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The Potential of Biogas Production from Wastewater of Shredded Pork Processing with Cow Manure

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ABSTRACT

Small and Medium Enterprises (SMEs) play a crucial role in driving the economy, especially in developing countries. Since they are essential employment resources and support local development, in SMEs relate to processed meat production, large amounts of wastewater containing blood, fat, and protein require high-efficiency treatment methods to prevent environmental pollution. If the wastewater is not treated appropriately, the impact will cause environmental pollution. Therefore, this research aims to study the potential of biogas production from wastewater of shredded pork processing (WSPP) to find the optimal substrate-to-inoculum ratio and evaluate its industrial application potential. The research also experimented following the biochemical methane potential method, where the total volume was 1000 mL, and the working volume was 400 mL. The experiment used the substrate-to-inoculum ratio (SIR) ratios, which were 1:2, 1:1, and 2:1 VS-based. The operating temperatures were 35 ± 2 °C in the mesophilic period. The study results showed that the most appropriate ratio for biogas production was 2:1 VS-based. During the 33 days of the experiment, it was found that the potential of the highest cumulative biogas and methane yield was 1640.19 ± 97.46 and 650.59 ± 48.04 N mL/g VS_{added}, respectively, which contained a maximum methane content of 68.60%. Moreover, COD, TS, and VS removal efficiency were 57.57 ± 2.28, 57.30 ± 2.19, and 1.49 ± 0.16, respectively. The research results demonstrated that the wastewater from the WSPP was a high-potential substrate for biogas production and would continuously be developed at the industrial level.

1. Introduction

The dominant role of the food processing industry is to create added value for the material type of food processing and the export opportunities of goods in 2023. Creating value through food production drived export opportunities, which is crucial for economic growth and supported the creation of 11,947 SME groups, particularly in food-related production [1]. Industries like meat processing, sugar, and palm oil production generate waste, including wastewater with blood, fat, and oil. production, and paper production. All these industries had material scrap and waste from processed meat production, which continuously gained popularity. On the other hand, food production inevitably had substandard meat and other wastes, such as wastewater from the WSPP etc. The wastewater generated during the processing process contains lightweight blood, fat, and oil, which float on the water surface [2]. If wastewater were released into natural water sources, human health would continuously impact the ecosystem of water-living things. The Chemical Oxygen Demand (COD) is limited to less than 120 mg/L to minimize environmental impact. Therefore, there was a campaign for factories to process the technology on wastewater treatment before releasing it into the water resources of the factory or the natural water resources. Consequently, efficient water treatment was necessary to support the expansion of WSPP. Previously, there were two main popular manufacturing methods of wastewater treatment: aerobic and anaerobic processes via physical, chemical, and technological biogas production [3]. The advantages of these processes were that they could process wastewater treatment, and the factory produced energy to power back. However, with the technology of biogas production treatment, the gas from anaerobic digestion decreased pollution in wastewater and the processes that naturally happened via various types of microorganisms performed to digest organic substances. Efficient for biogas production, reducing pollutants through microbial digestion of organic matter (1) hydrolysis in the proteins, carbohydrates, and fats into small molecules. Hydrolysis is the first stage of breaking down macromolecules. (2) Acidogenesis, a microorganism that will digest and convert small molecules to volatile fatty acids (VFAs). (3) Acidogenesis, another microorganism, will change some VFAs to acetic acid and hydrogen gas, and (4) Methanogenesis, the final step in the decay of organic matter, will change Methane gas; methane is the main biogas component. the main component of biogas. The components contain methane gas, carbon dioxide gas, water, hydrogen Sulfide, and others which will change the organic waste into biogas energy [4-6]. The main components of biogas production were Methane gas, which had an approximate ratio of 50% - 75%, and Carbon dioxide gas, which had an approximate ratio of 30% - 50% [7-8]. However, wastewater treatment in the processing meat industry is often faced with the problem of film or scum processing. Wastewater generated from the pork grinding process is heavily contaminated with fats, which pose significant environmental challenges. In related studies, many researchers have studied the production of biogas from wastewater or waste from food waste, fat, and animal waste, such as research of Patcharee and Jitaporn (2017) has been conducted to evaluate the potential for biogas production from organic waste in six agricultural industries. The sectors were the fish meal factory (chicken feather), the fish meal factory (fish), the processed squid factory, and the sardine factory. The researchers also collected wastewater from Each factory, which is equipped with a sump with a capacity of 20 L. The experiment also used waste conditioning of VS to 2 g/vs and fermented at 35 °C for 35 days. The experiment was conducted to study the potential of each agriculture industry to produce biogas batches. The research found that wastewater from the industries had a BOD of organic substances at 1.9 - 4.8 g/L, which was relatively low [9]. Koc et al. (2019) This research aims to study the amount of biogas from 3 types of food waste: protein from animals, vitamins from fruits, and carbohydrates from rice. Additionally, the anaerobic digestion in 20 L of fermenter was conducted at environmental temperature. The duration of the experiment took 42 days. The study showed that the fermenter that could produce the maximum methane gas was the protein fermenter, which created a methane content of 13.7%. The vitamin fermenter produced the lowest methane yield, generating only 6.1% methane. In this study, the researcher also found that the experiment could be exclusive. [10] (Srivichai Rodsrida, (2020) the study investigated biogas production through the anaerobic fermentation of concentrated food waste concentrated food waste, which was processed by a continuous batch reactor set and conducted at 37 °C. Moreover, it is processed with no acid-base control in the different organic loading rates (OLR) of 3.11 – 19.22 kg COD/m^3-day. The main components of methane and carbon dioxide were not found in hydrogen gas in the methane content process. The maximum OLR was 8.71 kg COD/m^3-day, related to the maximum organic substance digestion. Consequently, the potential was lower due to the overproduction of acid. Of affected the higher Alkalinity. The effect of the increase in Alkalinity was that the growth of microorganisms declined because of the higher toxicity of the OLR and the difficulty of digestion. Therefore, the research indicates that organic food waste substances were too intensive to produce methane content at 67% and the maximum of the organic substances' digestion of 38% [11]. Therefore, this research aims to study the potential of biogas production from WSPP wastewater, identify the optimal substrate-to-inoculum ratio, and evaluate its feasibility for industrial applications

2. Raw materials and inoculum

The study on biogas production potential from the WSPP feedstock preparation. Before collecting, it was used to wash meat and tools and clean the floors. After that, they stored at a temperature of 4 ± 2 °C before experimenting, as shown in Fig. 1(A). The wastewater was characterized by an intensely aromatic odor, coagulated fat, three distinct sediment layers, and a suspension floating on the water's surface. Additionally, cow manure was used to adjust the microbial by taking the inoculum into a fermented biogas system for around 7 to 14 days until it was not produced within the temperature of 35 ± 2 °C. Before fermentation, the inoculum must be separated from other materials, as illustrated in Fig. 1(B).The inoculum, consisting of cow manure sludge (CMS), was also utilized for the analysis of Chemical Oxygen Demand (COD), Total Solids (TS), Volatile Solids (VS), Volatile Fatty Acid (VFA), and alkalinity (Alk), with pH values also being determined.

(A) (B)

Fig. 1 The character of the wastewater of the shredded pork processing process (WSPP) (B) cow manure sludge inoculum (CMS).

2.1 The methods for processing the experiment of biogas predation

The methods for processing the biogas production experiment were the methods for finding the potential of methane production using the Biomethane Potential (BMP Test). All the experiments were conducted under the VDI 4630 standard. The research was conducted on the treatment that had been done using the anaerobic system. The experiment conducted in this research utilized a volume of 1000 mL. and used wastewater from the WSPP, which was fermented with CMS. The experimental ratio was separated into three conditions: 1:2, 1:1, and 2:1 VS-based, experimented with triplicates in each ratio. The working volume of anaerobic digestion was 400 mL in the glass bottle. The BMP experiment was conducted at a controlled temperature of 35 ± 2 °C using thermostats, water baths, and a water pump for 33 days. In preparation for the experiment, the number of volatile solids (VS) was controlled to ensure that no more than 5 g VS was added, as outlined in Equation (1).

$$BMP = V_{Biogas} / m_{Substrate\ (VS\ added)} \quad (1)$$

V_{Biogas} is the amount of biogas obtained, $m_{Substrate}$ (VS_{added}) the raw materials and inoculum to the BMP system. After that, all samples were analyzed in triplicate and were taken to examine the component value measured by and measured volume of daily biogas production by glass syringes. Then, the analytical using a biogas analyzer (GFM-406 series: Gas Data, United Kingdom). Table 1 shows the APHA standard method (APHA, 2005) [12], with each value representing the meaning of three replicates [13 - 14] as shown in Fig. 2.

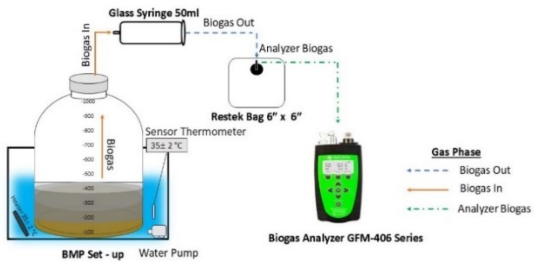

Fig.2 Diagram of biomethane potential test for wastewater of shredded pork processing with cow manure sludge inoculum.

3. Results and Discussion

3.1 The analysis results of raw material components

The analysis results of raw materials and basic sludge inoculum were used for the experiment in the biogas production process from the wastewater of the WSPP, which had a COD of 79,645 g/L and a pH value of 5.2 ± 0.01. The pH of the components and the wastewater quality were extremely high due to the rapid pH fluctuations affecting methanogen bacteria being too low to form an overloaded acid, which resulted in inefficient biogas production and failure in the end [14]. Therefore, the pH that occurred needed to relate to the system for a duration of 6.2, which was the appropriate state [15]. Additionally, the highest value of the inoculum was 12,813 mg/L, and the highest value of the wastewater from the processing process was 148,376 mg/L, which occurred under the state that had a high number of organic substances but less ability of acid production. The fatty acid collection caused the state mentioned. If the amount of acid could not be decreased, the microorganism would be prohibited [16]. The VFA/Alk ratio of the wastewater from the processing process was high at 0.94 ± 0.96 mg/L, which exceeded the standard [17]. The overabundant number of organic substances negatively affected the system's low value and the failure [18] of the process. The values of cow sludge inoculum were found to have a pH of 6.8 ± 0.21, which showed slight acid. The inoculum (CMS) has the potential to produce methane yield, so the inoculum has been popularly used for biogas production. The cow manure sludge was also environmentally durable, and the bacteria had a high growth ratio [19], as shown in Table 1.

3.2 The efficiency in COD TS and VS removal

The efficiency analysis of biogas production through the anaerobic process and considers the COD, TS, and VS removal in the 1:1, 1:2, and 2:1 VS-based ratios. The performance shown in Table 2 demonstrated the efficiency of the COD removal value was 52.67 ± 0.89%, 53.61 ± 0.43%, and 57.57 ± 2.28%, respectively. All the values showed the ability of biogas digestion of some organic substances, especially fat and protein, which decreased when the ratio rose. However, the efficiency results, with a ratio of 2:1, were due to the higher quantity of cow inoculum in the VS-based system [20].The cow inoculum had enzymes and microorganisms that could help the digestion process of complex organic substances to have an efficient digestion process [21]. Consequently, organic substances with a complex digested structure had greater efficiency. The solid removal in the process could decrease the amount of TS removal. The research on slaughterhouse water treatment specified that solid removal had an average duration of 47-65% [22]. The duration values were related to the study results, which were obtained by the ratio of 1:1, 1:2, and 2:1. The efficiency of solid removal was 50.49 ± 3.02%, 54.97 ± 1.47%, and 57.30 ± 2.19 %, respectively. The sedimentation of coarse particles often occurs when the proportion of organic substances in the system is high. These organic substances were agminated to be a bigger group, quickly precipitated, and efficiently removed from the system. The food resources for microorganisms but also the acceleration of the solid sedimentation process within the water treatment system. The efficiency of VS removal was 1.19 ±0.35%, 1.47 ± 0.33%, and 1.49 ± 0.16%, respectively. The efficiency of VS removal affected the remaining organic substances to be not inefficiently digested and led to worse VS removal in the system. Besides the control and change in the ideally better organic digestion factor, it significantly affected biogas production's high efficiency. Decreased the accumulation of residue in the system [23]. When considering the analysis results of the ratio of 2:1, it was found that the system could reduce the number of organic substances, which could be observed from the value of VFA/ALK. The VFK/ALK was average at 0.25 ± 0.08. The VFK/ALK was average at 0.25 ± 0.08. The average demonstrated the system's equilibrium between acid production and buffering ability. In the part of pH, the average was at 7.55 ± 0.12, which showed the appropriate state for the anaerobic digestion. The anaerobic digestion system methane production particularly mesophilic .the system could continue digestion and efficiently produce

Table 1 The characteristics of substrate and inoculum for anaerobic digestion.

Parameter	Unit	Substate (WSPP)	Inoculum (CM)
COD	g/L	52.44 ± 0.15	28.84 ± 0.72
TS	g/L	158.49 ± 51.65	60.52 ± 28.72
VS	g/L	148.38 ± 49.70	33.86 ± 15.42
pH	-	5.20 ± 0.01	6.80 ± 0.21
VFA	g/L as CH_3COOH	4.82 ± 1.04	4.93 ± 1.27
Alk	g/L as $CaCO_3$	6.69 ± 0.25	5.78 ± 0.71
VFA/Alk Ratio	g CH_3COOH/g $CaCO_3$	0.94 ± 0.96	0.44 ± 0.20

Table 2 The removal efficiency of anaerobic digestion.

Parameter	Unit	SIR (VS-based)		
		1:1	1:2	2:1
COD	%	52.07 ± 0.89	53.61 ± 0.43	57.57 ± 2.28
TS	%	50.49 ± 3.02	54.97 ± 1.47	57.30 ± 2.19
VS	%	1.19 ± 0.35	1.47 ± 0.33	1.49 ± 0.16

3.3 Biogas production and the potential of Methane gas production.

Biogas production and methane gas from wastewater that occurred during the WSPP were tested once in the BMP process [23]. The biogas production and methane content were evaluated using cow manure sludge as the inoculum, with nutrients added only once. The experiments in the SIR were 1:1, 1:2, and 2:1 VS-based. The fermentation period was 33 days, as shown in Fig. 3. The study of biogas production from waste that had high fat and protein in the ratio of 2:1 VS-based found that the amount of biogas began to increase on day 11 and could produce the highest gas production on day 19. The highest average daily gas was 162.50 ± 25.30 N mL/g VS $_{added}$. The accumulated biogas was 1640.19 ± 97.46 N mL/g VS $_{added}$. The amount of biogas also showed the potential for high biogas production, which is related to the entrancing of organic substances into the hydrolysis process of biogas production. Due to the qualifications of fat and protein in wastewater, the digestion period initially required more time than other ratios [24]. When the appropriate amount of lipid added, methane production significantly increased. Lipids could be decomposed into volatile fatty acids, the key precursors for methane production.[25] As a result, the methane yield increased by 47.70 ± 20.50% during the first 10 days. The highest methane production, 68.60 ± 21.97%, was observed on day 25. Therefore, this ratio represented the optimum balance of raw material and culture. This conclusion is further supported by the increased methane yield and the stabilization of anaerobic digestion for the experimental results of ratio 1:1 VS-based. The biogas was produced highest from day 0 to day 18, with an average of 162.50 ± 37.98 N mL/g VS $_{added.}$ The highest accumulated biogas was added at 1249.77 ± 70.31 N mL/g VS $_{added}$. When considering the experimental results of the biogas production, it was found that the biogas had increased from day 0 to day 16. The efficiency of the system process could produce the highest average biogas production at 50.92 ± 3.92 N mL/g VS $_{added}$. The highest accumulation of biogas was 163.39 ± 19.91 N mL/g VS $_{added.}$ It has been observed that prolonged fermentation times lead to a decrease in biogas production [26]. Since there was a high accumulation of VFA, the microorganisms in the group of methanogens did not work efficiently in the system's state of high acidity. The high acid would prohibit biogas production and affect the lower methane yield. Before digestion ended, methane gas was produced at the highest level, 61.70 ± 18.96%. For the experimental result, the ratio of 1:2 VS-based between the coordinator and the wastewater from WSPP had a more significant proportion of fat than other proportions. The wastewater from the WSPP contains high levels of fat and protein. Since fat is a macromolecule and water-insoluble, its hydrolysis requires additional processing. Microbes are unable to digest and convert them into nutrients. Consequently, wastewater conditions were needed to increase the efficiency of the hydrolysis process. From the experiment during the first day 0 to day 10, it was found that the efficiency of biogas production in the short term had the highest average of 65.97 ± 8.49 N mL/g VS $_{added}$. On the other hand, from day 11 to day 21, the biogas production fluctuated due to the decline of biogas and Methane production. The averages were 2.76 ± 14.91 N mL/g VS $_{added}$. The analysis showed that the exceeded standard value prohibited methane yield production and affected the decline of biogas production. The research found that the average methane content was 58.50 ± 16.83 %. The biogas production ended on day 29. From the research, the same type of wastewater can produce almost the same amount of methane gas in different ratios and SIR, with only slight differences [27]. The experiment also demonstrated that the ratio of 2:1 VS-based is most suitable for biogas production and had the best potential for methane production. As mentioned above, the experimental results could be expand to a larger scale in the industry because of the highest methane content of 68.60 %, a very high value in biogas production when the results were compared to standard biogas production and other research [28-29].

4. Conclusion

This research studied the potential of biogas production from the wastewater of the WSPP research and experimented with the anaerobic digester with a glass bottle, where the total volume and working volume were 1000 and 400 mL, respectively. The character of feeding organic substances was shifted by the SIR, which was 2:1, 1:1, and 1:2 VS-based. The study found that the SIR was 2:1 VS-based and had the highest biogas and methane yield at 650.59 ± 48.04 N mL/g VS $_{added.}$ Maximum methane content was 68.60%, and COD, TS, and VS removal efficiency was 57.57 ± 32.28, 57.30 ± 2.19, and 1.49 ± 0.16, respectively. The results demonstrated that wastewater from the WSPP is a viable substrate for biogas production when fermented with cow manure sludge at an optimal ratio. The author has added to the section expanding the experimental results of the biogas production system to address the problem of municipal wastewater discharge and scale it to a larger industrial level. This is a challenge and will be further expanded to the industrial level.

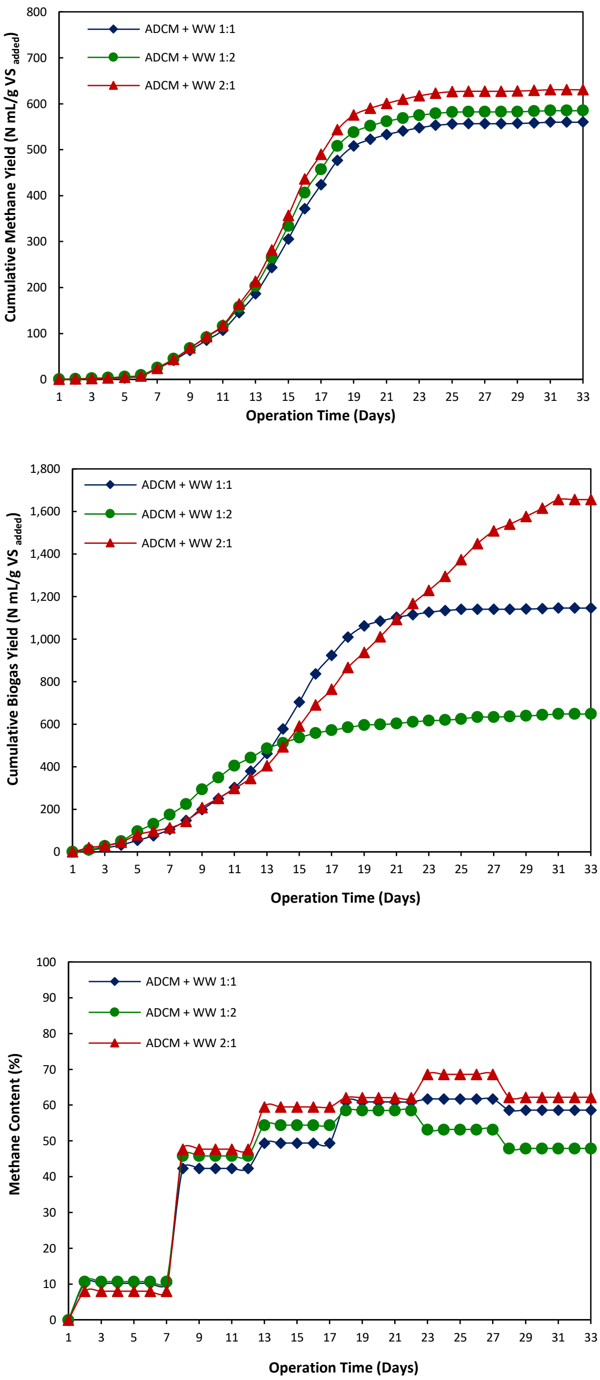

Fig. 3 Methane content during the BMP test for various SIR ratios.

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