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Upgraded Method of Biogas Production from Waste in Anaerobic Co-Digestion Process

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Abstract. In this paper, experimental research was accompanied to examine the yield of biogas from kitchen waste (KW), cow dung (CD) and chicken manure (CM) through using anaerobic co-digestion process. The experimental protocol was defined to detect the consequence of organic loading rate (OLR), temperature, and pH on the effectiveness of the yield of biogas. A transportable biogas reactor was invented for effective biogas manufacture which comprises an agitator and a heating system. The CD, KW and CM co-digestion ratios are 1:2:0, 1:2:2, 1:2:4 and 1:2:6 separately at loading rates of 360, 367.5 338.25 and 427.5 g/l were studied. The result presented that the uppermost degradation amount of 3.98 ml/g obtained from the loading rate of 367.5 g/l. Further, KW was co-digested at different temperatures 25, 35, 40, 45, and 50 °C respectively in same loading rate of 367.5 gm/l. The result showed that the highest rate of degradation 7.00 g/l was investigated at temperature 37 °C. Then KW was co-digested at different pH. Mono-basic phosphate (NaH_2PO_4) and di-basic phosphates (Na_2HPO_4) were used to yield buffer result for maintaining diverse pH level. Five diverse pH levels are 6.8, 7.0, 7.2, 7.4, and 7.6. The result showed that the highest degradation rate of 8.6 ml/g obtained from pH 7.4. The result from this study proved that optimum loading rate 367.5 g/l, temperature 36–38 °C, and pH 7.40 is more effective for biogas production.

Keywords: anaerobic digestion, renewable energy, poultry waste, biogas.

1 Introduction

Bangladesh is an energy starved under developed country, with a densely population of about 150million living in an area of 147 570 km^2. It is one of the utmost densely peopled countries in the world. At present the major energy production in Bangladesh is based on natural gas. About 33 % of the entire population is covered through electricity network and 4% are covered in natural gas. Around 82 % of entire electricity originates from natural gas [1]. Later, in 2005, the augmented gas mandate outpaced gas supply resultant a gas shortage. As the mandate is growing and the stock of the natural gas is declining, it is anticipated that precise early the stock of the nature gas will start to deterioration [2].

Burning of fuel woods as a fuel over decades has reduced the forest areas in developing countries like Bangladesh caused deforestation. According to an estimate about 7 million tons of fuel woods are consumed annually in Bangladesh and the consumption is increasing each year [3]. As a result, the country has reduced the forest area to a low of 9 % of its total area. On the other hand, according to BCSIR 2001 report, the annual biomass consumption in Bangladesh is about 40 million tons which causes deforestation and pollutes environment. Animal waste, agriculture and fuel wood are burnt in-efficiently (efficiency less than 10 %) [4]. Use of fuel woods, garbage and agriculture residues as a fuel is injurious for both health and environment because of the smoke ascending from them reason for air pollution. The incessant reduction of fossil fuel is stabbing the anxiety into the exploration for innovative energy sources to be used. Therefore, they are non-renewable in nature & the reserve will be depleted one day. So we ought to attention our interpretation on the alternative renewable sources of energy such as biogas, solar energy, biodiesel, tidal energy and wind power etc [5].

As an agriculture base country, Bangladesh has surrounded with amply of biomass that has been used for recovering energy making biogas or burning directly. Almost 80 % people of our country directly or indirectly depend on agriculture. For the period of winter seasons, vast quantities of vegetables are cultured in our country that will be a possible source of kitchen waste (KW). Because of deficiency of effective preservation and transportation, vast quantities of vegetables are misused that may be a great source of biogas [6].

Conventional chicken manure (CM) management has been primarily disposal by land filling. Chicken manure (CM) is characterized by a high content of organic compounds and this is the cause of its put risibility. Therefore, sludge before landfill disposal or agricultural application should undergo chemical and hygienic stabilization. One possible method of stabilization and hygienization involves methane fermentation [7].

Cow Dung (CD) is the undigested residue of plant matter which has passed through the animal's gut. CM is used to yield biogas to generate electricity and heat. The gas is rich in methane and is used in rural areas of India, Pakistan, Bangladesh and elsewhere to provide a renewable and stable source of electricity.

In comparison with the rural area there is a huge amount of sludge produced in urban area of Bangladesh. Therefore, CD has limited availability in many areas particularly in urban area. Preparation of biogas from CM have been using mainly in rural areas but there is also plenty amount of biomass (kitchen waste, sewage sludge etc.) in urban area that will be a possible source of biogas [8].

Due to high calorific value, biodegradability and nutritious value to microbes, these huge quantities of chicken manure, cow dung & kitchen waste can be employed to yield biogas which will generate a high quality renewable fuel product and which will be more price effective. Furthermore, manufacture of biogas will decrease the usage of fossil fuels, thus decreasing poisonous gas and CO_2 emission. This is consensus with Kyoto Summit Agreement [9].

This present research work was directed to utilize CD, KW, and CM. This paper defines momentarily the viewpoint of these wastes for biogas creation in Bangladesh. The major thing of this research was to compare the biogas manufacture rate by anaerobic co-digestion of KW (kitchen waste) with chicken manure and cow dung.

2 Research Methodology

2.1 Anaerobic digestion

2.1.1 Definition

Anaerobic Digestion (AD) is a multifarious biological procedure in which microorganisms break down into biodegradable organic compound i.e. kitchen waste, cattle manure, poultry dropping, water hyacinth, agriculture residues and another organic garbage in the lack of oxygen and thus formed biogas [10]. The popularity of AD is increasing day by day due to its high degree of waste stabilization, less energy requirement, fewer nutrients required and methane production.

2.1.2 Hydrolysis

In the first phase of hydrolysis primary fermentative bacteria change the un solvable composite organic matter for example cellulose into soluble molecules for instance amino acids, sugars and fatty acids. The enzymes convoluted in this procedure are celluloses, hemicelluloses, proteases, amylases; lipases [11]. The rate of hydrolysis is a function of factor such as pH, temperature, composition and particle size of substrate, and high concentration of intermediate products [12]. The solicitation of some chemical substances to improve the hydrolysis has been originate to result in a littler digestion time and delivers a higher CH_4 yield [13].

An example of a hydrolysis reaction wherever organic waste material is broken down into a simple sugar, in this situation, glucose is given below [14]:

$$C_6H_{10}O_4 + 2H_2O \rightarrow C_6H_{12}O_6 + 2H_2. \qquad (1)$$

2.1.3 Acidogenesis

Soluble organic components including the products of hydrolysis are converted into organic acids, alcohol, hydrogen, and carbon dioxide by the action of acid forming bacteria known as acidogens as illustrate in Figure 1.

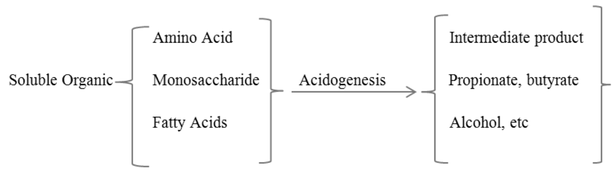

Figure 1 – Illustration of acidogenesis reaction

2.1.4 Acetogenesis

Acetogenesisis carried out by secondary fermenting bacteria also known as acid formers, change the product of the first phase to a simple organic acids, CO_2, H_2 as illustrate in Figure 2.

When digestion becomes so much acidic, acid forming bacteria is producing faster than the methane formers; this sours the digester and prevents the formation of CH_4 gas. So addition of alkali such as NaOH, $NaHCO_3$ is required [15].

The principle acids produced are: acetic acid (CH_3COOH), propionic acid (CH_3CH_2COOH), butyric acid ($CH_3CH_2CH_2COOH$), and ethanol (C_2H_5OH) [13].

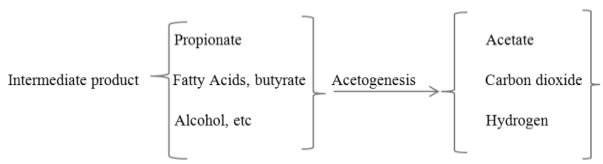

Figure 2 – Illustration of acetogenesis reaction

2.1.5 Methanogenesis

Lastly, in the 3rd phase, methane is created by bacteria known as methane formers (also known as methanogens) in 2 ways: whichever by means of cleavage of acetic acid molecules to produce CO_2 and methane (CH_4) or by reduction ofCO_2 with Hydrogen. Methanogenic bacteria are highly sensitive to oxygen concentration in the system, resulting in an inactive phase in the system as well as a high concentration of fatty acids in the environment [16]. Consequently, the pH value will be lower.

Aceticlastic microorganisms and hydrogenotrophic microorganisms are use acetate and hydrogen as substrate, correspondingly. Nearly 70 % of the carbon movement is via aceticlastic microorganisms, if this pathway deliver sample minor energy for microbial growth associated to the hydrogenotrophic one [17]. Near physical interaction between these 2 types of microorganisms confirms that the incomplete pressure of H_2 is within the optimum range that permits both reactions of hydrogen creation and ingesting to be exergonic. The methanogenesis responses can be conveyed as follows:

$$\begin{aligned} &CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O; \\ &2C_2H_5OH + CO_2 \rightarrow CH_4 + 2CH_3COOH; \\ &CH_3COOH \rightarrow CH_4 + CO_2. \end{aligned} \quad (2)$$

Around two thirds of methane is resulting from acetate alteration by methanogens. The other is the consequence of carbon dioxide reduction by Hydrogen [18].

2.2 Waste sources and processing

There are following sources of Kitchen Waste (KW), Cow Dung (CD) and Chicken Manure (CM). The present research work was directed to examine the creation ability of biogas as an alternative energy source from Chicken Manure, Cow Dung and kitchen waste by anaerobic digestion (AD). It was conducted in water analysis laboratory of Chemical Engineering and Polymer Science (CEP) department, Shahjalal University of Science and Technology (SUST), Sylhet-3114, Bangladesh from June, 2015 to March, 2016 (approximate 1 year).

Kitchen waste: KW was collected from different student halls of SUST, Sylhet.

Cow manure: CM (cow manure) was collected from the nearby village of the university.

Chicken manure: CM (chicken manure) was collected from nearby poultry farms of the university.

Afterward eliminating the plastic bags, bones, inorganic residues wastes and metals were cut into minor size in order to decrease size to get effective biogas manufacture[19]. Then these wastes were pounded into pest by exhausting hopper.

2.3 Experimental setup

The experimental setup of the lab scale described following below.

2.4.1 Lab-scale experiment

A simple lab-scale experiment was invented using ten digesters for kitchen waste through co-digestion of cowdung and chicken manure respectively. Five digesters were castoff for co-digestion of KW with cow manure (CM) and chicken manure (CM) at room temperature and another five digesters were used for co-digestion of kitchen waste with cow manure and chicken manure at 37 °C. Every digester was made of glass. The volume of digester was 1.0 l each and occupied volume was 0.8 l. In this present study the capacity of formed gas was stately by water movement technique as the capacity of the produced gas equivalent to that of barred water in the water accumulator. Each digester was linked to water compartment (plastic bottles) through a plastic pipe (gas pipe) that was used to permit the formed gas into water chamber. Additional water pipe was used to take the expatriate water from the water compartment to the water accumulator that was fixed air closed by M-seal together the conclusions of the gas pipe were introduced unbiased at the highest of the digester and the water compartment. The water pipe was introduced just bottommost of the water compartment and top of water accumulator. The biogas lab-scale experimental set up schematic diagram are shown in Figures 3, 4.

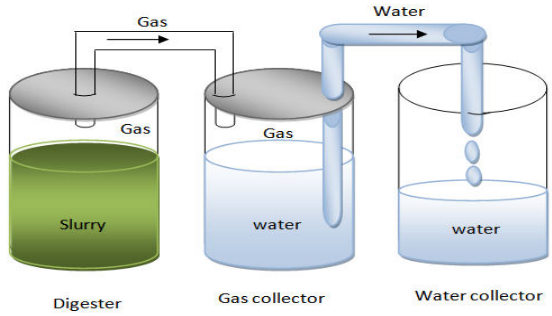

Figure 3 – Schematic diagram of the lab-scale experimental set-up

Figure 4 – The lab-scale experimental set-up [6]

2.4.2 Pilot-scale experiment

A simple pilot-scale experiment was fabricated a digester which was made of plastic and volume was about 60 liters. The digester was connected to water chamber (plastic bottles) by a plastic pipe (gas pipe) which was used to pass the produced gas into water chamber. Another plastic pipe (water pipe) was used to take the displaced water from the water chamber to the water collector which was fitted air sealed by M-seal. Both the ends of the gas pipe were inserted just at the top of the digester and the water chamber. The water pipe was inserted just bottom of the water chamber and top of water collector. Figure 5 illustrates the schematic diagram of the portable biogas digester.

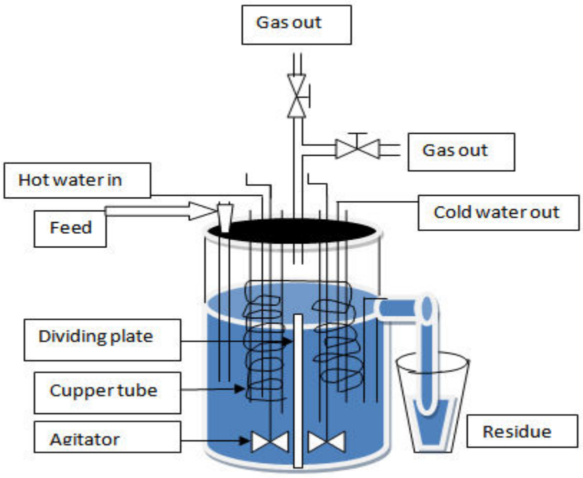

Figure 5 – A portable biogas digester with stirrer and heating system.

3 Results and Discussion

3.1 Change of pH with degradation

Lab-scale experiments were operated in batch mode. The values of pH changes with time from the day of charging the feed. Five samples were charged with feed ratio CM:CD:KW= 1:2:4 (loading rate 367.5 g/l). The change of pH observed in every 24 hours. The changes are given below in Figure 6.

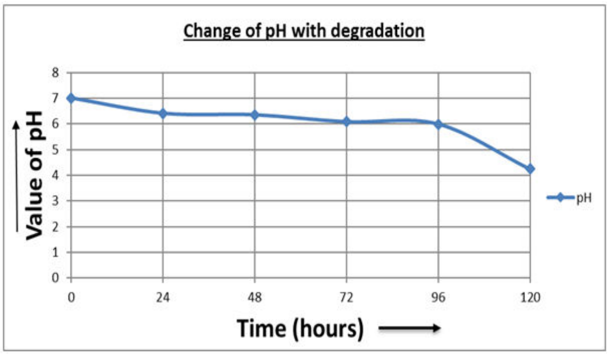

Figure 6 – Change of pH with degradation

Effect of different organic loading rate on biogas production in the co-digestion of CM, CD and KW: used CM, CD and KW as feed. The feeds are charged in various ratios like CM, CD and KW are in the ratios of 1:2:0, 1:2:2, 1:2:4 and 1:2:6. The loading rates are 427.5, 338.25, 367.5 and 360 g/l respectively. For these loading rates the gas productions are shown in Figure 7.

Comparison of degradation rate in different organic loading rate (OLR) for the co-digestion of chicken manure (CM), cow dung (CD) & kitchen waste (KW) is presented in Figure 8

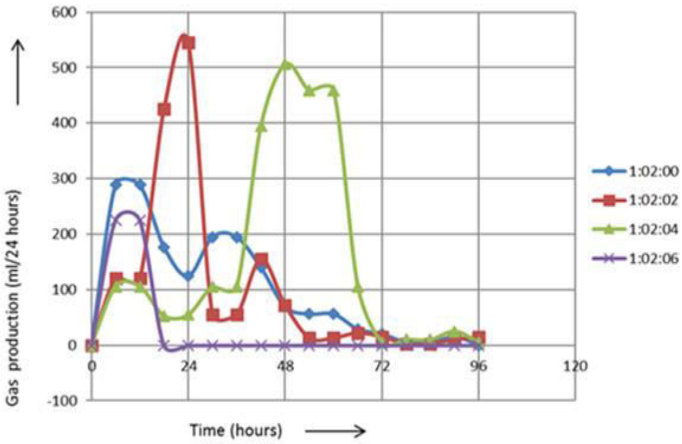

Figure 7 – Rate of biogas production in different organic loading rate

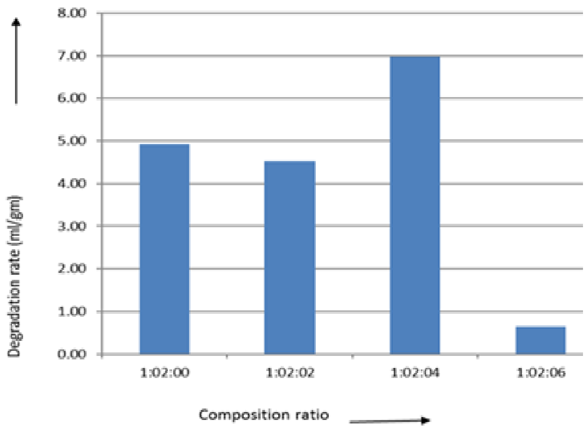

Figure 8 – Comparison among the rate of degradation in different organic loading rate

Effect of pH on gas production rate with same organic loading rate at room temperature (around 20 °C) : Chicken manure (CM), cow dung (CD) and kitchen waste (KW) ware co-digested in five different digesters with pH 6.8, 7.0, 7.2, 7.4 and 7.6 at room temperature (around 20 °C). Due to low temperature the gas production rate was very low. The comparison of the gas production rate is shown in Figure 9.

Comparison of degradation rate in different organic loading rate (OLR) for the co-digestion of chicken manure (CM), cow dung (CD) and kitchen waste (KW) at room temperature (around 20 °C) is given Figure 10.

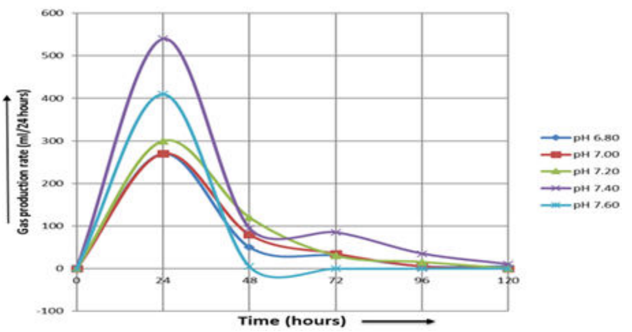

Figure 9 – Comparison of gas production rate among the digester with different pH and same organic loading rate at room temperature (around 20 °C)

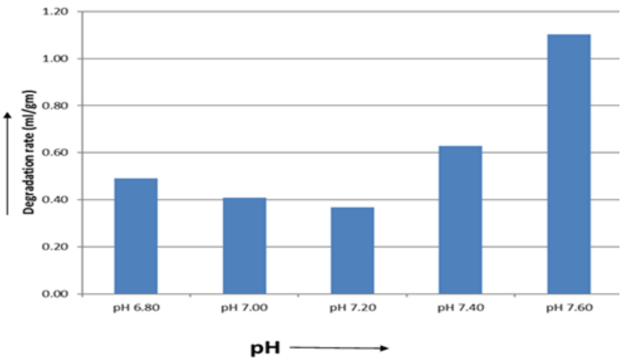

Figure 10 – Comparison of the rate of degradation among the digester with different pH, in the same organic loading rate at room temperature (around 20 °C)

3.2 Effect of pH on gas production rate with same organic loading rate at 37 °C temperature

Chicken manure (CM), cow dung (CD) and kitchen waste (KW) ware co-digested in five different digesters with pH 6.8, 7.0, 7.2, 7.4 and 7.6 at 37 °C temperature. In this optimum temperature the gas production rate was much better. The comparison of the gas production rate is shown in Figure 11.

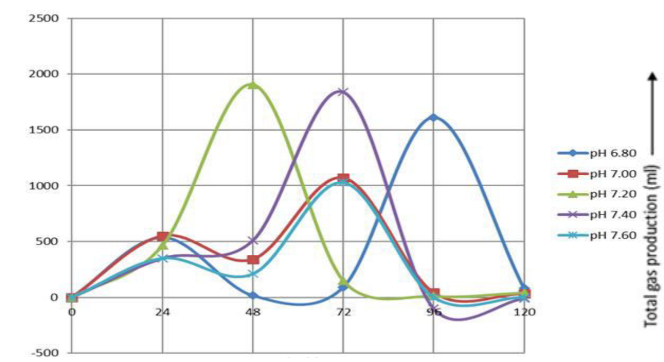

Figure 11 – Comparison of gas production rate among the digester with different pH in the same organic loading rate at 37 °C temperature

Comparison of degradation rate in different organic loading rate (OLR) for the co-digestion of chicken manure (CM), cow dung (CD) and kitchen waste (KW) at 37 °C temperature is given Figure 12.

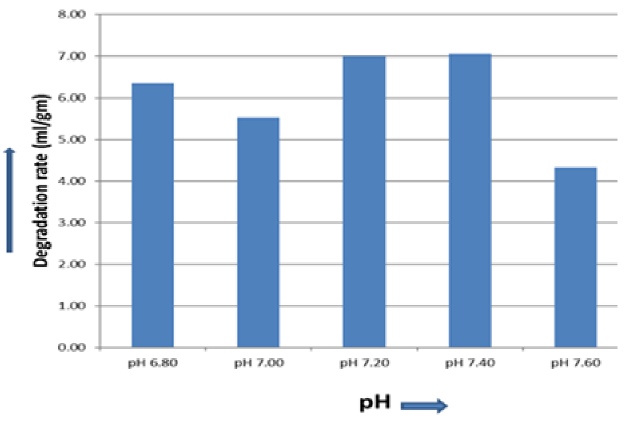

Figure 12 – Comparison of the rate of degradation among the digester with different pH, in the same organic loading rate at 37 °C temperature

3.3 Comparison of total gas production between room temperature (around 20 °C) and 37 °C temperature

Chicken manure (CM), cow dung (CD) and kitchen waste (KW) ware co-digested in the ratio of CM:CD:KW = = 1:2:4 in five different digesters with pH 6.8, 7.0, 7.2, 7.40 and 7.60 at room temperature (around 20 °C) and 37 °C temperature. In room temperature the gas production was very low, since the temperature was very low and it was very hard for the microorganism to survive and propagate. But at 37 °C temperature the gas production rate was much better. Comparison of total gas production between room temperature (around 20 °C) and 37 °C temperature in different pH and same organic loading rate 367.5 g/l is given in Figure 13.

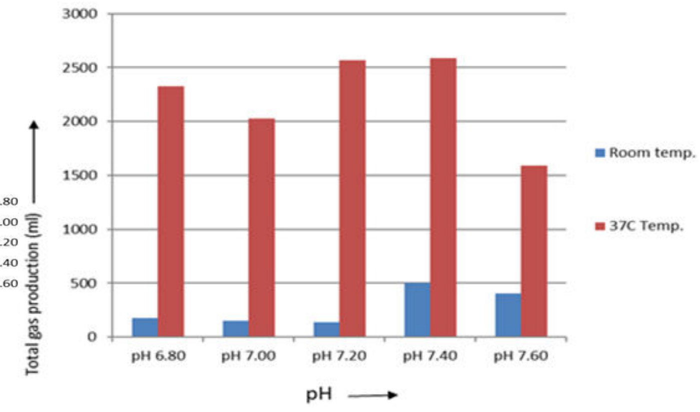

Figure 13 – Comparison of total gas production between room temperature and 37 °C temperatures

3.4 Pilot plant gas production

In pilot plant all the parameters are optimized, now the organic loading rate (OLR) was 367.50 g/l, Temperature 37 °C, stirring in every 12 hours (2 times in a day), and pH is around 7.40. For this condition the rate of gas production increased very rapidly. The gas production rate in that condition is shown in below Figure 14.

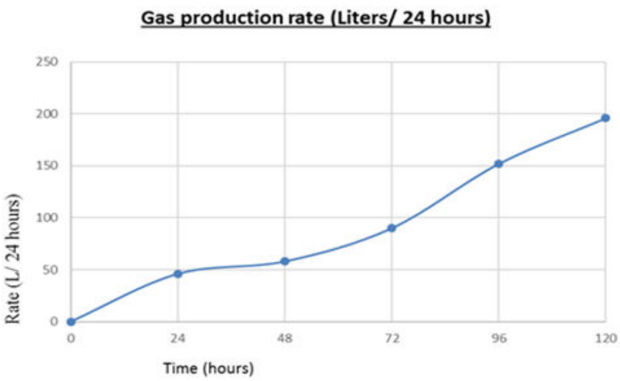

Figure 14 – Rate of gas production in optimized parameters

4 Conclusions

In a world where we feel the need of energy security more acutely with every moment, there is little space for ignoring the essence of development of the renewable energy sector. The search for alternative source of energy such as biogas should be intensified so that ecological disasters like deforestation, desertification, and erosion can be arrested. Analyzing the experimental dataset, it was found that, anaerobic co-digestion of KW (kitchen waste) with (CM) cow manure made more biogas compared toco-digestion of KW with sewage sludge and the manufacture of gas was not uniform. The digester showed that the biogas production was upper at 37 °C (mesophilic) than room temperature. At this temperature, the digester (co-digested SS/CM with KW) showed higher degradation rate than another two digesters at loading degree of 200 g/l. According to above temperature and loading rate, treatment of KW by the NaOH was also gave more biogas production than other untreated KW. The production of biogas is influenced by various factors such as temperature, pH condition of the input charges, nutrient concentration, loading rate, toxic compound etc. By generating biomass fuel from the abundance sources, Bangladesh can solve a big portion of energy deficiency. Research and dissemination of biomass fuel throughout the country should be given priority in solving our energy crisis. We are able to measure the gas production rate but we cannot still apply it in our real life. The anaerobic co-digestion of kitchen waste with cow manure and sewage sludge are established to be an impressive technique for energy savings and environmental protection, nonetheless it is vibrant that with spread on adjustment and better equipment of conditions we are able to give additional realistic results.

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Модернізований спосіб виготовлення біогазу з відходів в анаеробному процесі спільного травлення

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Анотація. Експериментальні дослідження супроводжувались вивченням прибутковості біогазу від відходів із застосуванням анаеробного процесу спільного травлення. Визначено протокол еекспериментальних досліджень для виявлення впливу норми органічної навантаження, температури та pH на ефективність виходу біогазу. Створений біогазовий реактор для ефективного виробництва біогазу, який містить мішалку і систему опалення. Вміст CD, KW і CM співвідносяться як 1: 2:0, 1:2:2, 1:2:4 і 1:2:6 при навантаженнях 360, 367.5, 338.25 та 427.5 г/лвідповідно. Результати показали, що найвища ступінь деградації становить 3.98 мл/г, отриманої для швидкості завантаження 367.5 г/л. Крім того, було отримано показник KW для різних температур (25, 35, 40, 45 і 500 °C) для однакової швидкості завантаження 367.5 г/л. Отримані результати свідчать, що найбільша деградацію 7 г/л відповідає температурі 370 °C. Також параметр KW змінювався для різних pH. Для одержання результату при підтриманні різного рівня pH використовувався моно- (NaH_2PO_4) і ди-основний (Na_2HPO_4) фосфати для 5 різних рівнів pH (6.8, 7.0, 7.2, 7.4 і 7.6). У результаті найвища швидкість деградації 8.60 мл/г була отримана для pH 7.4. Результати дослідження доводять, що оптимальна швидкість завантаження 367.5 г/л, температура 36–38 °C, pH 7.4 є найбільш ефективною для виробництва біогазу з відходів в анаеробному процесі спільного травлення.

Ключові слова: анаеробне травлення, відновлювальна енергія, відходи, біогаз.