Effect of co-digestion on biogas production using poultry litter as feedstock

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Abstract: The demand for energy has been promptly increasing due to rapid growing world population and increased growth of industries. In the pursuit of renewable energy production, the anaerobic digestion of organic wastes was a proved technology that is shaping up to be the one of the reliable source of alternate energy. Even though the anaerobic digestion is an effective method of renewable energy production there are few factors that inhibit biogas production using poultry litter as a feedstock. Among the various factors the low carbon nitrogen ratio of the poultry litter is the important factor. The C/N of the feed can be increased by co-digestion with the carbon rich biomass feedstock. In this research the inhibiting factors of anaerobic digestion can be eliminated through the co-digestion of the poultry litter with water hyacinth in the batch type digesters. Initial samples placed within two batch type reactors. Namely, pure poultry droppings, poultry droppings and water hyacinth in a 1:0.25 ratio. Batch type production of these samples at mesophilic conditions of 30 – 40 °C and a pH of 6.8-7.2 a constant increase of 15% in biogas production by co-digestion. The carbon nitrogen ratio of the poultry litter can be increased by the addition of water hyacinth which provides ample atmosphere for the anaerobic microorganisms. Through this research we can ensure that the biogas production can be enhanced by co-digestion of the feedstock. By adopting the biogas technology the rural population can be self-sufficient when it comes to energy generation and usage.

Keywords— co-digestion, water hyacinth, C/N ratio, ammonia formation, ammonia nitrogen

1. INTRODUCTION

Energy plays a vital role in the modern world where every process gyrates around the energy production and consumption. The energy we are using currently is mainly obtained from the fast depleting fossil fuels. The usage of fossil fuels also causes a number of environmental issues due to the emission of harmful gases while combustion[1]. This induces the quest for the alternate sources of energy which is basically a green energy. Biogas provides a clean and alternate source of energy for the rural people of India. The biogas technology provides energy in the form of methane which is a combustible gas and the digested slurry can be used as a manure[2]. Biogas technology is an effective method of renewable energy generation, still there are a number of factors that affects the biodegradation process. The factors that affects the anaerobic digestion of poultry wastes are low C/N, hydraulic retention time (HRT), temperature, pH, volatile solids concentration, total solids and type of digester used[3]. Among the various factors affecting the biogas generation, the low C/N of the poultry wastes is of serious concern[4][5]. This is because of the formation of ammonia inside the digester during digestion. The higher concentration of nitrogen in the digester gets converted into ammonia during biogas digestion[6]. The conversion of nitrogen into digester is directly proportional to the pH of the feed[7][8]. The chickens are feed with huge amount of protein rich foods for their prompt growth[9]. The protein in the feed gets converted into nitrogen in their droppings. The excessive ammonia concentration have to be reduced before loading the slurry in to the biogas digester. The optimum value of carbon nitrogen C/N ratio in the digester for the anaerobic digestion is 25-30:1. The proper composition of feedstock should be maintained for efficient operation of the plant, so the C: N ratio will be at desired range in the feed[10]. During anaerobic digestion, it is found that microorganisms utilize carbon 25–30 times faster than nitrogen. As the microorganisms utilize carbon fastly, we need to maintain the C: N ratio of 20-30:1 for a better operation to takes place. Moisture and C/N ratio have amajor influence on a successful digestion process. High moisture content, of more than 75%, inhibits a quick start to the digestion process. According to Desai et al., the combination of whey and poultry manure had been found to be capable of maintaining the proper C/N ratio in the reactor. It has been shown that the digestion of the mixture of these wastes was...
more efficient in producing methane than of each material individually. To attain a desired range of C: N ratio of 30:1, Waste material that is low in C can be combined with materials high in N the C: N ratio will vary accordingly[11].

The C/N in the anaerobic digestion of poultry wastes is only in the range of 6-8:1[12]. There are number of techniques to increase the C/N of the feed thereby increasing the biogas yield and reducing the ammonia concentration in the slurry. The C/N of the poultry waste can be increased by changing the operational parameters, addition of additives, co-digestion of poultry waste with carbonaceous feeds, dilution of the digester feed and by using ammonia stripping techniques[12][13][14].

The co-digestion of water hyacinth with poultry wastes is the cost effective method to increase the C/N ratio and also to enhance the biogas yield[15]. The purpose of this study is to enhance the biogas yield by co-digesting water hyacinth with poultry litter and to study the effect of C/N ratio and pH on the biogas yield.

2. BIOMETHANATION

The process of conversion of organic matters into biogas in the absence of oxygen is called as anaerobic digestion. The process is carried out by action of various groups of anaerobic bacteria in the oxygen free condition[1][16]. The process occurs in an anaerobic environment through the activities of acid and methane forming bacteria that breakdown the organic matter and produce methane (CH₄) and carbon di oxide (CO₂) in a gaseous form.

ORGANIC MATTER + H₂O→CH₄ + CO₂ +H₂S

Four basic types of bacteria are involved in the production of biogas from the feedstock. They are, Hydrolytic bacteria, which will break down complex organic waste into simple organic compounds sugar and amino acids. Fermentative bacteria then convert those products into organic acids. Acidogenic bacteria convert the acids into hydrogen, carbon dioxide and acetate. The Methanogenic bacteria produce biogas from acetate acid, hydrogen and carbon di oxide. The production of biogas from the organic matter involves four processes, namely[17][18]

- Hydrolysis
- Acidogenesis
- Acetogenesis
- Methanogenesis

2.1 Hydrolysis

Hydrolysis usually means the breakdown of chemical bonds by the addition of water, where a carbohydrate is broken into its component sugar molecules by hydrolysis. Generally, hydrolysis is a step in the degradation of a substance. During the hydrolysis or liquefaction stage, the complex organic wastes (proteins, lipids and carbohydrates) are broken down into smaller compounds[19].

Carbohydrates → sugars

2.2 Acidogenesis

A biological reaction where simple monomers are converted into volatile fatty acids. Volatile organic compounds are the intermediate product generated by methanogenic bacteria during the transformation of manure into biogas (Hanreich et al, 2011)[20].

Sugars → volatile fatty acids

2.3 Acetogenesis

A biological reaction where volatile fatty acids are converted into acetic acid, carbon dioxide, and hydrogen. The acetogenic stage involves conversion of hydrolytic by products into simple organic acids, carbon dioxide and hydrogen. Simple organic acids include Acetic acid and propionic acid (Ferry, 1997).

Volatile fatty acids → CH₃COOH + CO₂ + H₂

2.4 Methanogenesis

A biological reaction where acetates are converted into methane and carbon dioxide, while hydrogen is consumed. The methanogenic stage involves conversion of simple organic acids into inorganic gases, primarily methane and carbon dioxide (Martin, 2007)[21].

The acids produced are processed by methanogenic bacteria to generate methane, which is described in the following equations (Kossmann et al, 2007).

CH ₃ COOH → CH ₄ + CO₂  
Acetic acid methane carbon dioxide

The various steps involved in the biogas generation is given in the figure 1[22].
3. MATERIALS AND METHODS
The study was carried out in environmental conditions at Coimbatore (latitude of 11.07°N and longitude of 76.98°E) during month of January 2016. The readings were taken in mesophilic conditions using a mercury in the bulb thermometer, PH meter and wet type gas flow meter.

3.1 Sample collection
Poultry litter was collected from a brooder house in Coimbatore. Water hyacinth plants were taken from Singanallur Lake, Coimbatore. They were cleaned for the removal of mud and other matters associated with it.

3.2 Digester design
The digester was designed in order to accommodate the biogas generated and the slurry in a leak proof manner. The fixed dome digester was selected because of its ease in the construction and its ease in the gas storing. Digester was fabricated by implementing the piping methods, using Polyethylene Terephthalate (PET) cans and PVC pipes. The digester was fitted with a drain pipe to take the feed for PH analysis during every day operation. The upper portion of the PET are attached with the shut off valve (ball valve) for the ease of opening and closing. The shut off valve was piped in a way to attach with the gas flow meters. The shut off valve is then followed by a gas valve to control the gas flow rate while measuring. The digester was treated with the cow dung before the addition of feeds, this increases the accumulation of fermentive bacteria.

3.3 Preparation of feedstock
The poultry droppings are collected from the poultry farm and the wastes are cleaned by removing impurities such as feather, mud and stones etc. The organic waste are dried and then it was powdered for the fit to the proximate analysis. The wastes are then measured for the condition of its alkalinity or acidity by using pH meter. The optimized level of pH was attained by using the NaOH solution to the slurry or by mixing it with the acetic acid[23][24][25]. The organic waste are inspected for its quality of feeding it with the digester. The batch 1 contains pure chicken droppings, batch 2 contains poultry droppings with 25% of water hyacinth mixed with the water in the ratio of 1:1 respectively. The slurry was mixed in such a way to create a homogenous mixture and the pH of the slurries are noted down. The homogeneous mixture of about 8 litres was filled in the digester by the use of measuring jar.

3.4 Analytical methods
The slurry in the digester was measured for its acidity or alkalinity by using the digital pH meter at a regular day interval. The gas generated was
passed in the silica gel for the removal of CO$_2$ and then it was passed to the metal chips for the removal of hydrogen sulphide. The scrubbed gas was flowed into the wet type gas flow meters for measuring the biogas production. The temperature of the gas noted with the aid of the thermometer. The gas generated was stored using the football bladders.

4. RESULTS AND DISCUSSIONS

The gas generated was measured using a wet type gas flow meter for a retention time of 14 days. The variation in Ph the retention period was noted. The digester was exposed to the atmosphere in order to get utilized the surrounding temperature and the gas temperature are in the range of 38-42 °C. The gas generation from the poultry droppings is due to the enrichment of nutrition content in it. The carbon content in the slurry produce the energy and the nitrogen content enhances the bacterial growth, in response to this it also creates a bad odour during at the time of fermentation.

4.1 Batch 1 Digestion of Raw poultry litter

From the figure 3, maximum biogas production of 5.15 liters was produced in the 9th day of the digestion process. After the 9th day the gas production starts decreasing at a steady rate. This decrease in the biogas production is mainly due to the formation of ammonia inside the digester during the digestion process.

4.2 Batch 2 Digestion of Poultry litter + 25% Water Hyacinth

From the figure 3 maximum biogas production of 6.45 liters and 6.14 liters was obtained in the 6th and 10th day respectively. The formation of two peaks in the biogas yield is due to the co-digestion of two feeds. The biogas production is high when compared to the biogas production of raw poultry litter. The carbon nitrogen ratio gets enhanced by the addition of water hyacinth.

4.3 Cumulative Biogas yield

From the figure 3, maximum biogas production of 5.15 liters was produced in the 9th day of the digestion process. After the 9th day the gas production starts decreasing at a steady rate. This decrease in the biogas production is mainly due to the formation of ammonia inside the digester during the digestion process.
The biogas production of the co-digested poultry litter exceeds the raw poultry litter from the fifth day of the bio-digestion process. The volume of the biogas generated from the mixture of poultry droppings and water hyacinth was high in 8th day compared with the pure poultry droppings which can be inferred from the fig.5. Maximum biogas production of 6.25 liters was recorded on the 8th day. The enhancement factor is due to the presence of abundant carbon content in the water hyacinth. The carbon to nitrogen content in the slurry were enhanced from 15:1 to 25:1 by the addition of water hyacinth with the poultry droppings. The optimum condition for the effective conversion process is in the range 25:1 to 30:1. About 25% increase in the cumulative biogas production in co-digestion when compared to the digestion of raw poultry litter. This is because of the lack of sufficient carbon in the digestion of raw poultry litter and formation of ammonia nitrogen during the digestion process. On the other hand the addition of water hyacinth supplies the required carbon for the successful completion of the anaerobic digestion process. The retention time is high when compared to the digestion of raw poultry litter. 

The PH of the digesters reduces in a steady rate with the increase in the retention time. Maximum biogas production was achieved when the PH of the digester is near to the neutral value. PH is a measure of acidity or alkalinity. Maintenance of the system PH in the proper range is required for efficient anaerobic digestion. The suitable PH value for biogas production ranges between 7.0 and 7.2. Biogas production reduces when the pH value is less than 5 as the bacteria population decrease in acidic conditions. In anaerobic digestion, the amount of carbon dioxide and volatile fatty acids produced will affect the pH of the feed. The Methane production is more than 25% when the pH is above 5.0. A slight pH decrease when co-treating water hyacinth in comparison to processing manure is attributed to the lower alkalinity and ammonium content of water hyacinth, as compared to manure.

5. CONCLUSION

From the results, mixture of poultry droppings and water hyacinth at a ratio of 1:0.25 has a high yield of biogas production and an increase of 15% from the pure poultry droppings was observed at the sixth day. The enhancement of the gas yield was because of attaining the optimum C: N ratio of the feed stock. The excess carbon in the water hyacinth supplies the carbon requirement for the bacteria during the digestion process. The accumulation of ammonia inside the digester while digesting can be greatly reduced by this co-digestion method. In agreement with the previous researches, the maximum biogas production is achieved when the PH is near to the neutral value. This study reveals that the anaerobic digestion was an effective alternating technology to convert the organic wastes into a useful energy which can be used for sustainable development and also for the safe disposal of poultry litter and also poultry wastes.
6. REFERENCES


