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ACIDOGENIC OFF GAS DIVERSION: A KEY SOLUTION OF TWO STAGE ANAEROBIC DIGESTION PROCESS FOR FOOD WASTE TO BIOENERGY

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Abstract

Food waste from households and commercial sources such as canteen, cafeteria and restaurant are usually disposed off in landfills. Limited space and environmental impacts viz generating greenhouse gases and polluting groundwater table are some of the major concerns of food waste disposal in landfill. However, bio processing is a promising alternative for the treatment of food waste due to its high organic content and the potential to recover value added products like biogas and soil conditioner. Two stage anaerobic digestion systems is one of the developed technology in anaerobic digestion system where more energy can be recovered from waste material. But due to its complexity and energy loss researchers need to find probable solution to this and lots of research is going on now a day to improve its energy production rate. Acidogenic off gas diversion is one of the most prominent technology acquire attentions recently. In our discussion we will discuss various prospects of this technology to increase food waste degradation rate.

Keywords: Food Waste; Biogas; Anaerobic Digestion; Acidogenic off Gas Diversion.

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1. Introduction

1.1. Food Waste as Energy Source

Globally, food wastes represent about 30-50% of the MSW in different countries. Considering the quantity of this waste, now many countries are diverting food waste to 'waste-to-energy' treatment technologies to combat global warming, because degradation of organic wastes in the landfills contribute to methane (CH_4) emission, representing ~3% of the total greenhouse gases emitted. With constant increase in energy demand and fuel prices, technologies that can generate energy from the organic wastes in a sustainable way will be helpful to save more energy. Among the waste to energy technologies, anaerobic digestion is considered as a viable technology for food waste treatment due to its high moisture content and potential to produce about 200 to 500 L of CH_4 kg^{-1}VS (Cho et al., 1995; Hansen et al. 2004). Food waste (FW) has the following typical characteristics a) high moisture content b) good nutrient status and c) high fermentability.

1.2. Food Waste Composition

Food waste also has large quantities of organic materials such as proteins, carbohydrates and lipids, varying amounts of suspended solids depending on the source, hence possess high biochemical oxygen demand (BOD). Fruits, vegetables and tubers dominate the food waste. According to the FAO data on global quantitative food losses and waste per year are roughly 30% cereals, 40-50% root crops, fruits and vegetables, 20% oil seeds, meat and dairy plus 35% for fish. Out of the total food waste generated in India, fruits and vegetables constitute 35-40%. India, China and other South Asian countries together contribute nearly 50% of the total food waste generated in the world. Food waste generated from these regions typically contains fruits and vegetables-35-50%, meat-20 %, fish and sea food-30 % and dairy products-20% (FAO, 2009). Fresh vegetables, salad and fruits dominated in the food waste generated at Turkey (70%), Asia (45-50%), USA (43%) and UK (36%). Dairy and egg waste are majorly found in Netherlands (33%) and bakery waste in Austria (20%).

2. Biogas Production Scenario in India

Anaerobic digestion is a biological conversion process without an external electron acceptor, such as oxygen, nitrate and sulfate. Anaerobic digestion process is known as the most feasible technology for treating organic waste including food waste. It has also been extensively used in China and India to recover bioenergy from farm yard waste, such as manure. Biogas produced from anaerobic digestion can be used for heating, cooking and lighting applications. In 2014-15, about 20,700 lakh cubic meters of biogas is produced in our country, which is equivalent to only 5% of the total LPG consumption in the country. A total of 4194 single phase biogas plants were established during this period in 8 different states. When these biogas plants were inspected, unfortunately around 4.5% of them were non-functional. One of the main reasons could be using old technology that could have led to construction & maintenance defects.

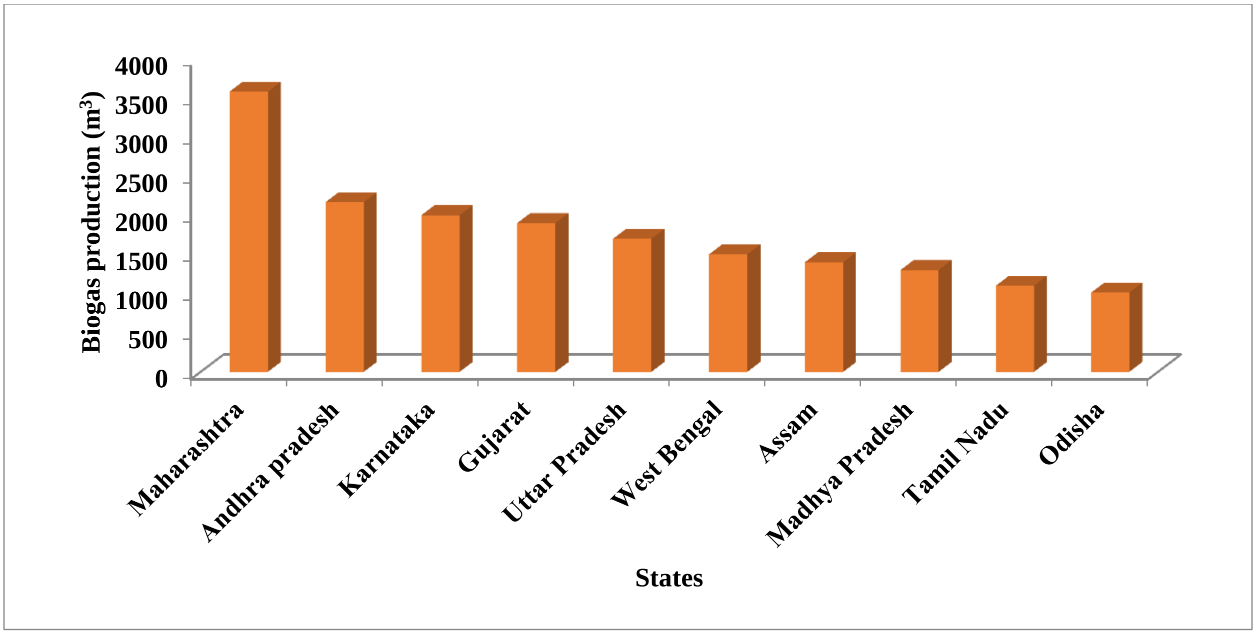

Figure 1: Production of biogas in 2014-15 from various states in India

3. Two Stage Anaerobic Digestion Process and Biogas Production

Two phase anaerobic digestion technology would be a probable solution to this problem. In this process, acidogenic and methanogenic phases which were physically separated were demonstrated to have increased stability, operational flexibility and increased processing rate of the substrate. However, considering the operational complexities with additional module, the increase in methane yield was not significantly high when compared to the single-phase reactors implying that the full advantages of this system has not been revealed (Lehtomaki et al., 2008; Selvam et al., 2010; Nizami et al., 2011; Yu et al., 2012). Modernization of two-phase anaerobic digestion process is necessary to address this issue.

3.1. Problems Associated with Two Stage Anaerobic Digestion Process

In two phase system, after grinding, food waste is added in open pretreatment chamber to enable hydrolysis, acidogenesis and acetogenesis. Then the partially digested food waste is fed into the methanogenic chamber for methane production. But the methane yield in two phase system at mesophilic condition is quite less than other studies reported in the literature (0.4-0.52) m^3/kgVS at thermophilic condition (Liu et al., 2009; Kobayashi et al., 2012; Banks et al., 2012). The mass balance analysis on two phase anaerobic digestion system indicates that only 52% of soluble product contributes towards methane production. This is equivalent to 79% of 1g TOC. According to literature, more than 40% of energy is generally lost in form CO_2 or H_2 during two step processes. Acidogenic off gases (CO_2 and H_2) are directly escaping into the atmosphere, leading to "C" emission as well as energy loss. Based on a carbon mass balance analysis from previous studies of food waste in a two-phase anaerobic digestion process, ~ 28% of the solids are left undigested, 20% of the carbon in digested volatile solids (VS) is lost from the acidogenic phase as CO_2 (Selvam et al., 2010; Xu et al., 2011, 2012).

3.2. Key Solution to Store Energy During Two Stage Anaerobic Digestion Process

There are two possibilities for CO_2 reduction in the methanogenic chamber. One pathway is the homoacetogens-mediated acetate production (eq 1) (Nie et al., 2007; 2008). Alternatively, the CO_2 and H_2 can directly be reduced to CH_4 by hydrogenotrophic methanogens (eq. 2), which play significant role in the methanogenic reactors.

$4\ H_2 + 2CO_2 \rightarrow\ CH_3COO- + H+ + 2\ H_2O\ \Delta G0= -95$ kJ/mole………(Eq 1)
$4H_2 + CO_2 \rightarrow CH_4 + 2H_2O \quad \Delta G^0= -131$ kJ/mole…….Eq (2)

As Schievano et al. (2012) reported, the use of an H_2 producing acidogenic stage may alter the acidogenic leachate quality that influences the overall efficiency of the AD process. In the diphasic anaerobic digestion (LBR-UASB) study done by Xu et al., (2011, 2012), they diverted the off-gas from the LBR to the methanogenic UASB reactor. Results revealed that this process design (1) increased the digestion of solids in the LBR by 15.4%, (2) increased the overall methane production by 26% as well as increased the methane yield to 0.39 L CH4/g COD removed against 0.33 L CH_4/g COD removed in the control. In another study reported by (Yan et al., 2016) for maximum energy recovery H_2 and CO_2 produced in the acidogenic reactor was fed to the methanogenic reactor which increased the energy production by 30%. They observed head space H_2 partial pressure affected the soluble product speciation and pH in LBR (hydrolysis and acidogenic chamber). Continuous mode of LBR operation enables to obtain a regular feed stock and increases the methane yield (Xu et al., 2012). *p*H and VFA distribution greatly influences the methane production and energy recovery in anaerobic digestion system. Rapid acid production during the initial stage of the acidogenesis increases the production of ethanol (Karthikeyan et al., 2011; Xu and Wong, 2011). A proper volatile fatty acid distribution (acetate to butyrate ratio and acetate to propionate ratio) is necessary for higher methane production (Karthikeyan et al., 2016). A high concentration of VFAs has been reported to inhibit methane production from VFAs by mixed anaerobic microorganisms too (Siegert and Banks, 2005; Wang et al., 2005). The key factors affecting the metabolic pathways and leachate quality are low pH, acid accumulation and headspace H_2 concentration in acidogenic reactors. In the two-phase setup, the quality of acidogenic leachate would significantly influence the methane production in the methanogenic chamber. In a steady state, the microbes could adapt to the condition and in the long run, the H2 production in the acidogenic chamber could be increased.

4. Conclusion

Targeting probable cause of less methane yield in the biogas plant can be explained with following reasons. First, residual organic matter after hydrolysis/acidogenesis is quite high and partially digested matter sent to methanogenic tank, implying that the hydrolysis process needs to be improved. Secondly, energy loss from hydrolysis/acidogenic chamber should be minimized. The generated Lactic acid shows very low *p*H (around 3.3 to 3.8) should be inhibited and using buffering agents. Continuous details study is required for identifying the route of increased methane production using acidogenic gas transfer and investigating the factors affecting the leachate quality and dynamics of fatty acids in hydrolysis/acidogenicand methanogenic reactor. Finally a kinetic model is required for operating the hydrolysis/acidogenesis in a continuous mode for higher energy recovery from food waste using two stage approaches.

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