

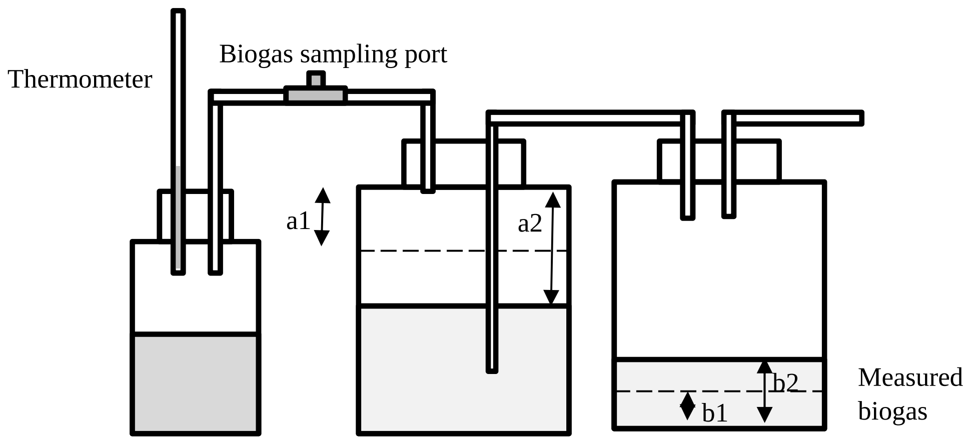


*Figure 3: Biogas collection set.*

### 2.4 Preparation of the experimental set

The experimental set used in this research was a batch experiment with controlled of dry substrate at 3 g. The methods were done by combining fermentation of waste from all 4 beverage factories with a constant amount of microbes and fermented all of milk : coffee : beer : energy drink in right amount with ratios 1:1:1:1 ,1:2:1:1, 1:1:2:1, 1:1:1:2 and 2:1:1:1. Biogas sample collection could be done by using water to replace the inside of the gas storage bottle. In order to displace the gas inside the bottle, go back through the first valve to the prepared gas storage bag. The gas passed the silica gel first to expel the moisture before the gas entered the gas storage bag and before using for sampling gas. The air was ejected from the bag using the air pump from the bag. After receiving the biogas sample, the gas collection tube would be pumped from the gas storage bag for injecting into the gas chromatograph Shimadzu Model GC-14B to find the percentage of methane gas percentage.

## 3. Results and Discussions

### 3.1 The amount of biogas from the fermentation of waste from all 4 beverage factories and microorganisms

The results of combined fermentation of all 4 waste samples with microorganisms such as milk, beer, coffee and energy drinks. There were 5 ratios in order to study the optimum ratio of the fermentation of all 4 waste samples. Recording the volume of biogas produced in each day by replacing of water and analysing the gas composition with the gas chromatography in order to find the amount of methane that was generated.

Amount of biogas occurred rapidly after 1 day of fermentation because bacteria decompose organic substances in the biogas system was high for 4-5 days and after the 5th day, the biogas system began to decline since the experiment was a single nutrient addition to the system. It might be because the amount of nutrients began to decrease. From the experiment, it was found that the ratio of milk : coffee : beer : energy drink at 2:1:1:1 had the highest bio-gas content at 279 mL/day and at the ratio of milk : coffee : beer : energy drink at 2:1:1:1 had the bio-gas content at 200, 139, 123 and 83 mL/day, respectively as shown in Figure 4 and cumulative gas volume as shown in Figure 5. From the Figure 4, the initial time from day 1 to day 2 the bio-gas content was dramatically decreased because the ration 1:1:1:1 and 2:1:1:1 had high amount of fat and protein components which were different from other ratios which had low fat and protein value. Therefore, the bio-gas obtained from the high protein fermented waste could be dropped easily at initial time. This research was done at room temperature which was easily operated and cost low price which could be the benefit for the industrial waste investigation. For further experiment, high temperature should be analysed for bio-gas production from waste product which could be obtained better results compared to room temperature.

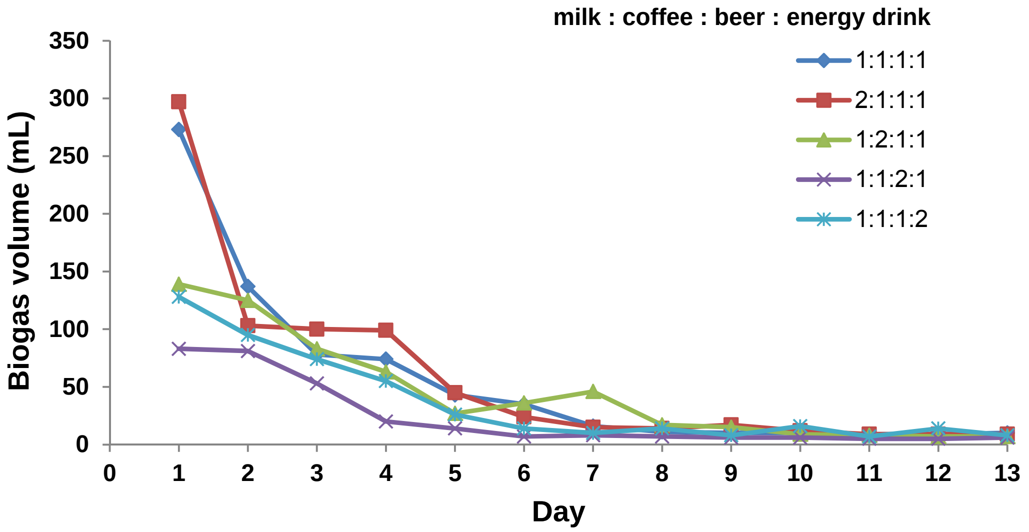


*Figure 4: Daily biogas content of microbes and waste from the beverage industry in all 4 samples.*

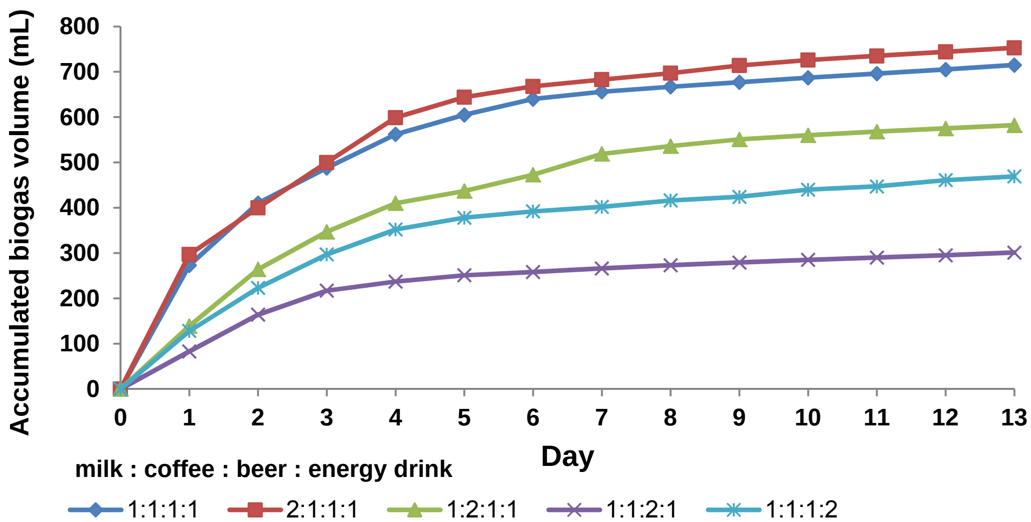


*Figure 5: Accumulated biogas volume of microbes and waste from the beverage industry in all 4 samples.*

### 3.2 Total accumulated gas content and percentage of methane gas

The amount of biogas accumulated in each ratio from the fermentation for a total of 13 days showed that the biogas content at the ratio of milk : coffee : beer : energy drink at 2:1:1:1 had the highest cumulative biogas at 750 mL. It was because most milk components are fat and protein. At the ratio of milk : coffee : beer : energy drink at 1:1:1:1 ,1:2:1:1, 1:1:1:2 and 1:1:2:1 had the cumulative biogas at 709, 577, 467 and 302 mL, respectively. The amount of methane was 12.97, 10.20, 7.36, 6.23 and 5.50 as shown in Table 1. It might be caused by the amount of fat and protein, causing the amount of biogas to be different as shown in Table 2. The organic matter, the amount of fat and the bacteria would better decomposed than organic matter that had the composition of protein and carbohydrates, respectively. Due to the structure of fat (Asadullah, 2014) had a higher carbon content than protein and carbohydrates. As a result, the rate of biogas production was higher (Alves et al., 2009)

*Table 1: Total accumulated gas content and percentage of methane gas.*

| Milk : coffee : beer : energy drink | Accumulated gas content (mL) | Methane composition (%) | Methane gas content (mL) |
|---|---|---|---|
| **1:1:1:1** | 709 | 10.20 | 72.31 |
| **2:1:1:1** | 750 | 12.97 | 97.28 |
| **1:2:1:1** | 577 | 7.36 | 42.47 |
| **1:1:2:1** | 302 | 5.50 | 16.61 |
| **1:1:1:2** | 467 | 6.23 | 29.09 |

*Table 2: Amount of waste components in each ratio.*

| Components | Ratio (milk : coffee : beer : energy drink) | | | | |
|---|---|---|---|---|---|
| | 1:1:1:1 | 2:1:1:1 | 1:2:1:1 | 1:1:2:1 | 1:1:1:2 |
| **Protein** | 3.89 | 5.42 | 5.14 | 4.74 | 3.98 |
| **Fat** | 3.76 | 3.37 | 2.63 | 2.13 | 2.13 |
| **Protein/Fat Ratio** | 1.03 | 1.61 | 1.95 | 2.23 | 1.87 |

### 3.3 Degradation efficiency of organic substances

From the experiment, it was found that the efficiency of degradation of organic matter in all ratios decreased with the end of the experiment. It corresponded to the rate of biological gas in the first phase of the experiment. After that, all ratios began to decrease with the rate of biogas starting to slow down because the organic matter was low and difficult to degrade. At the ratio milk : coffee : beer : energy drink at 2:1:1:1 had the highest removal percentage equal to 69.30% which corresponded to the highest amount of biogas generated at the ratio milk : coffee : beer : energy drink at 1:1:1:1 ,1:2:1:1, 1:1:1:2 and 1:1:2:1 at 55.70, 46.80, 35.20 and 17.20%, respectively as shown in Table 3.

*Table 3: Degradation efficiency of organic substances.*

| Ratios | COD in let (mg/l) | COD out let (mg/l) | COD removal (mg/l) | Percentage of COD removal (%) |
|---|---|---|---|---|
| **2:1:1:1** | 17217 | 5283 | 11934 | 69.30 |
| **1:2:1:1** | 9042 | 4004 | 5038 | 55.70 |
| **1:1:1:1** | 12412 | 6604 | 5808 | 46.80 |
| **1:1:1:2** | 14114 | 9144 | 4970 | 35.20 |
| **1:1:2:1** | 13614 | 11278 | 2336 | 17.20 |

## 4. Conclusions

Industrial waste from beverage production from 4 factories which were milk : coffee : beer : energy drink were chosen in this research due to high COD value that indicating the concentration of organic substances to produce biogas. The optimum ratio of the fermentation from 4 industrial waste beverage production plants was studied to find the maximum amount of biogas and methane gas by using Co-Digestion and also studied the microorganisms from the pig farm in a batch experiment. The results showed that all 4 waste samples were able to be fermented together. The experiment had no temperature control. It was performed at room temperature conditions. From the experiment, it could be summarized the amount of biogas accumulated throughout the experiment that the ratio of fermentation of 4 waste samples with the optimum microbial ratio caused the highest amount of methane gas at the ratio 2:1:1:1 with 12.79%. This was due to the proportion of the mixture was mainly composed of organic substances such as carbohydrates, fats and proteins. The amout of methane gas at the ratios of 1:1:1:1 ,1:2:1:1, 1:1:1:2 and 1:1:2:1 were 10.20, 7.36, 6.23 and 5.50, respectively. The fermentation of 4 waste samples were a good solution to eliminate these waste. Therefore, the production of renewable energy by combined fermentation could help to reduce pollution in the environment and use of waste to be more efficient.

**Acknowledgments**

This research partially conducted under the support of Department of Advanced Manufacturing Technology and Department of Manufacturing Engineering, Faculty of Engineering, Pathumwan Institute of Technology and the Ratchadaphiseksomphot Endowment Fund of Chulalongkorn University. There was gratefully acknowledged for provided facilities and experiment being required for this research.

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