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BIOGAS PRODUCTION FROM RENEWABLE LIGNOCELLULOSIC BIOMASS

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Abstract

Effect of raw and biologically treated lignocellulosic biomass using cow dung slurry for biogas production is reported. Biomass is an energy source. Water containing biomass such as sewage sludge, cow dung slurry and lignocellulosic waste, has several important advantages and one of the key feature is renewability. Cow dung slurry has the potential to produce large amounts of biogas. Four categories of bacteria viz., hydrolytic, fermentative, fermentative acidogenic and acidogenic-methanogenic bacteria are involved in the production of biogas. The different characteristics of the cow dung slurry were determined according to standard methods. Hemicellulose, cellulose and lignin content of the lignocellulosic waste were also determined in our earlier studies. The substrates were digested under anaerobic condition for 5 days. The total biogas and methane produced during anaerobic digestion were estimated on 5^{th} day. The total biogas produced during digestion was estimated by water displacement method. Biological methane production was estimated by using Saccharometer.

Key words: Cow dung slurry, lignocellulosic biomass, anaerobic digestion, bio-gas.

Introduction

Energy affects all aspects of modern life. Energy is one of the vital inputs to the socioeconomic development of any country. The demand of energy is increasing at an exponential rate due to the exponential growth of world population. The objective of an energy system is to deliver to consumers the benefits that energy use offers, including illumination, cooked food, comfortable indoor temperatures, refrigeration, telecommunications, education and transportation (UNDP, 2004).

India's economy is primarily based on agricultural production and a variety of agro-wastes are produced in large volumes [REIDIT, 2008)]. It was reported that the annual yields of groundnut shell (GNS), corn husk (CH) and rice husk (RH) are 1.65, 1.67 and 28.2 million tons, respectively [http://www.hedon.info/AgriculturalResidues.]. Only a small quantity of these was used to make paper or feedstuffs for livestock, the rest are mostly burnt or discarded causing environmental pollution. Biomass has been recognized as a potential source for the renewable energy to substitute the declining fossil fuel resources. The majority of biomass energy is produced from wood and wood wastes (64%), followed by municipal solid waste (24%), agricultural waste (5%) and landfill gases (5%). Most biomass consists of hemicelluloses, cellulose, lignin and minor amounts of other organics. Lignocellulosic biomass (LB) is most abundant renewable biological resource. LB constitutes a major portion of agricultural and forest wastes and industrial effluents. Pretreatment of LB includes hydrolysis of cellulosic materials to reducing sugars. Pretreatment aims to get rid of lignin, hemicelluloses, reduce crystallinity of cellulose and increase surface area of materials to improve formation of sugars. Advantages of biological pre-treatment include inexpensive, low energy requirement and mild environmental conditions.

Anaerobic digestion occurs in the absence of air and is typically carried out for a few weeks. Anaerobic digestion of organic substrates to produce methane and carbon dioxide has been a well-developed biological treatment for waste water and waste. Biogas production achieved by methanogenic pathway by anaerobic digestion of bacteria has caught the attention of researchers due to its dual function of generating biogas and decontaminating organic pollutants in the environment.

Biogas is an environment friendly, clean, cheap and versatile gaseous fuel. It is mainly a mixture of methane and carbon dioxide obtained by anaerobic digestion of biomass, sewage sludge, animal wastes, and industrial effluents. Methane and carbon dioxide make up around 90%of the gas volume produced, both of which are greenhouse gases. Hence the capture and fuel use of biogas is beneficial in two ways: (a) fuel value, and (b) conversion of methane in to carbon dioxide, a plant-recyclable carbon.

Materials and Methods

Source of Inoculum:

Biogas producing cowdung slurry (CDS) was collected from the suburb of Coimbatore city, Tamilnadu, India. The lignocellulosic biomass (LB) such as sweet sorghum stover (SSS), paddy straw (PS) and groundnut shell (GNS) which were used in our earlier studies (Gnanambal et al., 2014) were used. The different characteristics of the cow dung slurry were analyzed.

Experimental procedure

Fermentation experiments were performed according to Fan *etal*.,2003, in 250ml serum glass bottles consisting of cow dung slurry (15%)-15ml,5 g of raw and pre-treated crop residues, and15ml of nutrient stock solution (prepared using following (in g/ L) NH_4Cl – 0.5, KH_2PO_4 – 0.25, K_2HPO_4 – 0.25,$MgCl_2.6H_2O$ – 0.3, $FeCl_3$ – 0.025, $NiSO_4$ – 0.016, $CoCl_2$ – 0.025,$ZnCl_2$ – 0.0115, $CuCl_2$ – 0.0105, $CaCl_2$ – 0.005 and $MnCl_2$ – 0.015) which was slightly modified from Lay et al., 1999. The final working volume was made up to 100ml with distilled water. These flasks were deoxygenated with nitrogen gas for the development of anaerobic environment. These flasks were incubated at 37± 1°C in an orbital shaker with a rotation speed of 100rpm to provide better mixing of the substrates. The experiment was kept under anaerobic condition for 5 days. All the experiments were performed in duplicates and the average values are reported.

Chemical analysis

The total biogas produced during digestion was estimated after 5 days by water displacement method. The volume of biogas produced was determined using plastic syringes of 5-10ml. A measuring cylinder filled with water was kept upside down on a water tub. The biogas in the sludge digesting bottle was syringed out through a tube, the end of which was inserted into the measuring cylinder. The volume of water displaced by the entry of the biogas was interpreted as total biogas production (ml).

The total biomethane produced during digestion were estimated after 5 days using a saccharometer (Fig.1). A saccharometer was filled with concentrated (>5%) sodium hydroxide solution. Using a standard 5ml syringe with a long (5cm) needle, the gas sample was withdrawn from the digestion bottles and carefully injected into the saccharometer in such a way that the gas should move towards graduated arm of the glass tube. The displaced volume represented the volume of biogas minus $Co_2$and H_2S, which is pure methane.

Results and discussion

In this study, pretreated substrates resulted in an increase in methane yield and a decrease in the time required for digestion. All the substrates were co-digested with cow dung slurry (CDS). The main effects that pretreatment have on different substrates can be identified as particle-size reduction, solubilisation, biodegradability, enhancement, and loss of organic material. Particle – size reduction has been the most commonly used factor to describe the increase in substrate surface area resulting from pretreatment of biomass (Hendriks et al., 2009, Bougrier et al., 2006and Giuiliano et al., 2013).The biodegradability and the potential biogas production of lignocellulosic materials mainly depend on their content of cellulose, hemicelluose and lignin. The white-rot fungus easily degraded cellulose, hemicelluloses and to remove the content of lignin, reducing the crystalline structure of cellulose and increasing the porosity of the materials and the surface area available to the attack of microorganisms. In our earlier studies (Gnanambal *et al.*, 2014), the lignocellulosic biomass was fermented using *Pleurotus florida* by solid state fermentation and the biochemical constituents of the lignocellulosic biomass was determined. Lay et al., 2012, reported that the nutrient addition could enhance the total biogas production. The appropriate balance of nutrients is very important for the anaerobic digestion of rice straw. The advantage of co-digestion with animal manure is that optimum C:N ratios are established without adding chemicals and higher methane yields are the result (Wilkie etal.,1986;Demirel and Scherer,2011;Zhang etal.,2011). When rice straw was co-digested with dairy manure, the most efficient methane production per unit COD destroyed occurred when the non-lignin carbon to nitrogen (as TKN) ratio was between 20 and 30 (Gadre et al., 1990).

Comparing all the three raw and biologically pretreated lignocellulosic substrates, pretreated paddy straw produced maximum methane content (68%) and pretreated sweet sorghum stover produced maximum biogas content (340ml) on 5^{th} day of anaerobic digestion (Table 1).

Table 1: Comparative biogas and methane yield on lignocellulosic biomass

S.No	Lignocellulosic biomass	Biogas (ml)	Methane yield (%)
1	Paddy Straw treated	240	**68**
2	Paddy Straw raw	180	62
3	Sweet Sorghum treated	**340**	66
4	Sweet Sorghum raw	240	60
5	Groundnut shell treated	200	64
6	Groundnut shell raw	180	60

Pretreated paddy straw substrate resulted in higher methane content since it is a substrate mostly composed of easily-degradable sugars, which appears to achieve its biogas potential in 5 days. In this study, the CDS might have provided nutrients for the growth of biogas producing organisms. Micronutrients such as minerals and vitamins have been reported to be important for the growth and metabolic activity of methane producing bacteria and could possibly have been present in the CDS. The most important parameters for characterizing cow dung slurries are total solids content (TS) and volatile solids content (VS).Chemical analysis showed that CDS consists of appropriate amounts of total solids (1.8%) and volatile solids (1.4%) for biogas production (results not shown). Presence of pretreated SSS in anaerobic digestion, supported better production of biogas compared to PS and GNS. These results suggest that pretreated SSS is playing the vital role in the biogas production. In view of the variation in biogas and methane yield with different substrates and its production by fermentation is associated with availability of carbon source (Mangnusson et al., 2008, Zhang et al., 2007, Fan et al., 2003). It was noticed that more soluble sugars released to fermentation medium by the SSS was observed compared to GNS and PS denoting the higher biogas yield. The experiment also reveals that there is only negligible change (4-6%) in the methane yield when the substrates were biologically pretreated. This variation of biogas and methane yields under similar fermentation conditions but with different substrates suggested the importance of substrate composition on methane yield. Fig.1 and Fig.2 depicts the graphical representation of biogas production and methane yield from lignocellulosic biomass.

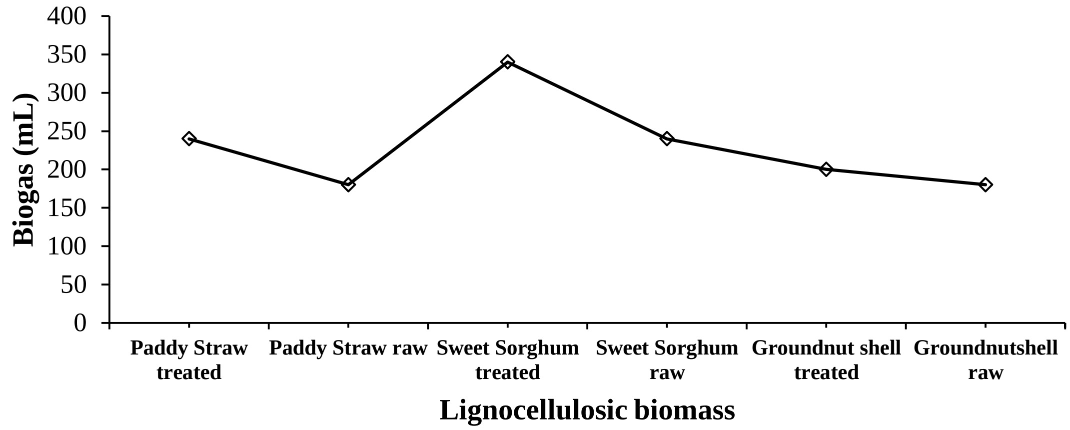

Fig.1. Biogas production from lignocellulosic biomass

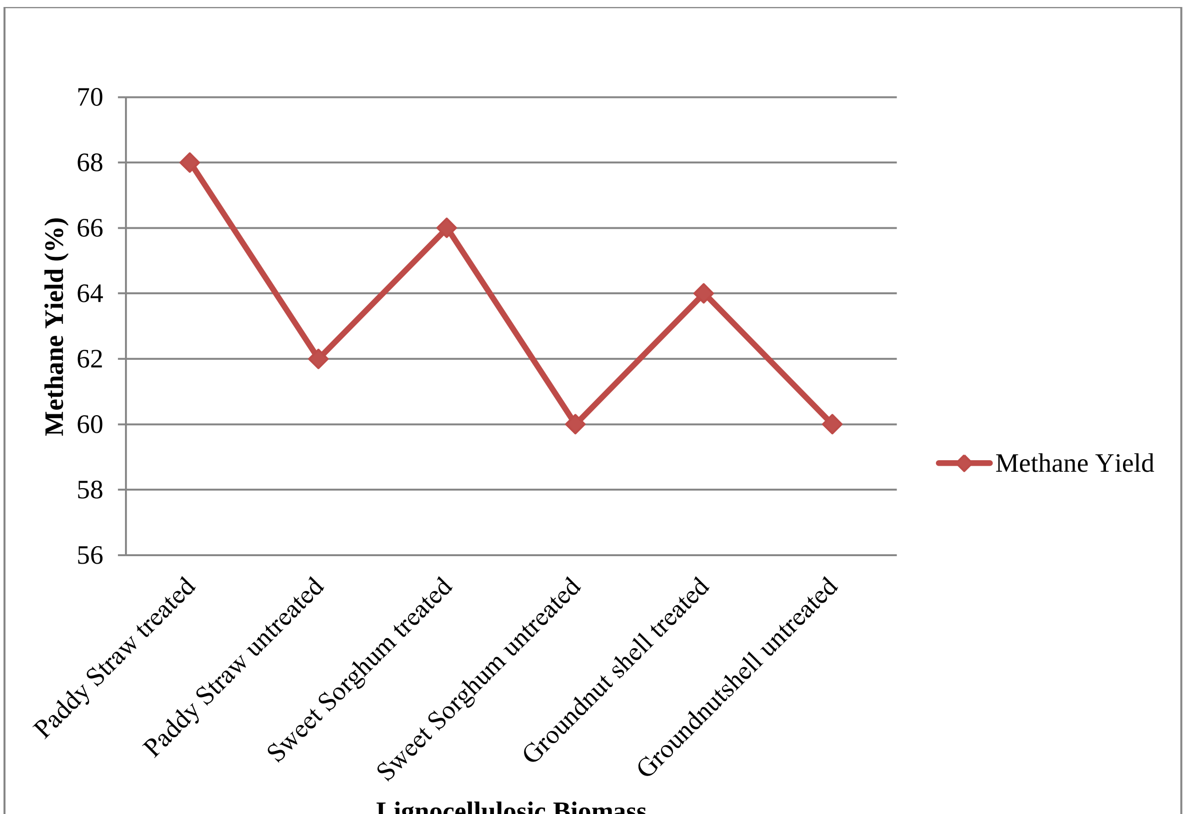

Fig.2:Methane Yield from Lignocellulosic Biomass

Conclusion

Overall, the present study emphasizes the role of each substrate material for production of biogas and methane yield using natural LB such as PS, SSS, GNS and cow dung slurry as inoculum. Among all the three substrates, PS and SSS presence is essential and GNS is the least important component for maximizing biogas production among selected substrates. Further work is in progress with respect to mono and codigestion of mixed substrates with CDS as inoculum and their potency evaluation for biogas and methane production at individual level and mixed level.

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