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Full Length Research Paper

Anaerobic composting of pyrethrum waste with and without effective microorganisms

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This study investigated the use of effective microorganisms (EM) for enhancement of biogas production through composting of solid pyrethrum remains after extraction of pyrethrins (marc). The laboratory scale experiment involved composting of the waste as substrate mixed with EM at different ratios consisting of a control, substrate with EM at of 1:250, 1:500, and 1:1000 v/v. Results show highest production of biogas at EM ratio 1:500 v/v, while biogas produced at EM ratio of 1:250 v/v had the highest methane yield. It was also found that carbon to nitrogen (C/N) ratios for all mixtures fall within the optimal range (10:1 to 15:1) as compared to the control, which was out of range. This study was able to establish an optimal mixing ratio of the substrate and EM preferably to be 1:250 v/v at a dilution ratio of 1:4 m/m since it is observed to have the highest methane composition of 69% compared to the other treatments. The composted pyrethrum waste at all ratios can also be used as bio-fertilizer since the final COD of the compost is on an average of 134 g/L, suitable for soil conditioning.

Key words: Biogas, composting, effective microorganisms (EM), methane, marc.

INTRODUCTION

Urban development is often associated with increase in the volume of solid wastes, constituting a major concern for all urban administrations (WIPO, 2004; Chaggu et al., 1998). The most common disposal method practiced is crude dumping (Yhedgo, 1994), which can cause pollution of ground and surface water sources (Kaseva and Mbuligwe, 2000; Mbuligwe and Kassenga, 2004). Composting has been established as one of the low cost alternatives for minimizing the volume of solid waste disposed of to the environment, with a potential for economic gain from resource recovery (Yhedgo, 1994) by converting putrescible organic matter into plant nutrients (Chaggu et al., 1998). The final product of composting is a soil conditioner, which returns nutrients of organic matter to farm soil thus closing the organic loop. The compost can potentially replace synthetic fertilizers, which are also a source of groundwater pollution (Temu and Mrema, 2007).

As a result of these improvements, the soil becomes more resistant to stresses such as drought, diseases and toxicity, enhances uptake of plant nutrients, and an active nutrient cycling capacity because of rigorous microbial activity. These advantages manifest themselves in reduced cropping risks, higher yields and lower outlays on inorganic fertilizers for farmers (WIPO, 2007).

The use of effective microorganisms (EM) has found its way to aquaculture, garbage treatment and sanitation. Under the effect of selected bacteria, the decomposition of organic substances is quicker and particularly, it does not emit gases of offensive smells such as hydrogen sulfide, ammonia, etc. The environment is consequently rendered pollution free. Additives (common nutrients such as starch, cellulose, sugar and vitamin-rich substances, preferably rice bran, sawdust, treacle, slops and oil cake) stimulate the growth of bacteria, particularly cellulose decomposing bacteria, at the initial phase of the decomposition, thereby increasing the capability of decomposing biodegradable organic matters. Combination of additives, EM and cellulose decomposing bacteria also maintains elevated temperature in the composting process. The treatment has low initial investment and operational cost (WIPO, 2004). The main focus of this research is to determine the effect of adding EM for enhancement of anaerobic composting of solid wastes

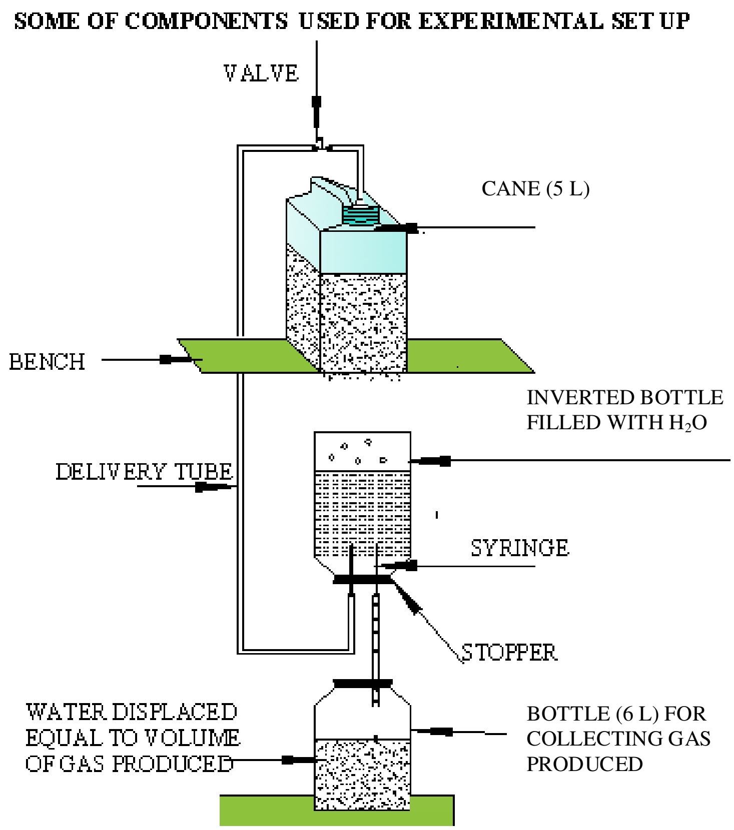

Figure 1. Arrangement of the experimental unit.

resulting from pyrethrum extraction in order to determine its feasibility as bio-fertilizer and a substrate for biogas production.

MATERIALS AND METHODS

The substrate for anaerobic digestion was collected from Pyrethrum Company Tanzania Ltd., located at Mafinga in Iringa region. The substrate was then mixed with water at a ratio of 1:4 w/w to raise the moisture content from 15 to about 50 to 70%, which is a suitable range for microorganisms responsible for decomposition (WIPO, 2007). The pH was adjusted from 5.2 to a suitable range of 6 to 7 as suggested by WIPO (2007) by addition of 300 ml of ash to each reactor. Activated EM was made by mixing 500 ml of EM-1® with 500 ml of molasses and 10 L of de-chlorinated water at a ratio of 1:1:20 (v/v/v). The mixture was left to ferment in 10 L air tight plastic bucket for 10 days.

The reactors consisted of 5-L plastic canes and 6-L plastic bottles for collection of displaced water. Delivery tubes were used for transportation of biogas from the reactors to the 5 L glass bottles full of water in which the gas generated displace water due to pressure created in the bottle. Syringe needles of 10 cm^3 were used to enhance equal exchange of biogas and water which is facilitated by pressure differences.

Experimental setup

The arrangement consists of 5 L plastic cane for anaerobic composting, 2.5 L capacity inverted glass bottles for quantification of biogas, 6-L capacity plastic canes for collecting displaced water that are equivalent to volume of biogas produced; a stopper with two fittings for needles and tubes as shown in Figure 1. Activated EM was dosed at different proportions to determine its influence on the rate of production of biogas.

The setup had four treatments, each with three replicates. The treatments consisted of a control without EM, substrate mixed with EM at a ratio of 1:250, 1:500, and 1:1000 by weight (Figure 2). Each treatment consists of the same dilution ratio of 1 kg of substrate with 4 L of water.

Characterization of substrate material

Substrate material was analyzed for COD, pH, moisture content, total solids, volatile solids, organic carbon, total nitrogen, and temperature prior to and after composting. COD, organic carbon content and total nitrogen were determined as per standard methods (APHA, AWWA, WEF, 1992) and used to quantify C/N ratio of the final compost.

Biogas quantification

Biogas production was measured using liquid displacement method. Twelve bottles (2.5 L) were filled with water, closed with stoppers, inverted and fitted in holes of the wooden stand. Each stopper had two 10 cm^3 syringes inserted and connected to serve for biogas inlet from the anaerobic reactor and outlet for the displaced water. The displaced water was collected in the 6 L bottles, whereby the volume of liquid displaced represents the amount of biogas produced.

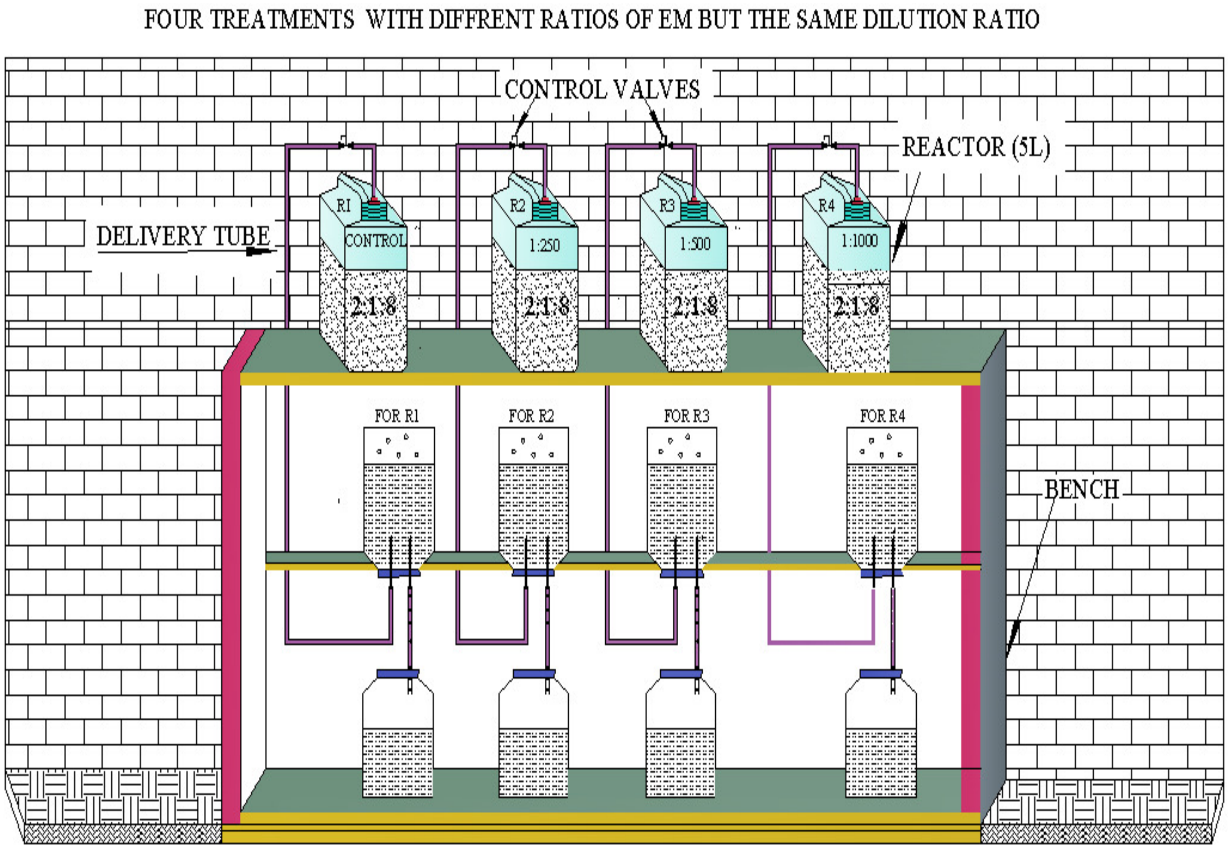

Figure 2. Arrangement of treatments.

Table 1. Preliminary results of the marc sample.

Sample parameter	Value obtained	Value after buffering/dilution
COD (g/L)	481	-
C/N ratios	29:1	-
Moisture content (%)	15±3.06	65±1.3
pH	5.2	6.7

Characterization of biogas composition

The biogas collected was analyzed for methane content and other gases, using displacement method by using 15% potassium hydroxide (KOH) solution. A sample of biogas of known volume (100 ml) was tapped using a syringe and injected in a small bottle containing KOH. Carbon dioxide present in the biogas dissolve in potassium hydroxide solution leaving methane gas and some trace gases which displace its volume. Since the volume of original sample was known, the volume of methane was then quantified.

Moisture content, total solids (TS), volatile solids (VS), and fixed solids (FS)

Moisture content of substrate before and after being mixed with water and ash, percentage total solids, volatile solids, and fixed solids of sample were determined as per standard methods (APHA, AWWA, WEF, 1992).

RESULTS AND DISCUSSION

Preliminary characteristics of substrate materials

Initial characteristics of marc before composting are as shown in Table 1. The COD for raw marc was 481 g/L, indicating high amount of organic matter that will potentially be an adequate source of food for micro-organisms essential for composting process as discussed by Dezuane (1997). The pH of the sample was 5.2, and according to WIPO (2007), the initial pH of the materials to be composted normally ranges between 6 and 7. As such, ash (pH= 10.3) was added to the sample in order to adjust the pH to 6.7. The carbon to nitrogen (C/N) ratio of initial Marc was found to be within the recommended range of 25:1 to 30:1 as suggested by WIPO (2007).

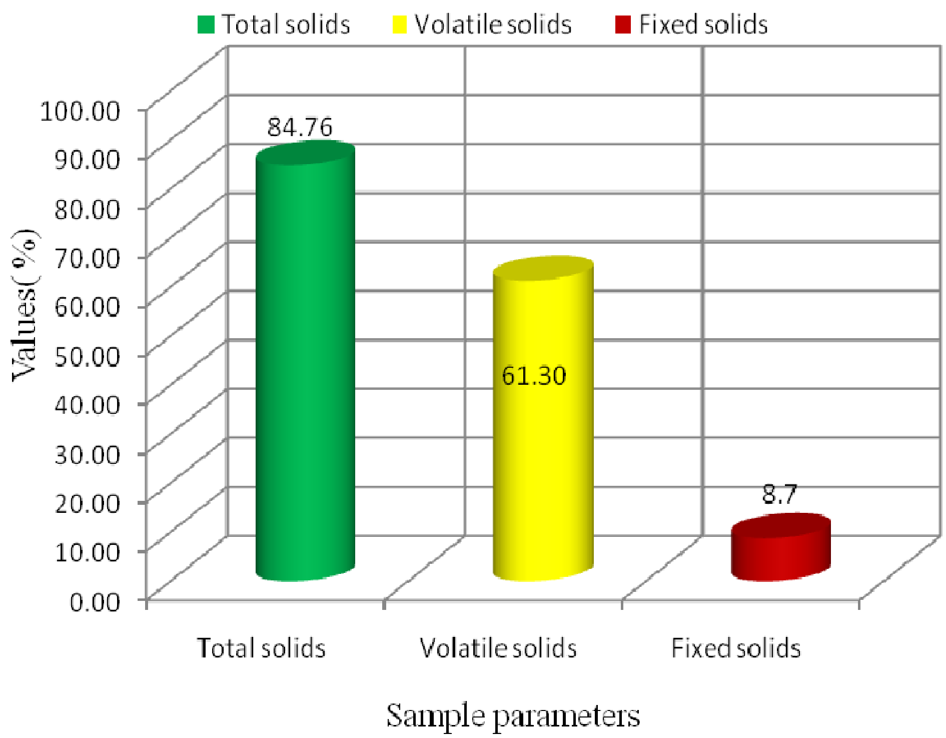

Figure 3. Sample parameters before composting.

Table 2. Average values of parameters affecting anaerobic digestion.

Parameter	Without EM	EM (1:250)	EM (1:500)	EM (1:1000)
Final pH values	5.7	4.7	4.3	5.3
Moisture content of composts (%)	67	71	74	69
C/N ratios of final composts	19:1	11:1	12:1	15:`1
COD (g/L)	236	127	130	145

Initial moisture content of raw marc was 15±3.1%, which was below the recommended range of 50 to 70% as per WIPO (2007) for anaerobes to grow. Water was mixed with the sample at a ratio of 1:4 w/w, to attain moisture content of 65±1.3%.

Total solids (TS), volatile solids (VS) and fixed solids (FS)

Results indicate that large percentage of the sample is biodegradable materials since its fraction of volatile solids is larger (61.30%) than fixed solids (8.7%) which are non-biodegradable materials. Percentage total solids, volatile solids, and fixed solids are shown in Figure 3.

Physical and chemical characteristics of EM

After ten days of fermentation, the pH of activated EM was 4.6, its color became grayish with white layer at the top. These characteristic features are an indication that shows that activated EM after ten days of fermentation can be used for the purpose.

Characterization of the final compost

Table 2 shows the characteristics of the final compost in terms of pH, moisture content, C/N ratio and COD. It can be observed that the final pH of control and EM dose reactors ranged from 4.3 to 5.7, which is suitable for survival of acid-forming bacteria although this pH range inhibits the survival of methanogens responsible for biogas production, whose survival pH range is 6.5 to 8 (Martin, 2007). Moisture content of final compost for the mixture of EM/substrate ratio of 1:500 had the highest value of 74%, which is out of the range of 50 to 70% as suggested by WIPO (2007), which curtailed the biogas production at day 34. As regard to C/N ratio, it was

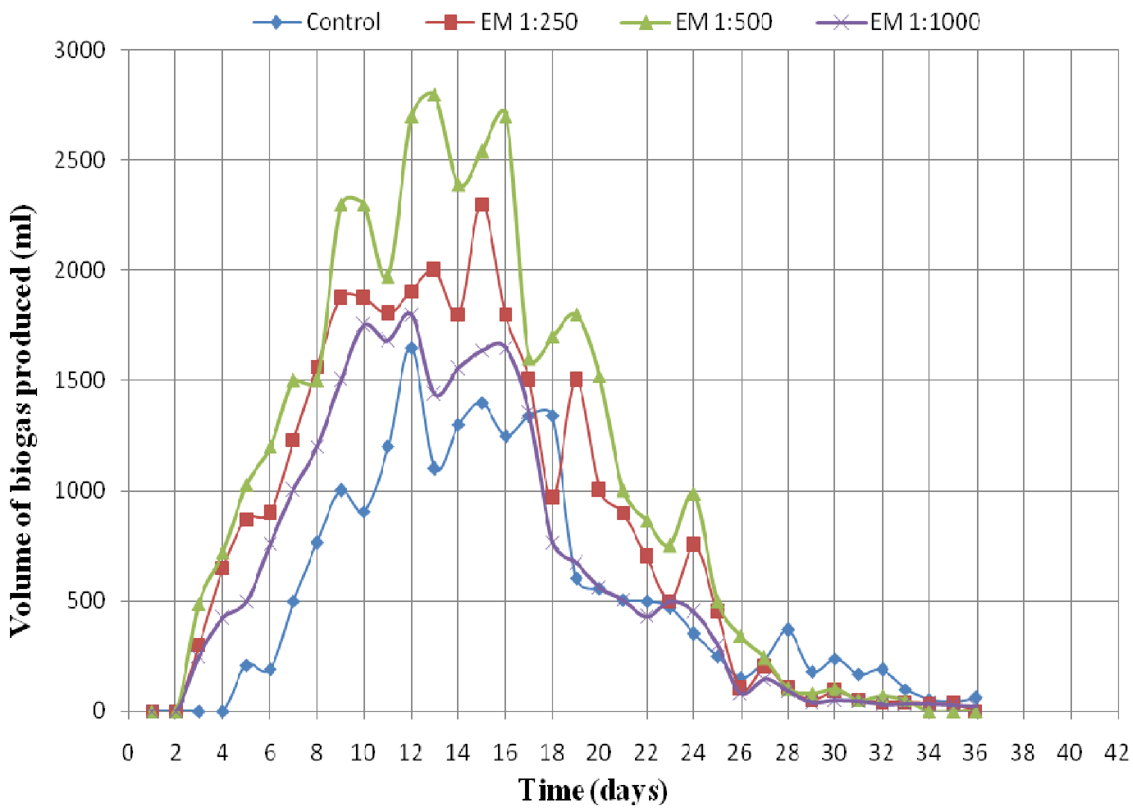

Figure 4. Daily biogas production.

observed that the final composts were all within suitable range recommended for bio-fertilizers. Results in Table 3 also show substantial decrease of COD for all reactors from the initial value of 481 g/L to an average of 134 g/L for the EM/substrate mixtures, as compared to the controls, which decreased to 236 g/L, indicating higher rate of biodegradability in EM composts than in control composts.

Biogas production

Figure 4 depicts that there was no biogas production during the first two days for all four reactors during which acclimatization of microbes was presumed to be taking place. Reactors of with substrate: EM ratios 1:250, 1:500, and 1:1000 started producing biogas on day 3 in contrast with the control reactors which started producing biogas in day five. This is an indication of the effect of adding EM to the composting process, prompting higher numbers of microbial population essential for the process.

The rates of biogas production for all reactors reached maximum values between day 10 and 16 before dropping to zero on day 36 for EM 1:500, during which time, other treatments still produced some little amounts of biogas (50, 35, and 30 ml, for control, EM 1:250 and EM 1:100 respectively). Biogas production for the control treatment lasted longer, up to day 42.

Cumulative biogas production

The total volume of biogas produced during the whole experimental run for each treatment is shown in Figure 5. Higher amount of biogas (37.88 L) was produced in EM dose of 1:500 during the entire composting period compared to the control that produced lowest yield. This could be due to higher rates of hydrolysis, acidogenesis, acetogenesis and methanogenesis in this dose than in other doses, as a result, it became mature earlier during day 36 compared to other treatments. Control treatment had the lowest biogas yield possibly due to the fact that EM increases the amount of gas produced; hence, those reactors having EM dose have high yield production than control reactors.

Methane content

The amount of methane for different treatments is shown in Figure 6. Presence of high percentage of CH_4 indicates that biogas produced has high quality than that producing low percentage of CH_4. In this study, it was observed that a reactor with EM 1:250 had the highest percentage of

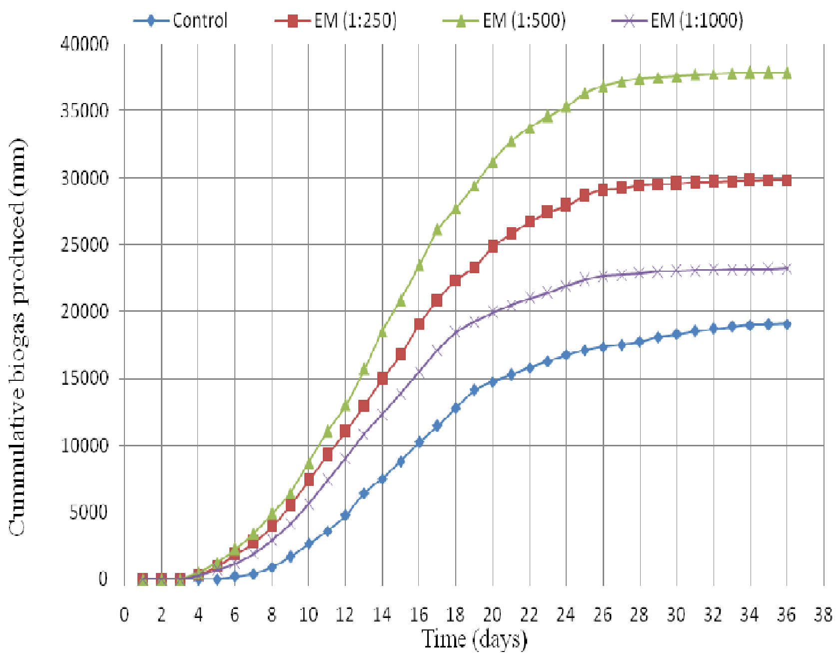

Figure 5. Cumulative biogas produced daily from pyrethrum wastes.

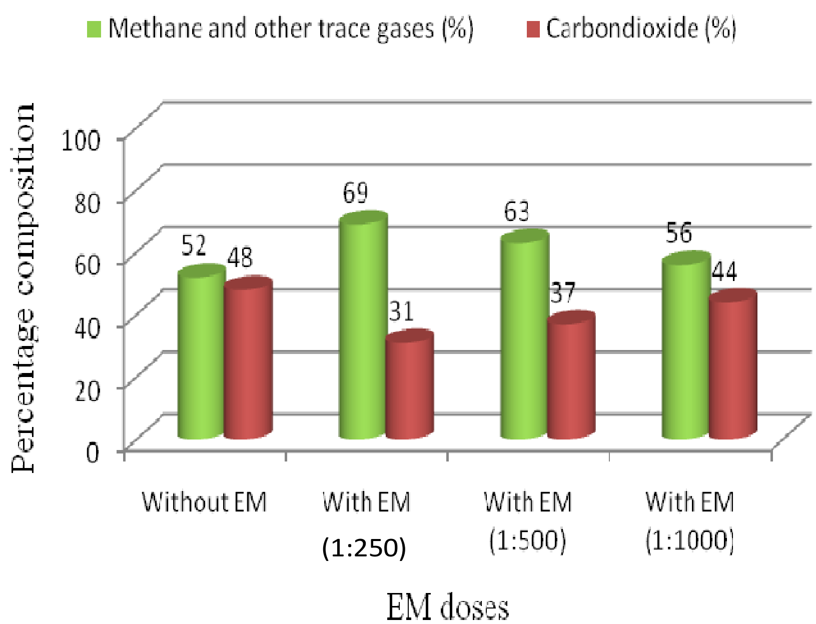

Figure 6. Composition of biogas produced.

methane than other reactors; the lowest percentage was observed to be in control reactors.

Conclusions

Results from this study show that mixing EM with substrate from pyrethrum solid remains (marc) with the same dilution ratio (1:4 w/w) at different ratios (1:250, 1:500, 1:1000 v/v) produces higher amount of biogas than non EM dose reactors, possibly due to increase in microbial population in EM-treated reactors. For production of good quality of biogas, EM dose of 1:250 was found to be the best, since the percentage composition of methane was found to be the highest, corresponding to high amount of EM added (16 ml) compared to other EM doses. Composting with EM ended up with a final compost of C/N ratios of 11:1, 12:1, and 15:1 for EM 1:250, 1:500 and 1:1000, respectively, which were within the suitable range for use as a bio-fertilizer unlike control composts whose final C/N ratio of 19:1 was out of the suitability range, implying that the compost was still premature.

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