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Original article

An experimental approach to produce biogas from semi dried banana leaves

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ABSTRACT

The fallen semi dried banana leaves is selected for biogas production because of its energy potential and availability as agro waste materials in different countries. In this study methane content in the produced biogas from semi dried banana leaves is tested taking different sample quantities(25 g, 50 g, 75 g) and size(2 mm, 6 mm) of leaves. Small amount of urea (2% of biomass w/v) is added to the sludge solution (500 ml) to improve the bacterial activity in the anaerobic digestion process. The results indicate that with the decrease in sample size from 6 mm to 2 mm the methane production is increased. Maximum methane yield is found to be 65.28% in the produced biogas with a calorific value of 23.61 MJ N m^{-3} for 50 g sample of 2 mm size using same amount of urea and sludge solution.

Introduction

Energy is the backbone for the growth of any country. Currently the world is facing energy crisis problem due to the immense use of the non renewable energy sources to coadjute the civilization. Continuous efforts are made to boost the renewable energy sources available on the planet to extricate the energy crisis problem. Biomass which is readily available everywhere, is the primary source to produce energy through direct burning. Due to its low sulphur and nitrogen content, it reduces the emission of pollutant gases like NO_x, SO_2 etc. during its combustion. Energy generation practices from biomass are of two types: thermo chemical process (direct combustion, pyrolysis, gasification and liquefaction), and bio- chemical process (fermentation and anaerobic digestion). Due to moisture content and conversion process net heat loss in direct combustion and gasification is 20% and 30% respectively of the gross heat content [1]. Biomass with high moisture content will be suitable for energy generation by biological conversion process [2]. Anaerobic digestion is the most suitable process to produce biogas from biomass by microorganisms in the absence of oxygen leading to a renewable form of energy that can be considered as the better substitute of fossil fuels. In anaerobic digestion, there are four basic processes involved in the biomass production. Initially, the organic matters undergo hydrolysis process by enzymes to convert polymers into monomers. Later the organic matter and the products of hydrolysis are converted to various products like organic acids, alcohols, hydrogen and carbon dioxide by acetogens. Hereafter, this same bacteria converts the products of its previous activity into acetic acid, hydrogen and carbon dioxide.

Finally, methane production occurs by the methanogen bacteria using those acetogen products. The slurry, which is the by product of the digestion can also be used as a bio-fertilizer or soil conditioner. The main benefits of this process is the production of biogas (mainly methane), which can be utilised for electricity production, cooking, steam generation, heating even in rural areas also [3,4]. Sorathia et al. studied about biogas production and various factors which affect production rate. They found that biogas can be the cheapest alternative of fossil fuel, while increase in pH content and temperature decreases the production rate of anaerobic digestion [5]. Chen et al. investigated the major challenges of biogas reactor. They found that methane forming stage is the most sensitive one which is influenced by the pH content, temperature and the total solid content of the reactor [6]. Meabe et al. studied the anaerobic reactor performance by mesophilic and thermophilic process. They found that the high temperature and pH decreased the biogas production by realizing more fatty acids [7]. Siegrist et al. found that acetotrophic methanogenesis biodegradation decreased in pH below 6.2, while for pH value above 7.4 it shows the same negative effect due to the accumulation of free ammonia

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[8]. Zhou et al. studied the effect of pH variation (6–8) upon bacterial growth in bio-digestion process. They found pH 7 was the most favourable condition for biogas production by majority of methanocorpusculum bacteria among the various methanogens [9]. Lin et al. observed the daily methane production and total biogas production increased gradually up to 500 C [10]. Crocamo et al. studied the anaerobic digestion of Vetiveria Zizanoides, a very rapidly growing grass, the amount of biogas produced from it is not negligible and the cost of production is also low without pretreatment process [11]. Kokar et al. studied about the solar heated biogas plant and found that most of the biogas reactors are maintained in mesophilic temperature range (25–400 C) due to its higher stability and lower energy requirement [12]. Liu and Ge successively implemented the effect of urea addition in anaerobic digestion process to increase the nitrogen content. They observed, with addition of 2% urea (W/V) the giant reed, one type of grass that grows in damp soils, yields 18% higher methane than the fresh giant yield with the production of ethanol during the ensilage process [13]. Gopinath et al. studied the effect of urea addition in pineapple pulp waste which yields 19% more biogas than the usual. They also added various metal ions to enhancing its performance [14].Feng et al. studied the effect of trace element addition in anaerobic digestion. They found that with addition of trace elements like Co, Ni biogas production increased [15]. Abdelsalam et al. investigated the effect of nano-particle addition in biodigestion process. They concluded that nano-particles decreases the lag phase which increases biogas production [16].

The present problem pertains to rampant tree felling in India to provide a solution to the day-to-day cooking problem for the mass addressing to the environmental pollution. While the wood from the tree is used for cooking, the leaves concerned are actually left behind to be decomposed naturally. Utilisation of these unused vegetable wastes is one of the main concerns of the Indian government. The remarkable expansion of global biofuel production from renewable sources in recent years stems mainly from the fluctuation in the price of fossil fuels and its bad environmental consequences. India's assorted climate facilitates the production of various types of fruits and vegetables. It ranks second in the world's fruit and vegetable production after China. In India, the wastes from these products are generated in large quantities which make the atmosphere unhealthy. These wastes constitute around 5.6 Million tonnes annually [17]. Agro industrial wastes are increasingly being used as a biomass, for generating energy. With an annual production of 265 lakh tonnes, banana is the most cultivated fruit of India. Banana trees are also richly available all over India. But in banana cultures vast quantities of wastes including the skin, pseudo stem and stalk are generated, around 100 kg of fruits, 160 kg of stalks, 480 kg leaves and 440 kg of skins. These wastes are spread over the fields and left to decompose naturally [18]. Previously research was going on various parts of banana tree to produce biogas. Kalia and Sonakya produced relatively higher methane at mesophilic condition of 35 °C using sundried banana stems and fresh cattle dung slurry [19]. Similarly Bardiya et al. found increase in methane production with 58% of substrate utilisation by using chopped banana peel and pineapple waste with cattle dung slurry [20]. Kamdem et al. experimented on production of biogas from each of the morphological part of the banana tree in 50 ml of culture volume of each sample, with an initial pH of 7.3. They found that leaf blades produced less biogas than other samples, while biogas produced from leaf blades are richest in methane (78%) [21]. Van Dyk et al. studied the bioconversion of different liganoicellulosic substrate using enzymatic hydrolysis. They found that due to the low density of liganocellulosic waste they require some pre-treatment before digestion [22]. Liao et al. investigated the biogas production from low organic content sludge and found the sludge having organic content less than 50% decreased the biogas production to 25–30% [23]. Wang et al. studied the biogas production of corn stover by using pyrolysis process. With the help of fluidised bed pyrolysis reactor, they recorded methane production maximum up to 200.3 ml g^{-1} of total solid [24]. Many researchers developed empirical correlations for predicting the heating values of biomass using proximate and elemental analysis data. Erol et al. have developed 13 correlations to estimate the net heating values (NHV) of biomass samples based on proximate analysis data and total organic matter contents of the biomass on dry basis [25]. Fernandes et al. performed proximate analysis, heating value analysis, liganocellulosic fractions analysis of banana leaves in both dry and wet basis to evaluate the potential of banana leaves for generating energy [18]. Perez- Arevalo et al. developed prediction models to predict the higher heating value (HHV) for different biomasses on wet basis from elemental analysis data [26].

This study successfully investigated the utilisation of waste banana leaves and generation of useful biogas using simple biodegradation process (anaerobic digestion) using sludge water and urea.

Materials and methods

Composition and properties of semi dried and wet banana leaves

Proximate analysis and heating value data of both semi dried and wet banana leaves are shown in Table 1. The proximate analysis shows the volatile matter (VM), ash content, moisture (M) and fixed carbon (FC) of the leaves. In semidried banana leaves, content of volatile matter, ash, moisture and fixed carbon were found to be around 78.8, 8.7, 8.3 and 12.5% respectively with a heating value of 19.8 MJ kg^{-1}. Similarly in wet leaves the values were around 41.3, 12.2, 74.7 and 46.5% respectively with a heating value 5.5 MJ kg^{-1} [18]. Net heating value (NHV) can also be predicted using proximate analysis results and organic matter (OM) content in correlation (1) developed be Erol et al. in dry basis with regression coefficient 0.898, standard deviation 0.4876 and average absolute error (%) 1.7097 [25]. The OM is obtained by subtracting the ash content from 100%.

$$\begin{aligned} NHV = {} & -116 - 1.33[\text{Ash}] - 0.005[\text{VM}] + 1.92[\text{VM} + \text{Ash}] \\ & - 0.0227[\text{VM} \times \text{Ash}] - 0.0122[\text{VM}]^2 + 0.0299[\text{Ash}]^2 \\ & + 6133[\text{OM}]^{-1} - 0.82[\text{Ash}]^{-1} \end{aligned} \tag{1}$$

From correlation (1) for semi dried banana leaves the NHV was found to be 18.06 MJ kg^{-1}. Ultimate analysis shows the carbon (C), hydrogen (H), nitrogen (N), sulphur (S) and oxygen (O) content of the leaves which are shown in Table 2. Prediction of HHV of biomass can also be done by using 15 mathematical prediction correlations developed by Perez-Arevalo et al. based on elemental analysis data. Based on their conclusion the most useful and reliable correlation was used here to predict the HHV of banana leaves.

$$HHV = 7946.521 + 5.010[C]^2 \tag{2}$$

From correlation (2) for semi dried and wet banana leaves the HHV was found to be 17.42 MJ kg^{-1} and 9.21 MJ kg^{-1} respectively. Ligno-cellulosic fraction analysis was done by Van Soest and Wine method [27] which indicates the cellulose, hemicellulose and lignin content of the leaves are shown in Table 3.

Collection and pre-treatment of materials

Semidried samples were obtained from the fallen banana leaves. The samples were grinded and sieved to produce different sized particles (2 mm and 6 mm). Sludge solution was collected from nearest municipality waste water treatment plant and sieved