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Optimization of Anaerobic Process by Enzyme Treatment of High Concentration Organic Substances in Food Wastewater

Tae-Hwan JEONG[1], Woo-Taeg KWON[2]

1. First Author Researcher, Unionenv. CO. LTD., Korea, Email: jeongth@naver.com
2. Corresponding Author Professor, Department of Environmental Health & Safety, Eulji University, Korea, Email: awtkw@eulji.ac.kr

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Abstract

Purpose: Since 2013, marine dumping of wastewater has been banned, and research on eco-friendly and efficient land treatment has emerged. This study compared and tested changes in biogas production and anaerobic process efficiency depending on whether or not enzyme pretreatment was performed during anaerobic digestion from single-phase and two-phase to medium-temperature. **Research design, data and methodology:** The total sugar, direct sugar, pH, and acidity before and after fermentation were analyzed by G/C by anaerobic fermentation of the liquor wastewater, food wastewater 1, and food wastewater 2 at 30°C for 67 hours, and the amount of methane gas generated was analyzed by balloon volume. **Results:** It was found that stable organic acid concentration and pH were found in the enzyme-treated food wastewater 2, and the amount of methane gas generated was also increased. **Conclusions:** When anaerobic digestion of the liquor wastewater and the food wastewater together, the performance of enzyme pretreatment resulted in increased digestive efficiency. It will be the basic data that can contribute to carbon neutrality and greenhouse gas reduction by increasing the production of biogas.

Keywords : Food wastewater, Anaerobic process, Enzyme, Biogas, Methane gas

JEL Classification Codes : I30, I31, I38

1. Introduction

Since 2013, marine dumping of wastewater has been banned, allowing food wastewater containing high concentrations of organic matter and oil to be treated only on land (Kim & Jung, 2022). Therefore, there is a growing need to seek economical and eco-friendly treatment methods, and anaerobic digestion corresponds to a method that satisfies this.

Anaerobic digestion is divided into a single phase when the reaction of acid production and methane production occurs in one reaction tank and two phases when the reaction occurs in two reaction tanks (Park & Seo, 2020). In particular, medium-temperature digestion (30 to 35 °C) is a widely used method because it can stably produce biogas (Park & Seo, 2020).

In this study, the maximum treatment efficiency of the existing single-phase and two-phase anaerobic digestion methods used to treat food wastewater was derived and a method was devised to compensate for the shortcomings that take a lot of time to treat the insoluble organic concentration of food wastewater. In addition, biogas production can be increased by mixing and food wastewater and liquor wastewater, which can also be used as an energy source, allowing organic matter to be treated in an eco-friendly way.

2. Literature Review

Acid-alkali treatment, ultrasonic treatment, ozone treatment, electromagnetic wave treatment, treatment by the injection of trace elements, and pretreatment by enzymes exist in food wastewater solubilization treatment. Among them, pretreatment by enzymes reduces the digestion rate time and increases the processing efficiency by enzyme-treating high-concentration organic matter from polysaccharides to monosaccharides.

As a result of anaerobic digestion of food waste by pretreating fermentation coenzymes, methane production speed increased by 651% and fermentation coenzymes effect increased by 286% in a paper on biogas efficiency through pretreatment using food waste fermentation coenzymes (Kim, 2021).

However, due to the high cost of purchasing enzymes and limited applicability (Kim, 2021). It is not easy to find papers on the treatment of food wastewater using enzymes.

3. Research Methods and Materials

3.1. Experimental Materials

As the sludge used in this experiment, MH distillery company and C company's food wastewater were used.

Table 1: Properties of Materials Used in the Experiment

Category	Food Wastewater	Liquor Wastewater
pH	4.1	3.8
TS(%)	11%	5.6%
TCODcr(mg/L)	100,000	50,000
T-N(mg/L)	1,500	1,000

3.2. Experimental Equipment and Methods

A comparative experiment was conducted on changes depending on the presence or absence of enzymes in the liquor wastewater and the food wastewater. The experimental period is from March 24, 2022 to March 27, 2022, and the samples are liquor wastewater, food wastewater 1 (pre-crushing raw wastewater source solution), and food wastewater 2 (receiving wastewater), and the input enzymes are A enzyme(A-240L) and B enzyme (S-Fuel).

In this study, the amount of anaerobic digestive gas was tested with the balloon volume.

3.3 Experimental Method

(1) Liquor wastewater

Cool the liquor wastewater at 30°C and mix 800mL of the liquor wastewater and 1mL of anaerobic digestive solution.

(2) Food wastewater

Mix 800mL of food wastewater 1 and 1mL of an active anaerobic digestion solution and install a balloon. Mix 800mL of food wastewater 2 with A enzyme + B enzyme and install a balloon.

(3) After fermentation at 30°C for 67 hours, measure the amount of biogas by checking the balloon size.

3.4. Analysis Method

(1) Liquor wastewater

Conduct G/C analysis after anaerobic fermentation at 30°C for 67 hours. The amount of methane gas is compared by the balloon volume.

(2) Food wastewater

Before fermentation, G/C analysis (food wastewater distillation) of total sugar, direct sugar, pH, and acidity. After fermentation, a balloon volume G/C analysis of the amount of gas generated per residual total and per residue is performed (food wastewater distillation).

4. Results and Discussion

Table 2 and Figure 2 and Figure 3 show the changes in distilled wastewater, food wastewater 1, and food wastewater 2 after 67 hours of fermentation.

Table 2: Comparison of 67-hour Fermented Samples

NO	Sample (800mL)	Enzymes
1	Distilled wastewater (Yeast 1mL)	-
2		Liquefied enzyme + glycated enzyme
3	Food WasteWater-1 (Pre-crushing undiluted solution)	-
4		Liquefied enzyme + glycated enzyme
5	Food WasteWater-2 (Waste received)	-
6		Liquefied enzyme + glycated enzyme

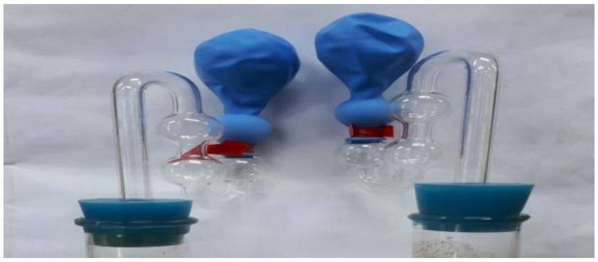

Figure 2: Comparison of the Balloon Volume of Distilled Wastewater, Distilled Wastewater + Enzyme

Figure 3: Comparison of the Balloon Volume of Food Wastewater 1, Food Wastewater 1+ Enzyme, Food Wastewater 2, Food Wastewater 2+ Enzyme (from Left)

It can be seen that the second and fourth balloons in Figure 3, which are fermented with enzymes, are more swollen than the balloons on each left.

Table 3 and Figure 4 show the change in gas generation after 67 hours of fermentation.

Table 3: Comparison of Gas Generation After 67 Hours of Fermentation

NO	Sample (700mL)	Enzymes	Gas Generation Weight (g)
1	Wastewater-1 (Before centrifugation - undiluted solution)	-	4.12
2		Liquefied enzyme + glycated enzyme (35uL+70uL)	8.11
3	Wastewater-2 (Waste amount received after centrifugation)	-	0.39
4		Liquefied enzyme + glycated enzyme (35uL+70uL)	0.95

Figure 4: Comparison after Fermentation of Food Wastewater 1, Wastewater 1+Enzyme, Wastewater 2, Food Wastewater 2+Enzyme(from Left)

It can be seen that the gas generation amount of food wastewater 1+enzyme was 8.11 g, about twice as high as the gas generation amount of food wastewater 1, 4.12g. In addition, it can be seen that the gas generation amount of food wastewater 2 + enzyme is 0.95g, which is more than twice as high as the gas generation amount of food wastewater 2, 0.39g.

Table 4 and Table 5, and Figure 5 show the results of analysis of total sugar, direct sugar, pH, and acidity before and after fermentation, and the comparison of changes in gas generation with balloons.

Table 4: Total Sugar, Direct Sugar, pH, and Acidity Analysis Results before Fermentation

NO	Sample (Food wastewater 900mL)	Before Fermentation			
		Total sugar (%)	Direct sugar (%)	pH	Acidity
1	Food wastewater (Blank)	5.01	1.05	4.35 (19.4°C)	13.8
2	Food wastewater + Liquefied enzyme + glycated enzyme	-	-	-	-

Table 5: Total Sugar, Direct Sugar, pH, and Acidity Analysis Results after Fermentation

NO	Sample (Food wastewater 900mL)	After Fermentation (30°C/67hrs)		
		Total sugar remains(%)	Direct sugar remains(%)	Alc(%)
1	Food wastewater (Blank)	1.65	0.09	0.3
2	Food wastewater + Liquefied enzyme + glycated enzyme	0.53	0.17	1.5

After fermentation, total sugar in food wastewater(blank) was reduced by about 67%, and direct sugar by about 91%. Alc (%) is about 5 times higher in sample No. 2 with enzyme, indicating that anaerobic digestion after enzyme treatment has high digestion efficiency.

Figure 5: Comparison of Gas Generation Balloon after Fermentation

The two balloons on the left are samples without enzyme, and the two balloons on the right are samples with enzyme. It can be seen that the balloon size is larger after fermentation of the sample containing the enzyme.

Table 6: Food Wastewater Storage Tank Analysis Results

Analysis Date	Sample	Total Sugar (%)	Direct Sugar (%)	Temperature (°C)	pH	Organic Acid (ppm)
2023/03/20	Food Waste water Storage Tank-3	3.20	0.42	17.0	3.72	4,694

In order to measure the organic acid concentration before and after the enzyme input, food wastewater storage tank No. 3 was analyzed before the experiment and the organic acid concentration was found to be 4,694 ppm.

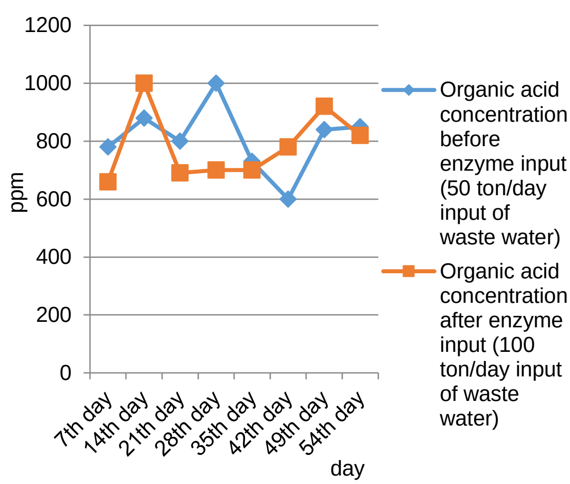

Figure 6: Organic Acid Concentration before and after Adding Enzyme

In Figure 6, the blue line is the concentration of organic acid when 50 ton/day of the wastewater is added without adding the enzyme, and the orange line is the concentration of the organic acid when 100 ton/day of the wastewater is added after the enzyme is added. It can be seen that the amount of organic matter increased by about 2 times after adding the enzyme, but the organic acid concentration appeared stable, similar to 50 ton/day before adding the enzyme.

In anaerobic digestion, when organic acids are not sufficient, the pH of the digestion tank decreases due to insufficient buffering capacity, making it difficult for methanogenic bacteria to grow, making anaerobic digestion difficult (Lim, 2015). However, in the experimental results of this study, as a result of pretreatment anaerobic digestion with enzymes in an anaerobic digestion tank, the organic acid concentration was stably maintained around 1000mg/L and operated around pH7.3~7.8 with little change in pH. The amount of methane gas generated after enzyme pretreatment increased by more than 20% compared to anaerobic digestion without enzyme pretreatment.

5. Conclusions

This study compared the change in methane gas generation amount and anaerobic process efficiency in a limited digester capacity according to the input of enzymes in liquor wastewater and food wastewater. Liquor wastewater, food wastewater 1(without enzymes), and food wastewater 2(with enzymes) were anaerobically fermented at 30°C for 67 hours, and G/C analysis was performed on total sugar, direct sugar, pH, and acidity before and after fermentation, and methane generation was analyzed by balloon volume. As a result, when the liquor wastewater and food wastewater were treated, an anaerobic digestion tank was operated after enzyme pretreatment, and excellent and stable residual organic acid concentration and pH were obtained. The amount of methane gas was about 2,000m^3 per 20 to 25 tons of food wastewater removal solution, indicating that the amount of methane gas was increased.

This study made possible the mixed-linked treatment of food wastewater and liquor wastewater by enzymatic pretreatment, and it is expected that this will be a basic study on how to increase biogas production. In addition, it is possible to utilize organic waste energy by processing the highest concentration of organic matter in a limited digester capacity, and to utilize the food evaporation liquid as an organic carbon source. It is thought that more efficient treatment of food wastewater will contribute to global environmental aspects such as carbon neutrality and greenhouse gas reduction.

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