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Anaerobic Digestion of Food and Market Waste; Waste characterisation and Bio-methane Potential: A Case study in Sri Lanka

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Abstract

Anaerobic digestion is the process that generates biogas. This process can be used successfully to treat municipal organic solid wastes and kitchen waste to produce valuable end products, such as Methane gas and fertilizer.

This research is aimed at finding out how a large scale market place could successfully utilize its organic waste as opposed to land filling or dumping. The study involved determination of composition and characterization of waste produced over a season, and investigating the possibility of biogas generation using anaerobic digestion process. The study site was a large market place situated in close proximity to Colombo, the main city of Sri Lanka.

The study revealed that the composition of the market waste as; vegetable wastes: 45%, fruit wastes: 35%, packing material: 15% and restaurant food waste: 3%. The waste also composed of materials in the form of stones, plastics, wood but was less than 1.3 % of the total waste quantity. Total average waste production per day was about 1ton. The average pH value, percentages of water present, solids and volatiles present in fruits and vegetable were found to be 6.38, 92%, 8.08% and 6.18%, respectively.

Bio Methane Potential (BMP) in respect to fruit and vegetable waste and food waste were found to be 0.3m^3 and 0.56 m^3 CH_4/kg, respectively, measured at atmospheric conditions, 100kPa and 25^{o}C. This is translated into corresponding energy quantities generated in the form of methane approximately to be 10.5 and 20 MJ/kg from fruit and vegetable waste and food waste. The biodegradability of fruit and vegetable waste and food waste were calculated as be 59.3%, 83.6%, respectively.

Introduction

The organic waste generated by agriculture, industry and households can be hazardous for environment when managed improperly.

Utilization of waste for useful purpose is given major consideration in recent times. Considering the fact the largest fraction of waste are of organic nature, anaerobic digestion can be used to generate biogas as an economically viable option [1].

Treatment of organic waste using anaerobic digestion has become common in the past few decades. This is primarily due to three main factors: firstly disposal of organic solid waste in more environment friendly manner as opposed to land filling, secondly derivation of a renewable fuel, and thirdly, lower cost involved in commencing and operating anaerobic digestion systems [2]. Further, the digestate resulting from anaerobic digestion as a byproduct is used as bio fertilizers, which add more value for the process [3].

On a worldwide scale, urbanization and rapid population growth has led to an enormous increase of solid waste generation per unit land area. Particularly, urban and semi-urban areas of low and middle income countries are confronted with great challenges concerning appropriate solid waste management practices. Inadequate management and uncontrollable dumping of garbage lead to several adverse consequences: It not only leads to destruction of environment beauty, but also to a high risk of polluting surface and ground water through leachate, and furthermore, promotes the breeding of flies, mosquitoes, rats and other disease vectors. In addition, it emits unpleasant odors and methane, a major greenhouse gas contributing to global warming [4.] While Anaerobic Digestion (AD) for treating of animal dung is fairly common in rural areas of developing countries, information on technical and operational feasibilities concerning the treatment of organic solid waste and food waste is limited. Regarding the enormous waste problems in the urban areas of these countries, the question arises whether AD could be an appropriate and sustainable method to treat organic household wastes as well as wastes from marketplaces and restaurants.

The Economic Centre (EC) at *Ratamalana*, located in close proximity to Colombo in Sri Lanka was launched by the Trade, Marketing and Consumer Services Ministry of Sri Lanka as a large scale government-owned perishables wholesale market place. This complex is situated at the heart of a highly industrialized, urbanized and highly populated area. About 130 large scale stalls have been established in the EC selling vegetables, fish, meat, dry provisions and other consumer goods.

A large quantity of organic waste is produced daily in the EC and disposal of the waste produced, mainly organic wastes (fruit and vegetable, restaurant waste, fish & meat waste) is a serious concern, due to non-availability of a proper waste disposal procedure. The organic waste is often discarded in a disorganized manner and rising heaps of wastes attract flies and rodents, thus creating a public health hazard. From time to time, these heaps of waste are collected and transported away by the local municipality for dumping in yards nearby, where the waste is dumped and exposed to the environment.

Due to the high decomposition potential and production of methane as a final product, Anaerobic Digestion can be recognized as one of the best options for treating this waste, since it results in two valuable final products, biogas and compost that may be utilized as an energy source and as soil fertilizer, respectively.

Waste characterization is a key aspect in design and operation of anaerobic digesters, as it affects the amount of biogas generation and stabilization of anaerobic digestion process [5].

The major feedstock parameters involved in anaerobic digestion are, volatile solid content, moisture content, nutrient content, bio degradability and size of particles. The biogas production or Bio Methane Potential (BMP) is an indication of the bio degradability of a particular feedstock [6].

The Bio Methane Potential (BMP) test is a method of measuring the amount of biogas produced per gram of volatile solids (VS) contained in the organic substrate in the anaerobic digestion process. This test can be performed in laboratory conditions using a known quantity of substrate by providing anaerobic conditions. Various methodologies are applied in determining BMP according to published literature [7, 8].

This study aimed at examining the potential of biogas generation of food and organic waste produced at the EC by anaerobic digestion. Characterization and quantification of the wastes was also carried out as it is a very important aspect for the feasibility of the anaerobic digestion process. Further, determination of chemical parameters of feedstock and estimation of methane yield of substrate was carried out to determine biogas production.

Materials and Methods

Waste Selection and Quantification

A site survey was carried out to identify composition of market waste and to quantify organic waste (food waste, vegetable and fruit waste etc.) produced at the EC. Further, the current practice of waste disposal was studied to evaluate problems at present.

Waste Sampling

To determine the compositional variability of organic waste over a season, weekly sampling was performed for a period of eight weeks. Waste samples of 5kg size were taken from the mixed waste and analyzed for compositional variability, and values were averaged to have the mean values for each category of waste.

Waste Characterization:

Samples were analyzed for pH, total solids and volatile solids according to the standard method (APHA, 2005)

Bio Methane Potential Test

Each BMP test was performed under controlled lab condition in a 1000ml glass bottle. The bottles were partially filled with substrate and inoculum to induce anaerobic conditions. Then, each bottle was added with water up to a 500ml total volume. To prevent any changes in the pH, small amounts of Na_2CO_3 (0.1 - 0.60g) were added and then each bottle was tightly sealed.

All bottles were shaken for 30min at 80rpm by a bottle shaker and then immersed up to half of the bottle height in hot water of 35˚C, using a water bath.

Each bottle was connected via a capillary tube to the inverted glass bottle (1000ml) containing 2% NaOH. This was done once per day for all the bottles.

The daily methane gas production by volume was measured for a consecutive five weeks by the displacement of an alkaline solution in a measuring bottle and that was collected in a graduated cylinder. As CO_2 contained in the biogas is dissolved in the alkaline solution, measurements indicated only the volume of methane.

Temperature and pH in each BMP bottle were also monitored for at least once a day with a thermometer and a pH meter, respectively.

Results and Discussion

Waste Composition

Table 1 shows the major components of wastes generated in the market that include vegetable wastes (≈46%), fruit wastes (≈35%), and packing materials (hay, straw, paper, etc. ≈15%). Materials in the form of plastics, wood etc. were present in around 1% of the waste quantity. The organic waste in terms of fruit and vegetable is estimated approximately 800kg per day. These wastes along with the other inorganic waste are collected and dumped in a nearby landfill site without any treatment.

Table 1 - Composition of Waste

Item	Amount of Waste (kg/day)	%
Vegetable Waste	450	45.31
Fruit waste including banana stems	350	35.26
Packing materials(Hay, Straw, Paper, Cardboard)	150	15.10
Restaurant waste (Food Waste)	30	3.02
Materials in the form of Plastic Wood etc.	13	1.31
Total waste produced (approximately)	**993 kg /day**	

Chemical Parameters of Fruit and Vegetable Waste (FrVW) and Food Waste (FW):

PH Values of the Fruit & Vegetable Waste and Food Waste

The average pH value for FrVW is 6.38 and 3.95 for food waste and 5.7 for mixed waste of both FrVW and FW. According to observations, the methane producing bacteria thrive best under neutral to alkaline conditions. According to research findings, food waste is observed to be more acidic for the growth of the methanogen bacteria.

Total Solid % of the Fruit & Vegetable Waste (FrVW), Food Waste (FW) and Mixed Waste (MS):

The average percentage of Total Solids of fruit and vegetable waste accounts for 8.08 and 21.9 for Food waste. The total solid percentage for mixed waste is 15.23. It is observed that FrVW has low amounts of total solids due to high moisture content. Compared to FrVW, Food waste has a higher total solids content which can be beneficial in terms of anaerobic digestion.

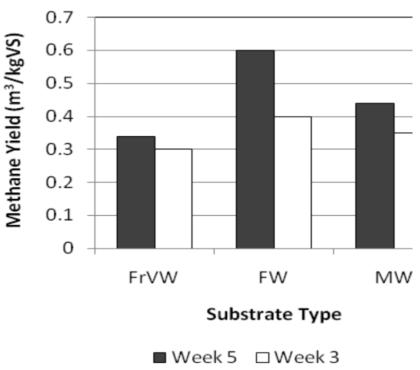
Volatile Solids % of the Fruit & Vegetable Waste, Food Waste and Mixed Waste

The average percentage of Volatile Solids of fruit and vegetable waste accounts for 6.18 and 19.98 for Food waste. The total solid percentage for mixed waste is 14.6. It is observed that FrVW has a low amount of Volatile solids compared to FW, Food waste is having higher Volatile solids content which can be beneficial in terms of anaerobic digestion.

BMP Test Results in Analyzing Methane Yield of Feedstock Material

Methane yield observed for different substrates were found to be varying, with food wastes giving the maximum in weeks 3 and 5 as shown in Figure 1. The differences in yield showed increasing trend with the residence time, as seen in Figure 2.

Figure 1 - MethaneYield from different Substrates in Week 3 and 5



Torsten Fransson of KTH who has been the master mind behind this program.

References

[1] Kiran, E.U., Trzcinski, A.P., Jern Ng, W., & Liu, Y. (2014). Bioconversion of food waste to energy: A review. Fuel, 134, 389–399.

[2] Weiland, P. (2010). Biogas production: Current state and perspectives. Applied Microbiology and Biotechnology, 85, 849–860. Yhdego M. (1995): Urban solid waste management in Tanzania: Issues, concepts and challenges; Resources, Conservation and Recycling 14 (1995) 1-10

[3] Hidalgo, D., Sastre, E., Gómez, M., & Nieto, P. (2012). Evaluation of pre-treatment processes for increasing biodegradability of agri-food wastes. Environmental Technology, 33(13), 1497–1503

[4] Liebetrau, J., Reinelt, T., Clemens, J., Hafermann, C., Friehe, J., & Weiland, P. (2013). Analysis of greenhouse gas emissions from 10 biogas plants within the agricultural sector. Water Science and Technology, 67, 1370–1379

[5] Zhang, B., Cai, W., & He, P. (2007). Influence of lactic acid on the two-phase anaerobic digestion of kitchen wastes. Journal of Environmental Sciences, 19, 244–249

[6] Labatut, R.A., Angenent, L.A., & Scott, N.R. (2011). Biochemical methane potential and biodegradability of complex organic substrates. Bio resource Technology, 102, 2255–2264

[7] Raposo, F., de la Rubia, M.A., Fernández-Cegrí, V., & Borja, R. (2011). Anaerobic digestion of solid organic substrates in batch mode: An overview relating to methane yields and experimental procedures. Renewable and Sustainable Energy Reviews, 16(1), 861–877.

[8] Angelidaki, I., Alves, M., Bolzonella, D., Borzacconi, L., Campos, J.L., Guwy, A.J., et al. (2009). Defining the biomethane potential (BMP) of solid organic wastes and energy crops: A proposed protocol for batch assays. Water Science and Technology, 59, 927–934

[9] American Public Health Association (APHA) (2005). Standard methods for the examination of water and wastewater (21th ed.). Washington DC: APHA.

[10] HilkiahIgoni, M. F. N. Abowei, M. J. Ayotamuno and C. L. Eze (2008), Effect of Total Solids Concentration of Municipal Solid Waste on the Biogas Produced in an Anaerobic Continuous Digester