

Increasing biogas production of rumen fluid using cattle manure collected at different time as a substrate

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Abstract: The effect of cattle manure collected at different time inoculated with rumen fluid of cattle on biogas production at mesophilic condition was evaluated. A laboratory experiment was carried out using 1000 ml biodigester and performed in batch operation mode. Approximately 100 grams of fresh cattle manure (M) was assigned to each biodigester and mixed with rumen fluid (R) and distilled water (W) into three different M:W:R ratio; 1:1:0; 1:0.5:0.5; and 1:0:1 respectively. All the treatments were prepared in triplicates. The pH of the slurry was recorded before and after the biogas production was determined. The biogas production was recorded at every three days interval for 24 days. The results obtained shows that the pH of the mixture before and after the biogas production provided a reading of 7.34 and 7.15. Significant different ($P < 0.05$) was observed in the cattle manure collected at 0 h and 24 h between the treatment group and control. The best performance biogas production was observed if the rumen fluid used between the ranges of 25–50% of rumen fluid. Cattle manure collected after 12 h of defecation recorded with the highest biogas production compared to 0 h and 24 h of cattle post-defecation. The highest biogas produced was recorded in T3 throughout the experimental periods.

Keywords: rumen fluid, inoculums, biogas, mesophilic condition

I. Introduction

Livestock waste is an important source of greenhouse gas emissions, particularly in developed countries where large numbers of animals are intensively kept in housed. Biogas is a term used to represent a mixture of different gases produced as a result of the conversion of volatile solids by the action of anaerobic micro-organisms on domestic and agricultural waste [1]. The biogas production is limited by the amount of volatile solids added to the digester. It usually contains 50% and above methane (CH₄) and other gases in relatively low proportions namely, CO₂, H₂, N₂ and O₂ [2]. Most of the organic acids and all of the H₂ are metabolized by methanogens, with the end result being production of a mixture of approximately 55% to 70% CH₄ and 30% to 45% CO₂, called biogas. The mixture of the gases is combustible if the methane content is more than 50 % [3]. The methanogens are slower growing and more environmentally sensitive to pH, air, and temperatures than the acidogenic bacteria. Usually, the methanogens require a narrow pH range (above 6), temperatures at or above 21°C, and adequate time (usually more than 15 days), to most effectively convert organic acids into biogas [4]. Anaerobic digestion may be seen as a technology that are widely used in the treatment of organic waste for biogas production. It is a natural process in which bacteria convert organic materials into biogas. This technology utilizes manure for biogas production and it is one of the most promising uses of biomass wastes as it provides a source of energy and at the same time resolving ecological and agrochemical issues [5]. The process occurs in an anaerobic (oxygen-free) environment through the activities of acid- and methane-forming bacteria that break down the organic material and produce CH₄ and CO₂ in a gaseous form. A number of studies has been conducted to increase biogas yield in the anaerobic digestion. An attempt to improve the biomass conversion efficiency and biogas yield are abundant which include; pretreatment of manure by separating solids from digested materials [6]; improving substrate composition by co-digesting with other substrate [7]; improving contact between bacteria and substrate using stirring [8]; and improving nutritional requirements of the bacterial population in the biodigester [9]. To our best knowledge, the information of biogas production of different levels of rumen fluid using cattle manure collected at different time as a substrate is rather limited. Therefore the aim of the current work was to determine the effective time of using the cattle manure as substrate for biogas production.

II. Materials and Methods

2.1 Sample preparation

Both cattle manure and the rumen fluids used in this research were taken from a teaching abattoir located at Department of Animal Science, Faculty of Agriculture, Universiti Putra Malaysia. The animals were fed with basal diet containing of 60% roughages and 40% of concentrates based on daily intake of 3% DM per bodyweight. Approximately, 2 kg of rumen content was homogenized mixed with 15 liters of distilled water. The solid content is then separated from the slurry by a filter sieve before adding the cattle manure. The manure was collected at three different time; 0 h, 12 h and 24 h respectively. The manure and rumen fluids sample collected were manually homogenized to ensure proper mixture of all the contents. The pH of the mixture was recorded.

2.2 Experimental apparatus set up

A laboratory test of 1000 ml biodigester was operated in batch operating system. The experimental apparatus consists of biodigester and biogas measurement. The biodigester was made from conical flask bottle that are tightly plugged with rubber stopper and equipped with valve for biogas measurement. The temperature of mixture was maintained between 34°C to 38°C value thermostatically controlled electrically by heated water bath. Biogas formed was measured by using ‘liquid displacement method’ as described previously by [5].

2.3 Experimental design and procedure

Approximately 100 gram of cattle manure (M) was used as substrate. Approximately 100 gram of the manure collected at three different time were fed into each biodigester and mixed with rumen fluid (R) and distilled water (W) into three different treatment groups (M: W: R); T1 (1:1:0) control; T2 (1:0.5:0.5); and T3 (1:0:1) that are correspond to 0; 25; 50 % of rumen fluid, respectively (Table 1). The composition of the substrates and inoculums used in this study is presented in Table 1. Prior to experiment, the biodigester was flushed with CO₂ to provide an anaerobic condition. Biogas formed was measured at every at every three days interval for 24 days All of the samples in this experiment were run in triplicates. Significance differences between treatments and control were determined statistically using SAS by Dunnet.

Table 1: Three different M: W: R ratio contents

	M:W:R ratio	MANURE (g)	WATER (ml)	RUMEN (ml)	RUMEN %
T1	1:1:0	100	100	0	0
T2	1:0.5:0.5	100	50	50	25
T3	1:0:1	100	0	100	50

Keys: M=manure; W=water; R=rumen fluid.

III. Result and Discussion

The pH of the mixture before and after the biogas production experiment provided a reading of 7.34 and 7.15. Measured pH values are close to neutral. [10] reported that the pH of a normal and healthy anaerobic digestion system is generally in the range of 6.5 to 8.5. Under normal conditions, the digestion process balances excess acidity or alkalinity on its own. In general, substrates consist of manure and rumen (25 to 50% R) exhibit higher cumulative biogas production than substrates contain manure and water only (0% R). In other words, specific biogas production per ml of rumen fluid mixed with the manure is higher than the sample that does not contain the rumen fluid. Significant different (P<0.05) was observed in the cattle manure collected at 0 h and 24 h between the treatment group and control (Fig. 1). However, the similar result was not observed in the cattle manure collected at 12 h where the biogas produced in T2 (25% R) was somewhat similar with T1 (0% R) (Fig. 2).

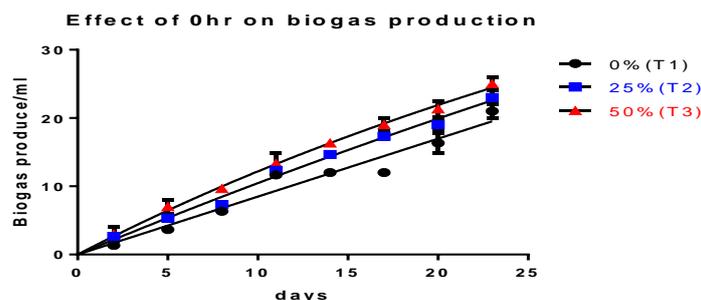


Figure 1: Biogas production from cattle manure collected at 0 h.

Cattle manure collected after 12 h of defecation recorded with the highest biogas production compared to 0 h and 24 h of cattle post-defecation (Fig. 2). The highest biogas produced was recorded in T3 throughout the experimental periods (Fig. 2). In this treatment group, the least biogas produced was recorded in 0 h with less than 25 ml being produced while the highest was in 12 h with 37 ml of biogas produced. The biogas production in 0 h was slowly increased form day to day (Fig. 1). Unlike 0 h, cattle manure collected at 12 h and 24 h demonstrate rapid production of biogas with more than 10 ml of biogas being produced in less than three days in all treatment groups except for T1 in cattle manure collected at 24 h (Fig. 3). In this study, the biogas produced in all of the treatment groups increased as observation days increased which corroborated with the findings of [11] that observed a very slow rate of biogas being produce at the beginning of the experiment. At the beginning (first few days) biogas production was higher and peaked about 15 to 17 mL in cattle manure collected at 12 h and 24 h at day 3. This was because of digestion of the readily biodegradable organic matter in the manure and inoculum mixture. Later the gas production started to reduces due to the fading out of the readily degradable organic matter at day 10 and this period termed as lag phase or starting up. The lag phase is the time required to initiate the biogas production while the microorganism (bacteria) get used to with the digestion environment, and microorganism and manure mix get assimilated. This is predicted due to the biogas production rate in batch condition is directly corresponds to specific growth rate of methanogens in the biodigester. [12] whose also reported that no such significant difference ($P > 0.05$), observed in the volume of biogas produced in the first to third week.

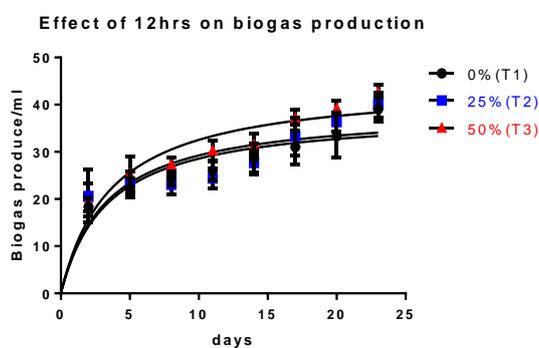


Figure 2: Biogas production from cattle manure collected at 12 h.

In the anaerobic environment, the predominance of CO_2 over CH_4 in gas production at the initial stage indicated the strong activity of hydrolysis. In contrast, higher CH_4 content over CO_2 in the gas production implied strong activity of the methanogens [13]. Therefore, biogas production gradually increased until day 10 and stabilized to a value of approximately 30-37 ml of biogas (Fig. 2 and Fig. 3). In general, fresh manure should yields more methane than aged manure but in this study, it is not the case. Our study demonstrated that cattle manure collected at 12 h yield better results than 0 h and 24 h. The main reason behind this is remain unclear. However, we speculated that at 12 h, the cattle manure has partially degraded by the microorganisms especially fungi present in surrounding environment while the fresh manure (0 h) still contain high lignocellulosic materials that could reduce the degradation efficiency of bacteria in the biodigester. On the other hand, the nutrient in the cattle manure collected at 24 h may have depleted completely thus limiting the bacteria from getting it source of carbon from the nutrient in the manure to produce biogas.

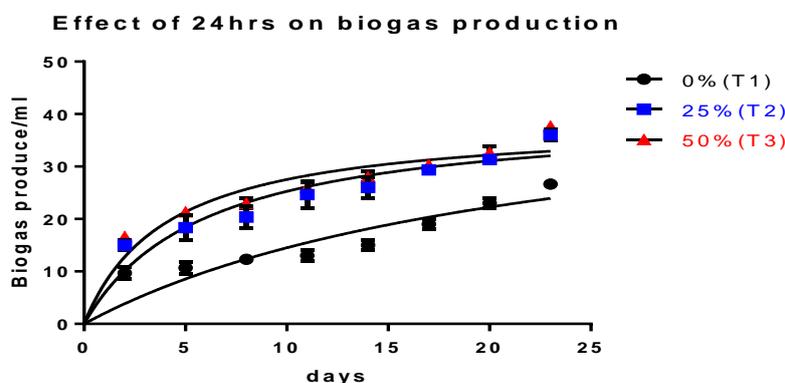


Figure 3: Biogas production from cattle manure collected at 24 h.

Apart from that, several reasons may also have contributed to the situation; (i) the methanogenic bacteria might not be present in large numbers; (ii) right amount of carbon and hydrogen molecules might not have been present, or (iii) the mixture may not have right amount of water added to it [14]. The lower methane production could also be a result of diet characteristics and may have contained compounds, such as ammonia or VFAs, in concentrations that would inhibit methanogenic activity [15]. High concentration of anaerobic bacteria content in liquid rumen works effectively to degrade organic substrate from manure. Rumen of the ruminant animals contains the highly anaerobic bacteria dominated by cellulolytic bacteria able to biodegrade cellulose material from manure [16]. Moreover, amount of biogas produced seemed proportional to the initial amount of inoculums [17] and the bovine rumen fluid inoculums had a strong effect on anaerobic bio stabilization of fermentable organic fraction of municipal solid waste [18].

IV. Conclusion

Based on the present study, it can be concluded that cattle manure collected at 12 h produced higher biogas than cattle manure collected at 0 h and 24 h. Apart from that, cattle manure inoculated with rumen fluid produced higher biogas than manure inoculated with water. These may be attributed to the activities of the microorganisms present in the rumen fluid that further degrade the remaining nutrient present in the manure. The best performance biogas production was observed if the rumen fluid used between the ranges of 25–50% of rumen fluid. The utilization of these substrates for biogas production could eliminate its disposal problems and create another abundant source of sustainable energy. The data generated from this study also provide a basis for future work in determining the population of methanogens in those treatment group at different measurement period using molecular approach such as Real-Time PCR. The data from this future analysis will explain why biogas is rapidly or slowly produce throughout the experimental period by evaluating the methanogens population present at specific point of sampling.

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