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Biodegradation of rice straw using thermophilic consortium for methane production by biochemical digestion

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Mitigate the ill effect of air pollution in North India due to burning of agriculture stubble biochemical digestion process having potential to control air pollution and biogas production. The aim of this study was to investigate the potential of thermophilic strain on rice straw digestion was carried out in batch reactor under pH 7–8 and temperature 55°C for 24 days. The biogas digester feedstock prepared with carbon to nitrogen ratio maintained as 20:1 with 8% solid content and dry biomass have 66.2% volatile solids. The research paper divided into two parts that includes elemental analysis and proximate analysis of paddy straw performed using CHNS analyzer. It is found that C/N ratio is around 60:1 in paddy straw, while hydrogen:carbon ratio as cellulose feed stock lies between 1:7. Proximate analysis reveals that volatile solid contents 66.20% wt. In the last part of the paper the biogas production discussed and observed that average methane and carbon-dioxide composition in biogas is 53.35% and 46.58%, respectively. The biogas production curve follows the lag, exponential, stationary and death phase as Gompertz model.

Keywords: Biochemical conversion, elemental and proximate analysis, methane, paddy straw.

Introduction

Clearance of paddy straw has been a big hitch for small scale farmer and local government, burning of residual easy option that causes soil erosion and discharge of pollutants. Only a part of residual is being used for composting and animal feed. Rice straw has rich contents of lignocelluloses biomass having a high content of cellulose having combustion energy of 15 kJ/g which when converted to methane, has a combustible energy. So, paddy straw can preserve as a useful substrate for biofuel production and, assist to controlling the environmental pollution caused by its burning and preventing soil degradation.

The mechanisms for enhancement of biogas yield with the help of sodium hydroxides pre-treatment, investigated[1,2]. The effect of process parameters on the untreated straw conversion to biogas with leachate recycling studied[3]. Studied and analysis the effect of co-digested swine faeces with rice straw in a batch single phase anaerobic digester at mesophilic conditions[4]. They performed experimental study on the solid concentration effect on biogas yield (anaerobic digestion) under various temperatures for paddy straw[5]. Biogas yield boost up to 26.2% with the pre-treatment of cariolus versicolor (lingo-cellulolytic fungus) in pre-treatment it reduced the cellulose 19.35%, lignin 19.1% and silica 32.5%[6]. Focused on the co-digestion of natural water, cow dung, rice straw and water hyacinth ratio (2:1:1:1), in batch reactor (5 L) at temperature (31°C), 7.1–7.4 of pH for 52 days resulted 61.47% biogas production[7]. Compared the technological overview of biogas production from biogas from lignocelluloses waste[8]. Worked on rice straw structures degradation by anaerobic digestion for biogas production. However, the efficiency of anaerobic digestion process controlled by kinetics and the operational conditions[9,10]. Observed in the experiment that hemicelluloses and lignin can be resistant to enzymatic action of anaerobic consortium[11,12]. Investigated the several studies focus on pre-treatment and an improvement of the degradation process[5,10,13]. Investigates the effect of chemical pre-treatments and rumen fluid to improve the hydrolysis of rice straw[14,15]. In addition to that biomass Knowledge Portal of India estimated the Punjab has huge potential for bioenergy production and wild consumption of biomass causes the respiratory problems. So the objective of this paper is analyze the technical aspects of anaerobic digestion of paddy straw from waste to clean energy production, and same conducted with association of National Institute of Bioenergy, Punjab in the month November-December 2018.

Materials and methods:

Biomass paddy straw was collected for biogas preparation from local area of Kapurthala. The feedstock such as paddy straw was cut into small pieces of 1 cm for the better yield of biogas and later they were grinded (1 mm size) in order to increase the surface area so that maximum area of the biomass becomes accessible to fermentative microbes in the digester. The biogas digester feedstock prepared with C/N ratio maintained as 20:1 with 8% solid content. The dry biomass was taken 40 g with 66.2% volatile solids. The paddy straw biomass was used in ground form (< 0.25–5.5 mm) and soaked overnight in water, 1:10 ratio. The thermophilic consortium was isolated from soil samples, collected from dump yard and stored at 4°C in refrigerator. The optimum temperature range is 50–55°C. It constitutes hydrolytic, acidogenic, acetogenic and methanogenic bacteria to carry out the anaerobic digestion process efficiently.

CHNS analysis was used to elemental analysis based of carbon, hydrogen, nitrogen and sulfur content of raw rice straw. Total Solids (TS) and total Volatile Solids (VS) for the rice straw were determined using standard techniques. The day to day methane production for each anaerobic digester was recorded using the water displacement method and the corresponding cumulative methane volume was calculated. Methane was analyzed using a gas chromatograph in presence of nitrogen as carrier. Soaking of feedstock for 24 h, was done prior to plant setup, this act as a pre-treatment step. Plant setup at laboratory scale includes three reagent bottles of 1 liter each connected to each other with the help of silicon tubing. The first bottle is known as digester bottle where anaerobic digestion of feedstock takes place under proper conditions (pH 7–8) and temperature (55°C) are maintained for the methanogens to work properly. Second bottle is filled with water up to certain level. The level of water is marked in order to check the displacement of water from second bottle to third empty bottle. The displacement of water takes place as a result of gas pressure. The amount of water displaced from second bottle to third bottle is considered as the amount of gas produced within 24 h. The produced gas is further analyzed by gas chromatography for its composition such as methane, nitrogen, carbon dioxide etc. Plant setup was done for paddy straw and cow dung used as inoculums (10%), with paddy:water ratios, in 1:10 at 55°C. These plants were further checked and analyzed for pH, temperature, and leakage and methane production regularly for 23 days incubation period

Results and discussion

Elemental analysis based on carbon, hydrogen, nitrogen and sulfur content was carried out of raw rice straw in daily basis in the month October-November and the average values of the collected sample of the rice straw are shown in Table 1. Carbon content is highest in the samples than other components and hydrogen lies within very narrow values less than 4.9, content of sulphur is nearly negligible in the average samples.

Table 1. CHNS analysis of raw rice straw (wt% basis)

Carbon (%)	Nitrogen (%)	Hydrogen (%)	Sulfur (%)
35.26	0.51	4.9	0.04

From the CHNS analysis of rice straw, it has been found that rice straw have a high C/N ratios even more than 60. By addition of cow dung and soil the C/N ratio optimized between 20–30 and thermophilic anaerobic operation carried out. It can only be digested in a mixture with manures (cow dung) and dump soil. During the anaerobic process, exothermic reaction takes place, virtue of that temperature increased. An increase C/N ratio is required in order to reduce the risk of ammonia inhibition.

Proximate analysis:

Collected biomasses were undergone for proximate analysis to measure the contents such as volatile solids or organic matter which will be utilized during anaerobic digestion process for biogas production. Standard methods (ASTM) were used for proximate analysis to calculate the Moisture content, Total Solids (TS), Volatile Solids (VS), and Ash content in each biomass as illustrate in Table 2.

Table 2. Proximate analysis of various samples collected for biogas production in % age

Sample	Moisture content (%)	Fixed carbon (%)	Volatile solids (%)	Ash content (%)
Paddy straw	6.70	13.30	66.20	13.8

The moisture content plays a crucial part in the selection of efficient techniques to convert biomass to bioenergy. Biomass resources with higher moisture contents can be converted through bio-chemical processes such as anaerobic digestion for biogas production. The estimated moisture content is in the collected sample of paddy straw in the ranges between about 6–7 wt%. The minor differences in reported values are chiefly due to agriculture residues obtained from different locations, climate differences. In addition, the handling and storage also contributes towards moisture content. The volatile contents of the rice straw samples were determined on dry basis. The moderate value of volatile content was found in the rice straw i.e. 65–70 %wt. The selected biomass samples, rice straw have substantially higher ash content due to higher volatile content in agriculture residual, lies in the range of 13–15% wt.

Production of biogas:

Fig. 1 illustrates the biogas production over a period of four weeks. It can clearly be seen that biogas production was the most dominating in the initial period of incubation. To begin starting period of incubation show similar patterns, and gradually increased from week 1 to 2. However, the rate of biogas production remained significantly higher from 0 to 10775 ml over this time frame. From first week to second week of the experiment, the increase in biogas production at a steady rate, finishing the period at 10150–10775 ml. With the exception of a slight fall in week 3, production of biogas reached a peak in the final week of around 14000 ml.

Biogas production also increased at a steady rate, in the last three to four days finishing the overall rise 600 ml. The biodegradable contents suitable for thermophilic strain used excessively in first two weeks and on later stage inhibitor molecules formation takes place.

Fig. 2 compares the amount of biogas, methane and carbon dioxide production from the paddy straw using anaerobic digestion throughout the process. In the early phase of digestion process CO_2 production is higher than CH_4 quantity. Cumulative CO_2 contents increased sharply reached a peak value of 1301.92 ml, that 58% higher than production of CH_4 in the same period. During this phase the thermophilic consortium lies in lag phase due to lower biochemical reaction temperature, but as reaction proceed the desirable

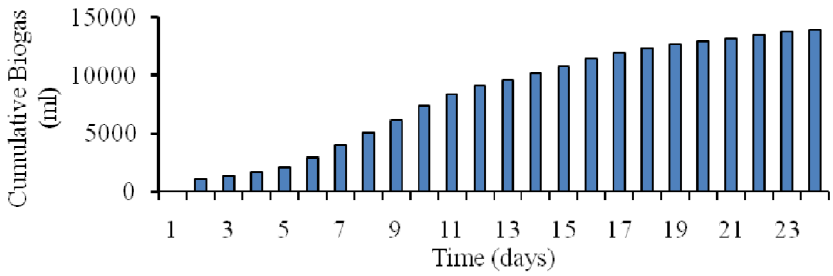

Fig. 1. Cumulative biogas production of all paddy straw used for biogas production.

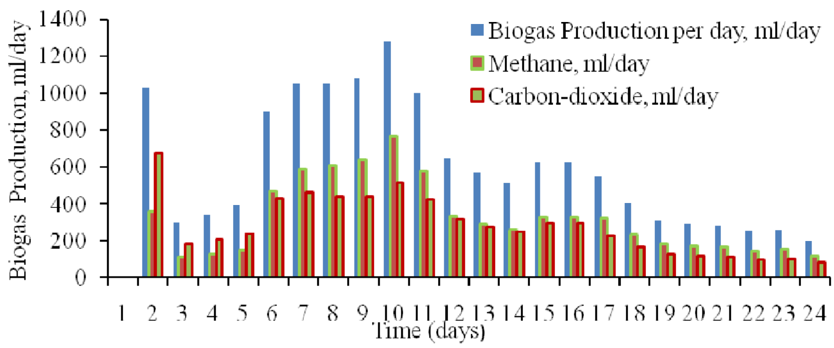

Fig. 2. Production of biogas, methane and carbon dioxide during anaerobic digestion from rice straw.

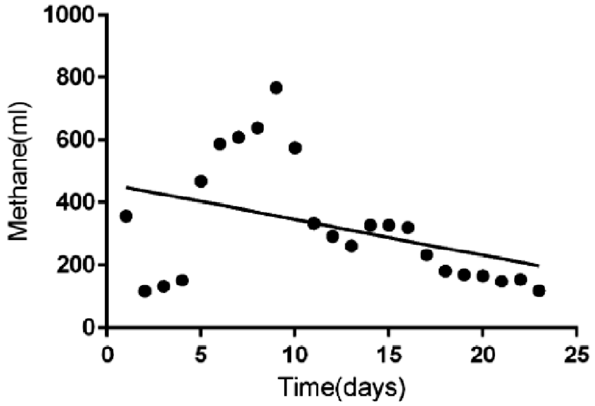

Fig. 3. Linear regression for production of methane during anaerobic digestion from rice straw.

components concentration dominates rest of digestion process. The optimum amount of methane production occurs on 8th and 9th day of digestion. Percentage of CH_4 and CO_2 in biogas varies with the temperature, raw material and biochemical reaction controlled by microorganisms.

The R2 value for linear regression for methane gas production is around 0.6 and P values of statistic are 0.0583 that is highly significant. The optimistic relationship between output and input for linear regression model is Y = – 11.44 x X + 460.6.

Conclusions

CHNS analysis indicates that paddy straw have high content of carbon approximately 35.26% and virtue of higher moisture contents that leads to shoot up volatile matter content. After the day one of incubation the lag phase starts and dominates up to five days. During lag phase regime total biogas collection was 2060 ml/day and CH_4 to CO_2 production ratio 1:2. From 6th day of incubation to 11th day exponential production of biogas, CH_4 and CO_2, but in this region the CH_4 production take over CO_2. 12–16th day of incubation exhibits the behaviour of stationary growth, then proceed to death phase due reduction in biomass. The maximum biogas production takes place on the tenth day of incubation and methane production on the same day was 766.72 ml/day. In anaerobic digestion of paddy straw using thermophilic strain, the total displacement 13940 ml observed. Out of that, CH_4 yield 7436.86 ml and CO_2 6493.74 ml and ratio between methane and carbon dioxide composition observed in biogas was 1.149:1 respectively, and temperature range of 50°C to 54°C to check the tolerance and performance in respect to biogas production with thermophilic consortia. The biogas yield obtained as 0.484 $m^3\ kg^{-1}$ of volatile solid. The production of biogas with respect to time follows the Gompertz semi empirical equation.

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