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Effect of Pre Digestion Time on Efficiency of Biogas Production

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Authors' contributions

This work was carried out in collaboration between both authors. Author GC designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: Waste-to-Energy transformation has been identified as a veritable option in the integrated waste management processing of Municipal Solid Waste. The use of biogas technology to produce energy and organic fertilizer from organic waste initially from livestock farm waste and agro-industrial waste is a potential way of MSW management.
The aim of this study was to determine the optimum time required for pre digestion of solid wastes before biogas production process begun.
Study Design: the study designed to operate on two batches and two phase experiments; the first batch was materials composted in four weeks and the second batch was in two weeks time in order to see which time will be effective on biogasification.
Place and Duration of Study: The study was done at the research center of the Environmental Engineering school, Ardhi university, between February and July 2013.

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Methodology: The method used was the volume displacement method where by the first phase experiment set up was aerobic composting that includes five reactors of printer paper to sugarcane waste in various proportions which were R1 (100:0), R2 (75:25), R3 (50:50), R4 (25:75) and R5 (0:100). During composting process temperature, moisture content, and pH, were monitored and process run for the periods of 30 days.The second phase experiment set up was bio gasification whereby the reactor allowed to ferment anaerobic for a period of 60 days. Each reactor contains composted printer paper with sugar cane waste and cow dung in the following ratios; substrate to seed for each composted reactor in every batch 100:0, 75:25, 50:50, 25:75 and 0:100. Initial temperature was measurements were determined since have effects on biogas production.
Results: The findings from this study show that, there is a significant biogas production from Co-digestion of pre-composted printed paper and sugar cane waste. Only R4 (25:75) and R5 (0:100) are the optimum ratios of printer paper to sugarcane waste during composting, Physical and chemical characteristics of both substrates (composted printer paper and sugar cane waste) and seed (cow dung) used for biogas production was in the range to support biogas production, Quantification of biogas produced was high from R4, R5, R3, R2 to R1.
Conclusion: materials pre-composted for four weeks yield more gas compared to two weeks composted materials and Sugarcane wastes as the stimulant materials increase biogas production since as the percent of sugar cane wastes increase the biogas yield also was increased.So the increase of pre digestion time seems to increase biogas yield in biogasification process.

Keywords: Biogas; anaerobic digestion; printed papers; sugar cane waste; composting.

1. INTRODUCTION

Waste-to-Energy transformation has been identified as a veritable option in the integrated waste management processing of Municipal Solid Waste. [1] Explained the "use of biogas technology to produce energy and organic fertilizer from organic waste - initially from livestock farm waste (various manures, slurry, and waste waters) and agro-industrial waste (abattoirs, wineries, vegetable processing plants, etc.); is a potential way of MSW management [2]. Nowadays there is a worldwide increasing energy demand. Energy sources generally can be divided into two main parts: non-renewable source energy like oil, coal, nuclear and natural gas; renewable source energy such as biomass, solar, wind and water [3]. Currently, global energy requirements are still extremely dependent on non-renewable fossil fuel. With the overuse of this limited fossil fuel the world now are facing the global energy crisis. It is necessary to search new sustainable energy source to fill the energy gap in the foreseeable future [4].

Biogas is a colorless, flammable gas produced via anaerobic digestion of animal, plant, human, industrial and municipal wastes amongst others, to give mainly methane (50-70%), carbon dioxide (20-40%) and traces of other gases such as nitrogen, hydrogen, ammonia, hydrogen sulfide, water vapor. It is smokeless, hygienic and more convenient to use than other solid fuels. Biogas production is a three-stage biochemical process comprising hydrolysis, acidogenesis/ acetogenesis and methanogenesis [5].

49 $(C_6H_{10}O_5)_n + nH_2O \rightarrow n\,(C_6H_{12}O_6)$ - Hydrolysis

50 $n\,(C_6H_{12}O_6) \rightarrow n\,CH_3COOH$ - Acetogenesis/Acidogenesis

51 $3nCH_3COOH \rightarrow n\,CH_4 + CO_2$ - Methanogenesis

Biogas has globally remained a renewable energy source derived from plants that use solar energy during the process of photosynthesis. Being a source of renewable natural gas, it has been adopted as one of the best alternatives for fossil f uels after 1970's world energy crisis. Biogas technology was introduced in Tanzania 1975 by the Small Industries Development Organization (SIDO). These early biogas plants adopted the floating drum technology from India and were mainly introduced in primary and secondary schools, rural health centers, and other institutions [6].

The printed papers are the one of the organic matter in which when digested by microbes have great chance of producing this commercial gas which is very important in environmental pollution management since the materials as a stimulant, high production of biogas expected from methane (CH_4) and carbon dioxide are the main gaseous products of the anaerobic methane fermentation of waste containing cellulosic materials like sugar cane wastes[7].

Theoretically, 1 kg of cellulose would produce 415 liters of methane [8].
Currently, our country is facing a problem of shortage of energy and solid waste management and we are looking for means to enhance agriculture production, so there is a need to search for alternatives means of sources of energy, looking new means of waste minimization and new disposal mechanisms and how we can improve the agriculture sector while preserving our environment for future generations. Biogas is one of the alternative sources [9]. Ability of biogas production from printer paper mixed with sugar cane waste as stimulant viewed as a potential source of energy, solid waste management mechanism and last product after biodegradation can be used as natural manure rich in nutrients [10]. The main objective of this study was to assess the effect of pre digestion time on the efficiency of biogas production from printed paper stimulated by sugar cane waste [11].

2. MATERIALS AND METHODS

2.1 Materials Used

The materials used for this experiment were cow dung (seed), waste printer paper and sugar cane waste (substrate). Other materials used were weight balance (maximum of 1 kg), plastic buckets of 10 L, water, gloves, measuring cylinder, scissors, delivery tube, stoppers, reactors, Super glue, pipe tape, perforated bench, and knives.

2.1.1 Printer paper

The printed paper waste was collected from ARU dustbins and dump site was collected cut into small pieces and composted by soaking in a plastic water bath in a variety of two and four weeks to allow pre-digested and the pH and temperature regulated throughout the study.

2.1.2 Stimulant materials (cow dung and sugar cane waste)

The Sugarcane waste was collected from the sugar cane juice cafe at Msimbazi Street Kariakoo city center. The waste was chopped into a small size, then followed by composting in a variety of two and four weeks. The materials allowed to compost without mixing of any other materials so as to ensure that the biogas production monitored well. Fresh cow dung was collected from the Feedlot slaughterhouse in Kibaha. The cow dung was taken afresh to ensure there is a enough microbial population.

Fig. 1. Chopped printed papers prepared for composting

Fig. 2. Sugar cane waste used in the composting process

2.1.3 Other materials

These tubes were about one inch diameter for transportation of biogas from the reactor to the gas collection bottle and transport displaced water from collection gas bottle to the collected water bottle. They were brought from Mwenge shopping center.

Syringes of 5 ml were bought at Butiama Pharmacy Mwenge. From these syringes the needle and lids were used. Needles were used to ensure gas produced, transported to the delivery tube. The lids of syringes were used as the outlet pipes on the biogas reactors.

The stoppers were obtained by cutting pairs of rubber shoes, which were brought at the Mwenge shopping center. They were used to tight digester and water collecting bottles.

Benches were manufactured in the Mwenge carpentry workshop. They were made for supporting the inverted bottles used for collecting gas.

2.2 Composting

Aerobic composting was carried out as time varies from two and four weeks time. The totals of five reactors were composted in the ratios of printer paper to sugar cane waste Table 1.

Table 1. Composting ratios used

Reactor	Printed papers to sugar cane wastes ratio
R1	100:0
R2	75:25
R3	50:50
R4	25:75
R5	0:100

2.2.1 Monitoring of composting process

Monitoring was mainly on factors affect composting, which are moisture content, temperature, aeration and pH. Also the optimum frequency of the turning of the compost feed materials designed for aeration and mixing was monitored.

2.2.1.1 Temperature

The temperature of the waste was measured by using two thermometers after every two days whose individual readings were averaged to give a representative temperature value. The ambient temperature was also measured.

2.2.1.2 Moisture contents

The moisture content test was performed after every after every three days to check suitability. When the moisture content was found to be in the range of 50-70%, and turning the compost feed materials in order to maintain oxygen. The ash content method was used whereby a sample was weighed in the crucible before and after being dried in oven at temperature between 103^0 C- 105ºC for 24 hours.

2.2.1.3 Ph

Composting process pH was monitored throughout the process after every two days. It was determined based on leachate produced using HachSenns 10N6 water pH-meter.

2.3 Biogas Quantification

The biogas produced from anaerobic digester of substrate was quantified by the water displaced method. The gas produced was drawn from the reactor by a hose tube into an inverted bottle containing water mounted on the bench where it displaced water equivalent to its own volume. The water displaced was transported by hose tube and collected into a container placed under each inverted bottle from which it was measured by using a graduated measuring cylinder and flask.The volume of the water measured is directly proportional to the volume of gas produced from the reactor [12].

The contents of biogas digesters were allowed to ferment anaerobic for a period of 60 days. Each reactor contains composted printer paper with sugar cane waste and cow dung with the variation of ratios 100:0, 75:25, 50:50, 25:75 and 0:100, substrate to seed for each composted reactor in every batch. Initial temperature, pH, COD and TS measurements for these materials were determined since have effects on biogas production. The biogas measurement was carried out using the water displacement method Fig. 2.

The whole experimental set up consist hundred 100 reactor systems. 50 reactors for two weeks composted substrate while another 50 reactors for those of four weeks composted substrate. One reactor contains three bottles in which first bottle contains slurry, another was inverted for gas collection and third bottle was empty for collection displaced water. Biogas measurement was carried out using the water displacement method.

3. RESULTS AND DISCUSSION

3.1 Composting

Commonly the temperature trend in the composting process is the factor of material being composted and shows microbial activity [13].

From the Fig. 3, shows temperature variation in the materials composted for 30 days. In which temperature of R4 and R5 was in range between 25ºC to 55ºC this indicate that mesophilic, thermophilic and fungi colonize and degrade the waste materials [13].

For R3 temperature was ranging from 23-50ºC which shows that the mesophilic and small population of the thermophilic bacteria colonize and degrade the waste.

For R2 and R1 only Mesophilic bacteria (optimum range 15-45ºC) which succeeded to colonize the compost during this period.

The composting temperature increase as the amount of sugar cane waste increase in the mixture with printer paper this was due to the fact that C: N ratio affect composting temperature. Sugar cane waste has the lower C:N of 50:1 compared to printer paper with 125-180:1 [14].

Composting of two weeks time was not successful, since the shows temperature variation of two weeks composting materials, in which all five reactors reach the temperature for mesophilic bacteria only to degrade the wastes. These reactors undergo incomplete composting since it does not reach the temperature which allows the growth of thermophilic bacteria [15] see Fig. 4.

3.2 Optimum Ratio of Printer Paper to Sugar Cane Waste during Composting

Only R4 (25:75) and R5 (0:100) attained a high temperature of above 50ºC which is thermophilic phase enough for compost to reach stability and kill pathogens. The pH of R4 and R5 drop from 7.5 to 6.2, it is supportive pH for the thermophilic phase to take place [16]. So due to that R4 and R5 are optimum ratio reach maturity during composting.

As the waste composted progressed the weight of the compost decrease due to reduction of organic waste into gases such as CO_2, SO_3^{2-}, NO_3^-, H_2O and other less complex organics [17].

The Fig. 5, show the weight reduction in percent for all five reactors in those two batches of two and four weeks composted materials.

It was noted that, weight of the wastes in R1, R2, R3,R4 and R5 achieve the weight reduction up to 50% for 30 days, composting time.Though the R5 facilitated a considerable reduction in weight compared to other reactors [18].

3.3 Biogas Produced from Composted Materials

3.3.1 Comparison in four weeks composted materials

High volume of methane was observed from R4 followed by R5, R3, R2 and R1 as shown in the figure below. Also ratio R52 (75:25) was observed to produce high volumes of methane compared to the all ratios from all reactors this due to the suitable influencing factors such as

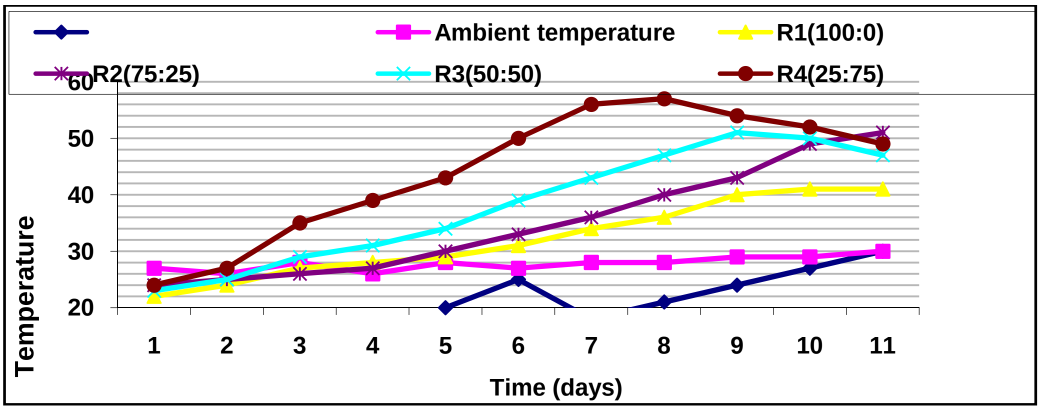

Fig. 3. Temperature variation in four weeks composted materials

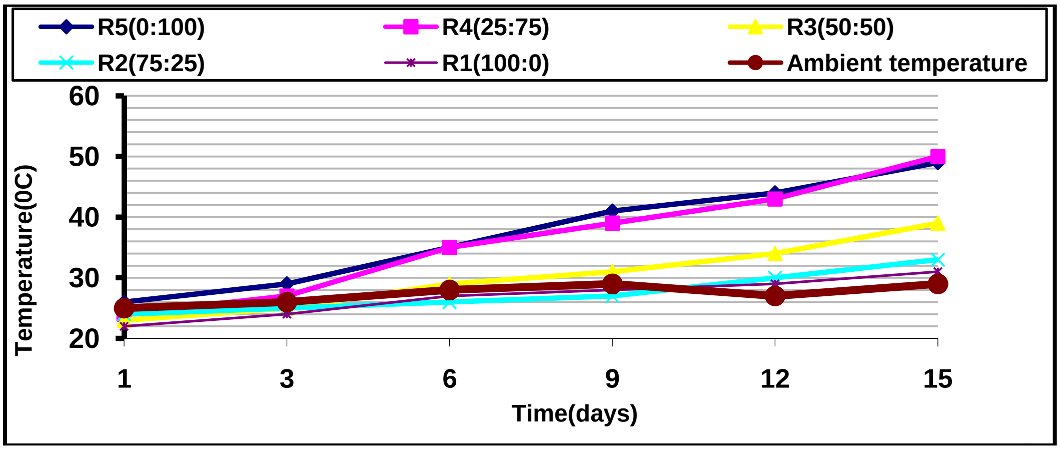

Fig. 4. Temperature variation in two weeks composted materials

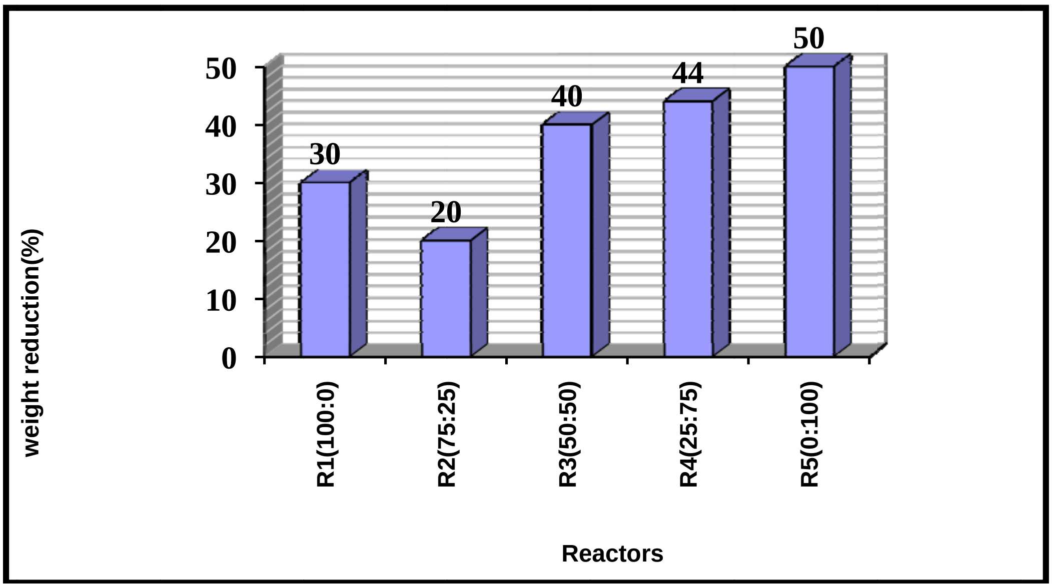

Fig. 5. Waste reduction by weight of the waste taken after 30 days of composting

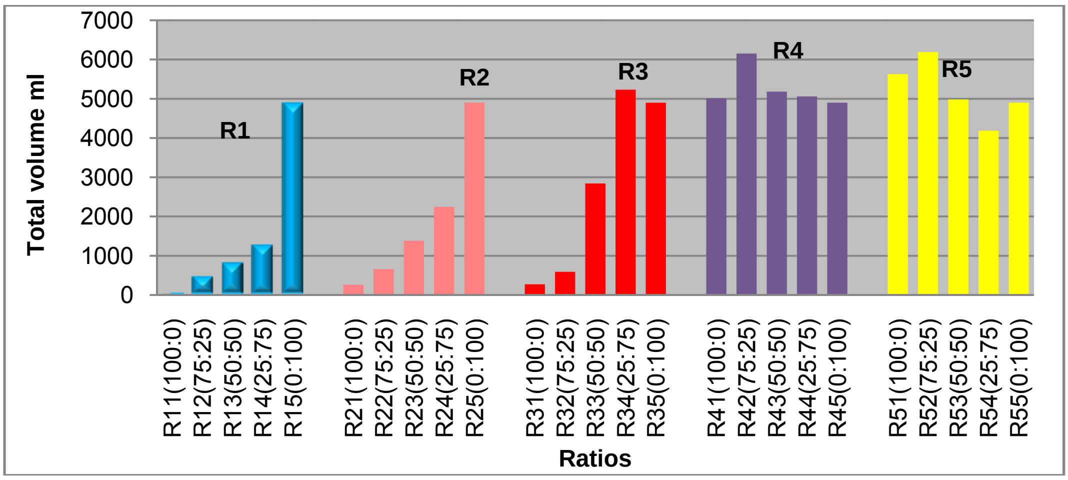

Fig. 6. A comparison of total methane produced from 4 weeks compost

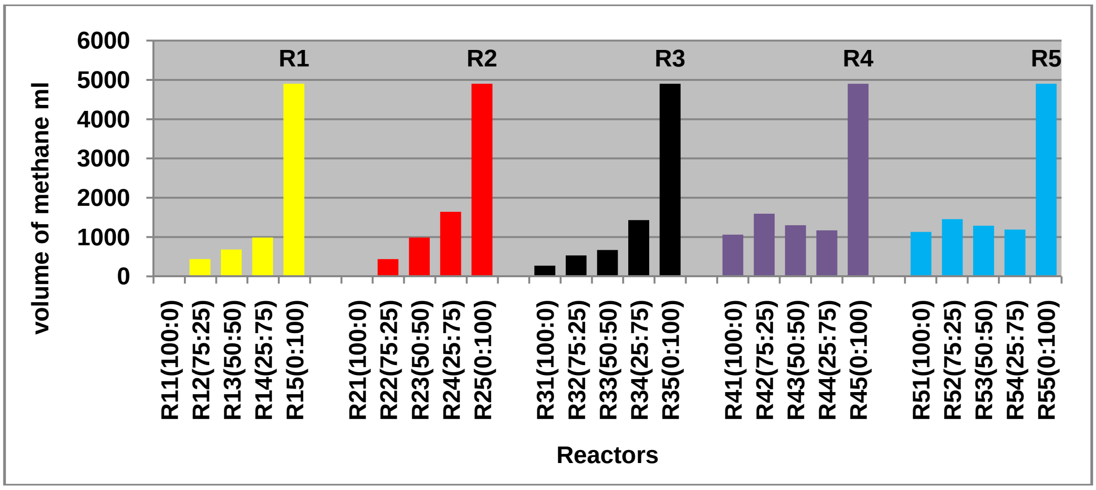

Fig. 7. A comparison of total methane produced from two weeks compost

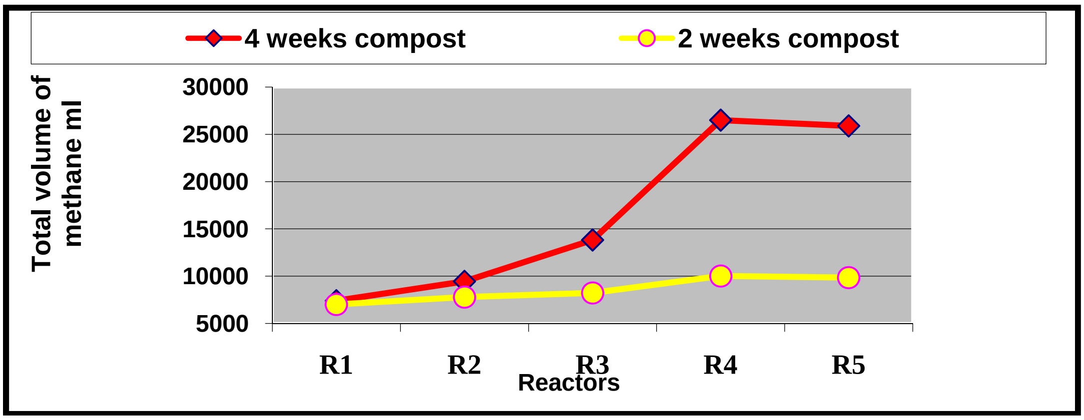

Fig. 8. Variation of biogas production from four and two weeks composted materials

pH, which was within the range (6.6-7.6) at the beginning [19], suitable temperature for the mesophilic anaerobes and suitable carbon to nitrogen balance.

3.3.2 Comparison in two weeks composted materials

High volume of methane was observed from R5 followed by R4, R3, R2 and R1 as shown in the figure below. Also ratios with seed only was observed to produce high volume of methane compared to all ratio from all reactors this due to the suitable influencing factors such as pH, temperature and suitable carbon to nitrogen balance [20].

3.4 Effect of Composting Time on Biogas Production

From the Fig. 8, the biogas production potential from materials pre composted for about four weeks yield more gas compared to those reactors which contain materials of two weeks materials. This was due to that printed paper are lignocelluloses wastes, Cellulosic wastes are generally known to be poor biogas producers because of their poor biodegradability [21]. One treatment method for improving the biogas production of various feedstocks is Co-digesting them with animal and/or plant wastes and increase pre-treatment time [22].

4. CONCLUSION

The findings from this study show that, there is a significance biogas production from co-digestion of pre-composted printed paper and sugar cane waste. Only R4 (25:75) and R5 (0:100) are the optimum ratios of printer paper to sugar cane waste during composting [23]. Physical and chemical characteristics of both substrates (composted printer paper and sugar cane waste) and seed (cow dung) used for biogas production were in the range to support bogus production [24]. It was observed that the biogas production potential from materials pre composted for about four weeks yield more gas compared to those reactors, which contain materials of two weeks materials [25].

Sugar cane wastes as the stimulant materials increase biogas production. So as the percent of sugar cane wastes increase, the biggest yield also was increased [26,27].

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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