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Biogas Production from the Paddy Straw Pretreated with Sodium Hydroxide and Co-Digestion with Cow Manure

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ABSTRACT

Paddy straw waste (PS) is an organic waste that is disposed in open land after preparation of rice harvest that is generated in equal or greater quantities than the rice itself. Generally, it is disposed in open land, which increases anthropogenic gases. Converting it into useful energy or value-added products may reduce disposal problems and anthropogenic activity. In this study, PS with different treatments of sodium hydroxide (NaOH) at 2, 4, 6 , 8 and 10% was co-digested with cow dung (CD) for obtaining biogas by anaerobic digestion. For this purpose, PS was mixed with CD at different proportions, namely 50:50, 40:60, 30:70, 20:80, and 0:100 percentages on a mass basis, the samples were used in five different anaerobic digesters. The samples were kept in different anaerobic digesters for the study. The effect of important input parameters like pH and Carbon to Nitrogen (C/N) ratio on the biogas production was studied. Maximum biogas production was obtained from the co-digestion of the substrate containing 30% ps and 70% Cd for a digestion time of 20 days, and d3 shows a max pH value of 7.16. Further, the biogas collected from the digesters was characterized to ensure suitability for use as a renewable fuel. Furthermore, the digested slurry was also analyzed for its use in agriculture. The results are presented in this paper.

Keywords: Biogas, Paddy straw, Cow dung, Anaerobic digestion.

1. INTRODUCTION

The increasing concentrations of greenhouse emissions are due to global warming and ozone depletion in the world. The pollutants from fossil fuel combustion released from dumping grounds or open land are one reason for global warming. Burning of fossil fuels is a global environmental problem. Biogas is used as an alternative due to the more friendly environmental energy sources. The waste that can produce biogas, such as animal manure, agriculture waste, faecal matter, and other agriculture residues, through anaerobic digestion [1]. Biogas would decrease the pollution of the environment by diminishing the use of fossil fuels and the production of greenhouse gasses [2]. Biogas has been looked upon as a totally controlled and promising source that can be produced from agricultural and animal wastes.

Consortia of micro-organisms in a group of hydrolytic, acidogenic, and methanogenic bacteria involved in biogas generation. Hydrolytic bacteria degrade the complex organic matter (carbohydrates, proteins, and fats) to simpler forms such as sugars, amino acids, fatty acids, and glycerol. Acidogenic and acetogenic bacteria break down these simpler forms of sugars, amino acids, fatty acids, and glycerol into CH_3COOH, H_2, and CO_2, which are further utilized by methanogenic bacteria to produce biogas.

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Paddy straw is the preferred substrate for bioenergy production. Recently, the demands for reducing and utilizing paddy waste has rapidly increased in Malaysia. Annually, about 3.66 million tonnes of paddy residue is left in the fields. Towards the year 2020, this value is forecasted to increase to 7 million tonnes per year due to emerging technology development in agriculture industries. The increasing paddy residue production in Malaysia will cause the abundance of availability of these resources and create the problem of waste management if this residue cannot be managed properly [3]. Burning paddy residue in the field will cause pollution [4]. Using the paddy residue in electricity generation can be one solution for waste management and also the pollution problem. Paddy straw is biodegradable in nature and effective for biomethane or biogas production through the AD process in action of microbial consortium activity [5]. AD process produces biomethane from biomass, a clean, renewable energy source currently representing approximately 15% of global energy consumption [6]. Fewer air pollutants and less CO_2 per unit of energy are released compared to non-renewable fossil fuels [7].

A number of research studies have suggested that paddy straw is one of the most suitable feedstocks for AD process owing to several advantages, such as their renewable nature, huge availability, low- cost, and high bio-degradability [8, 9, 10]. Further, the co-digestion of paddy straw feedstock with the combination of other wastes may increase the biogas production yield due to improved nutrient balance (e.g., C/N ratio), adjustment of additional buffering capacity, and dilution of toxic chemicals [11]. Paddy straw (PS) is considered one of the most prominent feedstocks for the AD process, and the paddy crop secures its position as the third-largest crop in the global market.The main aim of this study was to make an attempt to use the paddy straw (PS) as a co-substrate in combination with cow dung for the production of biogas. For this purpose, PS was mixed with CD at different proportions in five different anaerobic digesters like AD1, AD2, AD3, AD4, and AD5. Further, the study aimed to evaluate the various affecting parameters on biogas production. Finally, the samples of biogas obtained from the digesters were characterized to ensure the quality of using it as an alternative gaseous fuel. Further, the digested slurry was also analyzed to utilize as a fertilizer for the growth of crops.

2. MATERIAL AND METHODS

2.1 Feed stock

The fresh cow dung (Cd) was collected from a local farmhouse at Perlis. The visible straws present in the CM were removed manually. The collected CM was mixed with water in a ratio of 1:1 and stirred for 10 min at 2000 rpm. On the other hand, PS was collected from paddy fields around Perlis. The collected PS was dried for 48 h at 80 OC and stored at room temperature in a dry place for further experiments.

2.2 Sodium Hydroxide (NaOH) soaking pre-treatment of paddy straw

30 g of chopped, washed, and dried paddy straw were soaked in 200 mL of NaOH solution with various concentrations at 2, 4, 6, 8, and 10% for 24 Hours at room temperature. After that, the NaOH solution was drained off, and the soaked paddy straws were rinsed with tap water until they were clean and the color of the rinsed water became colorless. The rinsed paddy straw was then dried in the oven at 100 °C. The oven-dried pretreated paddy straw was then grounded using a grinding machine. The grounded and pretreated paddy straws were stored in polythene bags and have been used for proximate analysis.

2.3 Experimental setup

In this research work, experiments were conducted in laboratory-scale anaerobic digesters D1, D2, D3, D4, and D5 containing 50:50, 60:40, 70:30, 80:20, and 100:0 on a mass basis of CM: PS, respectively. The prepared samples of CM:PS mixture were diluted with water at a ratio of 1:1 and 1:3, respectively. The characteristics of the feedstocks at different proportions of CM and PS are given in Table 1. The prepared samples were kept in a 150 mL serum bottle with 100 mL working volume. The bottles were tightly capped with rubber septa and aluminum caps. The anaerobic digesters used in this study are shown in Fig. 1. The experiments were conducted at a mesophilic temperature 35 °C. All the reactors were flushed with nitrogen for 5 min before sealing the digesters. Since, there is no mechanical stirrer available in the laboratory for stirring the mixture. Therefore, to obtain a better reaction mixture, manual shaking was done. Each digester was shaken manually for 1 min twice a day prior to the measurement of biogas volume [12].

Figure 1: Anaerobic digester used in this study.

2.4 Biogas measurement and its composition analysis

To measure the composition of gas produced, a sample of gas was collected daily from the headspace of each digester using a gas-tight syringe (25 mL Perkin Elmer). Biogas composition was measured daily in terms of percentage volume.

2.5 Analytical methods and calculations

Firstly, feedstock characterization was carried out to ensure the suitability of the feedstock for anaerobic digestion, which included the proximate and ultimate analyses. The proximate analysis of all the samples was calculated, as recommended by APHA, and are given in Table 1. The ultimate analysis of the samples was done by a C-H-N-S elemental analyzer, shown in Table 2. The C/N ratio was determined by dividing the total carbon content to the total nitrogen content. The pH value of the feedstock was measured with a pH meter.

Table 1: Proximate analysis of CM and PS.

Substrate	**Weight % dry basis**			
	Moisture content	**Volatile matter**	**Ash**	**Fixed carbon**
Cow dung	73.4	14.3	4.1	8.2
Paddy straw	8.4	39.3	9.2	43.1

Table 2: Ultimate analysis of CM and PS.

Substrate	Weight % dry basis						
	C	**H**	**N**	**S**	**O**	**P**	**K**
Cow dung	38.24	4.63	1.64	0.05	51.34	0.06	0.05
Paddy straw	65.3	7.45	0.81	0.43	16.81	0.7	1.50

3. RESULTS AND DISCUSSION

3.1 Effect of pH

pH value is most of the parameter effect on biogas production of the slurry. pH value changes depending on the different stages of the anaerobic digestion process. The report of Mahanta et al. (2005) [13] that most methanogenic bacteria operate perfectly at a pH from 6.3 to 7.5. On the other hand, temperature greatly affects the growth and performance of methanogenic bacteria. At the initial stages of anaerobic digestion, the pH value of the substrate rapidly drops because it is digestible in hydrolyzed mode and converted into fatty acids. Due to the formation of higher amounts of fatty acids, the pH value may sometimes fall below 5 in the digester. Figure 2 portrays the pH variation with the digestion time by considering the average pH value every five consecutive days.

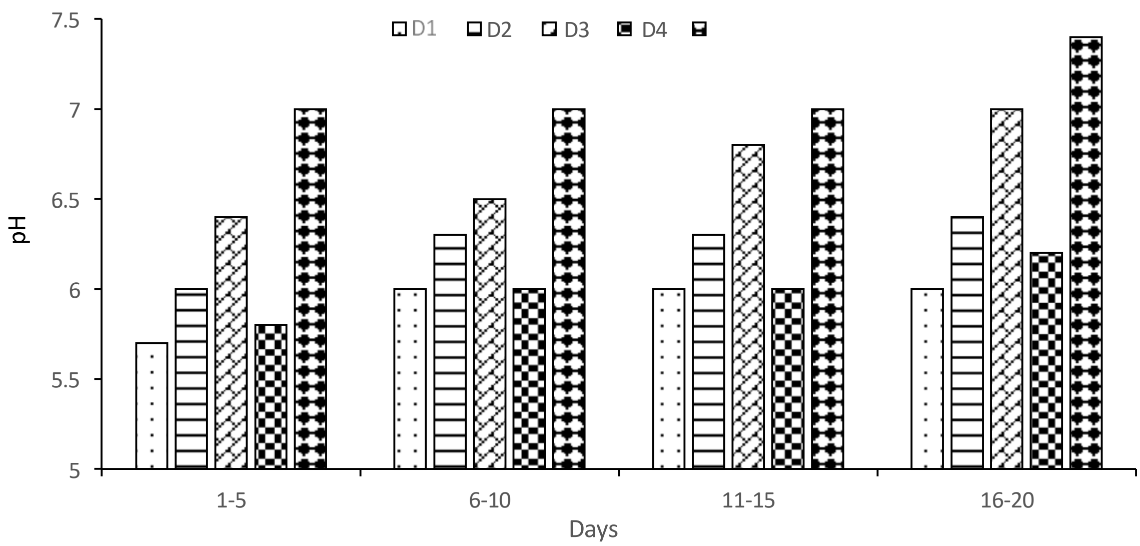

Figure 2: Variation of pH value at different times.

Based on Figure 2, among five anaerobic digesters, D5 has the highest pH. During 1-15 days of digestion, a maximum pH value of 7, 6, and 6.5 are obtained for the D2 and D3, respectively, which is about 7.19% and 14.97% less than the digester containing cow manure alone (D5), respectively. Because of hydrolytic and acetogenic bacteria are observed to be more frequent during those days. During the anaerobic digestion process, the digesters D1, D2, D3, D4, and D5 show their peak value on the 16th day, 17th day, 18th day, 19th day, and 20th day, respectively.

3.2 Biogas production

The fluctuation trend of daily biogas production can be seen for the samples set to the difference in concentration of Sodium Hydroxide (NaOH) solution, which is 2%, 4%, 6%, 8%, and 10% in Table 3 and Figure 3. This trend may be influenced by several factors that have affected the digestion of the co-digested paddy straw and cow manure by bacterial activity, such as the pH of the co-digestion mixture.

Table 3: Biogas production at different treatments of NaOH.

Biogas Production (mL)					
Days	**D1 (2% NaOH)**	**D2 (4% NaOH)**	**D3 (6% NaOH)**	**D4 (8% NaOH)**	**D5 (10% NaOH)**
1	27	24	27	27	19
2	20	8	14	12	17
3	70	20	78	42	107
4	31	7	27	31	51
5	44	5	46	38	56
6	72	17	56	32	78
7	56	15	23	33	65
8	65	21	7	51	107
9	30	5	7	6	93
10	0	0	10	0	18
11	49	0	10	0	7
12	97	6	22	10	82
13	67	7	9	0	0
14	25	0	0	0	62

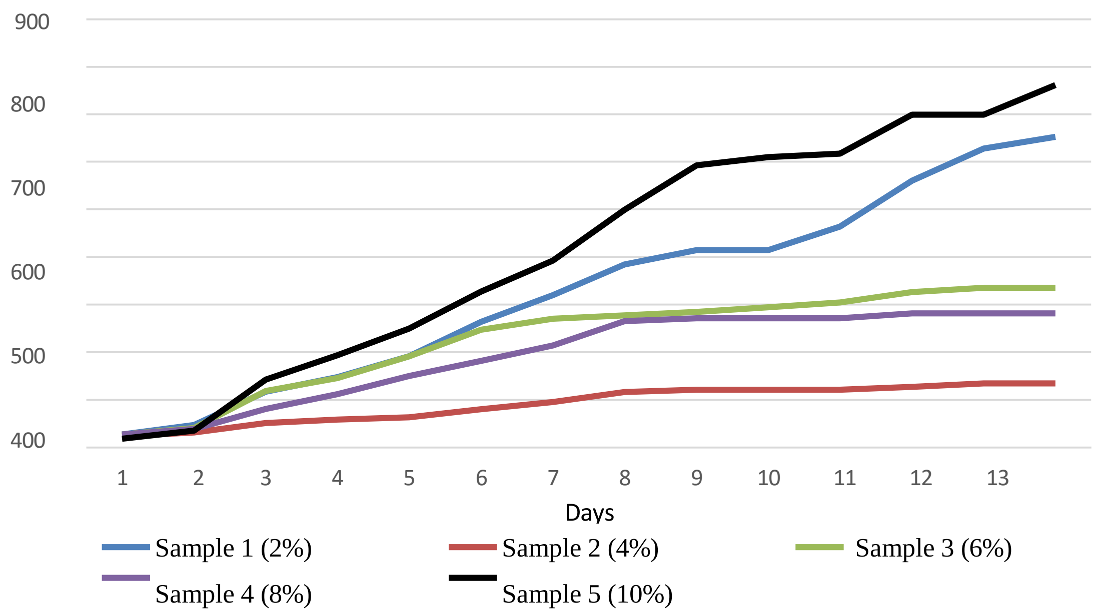

Figure 3: Biogas production of five samples.

It is very important always to ensure that the pH in the biogas digester is at a level capable of enhancing the growth of methanogens that will carry out the main process of biogas production, namely methanogenesis, because an inappropriate pH will begin to inhibit the growth of these bacteria as well as the production of biogas [14].

The accumulated biogas production reading may be influenced by the more efficient decomposition of paddy straw occurring in the digester pretreated by NaOH with a concentration of 10%. The decomposition of lignocellulosic materials such as paddy straw contributes to the production of volatile fatty acid, which is a food source for the culture of microbes in the digester. Therefore, the production of VFA in the digester should be nurtured, and some method to make this successful is by doing a pre-treatment process on the materials used, such as chemical pre-treatment. The NaOH solution mixed with pretreating the paddy straw will change the lignin structure and promote the solubility of the material [15], which will facilitate the digestion process by the culture of microbes.

4. CONCLUSION

To excess the possibility of using paddy straw for energy use and biogas production, PS is treated with 10% NaOH co-digested with CD, and the performance is assessed by considering the input parameters like pH and C/N ratio. Maximum biogas production can be obtained from the co-digestion of substrate containing 30% ps and 70% Cd for a digestion time of 20 days, and d5 shows a max pH value of 7.16, which indicates good for anaerobic digestion in biogas production.

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