Innovative Biogas and Bio-solids Generation from Anaerobic Sewage Sludge Digestion Using Acti-zyme as Biocatalyst as a Sustainable Measure for Developing Countries

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Abstract

Sewage sludge was anaerobically digested using Acti-zyme, a biocatalyst for generation of biogas and bio-solids as an innovative strategy for obtaining biogas. Acti-zyme loadings of 35-50 g/m^3 was employed for sewage sludge loading of 5-10 g/L. day in 250 mL reactors emanating the digesters. The agitation in the digesters was maintained at 60 rpm, at a mesophillic temperature of 37 °C for a period of 40 days. The biogas quantity produced was measured using the water displacement method daily. Samples of the biogas were collected and analyzed for bio-methane (CH_4), carbon dioxide (CO_2) and traces gases composition using gas chromatography. The bio-solids obtained were dewatered for destruction of pathogens and tested for nitrogen, phosphorous and potassium (NPK) content using uv-*vis* spectrophotometry. Optimum biogas quantity was produced at a sewage sludge loading of 7.5 g/L. day and Acti-zyme loading of 50 g/m^3 with 78% CH_4 unlike in Acti-zyme free digesters were a maximum of 65% CH_4 was obtained. High nitrogen content bio-solids with 8.17 %, 5.84 % and 1.34 % of NPK respectively were produced. Acti-zyme is therefore an attractive bio-catalyst for sustainable sewage treatment for co-generation of biogas and bio-solids.

Keywords: Acti-zyme, anaerobic digestion, bio-methane, biogas, bio-solids, NPK, sewage sludge

Introduction

Sewage is a type of wastewater that is generated from domestic and industrial use, which in most cases is treated for re-use and recycling purposes as a water scarcity control measure. Though its wastewater, sewage can be managed by sustainable treatment methods to achieve high value economic products. Several methods have been applied in anaerobic sewage treatment with the biological treatment using Acti-zyme, a biological catalyst being one of them (Manyuchi *et al*., 2014). During the anaerobic sewage treatment process, sewage sludge is obtained during the primary and secondary treatment stages and this can be value added through digestion by harnessing valuable products like biogas and bio-solids as a sustainable sewage management measure (Apedaile, 2001; Cao & Pawlowski, 2012). Sewage biogas is mainly composed of bio-methane (CH_4), carbon dioxide (CO_2), hydrogen sulphide (H_2S), hydrogen (H_2) and nitrogen (N_2) with compositions depending on the quality of sewage sludge used (Herout *et al*., 2011). Sewage biogas production is a four-step procedure which includes step 1: hydrolysis, step 2: acidogenesis, step 3: acetogenesis and step 4: methanogenesis (Zieminski & Frac, 2012). In addition, the bio-solids (digestate) which are a result of the sewage sludge digestion process can be applied as bio-solids due to the presence of fertilizer macronutrients; primarily nitrogen and phosphorous (NP) (Apedaile, 2001), though there is need to control the pathogenic material content mainly *E. Coli* (Lang *et al*., 2007; Lang & Smith, 2007).

Acti-zyme has biochemical properties that promote biogas production through hindering hydrogen (H_2), nitrogen (N_2), and hydrogen sulphide (H_2S) at the same time promoting the biodegradability of the sewage sludge (Manyuchi *et al*., 2014). Absence of sulphate reducing bacteria promotes the methanogenesis process which results in higher bio-methane during sewage treatment (Straka *et al*., 2007). In addition, Acti-zyme does not contain urease which has a potential of releasing ammonia that can be broken down into nitrogen (Manyuchi *et al.*, 2014). Nitrogen a constituent found in biogas must be in lower composition (≤ 10%) as it is a limiting component during the hydrolysis phase in biogas production (Wagner *et al*., 2011).

Research Objectives

This study focused on biogas and bio-solids production from digestion of activated sewage sludge using Acti-zyme exploiting the biochemical characteristics of Acti-zyme, anaerobically.

Methods

Sewage sludge was obtained from raw sewage obtained from the Chitungwiza Sewage Treatment Plant in Chitungwiza, Zimbabwe. Acti-zyme which was obtained from AusTech Australia was employed as the anaerobic bacteria during sewage sludge digestion. All experiments were repeated thrice and an average value used. Experiments were done for digesters with and without Acti-zyme for through determination of effect of Acti-zyme.

The sewage sludge was filtered and dried to 80% moisture content using a Mermet oven. 250 mL flasks representing the digesters were put in a water bath set at 37 °C to create mesophillic conditions at atmospheric pressure. The digesters were closed and sealed with aluminum foil paper to ensure anaerobic conditions. Outlets were created for movement of the biogas and sampling. Optimum Acti-zyme loading of 35-50 g/m^3 over retention period of 40 days were used in the digesters for biogas and bio-solids generation (Manyuchi *et al*., 2014). Agitation in the digesters was fixed at 60 rpm and sewage sludge organic loading ranging from 5-10 g/L. day were employed to determine the optimum biogas production conditions (Hesnawi and Mohamed, 2013).

The biogas quantity from the sewage sludge was measured through the displacement of water with a schematic layout represented in Figure 1 in milliliters per day (mL/day). The biogas generated was taken from the sampling points for composition analysis. A GC 5400 gas chromatography analysis was used for analyzing the biogas content and the composition was expressed as a percentage.

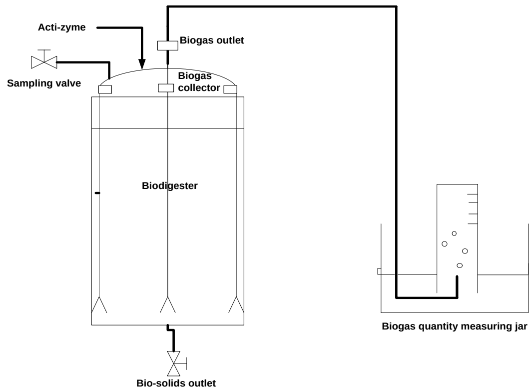

Figure 1: Schematic diagram for biogas generation from sewage sludge using Acti-zyme.

The sewage sludge and bio-solids pH was measured using an HI 9810 Hanna pH electrode. The moisture content in the sewage sludge was determined by heating 5g of sewage sludge sample at 105°C for 10 minutes and then recording the difference in weight as an indicator of the amount of water removed using an AND moisture analyzer. After the digestion process, the bio-solids were dried as a measure to reduce moisture content from 80% to 20%. Nitrogen, phosphorous and potassium (NPK) content in the bio-solids was measured using a Labtronics double beam *uv-vis* spectrophotometer content. *E. Coli* content was measured through the total plate count procedure (Lang *et al*., 2007; Lang & Smith, 2007).

Results

Biogas production increased with increase in Acti-zyme loadings from 35 g/m^3 to 50 g/m^3 on all sewage sludge loadings from 5 g/L. day to 10 g/L. day as compared to digesters without Acti-zyme (Figure 2). The optimum bio-methane rich biogas of 394 mL/day was obtained at 50g/m^3 of Acti-zyme and a sewage sludge loading of 7.5 g/L. day. Acti-zyme loading of 50 g/m^3 was found to be optimal in terms of bio-degradability of sewage (Manyuchi *et al*., 2014) whilst at the same time sewage sludge loading of around 6.9-9.2 g/L. day have been recommended for optimal biogas production (Hesnawi & Mohamed, 2013).

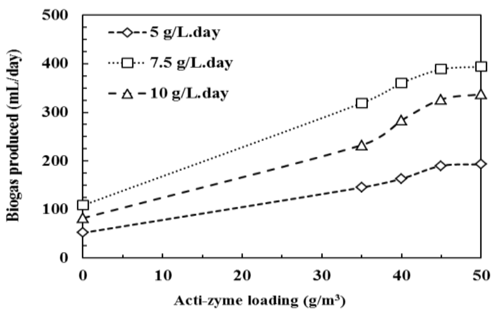

Figure 2: Biogas produced over varying Acti-zyme and sewage sludge loading.

A bio-methane rich biogas was produced with CH_4 composition ranging from 72-78 % with a peak being obtained for sewage loadings of 7.5 g/L. day at an Acti-zyme loading of 50 g/m^3 as compared to Acti-zyme free digesters which had a bio-methane composition of 53-65% (Figure 3). The biogas also contained CO_2 with ranges from 16-20 % and trace amounts of H_2S, N_2 and N_2. H_2S, N_2 and H_2. The trace gases were in lower quantities in digesters with Acti-zyme due to the capability of Acti-zyme to hinder their production effectively improving the quality of the biogas (Table 1) (Manyuchi *et al*., 2014). The bio-methane was found in high quantities due to the enhanced bio-degradability of the sewage sludge by Acti-zyme (Manyuchi *et al*., 2014).

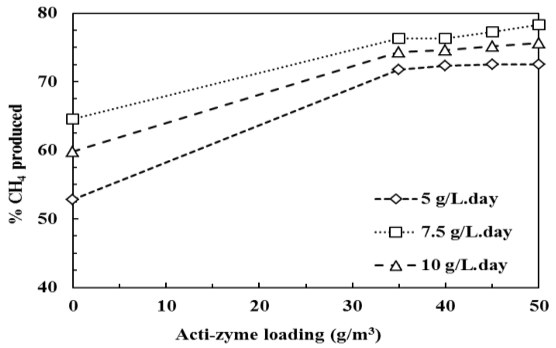

Figure 3: Bio-methane composition in sewage sludge at varying Acti-zyme loading and sewage sludge loading.

Table 1: Biogas composition from anaerobic digestion of sewage sludge

Gas	% (Acti-zyme)	% (without Acti-zyme)
CH_4	72-78	53-65
CO_2	16-20	22-27
Traces (H_2S, N_2, H_2)	5-9	8-12

The bio-solids obtained from the anaerobic sewage digestion using Acti-zyme had a final moisture content of 20% after drying. The bio-solids NPK content ranged from 8.17±0.15%, 5.84±0.03% and 1.32 ±0.02% as indicated in Figure 4. Therefore, the bio-solids obtained by this treatment method can be classified as high nitrogen content bio-solids (Evanylo, 2009). The reduction of water content in the bio-solids from 80% to 20% as well as the hindering effect of Acti-zyme for *E. Coli* activity resulted in a significant decrease in *E. Coli* content from 10^{12} to 10^6 cfu/L. Lower moisture levels hinder *E. Coli* growth making the bio-solids safe for application at the same time Acti-zyme inhibits *E. Coli* growth and reproduction in sewage (Lang *et al*., 2007; Lang & Smith, 2007; Manyuchi *et al*., 2014). The bio-solids had a pH of 7.26±0.54 and if there is a higher pH needed for application, lime stabilization is recommended.

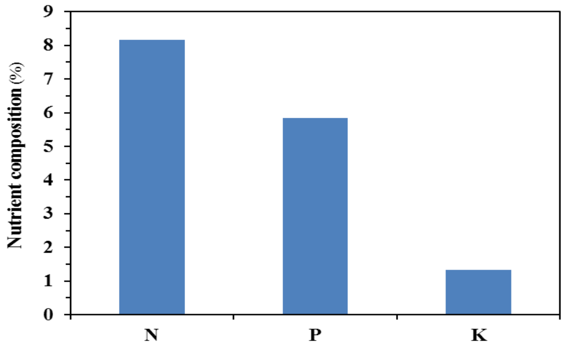

Figure 4: Bio-solids from anaerobic digestion of sewage sludge using Acti-zyme composition.

Discussion

Anaerobic digestion of activated sewage sludge utilizing Acti-zyme promotes production of bio-methane rich biogas which is almost free of H_2S and nitrogen and has lower CO_2 composition. Acti-zyme loading of 50 g/m^3 and sewage sludge loading of 7.5 g/L. day is essential for optimum biogas production over a 40 day period. Additionally, bio-solids which are rich in fertilizer NPK nutrients are produced and can be utilized as bio-fertilizers. This can result in sustainable management of sewage sludge in developing countries high value added products like biogas being used for micro-energy at the same time harnessing bio-solids.

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