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Biogas Potential from the Investigation of Paddy Straw Co-digestion with Cow Dung

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ABSTRACT

Paddy straw waste (PS) is an organic waste that is disposed of in open land after the preparation of rice harvest, which is generated in equal or greater quantities than the rice itself. Generally, it is disposed of in open land, which increases the amount of anthropogenic gases. Converting it into useful energy or a value-added product may reduce the disposal problem and anthropogenic activity. In this study, PS was co-digested with cow dung (CD) to produce biogas via anaerobic digestion. For this purpose, PS was mixed with CD at different proportions, 50:50, 40:60, 30:70, 20:80, and 0:100 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 effects of important input parameters, such as pH and the Carbon-to-Nitrogen (C/N) ratio, on biogas production were studied. A maximum biogas production was obtained from the co-digestion of a substrate containing 30% ps and 70% Cd, with a digestion time of 20 days, and d3 showed a maximum pH value of 7.16. Further, the collected biogas from the digesters was characterized to ensure its suitability for use as a renewable fuel.

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

1. INTRODUCTION

The increasing concentrations of greenhouse gases from global warming and ozone depletion. Global warming is affected by the continuously increasing energy crisis, depletion of fossil fuel resources, and severe environmental pollution [1]. Biogas is used as an alternative due to its lower ecological impact, clean energy production, and its role in addressing environmental pollution. The waste that can produce biogas, such as animal manure, agricultural waste, and other agricultural residues, through anaerobic digestion [2]. Biogas has been viewed as a highly controlled and promising source that can be produced from farming and animal wastes.

Paddy straw is the preferred substrate for bioenergy production. Recently, the demand for reducing and utilizing paddy waste has rapidly increased in Malaysia. Annually, about 3.66 million tonnes of paddy residue are left in the fields. By 2020, this value is forecast to grow to 7 million tonnes per year due to emerging technologies in the agricultural industry. The increase in paddy residue production in Malaysia will lead to abundant availability of these resources.

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However, it may create problems with waste management if this residue is not appropriately managed [3]. The burning of paddy residue in the field will cause pollution [4]. Using paddy residue for electricity generation can be one solution for waste management and pollution. Paddy straw is biodegradable and effective for biomethane or biogas production through the AD process driven by microbial consortium activity [5]. AD process produces biomethane from biomass, a clean, renewable energy source that currently represents approximately 15% of global energy consumption [6]. Fewer air pollutants and less CO2 per unit of energy are released when compared with non-renewable fossil fuels [7].

A number of research studies have suggested that paddy straw is one of the most suitable feedstocks for the AD process owing to several advantages, such as its renewable nature, wide availability, low cost, and high biodegradability [8, 9, 10]. Further, co-digestion of paddy straw with other wastes may increase biogas production yield by improving nutrient balance (e.g., C/N ratio), increasing buffering capacity, and diluting toxic chemicals [11]. Paddy straw (PS) is considered one of the most prominent feedstocks for the AD process, and the paddy crop ranks as the third-largest crop in the global market. The main aim of this study was to use 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 anaerobic digesters: AD1, AD2, AD3, AD4, and AD5. Further, the study aimed to evaluate the various parameters affecting the biogas production. Finally, the biogas samples obtained from the digesters were characterized to ensure their quality for use as an alternative gaseous fuel. Further, the digested slurry was analyzed and used as a fertilizer for crop growth.

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2. MATERIAL AND METHODS

2.1 Feedstock

The fresh cow dung (Cd) was collected from a local farmhouse in Perlis. The visible straws present in the CM were removed manually. The collected CM was mixed with water at a 1:1 ratio and stirred for 10 min at 2000 rpm. On the other hand, PS was collected from the paddy field 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 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, respectively, on a mass basis of CM: PS. The prepared CM:PS mixture was diluted with water at ratios of 1:1 and 1:3, respectively. The characteristics of the feedstocks at different CM/PS ratios are given in Table 1. The prepared samples were kept in 150 mL serum bottles with a working volume of 100 mL. The bottle was tightly capped with a rubber septa and an aluminum cap. The anaerobic digesters used in this study are shown in Fig. 1. The experiments were conducted at a mesophilic temperature of 35 ^{o}C. All the reactors were flushed with nitrogen for 5 min before the digesters were sealed. Since there is no mechanical stirrer available in the laboratory for stirring the mixture. Therefore, to obtain a better reaction mixture, manual shaking was performed. Each digester was shaken manually for 1 min twice a day prior to biogas volume measurement [12].

Figure 1: Anaerobic digester used in this study.

2.3 Biogas measurement and its composition analysis

To measure the composition of the 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 as a percentage volume.

2.4. Analytical methods and calculations

Firstly, feedstock characterization was carried out to assess its suitability for anaerobic digestion, including proximate and ultimate analyses. The proximate analyses of all the samples were calculated, as recommended by APHA, and are given in Table 1. The ultimate analysis of the samples was performed using a C-H-N-S elemental analyzer, as shown in Table 2. The C/N ratio was determined by dividing the total carbon content by 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 one of the most important parameters affecting biogas production in the slurry. pH values change during the different stages of the anaerobic digestion process. Pradeshwaran et al. [13] reported that the pH value of the digester should be kept at 6.8-7.2, which is suitable for anaerobic bacteria to perform well and yield good results. At the initial stages of anaerobic digestion, the pH of the substrate rapidly drops as it is digested in a hydrolytic mode, producing fatty acids. Due to the formation of a higher amount of fatty acids, the pH value in the digester may sometimes fall below 5. Figure 2 shows the variation in pH with digestion time, using the average pH for each of the five consecutive days.

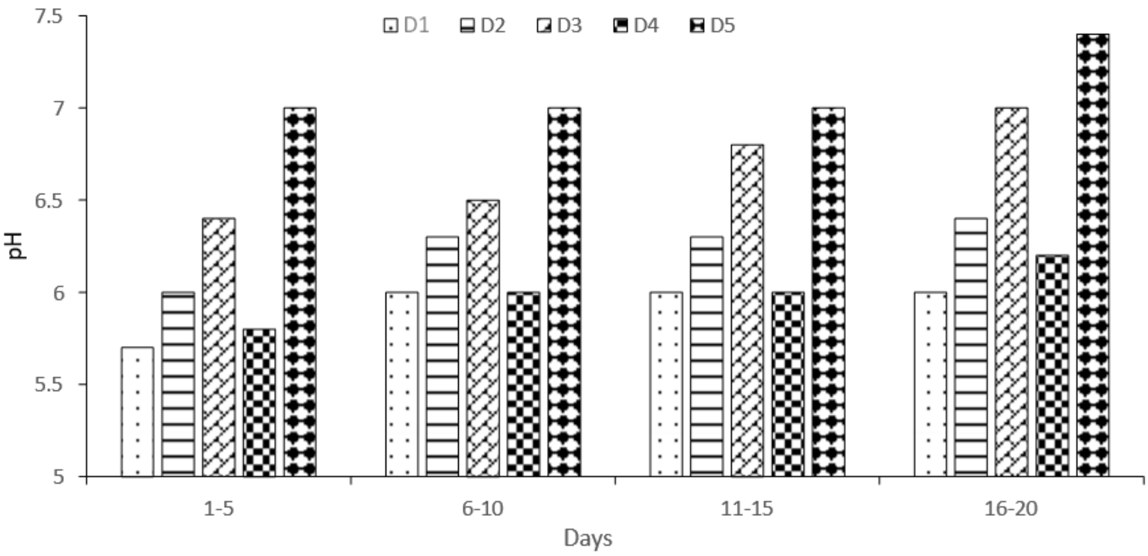

Figure 2: Variation of pH value at different times.

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

3.2 Effect of C/N

The carbon-to-nitrogen (C/N) ratio is the most influential parameter for biogas production. It was reported that the C/N ratio should lie in the range of 20-20:1 [14] for the optimum biogas production. If the C/N ratio is much higher than the range, then the biogas production will drop. This is because methanogenic bacteria will rapidly consume nitrogen to meet their protein requirements and will no longer react with the remaining carbon in the sample. If the C/N ratio is very low, it can accumulate as ammonia (NH3). In fact, NH3 will increase the pH of the slurry. A significant release of NH3 may be toxic to methanogenic bacteria in the slurry, thus decreasing biogas production [15]. Figure 3 depicts cumulative biogas production at different C/N ratios over 20 days of digestion.

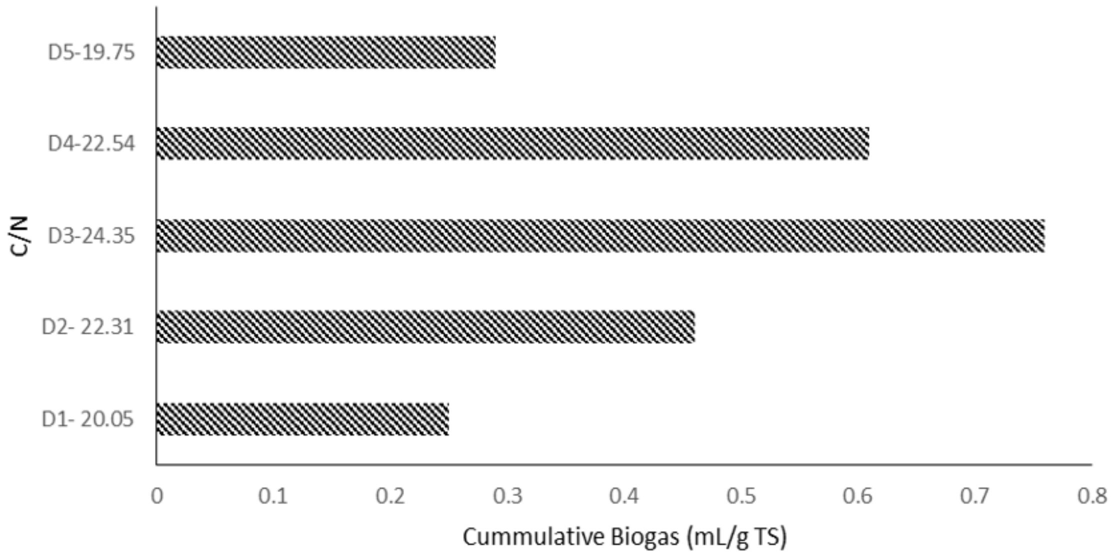

Figure 3: Cumulative biogas production at different C/N ratios.

It can be observed from Figure 3 that the anaerobic digester D3 gives a maximum biogas production of 0.76 ml/g TS, D4 gives 0.61 ml/g TS, D2 gives 0.46 ml/g TS, and D5 gives 0.29 ml/g TS. It can also be observed that the lowest yield for digester D1 is 0.25 ml/g TS. The C/N ratio is an important parameter, as feedstock with a higher value makes more carbon available for biogas production. However, if the nitrogen level is too low, it can affect microbial activity because microorganisms need nitrogen to maintain growth and metabolic activity. On the other hand, low C/N ratios can lead to high nitrogen levels, which can result in ammonia inhibition.

The co-digestion of PS content and CD can help balance and maintain optimal C/N levels and, consequently, adequate nitrogen and alkalinity levels [16]. The lowest biogas production for D1 might be due to the formation of NH3, which may be toxic to bacteria. It was also reported by Khalid et al. (2011) that a C/N ratio of 22-25 is the best condition for anaerobic digestion. The digester D3 has a C/N ratio of 24.35, which is well under the optimum range. However, with PS above 30%, the C/N ratio slightly shifts out of the optimal range and tends to decrease. As a result, excessive nitrogen will be liberated, which could inhibit methanogenic bacteria, thus reducing biogas production [17].

4. CONCLUSION

To explore the potential of paddy straw for energy use and biogas production, PS was co-digested with CD, and performance was assessed based on input parameters such as pH and C/N ratio. A 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 d3 shows a max pH value of 7.16, which indicates good conditions for anaerobic digestion in biogas production.

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