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Waste Management by Anaerobic Digestion of Kitchen Waste- A Review

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ABSTRACT: Kitchen waste (food waste) collected from hostels and canteen has high calorific and rich nutritive value to microbes due to which efficiency of methane production can be enhanced. Biogas (Green energy) as an energy source is cost effective and generates a high-quality renewable fuel. Biogas contains around 55-65% of methane, 30-40% of carbon dioxide. Methane has a calorific value of 10 kWh/Nm^3. Under anaerobic digestion the organic content is reduced, cow dung slurry along with the kitchen waste is used in the bioreactor as inoculum. The digested slurry is produced at the end of this process is used as a bio fertilizer. In this paper anaerobic digestion, biogas production and challenges for management of kitchen waste and usage of biogas as alternative to kerosene or LPG has been discussed.

KEYWORDS: Anaerobic degradation (AD), kitchen waste, (HRT) Hydraulic Retention time.

I. INTRODUCTION

The demand of energy has been greater than before over the years by rising of the world population and expansion of global industries especially for food and feed [1]. India produces 150 million tons of fruits and vegetables and generates 50 million tons of wastes per annum, therefore it become necessary to develop appropriate waste treatment technology for vegetable wastes to minimize greenhouse gas emission [2]. Bio-methane (biogas) is an alternative and renewable energy source produced through the anaerobic (oxygen free) digestion of organic matter whereby the organic matter is converted into a combustible biogas rich in methane. Biogas comprises of Methane (CH_4) and Carbon dioxide (CO_2) and may have small amounts of hydrogen sulphide (H_2S) and moisture. Bioconversion processes are suitable for wastes containing moisture content above 50% than the thermo- conversion processes [3]. Vegetable wastes due to highly biodegradable nature [4, 5] and high moisture content (75 – 90%) tend to be good substrate for bio-energy recovery through anaerobic digestion process. Kitchen waste is organic material having the high calorific value and nutritive value to microbes, that's why efficiency of methane production can be increased by several orders of magnitude. It means higher efficiency and size of reactor and cost of biogas production is reduced [6]. The main advantage in using anaerobic digestion is the biogas production, which can be used for steam heating; cooking and generation of electricity [7, 8, 9].

II. ANAEROBIC DIGESTION

Anaerobic digestion is a microbial decomposition of organic matter in which micro-organisms derive energy and grow by metabolizing organic material in an oxygen-free environment resulting into methane and carbon dioxide. This process is known as bio-methanogenesis, which occurs naturally in wetlands, rice fields, intestines of animals, manures and aquatic sediments, and is responsible for the carbon cycle in the ecosystems. Biological activity has been identified to be the cause for more than 80% of the flux of the atmospheric methane [10]. Anaerobic digestion is a biological process; it is strongly influenced by environmental factors such as - temperature, pH and alkalinity and toxicity. The main biological reactions which occur during the entire process of the anaerobic digestion are (i). Hydrolysis (ii) Acidogenesis (iii) Acetogenesis (iv) Methanogenesis leading to formation of methane. Hydrolysis claims to

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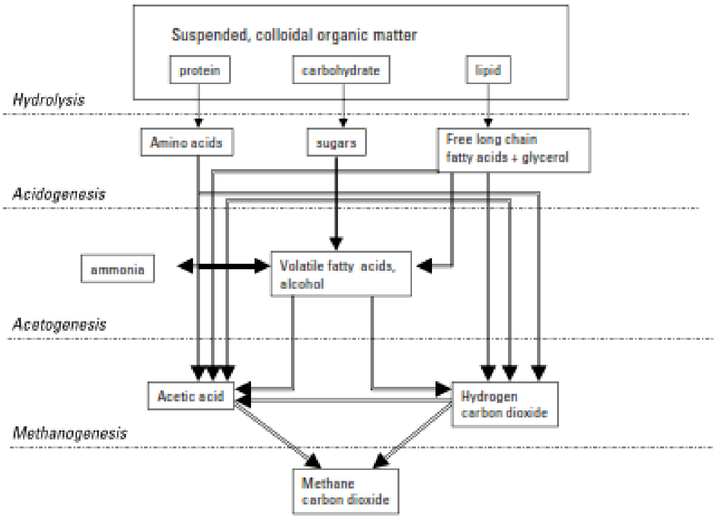
conversion of non-soluble biopolymers to soluble organic compounds. The reaction is catalyzed by enzymes excreted from the hydrolytic and fermentative bacteria. End products of this reaction are soluble sugars, amino acids; glycerol and long- chain carboxylic acids [11]. The organic waste undergoes anaerobic digestion resulting to the conversion to simple sugars. Acidogenesis, the biological process of acidogenesis is where there is further breakdown of the remaining components by acidogenic (fermentative) bacteria. Here VFAs are created along with ammonia, carbon dioxide and hydrogen sulfide as well as other by-products. The process of Acetogenesis is completed through carbohydrate fermentation and results in acetate, CO_2 and H_2, compounds that can be utilized by the methanogens. The presence of hydrogen is critical importance in acetogenesis of compounds such as propionic and butyric acid [11]. Thus the presence of hydrogen scavenging bacteria is essential to ensure the thermodynamic feasibility of this reaction [12].

$$(C_6H_{10}O_5)n + nH_2O \longrightarrow n(C_6H_{12}O_6) \text{ – Hydrolysis}$$

$$n(C_6H_{12}O_6) \longrightarrow n\,CH_3COOH \text{ -Acetogenesis}$$

$$3nCH_3COOH \longrightarrow n\,CH_4 + CO_2 \text{ - Methanogenesis}$$

Methanogenesis constitutes the final stage of AD in which methanogens create methane from the final products of acetogenesis (i.e. hydrogen gas, carbon dioxide and acetate) as well as from some of the intermediate products from hydrolysis and acidogenesis [13]. In this stage methane and carbon dioxide are formed by various methanogens [14]. Various microorganisms are active during this stage. Methanogens are sensitive to pH changes and presence of heavy metals and organic pollutants.



III PARAMETERS AFFECTING THE ANAEROBIC DIGESTION OF KITCHEN WASTES

Feed Stock Material for Anaerobic Digestion

As in the case of aerobic composting, there have been attempts to physically separate the organic fraction from the mixed municipal solid waste stream and subject it to anaerobic digestion [15]. Food waste has high water content and low lignin and lingo cellulose content that make it ideal for this digestive process. In the biodegradable waste, kitchen waste showed maximum quantity 2366.65 g (27.54%) followed by fruit waste 1566.6 g (18.38%), food waste 1034.1 g (12.08%), paper waste 943.7g (11.02%), plant waste 86.6g (1.01%) and textile waste 50.9 g (0.59%) [16].

pH

The pH plays a very important role in the anerobic digestion of the kitchen waste. The importance of the pH is due to the fact that methanogenic bacteria are very sensitive to acidic conditions and their growth and methane production are

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inhibited in acidic environment Methanogens prefer a pH environment between 7 and 7.5 [13] although there are several biogas plants operating at pH of 8 in Sweden [17]. During the startup of anaerobic digestion process of hydrolysis and acidogenesis lower the pH before any methane can be formed. It has been proven that the optimal range of pH for obtaining maximal biogas yield in anaerobic digestion is 6.5–7.5, the range is relatively wide in the plants and the optimal value of pH varies with substrate and digestion technique [18]. On the other side excess proliferation of methanogens can lead to higher concentration of ammonia, increasing the pH above 8, which is inhibitory to the acidogenesis [19].

Carbon to Nitrogen ratio

Methanogens utilize Nitrogen for their protein requirements. For higher C: N ratios, Nitrogen depletion will result in reduced biogas production. Higher ratios will result in excess Nitrogen leading to the formation of Ammonia. This increases pH level beyond 8.5 which then inhibits the activity of microbes and consequently gas production [20]. It is generally found that during anaerobic digestion microorganisms utilize Carbon 25–30 times faster than Nitrogen. Thus to meet this requirement, microbes need 20–30:1 ratio of C to N with the largest percentage of Carbon being readily degradable [21,22]. The optimum C: N ratio is also influenced by levels of Phosphorus and trace elements [23].

Temperature

One of the most important factors affecting anaerobic digestion of organic solid waste is temperature [24]. Mesophilic digesters have an operating temperature 25- 40 °C and thermophilic digesters have operating temperature range of 50-65°C. Thermophilic digesters allow higher loading rate and yield higher methane production.

Loading rate

Organic loading rate is a measure of the bio-conversion capacity of the anaerobic digestive system. The biological system when overloaded can result in low biogas yield. The inhibitory substances can lower the biogas yield. Excess substrate at the beginning of the process, leads to the build-up of undecomposed material such as fatty acids. This reduces the pH and creates an imbalance in the entire decomposition chain [13].

Retention time

Retention time represents the time period for which the fermentable material remains inside the digester. The longer retention period needs larger size digester and it allows more complete digestion of feed [25]. Retention time usually referred to as hydraulic retention (HRT) is usually between 10 and 25 days. Sometimes the retention time of the particulate material, or solids retention time (SRT) of the process is specified. In most situations, HRT and SRT are equal with the exception of digestion tanks where part of the residues are returned into the process, then SRT becomes longer than HRT [26].

IV. CONCLUSION

This paper reviewed various solid wastes for the biogas production by anaerobic fermentation amongst which kitchen waste contains low lignin content which is favorable for anaerobic digestion. The kitchen waste also has high nutritive and calorific value suitable for the production of biogas. The biogas production from kitchen waste can save the LPG gas consumption in the campus and provide substantial amount of manure which can be used as organic fertilizer for gardening in Kuppam Engineering College campus.

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