Optimization of Pilot scale Biogas Plant for mixed food wastes with cow dung by anaerobic digestion process

Prithiviraj. C[1*], Mondal. B[2], Sivarethinamohan. R[3*], Senthil Kumar. M[4]

[1] Department of Civil Engineering, Jei Mathaajee College of Engineering, Kanchupuram-631 552, Tamil Nadu, India (rajprithivi3@gmail.com)

[2]Department of Mechanical Engineering, GMR Institute of Technology, Rajam – 532 127, Andhra Pradesh, India (bappamondalme@gmail.com)

[3]Symbiosis Centre for Management Studies, Symbiosis International (Deemed University), Bengaluru, Karnataka, India (mohan.dimat@gmail.com)

[4]Department of Environmental Engineering, College of Engineering and Technology, Bule Hora University, Bule Hora, West Guji, Ethiopia.(senthilenvtce@gmail.com)

*Corresponding Authors

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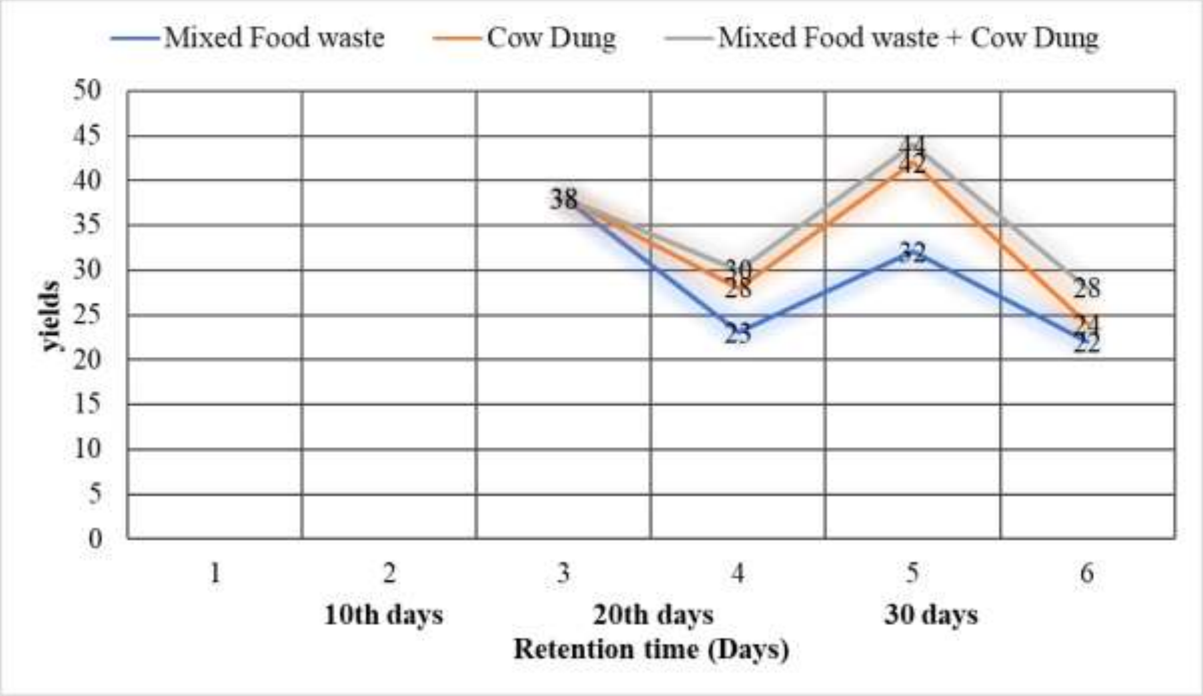
GRAPHICAL ABSTRACT



Abstract

The primary aim of this research is to identify the best anaerobic digestion process yield for generating biogas from mixed food waste in the combination of cow manure. For the biogas generation experiment, certain biodegradable domestic organic wastes gathered from restaurants, waste storage facilities, the fruit-and-vegetable market and manure from cows. Organic waste collection; 38g of mixed food waste, cow dung waste and its mixture collected from Yaaballo town. To match the digester's input size and to make digestion easier, all wastes were broken down into little (5 mm) pieces by using a mortar and pestle. Organic materials were kept in plastic bags till anaerobic digestion got started. Because high temperatures stimulated the growth of methanogenic bacteria in the digester, the findings from the research indicated that Mixed Food Waste and Cow Dung Waste produced the most biogas (44ml) at 45ºC in a short retention period. The temperature, PH, and retention time all significantly (P0.05) affect the production of biogas, according to the ANOVA results. It is possible to combine organic materials with equal amounts of high and low C:N ratios to get the ideal C:N ratios for digester use. The pH stability and increased methanogenic activities achieved by changing the C:N ratio of organic waste to provide the greatest biogas generation in Mixed

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Food Waste and Cow Dung Waste. For the best yield, the combination of diverse organic waste and the effects of various parameters on biogas production should be thoroughly studied.

Key words: Biogas production, anaerobic digestion, organic waste, and digester.

1. INTRODUCTION

Biogas is a renewable energy source, just like hydropower, solar, wind, geothermal, and ocean energy. Energy is now requirement for advancing the economy and raising living standards. Biogas digesters can be used to handle biodegradable food waste and produce energy [1]. Anaerobic digestion of food wastes such as industrial, food, garden, and fruit wastes can produce biogas that can help in the creation of sustainable energy [2]. Methane, carbon dioxide, and other gases are combined in the form of biogas, when hydrocarbon digested anaerobically. Greenhouse gases, mostly released by the burning of carbon-containing fossil fuels like coal, oil, and natural gas, are the primary cause of global warming [3]. Many food waste management initiatives aim to gather methane from landfill microorganism activity and burn food waste to produce energy. Biogas is a clean-burning, environmentally friendly fuel that can be used for transportation, electricity generating, and cooking [4]. In general, biogas has a methane content of 55–65%, a carbon dioxide content of 30–35%, and traces of nitrogen, hydrogen, and other contaminants [5]. The production and use of biogas has several environmental benefits, including the ability to be a renewable energy source, reduce methane emissions into the atmosphere, replace fossil fuels, and produce high-quality digestate that can be used as fertilizer [6]. Treatment of food waste using anaerobic digestion technologies has become a more desirable method for managing food waste as a result of growing demands for the generation of renewable energy and diverting of organic residuals from landfills to reduce greenhouse gas emissions and other environmental impacts [7]. By using a controlled biological breakdown process called anaerobic digestion, biogas, which contains roughly 60% methane and 40% carbon dioxide, may be efficiently captured, and used for energy production [8]. In both industrialized and developing nations, a sizable amount of municipal solid waste (MSW) is made up of food waste [9]. The importance of anaerobic digestion of organic wastes like food wastes as an alternative renewable source of energy has come to light as a result of climate issues brought on by the greenhouse effect, ozone depletion, etc [10]. Because of Ethiopia's rapid population expansion and growing living standards, food waste is typically produced at an ever-increasing pace from home, commercial, institutional, and industrial sources [11]. Reusing this beneficial feedstock for energy recovery and municipal solid waste reduction

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looks like a reasonable concept because food waste makes about 40–50% of the weight of municipal solid waste and contains high moisture and biodegradable organics [12]. For the treatment of food waste, numerous anaerobic techniques have been widely developed in different nations. The most appealing and economical approach for treating the sorted organic part of waste including food wastes, is anaerobic techniques [13] In 1957/58, biogas generation was first used in Ethiopia at the 115 km west of Addis Ababa Ambo Agricultural College. The fuel was produced using human excrement as the substrate [14]. The first biogas floating drum digester in Ethiopia was set up in the same college in October 1962. The digester in this floating drum biogas system, which has a volume of 7m^3, receives a daily charge of around 100liters of dung and water in a ratio of 1:1. Ethiopia's rural areas, where 85% of the population resides, are disproportionately affected by the issues of traditional biomass fuels constantly declining quality and myriad negative effects, as well as the unavailability of modern fuels [15]. It has been extensively investigated how different kinds of food waste can be digested anaerobically. Increased food production and consumption in Yabelo Town have led to a rise in food waste in urban areas [16]. As a result, the urban environment is deteriorating and becoming more difficult for humans to survive [17]. Therefore, it is an essential to investigate the anaerobic digestion process ability to produce biogas from food waste in order to solve this issue [18]. The main objective of this study is to characterize the composition of mixed food waste with cow dung in terms of optimum yield of biogas production by anaerobic digestion process. The determination of moisture, Volatile solids, C:N Ratio supports to identify the potential yield of biogas production.

2. Methodology

2.1 Description of study area

Yaaballo, the capital of Borana zone in the Oromia regional state, located in the southern part of Ethiopia, with coordinate’s 38^{0}11'24"E longitude and 4^{0}59"40'N latitude and 575 kilometers away from Addis Ababa along an asphalt road, at an altitude of 1577 meters above sea level. Lowlands and sub-tropical humid climates make up the majority of the agroclimatic zones studied [19]. There is a complete moisture deficiency in the area. It falls under the semi-arid and arid moisture areas categories. More than 90% of rural settlements are in lowlands and subtropical humid agroclimatic zones. Yaaballo district's population was 62,485 according to the CSA's 2007 population and household census [20].

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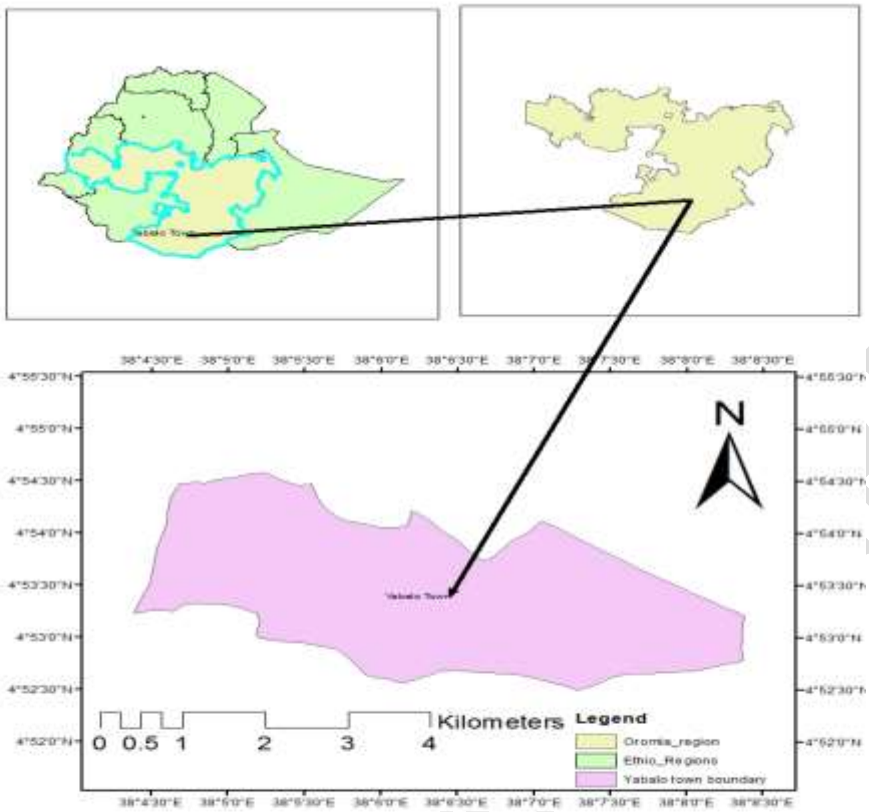

Figure .1 Map of the study area

2.2 Organic Waste and Inoculum Collection

Selected biodegradable home organic wastes, including food, fruit, and vegetable wastes gathered for the biogas generation experiment from hotels in Yaaballo as well as trash storage facilities [21]. Collection of organic wastes: In the town, restaurants, university, and household kitchens, 38g of various types of mixed food wastes (bread, rice, pasta, injera with meat and shiro wot, banana, papaya, avocado, and mango) and 38g of cow dung wastes were gathered [22]. Anaerobic microorganisms and fresh digestate waste effluent were collected. Cow dung used as an inoculum source because it naturally includes methanogenic bacteria that are necessary to initiate anaerobic digestion [23]. This enables the bacteria to multiply and shortens the period during which biological activity is retained. Bones, plastic components, and other non-digestible components were meticulously removed from the substrate [24]. To match the digester's input size and to make digestion easier, all wastes broken down into little (5 mm) pieces by using a mortar and pestle [25]. Organic materials were kept in plastic bags till anaerobic digestion got started.

2.3 Substrate Preparation for Anaerobic Digestion

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In this study, the production of biogas included the co-digestion of fruit, food, cow manure, and vegetable wastes [26]. The biogas substrates were ground and combined in the following ratios:

1. Mixed food wastes, including bread, rice, pasta, injera with meat, and shirowot were combined in about equal amounts to create one substrate [27].
2. Cow dung, also known as cow excavated waste, is treated in two ways.
3. The C:N ratio of organic wastes (including food waste and cow dung waste) was calculated prior to the manufacture of the mixed-waste substrate [28]. The Mixed-waste substrate then created with an optimal C:N ratio (28:1) by combining equal amounts of food waste and cow excavated manure. This substance is also known as treatment 2 or mixed garbage [29].

2.4 Preliminary Analysis of Organic Waste Materials

Before the anaerobic digestion process started, the volatile solid and C:N ratio of the physico-chemical parameters examined to assess moisture content [30]. The laboratory equipment's cleaned with 5% HCl, and the samples underwent pre-treatment by being dried in an oven for 24 hours at 105°C. A delicate balance was used to weigh the samples [31].

2.5 Determination of moisture

A pre-weighed, clean, and dry crucible added to 38 g of food waste, 38 g of cow dung, and 38g of mixed waste to assess the moisture content [32]. The crucible was then placed in a PC-controlled electronic hot plate oven at 105ºC for 24 hours. The samples taken out of the oven after 24 hours, and dry weight was measured [33]. Then, the moisture content of the samples expressed in percent weight by calculating the formulae mentioned below:

$$\%MC = \frac{Mw-MD}{Mw} * 100 \text{ ……………………………………. Equation (1)}$$

Where %MC is percentage of moisture content, M_w is the mass of the sample before drying and MD is the mass of the sample after drying.

2.6 Determination of volatile solid

The oven-dried samples were put in a muffle furnace at 550°C for around 5 hours to determine the volatile solids [34]. The weight of the crucible and the ash measured after 5 hours. Then the following formula was employed to calculate percentage of volatile solid [35].

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$$\%VS = \frac{DW-AD}{DW} * 100 \text{ ……………………………………. Equation (2)}$$

Where; VS (%) = percentage of volatile solid, DW = dry weight and AW = ash weight.

2.7 Estimation of Carbon to nitrogen ratio (C: N)

The samples from the oven drying process then examined using the ash technique to estimate the initial carbon concentration. After measuring the ash weight by burning the previously dried sample for five hours at 550°C in a muffle furnace [36], Where; DW = dry weight, AW= ash weight and 1.72 = conversion factor of organic matter content in food converted into total organic carbon. To measure the concentration of total nitrogen (here after called nitrogen) approximately a 20 g of pre-treated samples of Food-waste, Fruit-waste, Vegetable-waste, cow dung and Mixed-wastes were digested by concentrated sulfuric acid and concentration determined by Kjeldahl method [37]. Then, the amount of nitrogen present was calculated using the formula:

$$\text{N (\%)} = \frac{1401vs-vb\ Ntitrant}{Sample\ of\ wet*1000} = \text{x 100\% ……………………………Equation (3)}$$

Where; N (%) = Percentage of nitrogen, Vs = titrant volume of sample, Vb = titrant volume of blank, N= Normal concentration and 14.01 =Atomic mass of nitrogen. Since the amount of moisture content and nitrogen content in wet basis were known, the amount of nitrogen in dry basis calculated by using the formula:

$$\text{\%N (Dry)} = \frac{\%\ N\ wet}{100-\%\ MC} = \text{x 100 …………………………………Equation (4)}$$

Finally, the ratio of carbon to nitrogen was calculated as: C: N = $\frac{\%\ C}{\%\ N}$

2.8 Determination of water added to the digester

In order to produce biogas, the fermentation slurry's solid content should be adjusted to a total solid (TS) of 7–12%. In order to increase the digester's moisture content and digestion water was added [38]. Following the formulas shown below, 8% of TS solution (8% solids concentration) was used in the current study.

$$\frac{mTs}{A+B} = 8\% \text{ ………………………………………………………Equation (5)}$$

Where; mTS = mass of fixed total solid, A= mass of fresh or dried sample added, B= mass of water added to get 8% total solid in the digesters.

2.9 Experimental Design and Setup of Anaerobic Digester

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At the Borana Research Laboratory, the experimental analysis was completed (March up to April, 2022). Five 0.5 L anaerobic biogas digesters in conical shapes used for the studies [39]. In order to maintain a constant fermentation temperature, the experiment waste materials (three treatments) produced, transferred to a 0.5 L conical flask, mixed with inoculum, and placed in the water bath. The working volume of each conical flask digester was 0.4 L. Each gas-tight rubber was given one spherical orifice (1 cm in diameter), which acted as the biogas's outflow and connected to a gas bag and a Bunsen burner by a hose [40]. Five treatments with three replications of the anaerobic digestion process were used to produce biogas. Following were the three experimental protocols:

1. Treatment of mixed food wastes: 231 ml of water was added to 38 g of the pretreated mixed food waste, which was made up of an equal amount of bread, rice, pasta, meat, and shiro wot with injera.
2. Cow-dung treatment: 38 grams of prepared cow dung were combined with 70 milliliters of water.
3. Mixed wastes: 112 ml of water were added to 38 g of pretreatment mixed wastes, which contained an equal mixture of food waste and cow manure.

About 70% of the volume of the digester (a 0.5 L conical flask) filled with the substrate (pre-treated wastes), which is agitated to ensure homogenous mixing [41]. After that, 200cc of inoculum was introduced to each flask digester. The digester's mouse closed after the mixed waste fed into it. For the purpose of gathering samples of biogas, all flasks were closed with gas-tight rubber stoppers that had gas bag exits [42]. Each digester snugly fastened to the digester head and sealed with a 5 mm thick silicone seal. Conical flasks placed in a water bath (zhongjie, AC220V/110V50H, CN; JIA) with three different constant temperatures (20°C, 37°C, and 45°C) set and shaken for 30 seconds for each of the three treatments [43]. The digester shaken every five days to avoid feedstock settling and scam formation. Water displacement was used to measure the amount of biogas produced in the digester [44].

2.10 Sample treatment used for digester and gas production process

Known weight of mixed food wastes added to the digester.

Treatment1: Enjera 4g, Bread 4kg, Vegetables 4g, Fruits 4g, Macron 5g, Rice 4g, Pasta 4g

Treatment2: Enjera 5g, Bread 3g, Vegetables 3g, Fruits 4g, Macron 5g, Rice 4g, Pasta 3g

Treatment3: Enjera 3g, Bread 4g, Vegetables 4g, Fruits 3g, Macron 4g, Rice 5g, Pasta 4g

Final 1.5 liters water added to each treatment, digester then closed and checked for determination of the selected parameters at 10days interval for 30 days [45].

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2.11 Operation of digesters and receivers

The digester's cover had a hose attached to it that was fastened into the water container's cover, which was made of plastic and sealed tightly. To stop biogas from escaping, the gas valve on the opposite side of the cover closed. This gas valve was only unlocked when the biogas prepared to be tapped. The plastic container was likewise closed and the hose on the side of the plastic container fixed into the hole in the lid of the plastic containers for the displaced water [46]. Fruit waste, vegetable waste, and a blend of fruit and vegetable waste were among the different feedstock slurry types that added to the digester, each of which included 5M of NaOH. To keep air from getting inside the digester, the cover was tightly fastened to the digester [47]. The water in the plastic container compressed by the biogas as it was produced in the digester, and the water displaced into the second plastic container through the hoses.

2.12 Statistical Analysis

Utilizing the Statistical Analysis System (SAS) program SPSS, data collected is subjected to statistical analysis in order to ascertain the impact of the waste materials on biogas generation. The generation of biogas compared to alterations in pH, temperature, and ANOVA (one-way analysis of variance). LSD Tukey's-b tests used to determine which treatment was substantially different where significance is suggested [48].

3. Result and Discussion

3.1 Characterize the composition of the mixed food wastes with cow dung

The values for organic waste samples total solids, moisture content, volatile solids, and C:N ratio given in (Table.1). Cow dung waste has the highest percentage of total solid content (80%), and mixed food and cow dung waste has the lowest percentage of total solid content (77.9%). The two wastes with the highest moisture content (22.1%) mixed food waste and cow dung. Consequently, the digester only needed to have a modest amount of water added to it. Wastes from cow dung included the most volatile substances (8.5%). High volatile solid content is beneficial for digestion. The highest C:N ratio (25.88), which was optimal for methanogenic activity because the ideal C:N ratio spans from 20:1 to 30:1, was found in mixed food waste and cow dung waste [49]. Mixed Food Waste and Cow Dung Waste were combined in equal parts with low carbon waste ratios (Cow Dung Waste (20.75)), to reduce its C: N ratio to (25.88), which was necessary and ideal level, in order to provide stable pH for better methanogen activity which is displayed in Table.1.

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Table 1: Characteristics of organic waste samples used for experiment

S/N	Organic waste samples	Parameters						
		Wet Weight (g)	TS (%)	MC (%)	VS (%)	C (%)	N (%)	C: N (%)
1	Mixed Food waste	38	78.2	21.8	7.07	48.3	1.90	22.42
2	Cow Dung	38	80	20	8.5	52.5	2.53	20.75
3	Mixed Food waste + Cow Dung	76	77.9	22.1	3.4	53.9	2.10	25.88

3.2 Determinations of the optimum yield of biogas production

The values for organic waste samples total solids, moisture content, volatile solids, and C:N ratio given in (Table.2). At the end 10, 20 and 30 days the maximum yield of biogas was calculated. The wet weight of raw material was about 38g. The mixed food waste yield at 10th day was 23ml, 20th day is about 32ml and in 30th day it was 22ml. likewise for in 38g it was 28ml in 10th day, 42ml in 20th day and 24ml in 30th day [50]. For mixed food waste and Cow dung waste in 10th day the yield was 30ml, in 20th day it was 44ml and in 30th day it was 28ml. this table exhibits that the mixed food with cow dung at 20th day produce maximum yield in expressed in figure.2.

Table 2: Optimum yield of biogas production

S/N	Organic waste samples	Wet Weight (g)	Biogas yields(ml)		
			At the end of 10th days	At the end of 20th days	At the end of 30th days
1	Mixed Food waste	38	23	32	22
2	Cow Dung	38	28	42	24
3	Mixed Food waste + Cow Dung	38	30	44	28

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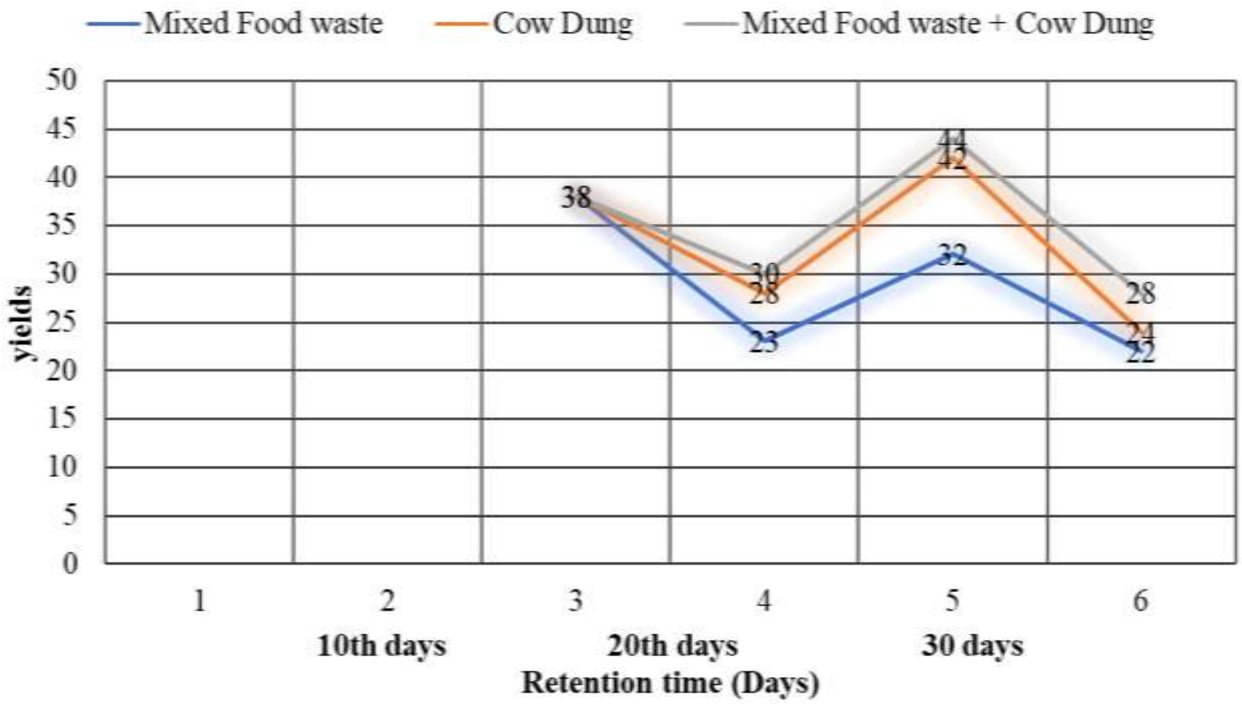

Figure 2: The optimum yield of biogas production for all treatment

3.3 Effect of pH on the optimum yield of biogas production

Mixed food waste produced the least amount of biogas compared to all other waste kinds. This could be because methanogenic activity was unstable, pH decreased, and more acids were produced during acidogenesis. This study also found that the production of biogas from cow dung waste was reduced, which suggests that the ammonia toxicity of the waste is high [50]. Because the C:N ratio might be altered by the presence of various sources of organic materials, this study demonstrated that Mixed Food Waste and Cow Dung Waste produce more biogas than other organic wastes. Due to the greater buffering impact of the digestion medium, adjusting the C:N ratio by co-digestion resulted in stable pH and better methanogenic activity is denoted in table.3. Because ruminants already have methane-generating bacteria in their stomachs, cow manure proved the best material for maintaining stability and producing biogas. The fact that it produced less gas than mixed and vegetable waste suggests that the organic materials in its stomach had already begun to ferment. The pH of mixed food waste was also the lowest (6.2), making it unsuitable for methanogenic bacteria since pH values below 6.5 resulted in higher levels of volatile fatty acids, which are poisonous to bacteria that produce methane in showed in figure.3.

Table.3 Effect of pH of Waste Material on Biogas Production

S/N	pH vs Biogas yields(ml)

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	Organic waste samples	Wet Weight (g)	At the end of 10th days		At the end of 20th days		At the end of 30th days	
			pH	yields	pH	yields	pH	yields
1	Mixed Food waste	38	6.55	23	3.89	32	6.44	32
2	Cow Dung	38	4.67	28	3.62	42	5.63	42
3	Mixed Food waste + Cow Dung	38	2.87	30	2.41	44	2.89	44

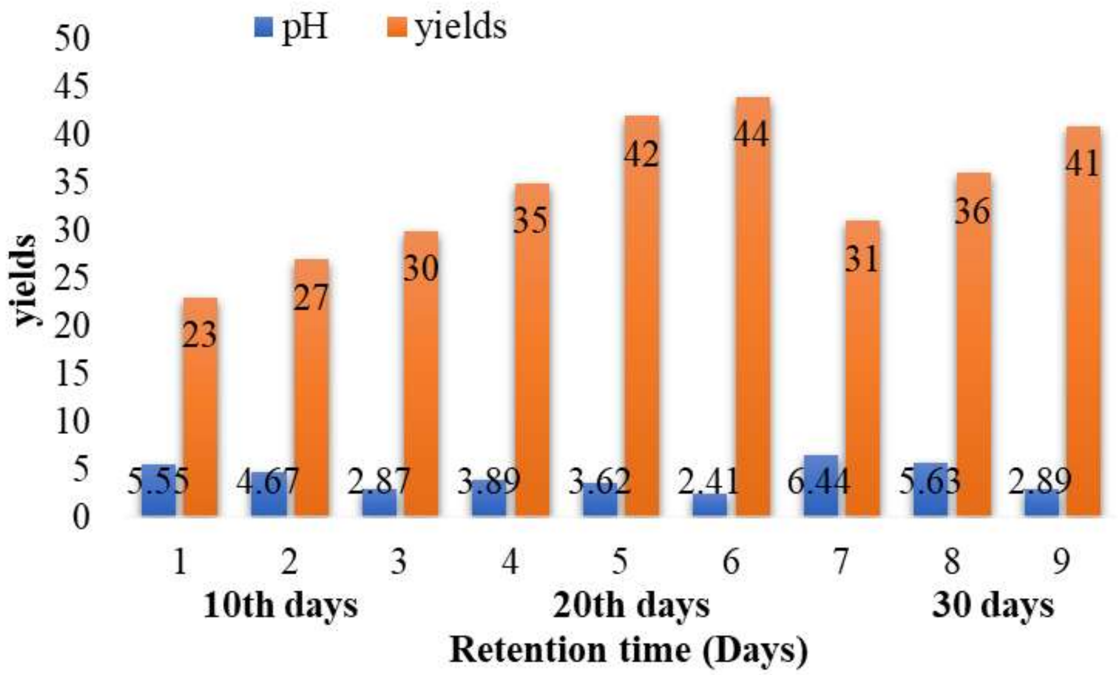

Figure 3. Effects of PH and Retention time on Biogas Production

3.4 Effects of Temperature on Biogas Production

Three temperature groups (20°C, 37°C, and 45°C) employed for anaerobic digestion in order to examine the impact of temperature on the production of biogas for all wastes. The operating temperature of the digester affected the biogas generation in several ways. The initial treatment groups were kept in a water bath at 20°C for incubation. In this treatment, biogas production began during the first ten days (1-10th day intervals), gradually climbed until the 11–20th day intervals, and subsequently decreased on the 21–30th day intervals (Figure.4). The generation of biogas generally increased gradually and linearly, peaking between days 11 and 20. At the conclusion of the 20th day of the retention period, 44ml of biogas from mixed food and cow dung waste had been created (Figure. 4). To shorten the time needed for anaerobic digestion, the second treatment groups were heated to a temperature of 37°C. The effectiveness and stability of the anaerobic digestion process were primarily influenced by temperature and substrate composition. When household organic wastes were utilized, there was a unique issue because not only the substrate composition but also operational temperature aspects must be taken into consideration [51]. Three replicated studies at 37°C operating temperature showed that the production of biogas and the decomposition of organic matter gradually increased and subsequently decreased during 11–20-day intervals (Figure.4). Biogas production increased continuously and reached its peak yield every 11 to 20 days. The digester may create more biogas at 37°C because the high temperature encourages the growth of methanogenic bacteria. Temperatures and anaerobic digestion biogas production connected which is proved in table.4. The impact of temperature was shown to account for approximately 44% of the variation in biogas output. Due to faster reaction times, the third experimental groups also heated to 45°C in a water bath, producing a significant amount of methane. In this treatment, biogas production began with the first ten days (1-10) and rose till the 10-day mark before declining after the 20-day mark (Figure .4). Therefore, measuring error or other parameters like pH, C:N ratios, etc. may account for around 56% of the variation in biogas production clearly mentioned in figure.4. In comparison to 20°C (23, 28, and 30 ml/g) and 37°C (22, 24, and 28 ml/g), biogas generation was significantly higher in 45°C (32, 42, and 44 ml/g), Mixed Food waste, and Cow Dung wastes.

Table. 4 Effect of Temperature on Biogas Production

S/N	**Organic waste samples**	**Temperature vs Biogas yields(ml)**		
		At 20°C	At 37°C	At 45°C
1	Mixed Food waste	23	22	32
2	Cow Dung	28	24	42
3	Mixed Food waste + Cow Dung	30	28	44

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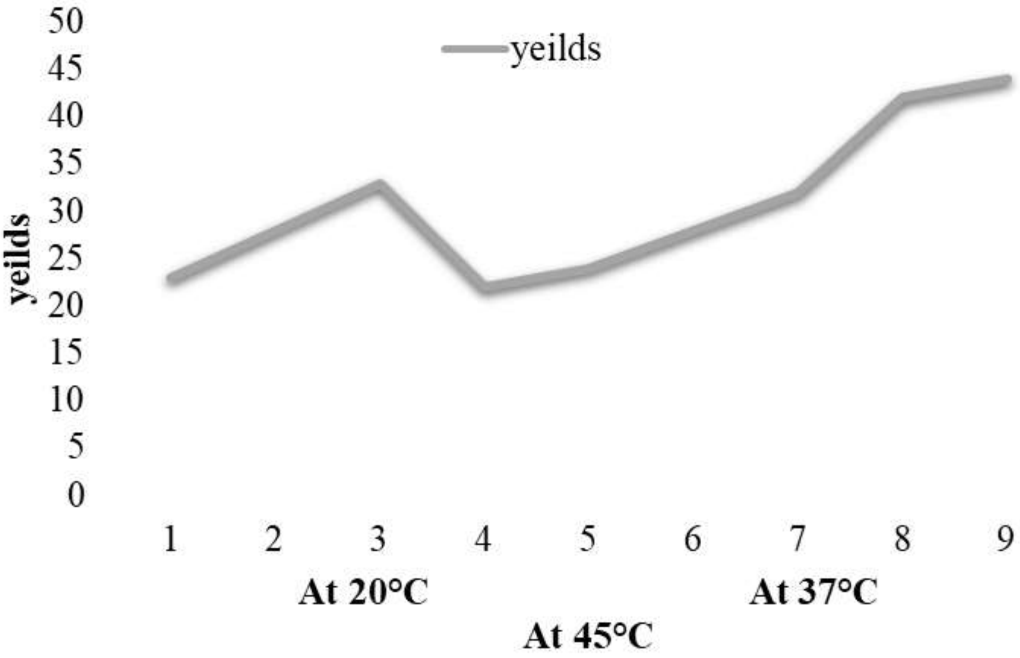

Figure 4. Temperature on biogas production

3.5 Effects of Retention time on Biogas Production

The yield from biogas reactor is depends upon the retention time. Table.5 showed the inter relationship between retention time (RT) and bio gas yield. In 1 to 10th day the biogas production was in average and start level which is based on retention time. The output of biogas peaked between the 11th and 20th days and again it comes down in 21 to 30th days. This result demonstrated that the retention time decreased as digestion incubation temperature increased because the activity of methanogenic bacteria reached the desired maximum level [52]. During the study, digestion at 45°C had a higher organic digestion rate than digestion at 37°C or 20°C when retention duration was shorter. In general, 45°C anaerobic digestion produced more biogas with a shorter retention time than digestion at 37°C and 20°C (Figure.5).

Table.5 Effects of Retention time on Biogas Production

S/N	**Organic waste samples**	**RT vs Biogas yields(ml)**		
		At the end of 10th days	**At the end of 20th days**	**At the end of 30th days**
1	Mixed Food waste	23	32	22
2	Cow Dung	28	42	24
3	Mixed Food waste + Cow Dung	30	44	28

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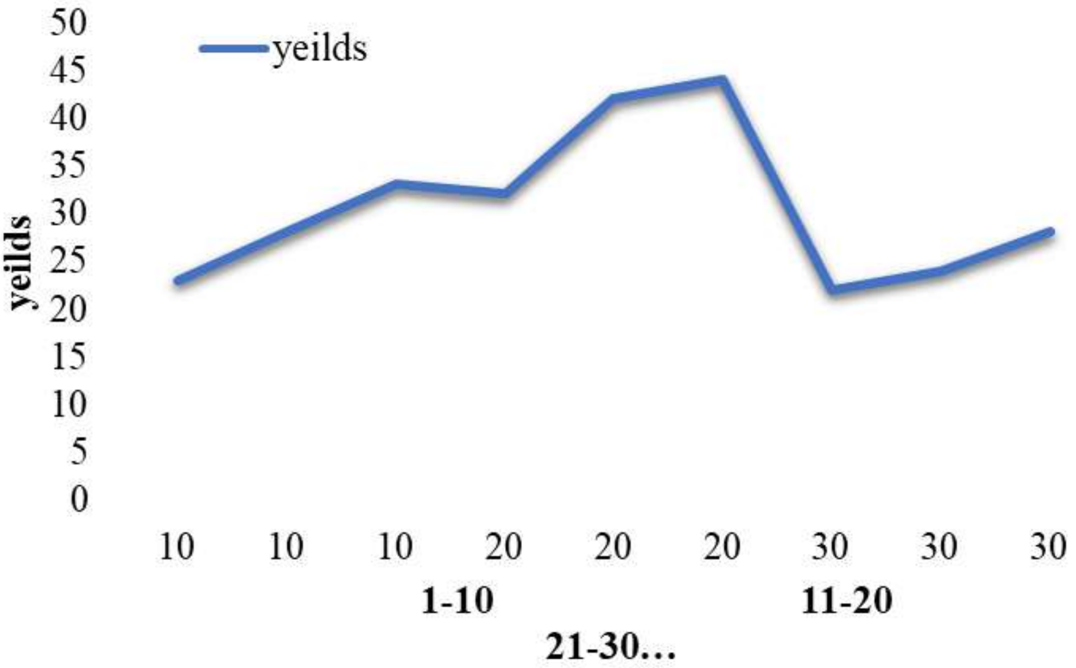

Figure 5: Biogas production VS retention time

3.6 Statistical Analysis

3.6.1. Temperature variation

The ANOVA's findings indicated that the temperature had a significant (P0.05) impact on the output of biogas. The temperature variation for mixed food waste, cow dung, and both mixed food and cow dung waste were different significantly (P>0.05) on biogas production, according to the LSD Tukeys b tests on the influence of temperature. According to Table.6, the generation of biogas significantly impacted by changes in digester temperature. The best biogas generation achieved at 37°C.

3.6.2. pH variation

The pH of mixed food waste, cow dung, and combined mixed food and cow excavated waste had a significant (P0.05) impact on biogas production, according to the ANOVA results (Table 6). It revealed that all the treatments had significantly (P0.05) differing mean pH values. The pH of the mixture of food and cow dung waste was significantly lower than the other waste types. It demonstrates the pH decreased during acidogenesis, when acetic, lactic, and propionic acids are produced is indicated in table.6. The pH of the therapy found to be between 2.87 to 6.55.

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3.6.3. Retention time

According to the ANOVA results of table.6 the retention period has a significant (P 0.05) impact on the production of biogas. Each type of trash produced the same amount (P0.05) of biogas, The LSD Tukeys b test on the impact of retention time on biogas generation. The mixed food and cow excrement produced the most biogas in the second ten days, followed by cow excrement and mixed food. It revealed that in all the treatments, the variation in biogas output peaked in the second ten days.

Table .6: ANOVA result for the effect of PH, Temperature and Retention time on Biogas yield

Parameters		Sum of Squares	df	Mean Square	F	Sig.
PH	Between Groups	14.389	5	2.878	1.603	.0370
	Within Groups	5.387	3	1.795		
	Total	19.775	8			
Temperature	Between Groups	882.000	5	176.400	5.513	.035
	Within Groups	96.000	3	32.000		
	Total	978.000	8			
Retention time	Between Groups	450.000	5	90.000	1.800	.0333
	Within Groups	150.000	3	50.000		
	Total	600.000	8			

4. Conclusion

According to the biogas production characterisation results, mixed food and cow dung waste had the lowest proportion of total solid content (77.9%) and cow dung waste had the greatest percentage (80%). The two wastes with the highest moisture content (22.1%) were mixed food waste and cow dung. Consequently, the digester only needed to have a modest amount of water added to it. Wastes made from cow dung contained the most volatile substances (8.5%). High volatile solids content is beneficial for digestion. Thus, without considering any other characteristics, cow dung waste proved advantageous for anaerobic digestion. The highest C:N ratio (25.88), which was optimal for methanogenic activity because the ideal C:N ratio spans from 20:1 to 30:1, was found in mixed food waste and cow dung waste. Mixed food waste and cow dung waste were combined in equal parts with low carbon waste ratios (Cow dung waste (20.75)), to reduce its C: N ratio to (25.88), which was the required optimal level, in order to make stable pH and higher methanogen activity. The optimum yield of biogas production for three sample obtained for the ten days gap of retention time. The greatest ideal biogas output received for mixed food waste and Cow dung at the end of 20th days which is 44ml. The lowest biogas production received for mixed Food waste at the end of 30th day of retention time which is 22ml, because high temperatures stimulated the growth of methanogenic bacteria in the digester, the study's findings indicated that Mixed Food Waste and Cow Dung Waste produced the most biogas (44ml) at 45^0C in a short retention period. The temperature, PH, and retention time all significantly (P0.05) affect the production of biogas, according to the ANOVA results. It is possible to combine organic materials with equal amounts of high and low C:N ratios to get the ideal C:N ratios for digester use. The pH stability and increased methanogenic activities achieved by changing the C:N ratio of organic waste to provide the greatest biogas generation in Mixed Food Waste and Cow Dung Waste.

Conflict of Interest

Authors declare no conflict of Interest.

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References

1. Hemant M. Jariwala, Yogesh C.Rotliwala, (2022), “Methane enrichment of bio-gas from carbohydrates using a single-stage process involving a bio-electrochemical system and anaerobic digester”, Materials today processing, Volume.57,pg.no. 1827-1832.
2. Ata Chitsaz, Shahram Khalilarya, Parisa Mojaver,(2022), “Supercritical CO_2 utilization in a CO_2 zero emission novel system for bio-synthetic natural gas, power and freshwater productions”, Journal of CO2 Utilization, Volume.59, 101947.

3. Ji-Luzheng, Ya-HingZhu, Guo-Taosun, Yan-Yan Dong, Ming-Qiang Zhu, (2022), “Bio-oil gasification for production of the raw gas as ammonia syngas”, Fuel, Volume.327, 125029.
4. Huei Yeong Lim, Shu Hui Tang, Yee Ho Chai, Suzana Yusup, Mook Tzenglim, (2022), “Co-pyrolysis of plastics and food waste mixture under flue gas condition for bio-oil production”, Sustainable Energy Technologies and Assessments, Volume.54, 102826.
5. Akash Kumar, Beibei Yan, Junyu Tao, Jian Li, Lata Kumari, Belay Tafa Oba, Moses Akintayo, Aborisade, Imtia Ali, Guanyi Chen, (2022), “Co-pyrolysis of de-oiled microalgal biomass residue and waste tires: Deeper insights from thermal kinetics, behaviors, drivers, bio-oils, bio-chars, and in-situ evolved gases analyses”, Chemical Engineering Journal, Volume.446, 137160.
6. Zhenshan Huang, Zaishan Wei, Huaiyong Jiao, Zhuoyao Chen, Zuotong Wu, Wenhao Huang, (2022), “Mechanistic insights into bio-stabilization of lead (II) in flue gas by a sulfate-reducing bioreactor”, Chemical Engineering Journal, Volume.450, 137564.
7. Andrea de Rezende Pinho, Marlon B.B.de Almeida, Pedro R R Rochedo, (2022), “Renewable-carbon recovery in the co-processing of vacuum gas oil and bio-oil in the FCC process – Where does the renewable carbon go?”, Fuel Processing Technology, Volume.229, 107176.
8. Haoxiang Wang, Jing Liu, (2023), “Emulsification and corrosivity study of bio-oil and vacuum gas oil mixtures with a novel surfactant system”, Fuel, Volume.333, 126460.
9. Changgwon Choe, Manhee Byun, Hyunhee Lee, Hankwon Lim, (2022), “Techno-economic and environmental assessments for sustainable bio-methanol production as landfill gas valorization”, Waste Management, Volume.150, pg.no.90 – 97.
10. Alessandr Singlitico, Jamie Goggins, Rory F.D.Monaghan, (2018). “Evaluation of the potential and geospatial distribution of waste and residues for bio-SNG production: A case study for the Republic of Ireland”, Renewable and Sustainable Energy Reviews, Volume.98, pg.no.288-301.
11. Junhao Lin, Shichang Sun, Chowgwei Cui, Rui Ma, Lin Fang, Peixin Zhang, Zonggang Quan, Xin Song, Ji Anglong Yan, Juan Luo, (2019), “Hydrogen-rich bio-gas generation and optimization in relation to heavy metals immobilization during Pd-catalyzed supercritical water gasification of sludge”, Energy, Volume.189, 116296.
12. Atichit Worasaen, Nattadon Pannucharoenwong, Chatchai Benjapiyaporn, Jarinee Jongpluempiti, Ponthep Vengsungnle, (2017) “Suitable Study of CBG Fuel by

ACCEPTED MANUSCRIPT

Considering in Wobbe Index From Compressed Bio-Methane Gas Plant, Khon Kaen University, Thailand", Energy Procedia, Volume.138, pg.no.278-281.

13. Rui Diao, Hao Lu, Yaojun Yang, Jin Bai, Xifeng Zhu, (2022), "Comparative insights into flue gas-to-ash characteristics on co-combustion of walnut shell and bio-oil distillation sludge under atmospheric and oxy-fuel condition", Combustion and flame, Volume.246, 112383.
14. Lixin Qian, Bojun Zhao, Haoyu Wang, Guangda Bao, Yulin Hu, Chunbao Charles Xu, Hongming Long, (2022), "Valorization of the spent catalyst from flue gas denitrogenation by improving bio-oil production from hydrothermal liquefaction of pinewood sawdust", Fuel, Volume.312, 122804.
15. Arkadiusz Piwowar, Maciej Dzikuc, Janusz Adamczyk, (2016), "Agricultural biogas plants in Poland – selected technological, market and environmental aspects", Renewable and Sustainable Energy Reviews, Volume.58, pg.no.69-74.
16. Song Cheng, Jianhua Shu Hongying, Xia Shixing, Wang Libo, Zhang Jinhui, Peng Chunyang, Li Xin Jiang, Qi Zhang, (2019), "Pyrolysis of Crofton weed for the production of aldehyde rich bio-oil and combustible matter rich bio-gas", Applied Thermal Engineering, Volume.148, pg.no.1164-1170.
17. Busra Gonca Kızılpelit, Filiz Karaosmanoglu, Seyma Ozkara – Aydinoglu, (2022), "A thermodynamic equilibrium analysis of hydrogen and synthesis gas production from steam reforming of acetic acid and acetone blends as bio-oil model compounds", International Journal of Hydrogen Energy, Volume.202, in press.
18. Malin Pettersson, Johanna Olofsson, Pal Borjeesson, Lovisa Bjornsson, (2022), "Reductions in greenhouse gas emissions through innovative co-production of bio-oil in combined heat and power plants", Applied Energy, Volume.324, 119637.
19. B.Debalina, Rajasekhar, B.Reddy, R.vinu, (2017), "Production of carbon nanostructures in biochar, bio-oil and gases from bagasse via microwave assisted pyrolysis using Fe and Co as susceptors", Journal of Analytical and Applied Pyrolysis, Volume.124, pg.no.310-318.
20. Yann Liang, Lianhong Zhang, Ming Yang, Yanhui Wang, Wendong Niu, Shaoqiong Yang, (2022), "Dynamic behavior analysis and bio-inspired improvement of underwater glider with passive buoyancy compensation gas", Ocean Engineering, Volume.257, 111644.
21. Sepehr Sanaye, Mohammed Hadi, Mohammadi, Mohsen Yazdani, Reze Barati, Rashvanlou, (2022), "Bio-gas augmentation and waste minimization by co-digestion

ACCEPTED MANUSCRIPT

process in anaerobic digestion system of a municipal waste water treatment plant", Energy Conversion and Management, Volume.268, 115989.

22. Dengyu Chen, Kehui Cen, Xiaozhung Zhuang, Ziyu Gan, Jianbin Zhou, Yimeng Zhang, Hong Zhang, (2022), "Insight into biomass pyrolysis mechanism based on cellulose, hemicellulose, and lignin: Evolution of volatiles and kinetics, elucidation of reaction pathways, and characterization of gas, biochar and bio-oil", Combustion and Flame, Volume.242, 112142.
23. Shuai Zhang, Qingyu Lei, Le Wu, Yugi Wang, Lan Zheng, Xi chen, (2022), "Supply chain design and integration for the Co-Processing of bio-oil and vacuum gas oil in a refinery", Energy, Volume.241, 122912.
24. Carmem T.Primaz, Tiago Schena, Eliane Lazzari, Elina B.Caramao, Rosangela A.Jacques, (2018), "Influence of the temperature in the yield and composition of the bio-oil from the pyrolysis of spent coffee grounds: Characterization by comprehensive two dimensional gas chromatography", Fuel, Volume.232, pg.no.572-580.
25. Paulina Parcheta, Lwona Koltsov, Janusz Datta, (2018), "Fully bio-based poly(propylene succinate) synthesis and investigation of thermal degradation kinetics with released gases analysis", Polymer Degradation and Stability, Volume.151, pg.no.90-99.
26. Marco Buffi, Alessandro Cappelletti, Andrea Maria Rizzo, Francesco Martelli, David Chiaramonti, (2018), "Combustion of fast pyrolysis bio-oil and blends in a micro gas turbine", Biomass and Bioenergy, Volume.115, pg.no.174-185.
27. M.U.Garba, Umaru Musa, A.G.Olugbenga, Yahaya S.Mohammad, Mohammed Yahaya, A.A.Ibrahim, (2018), "Catalytic upgrading of bio-oil from bagasse: Thermogravimetric analysis and fixed bed pyrolysis", Beni-Suef University Journal of Basic and Applied Sciences, Volume.07, pg.no.776-781.
28. Konstantin M.Zech, Sebastian Dietrich, Matthias Reichmuth, Werner Weindor, Franziska Muller-Langer, (2018), "Techno-economic assessment of a renewable bio-jet-fuel production using power-to-gas", Applied Energy, Volume.231, pg.no.997-1006.
29. Sara Gonzalez – Garcia Pablo, Comendador Morales, Beatriz Gullon, (2018), "Estimating the environmental impacts of a brewery waste–based biorefinery: Bio-ethanol and xylooligosaccharides joint production case study", Industrial Crops and Products, Volume.123, pg.no.331-340.

ACCEPTED MANUSCRIPT

30. Wasakorn Treedet, Ratchaphon, Suntivarakorn, (2018), “Design and operation of a low cost bio-oil fast pyrolysis from sugarcane bagasse on circulating fluidized bed reactor in a pilot plant”, Fuel Processing Technology, Volume.179, pg.no.17-31.
31. Konstantinos Atsonios, Kyriakos D., Panopoulos, Nikos Nikolopoulos, Angelos A.Lappas, Emmanuel Kakaras, (2018), “Integration of hydroprocessing modeling of bio-liquids into flowsheeting design tools for biofuels production”, Fuel Processing Technology, Volume.171, pg.no.148-161.
32. Wei Xie, Jianghui Liang, Hervan Mario Morgan Jr, Xiaodong Zhang, Kui Wang, Hanping Mao, Quan Bu, (2018), “Ex-situ catalytic microwave pyrolysis of lignin over Co/ZSM-5 to upgrade bio-oil”, Journal of Analytical and Applied Pyrolysis, Volume.132, pg.no.163-170.
33. Marija Saric, Jan Wolco Dijkstra, Wim G.Haije, (2017), “Economic perspectives of Power-to-Gas technologies in bio-methane production” Journal of CO2 Utilization, Volume.20, pg.no.81-90.
34. Zhong Ma, Rui Xiao, Huiyan Zhang, (2017), “Catalytic steam reforming of bio-oil model compounds for hydrogen-rich gas production using bio-char as catalyst”, International Journal of Hydrogen Energy, Volume.42, 3579-3585.
35. D.Goulding, D.Fitzpatrick, R.O.Connor, J.D.Browne, N.M.Power, (2017), “Supplying bio-compressed natural gas to the transport industry in Ireland: Is the current regulatory framework facilitating or hindering development?”, Energy, Volume.136, pg.no.80-89.
36. Hsiu-Po Kuo, Bi-Ren Hou, An-Ni Huang, (2017), “The influences of the gas fluidization velocity on the properties of bio-oils from fluidized bed pyrolyzer with in-line distillation”, Applied Energy, Volume.194, pg.no.279-286.
37. Nattadon Pannucharoenwong, Atichit Worasaen, Chatchai Benjapiyapom, Jarinee Jongpluempiti, Ponthep Vengsungnle, (2017), “Comparison of Bio-Methane Gas Wobbe Index In Different Animal Manure Substrate”, Energy Procedia, Volume.138, pg.no.273-277.
38. Yong S.Choi, Yaseen Elkasabi, Paul C.Tarves, Charles A.Mullen, Akwasi A.Boateng, (2017), “Catalytic cracking of fast and tail gas reactive pyrolysis bio-oils over HZSM-5”, Fuel Processing Technology, Volume.161, pg.no.132-138.
39. Vatsala Sugumara, Shanti Prakash, Emmandi Ramu, Ajay Kumar Arora, Veena Bansal, Vivekananda Kagdiya, Deepak Saxena, (2017), “Detailed characterization of bio-oil from pyrolysis of non-edible seed-cakes by Fourier Transform Infrared Spectroscopy

ACCEPTED MANUSCRIPT

(FTIR) and gas chromatography mass spectrometry (GC–MS) techniques", Journal of Chromatography B, Volume.1058, pg.no.47-56.

40. Le zhang, Renzhan Yin, Yuanfei Mei, Ronghou Liu, Wenjuan Yu, (2017), "Characterization of crude and ethanol-stabilized bio-oils before and after accelerated aging treatment by comprehensive two-dimensional gas-chromatography with time-of-flight mass spectrometry", Journal of the Energy Institute, Volume.90, pg.no.646-659.
41. Qiang Li, Yucong Geng, PanKe, Zheng Zhou, Dailirng, Xiaobo Yin, (2016), "The Exploration and Application of a New Dry Fermentation Biogas-pool", Procedia Environmental Sciences, Volume.31, pg.no.136-143.
42. S.Nilsson Paledal, K.Arrhenius, J.Moestedt, J.Engelbrektsson, K.Stensen, (2016), "Characterisation and treatment of VOCs in process water from upgrading facilities for compressed biogas (CBG)", Chemosphere, Volume.145, pg.no.424-430.
43. Fouad R.H.Abdeen, Maizirwan Mel, Mohammed Saedi Jami, Sany Izanihsan, Ahmad Faris Ismail, (2016), "A review of chemical absorption of carbon dioxide for biogas upgrading", Chinese Journal of Chemical Engineering, Volume.24, pg.no.693-702.
44. G.Zhang, Y.Li, Y.J.Dai, R.Z.Wang, (2016), "Design and analysis of a biogas production system utilizing residual energy for a hybrid CSP and biogas power plant", Applied Thermal Engineering, Volume.109, pg.no.423-431.
45. Michel Torrijos, (2016), "State of Development of Biogas Production in Europe", Procedia Environmental Sciences, Volume.35, pg.no.881-889.
46. Cheng Yan, Rau Munoz, Liandong Zhu, Yanxin Wang, (2015), "The effects of various LED (light emitting diode) lighting strategies on simultaneous biogas upgrading and biogas slurry nutrient reduction by using of microalgae Chlorella sp.", Energy, Volume.106, pg.no.554-561.
47. M. Lenin Sundar, A. Aravindan, S. Sujatha, S. Mahendran, G. Kalyani, D. Zunaithur Rahman, A. Vijayakumar, M. Senthil Kumar,(2020), "Biochar derived from Caulerpa scalpelliformis for the removal of Reactive Yellow 81 in batch and packed bed column", Biomass Conversion and Biorefinery, Volume.174, pg.no.203-211.
48. Kashif Mushtag, Asad A.Zaidi, Syed Jawid Askari, (2016), "Design and performance analysis of floating dome type portable biogas plant for domestic use in Pakistan", Sustainable Energy Technologies and Assessments, Volume.14, pg.no.21-25.
49. Senthil Kumar Muniasamy, Tariku Tadesse Gameda,Lenin Sundar Mallaian,Ilango Rengaraju,Jeyasudha Segaran,Yuvarani Periyasamy,Palpandian Murugesan,Suthagar Subramanian, (2022), "Investigation on Solar-Powered Electrocoagulation (SPEC) for

ACCEPTED MANUSCRIPT

the Treatment of Domestic Wastewater (DWW)", Advances in Materials Science and Engineering, Article ID 5389340.

50. Cheng Chen, Wenshan Guo, Huu Hao Ngo, Duu-Jong Lee, Kuo-Lin Tung, Pengkang Jin, Jie Wang, Yun Wu, (2016), "Challenges in biogas production from anaerobic membrane bioreactors", Renewable Energy, Volume.98, pg.no.120-134.
51. Franziska Appel, Arlette Ostermeyer-Wiethaup, Alfons Balmann, (2016), "Effects of the German Renewable Energy Act on structural change in agriculture – The case of biogas", Utilities Policy, Volume.41, pg.no.172-182.
52. Hynek Roubik, Jana Mazancova, Jan Banout, Vladimir Verner, (2016) "Addressing problems at small-scale biogas plants: a case study from central Vietnam", Journal of Cleaner Production, Volume.112, pg.no.2784-2792.

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