Plant Science Research 41 (1&2) : 41-43, 2019

Plant Science Research

ISSN 0972-8546

Rice stubble as a potential bio-energy substrate

Preseela Satpathy and Chinmay Pradhan[Ψ]
P. G. Department of Botany
Utkal University Vani Vihar, Bhubaneswar- 751 004, Odisha

ARTICLE INFO

Article history:
Received : 1 December 2019
Revised : 18 December 2019
Accepted : 30 December 2019

Keywords:

Rice straw
Biogas
Anaerobic Digestion Model
Stubble burning
Energy-from-waste

ABSTRACT

Stubble burning has greatly contributed to the rising air pollution and consecutively the health issues in India. The objective of this research was to conduct the bio-methane potential (BMP) assay of rice straw and convert the agricultural crop waste-to-energy (WtE). Batch experiments under anaerobic conditions were performed at 38 °C with rice straw and the inoculum was sourced from an industrial biogas plant. The total biogas production was continuously measured for 15 days with an ANKOM wireless gas production system. The experimental results demonstrated a biogas production of nearly 140 mL/g FM. Considering the thumb rule calculations, approximately 0.5 KWh electricity can be expected from 1 kg of rice straw. Post-digestion, the slurry from the anaerobic reactors where biogas is produced could be further utilized as organic fertilizers, further improving the organic content and quality of soil. The experiments demonstrated the possibility to generate energy from the otherwise discarded and wasted rice stubble as a sustainable alternative. Employing such residue-based biogas plants could not only generate a green energy, but can also provide farmers an incentive from the electricity and organic fertilizers produced and ultimately prevent the practice of stubble burning.

1. Introduction

Rice is the staple food for more than half of the total human population globally. India is the second largest rice producer in the world where an annual production of nearly 13,915 Gg (Giga gram) is reported from Punjab and Haryana alone (Grover and Chaudhry, 2019). Waste is an obvious repercussion of such a huge activity. Rice crop residues rank as the world's third largest agricultural wastes and in India, the rise of mechanical harvesters has significantly contributed in generating increasing crop residues. Mechanical harvesters are undeniably effective and save time and labor. However, a consequence remains that a remarkable portion of the crop residue is left on the fields and numerous studies report that as much as 1.5 kg of stubble is generated per kg or rice harvested (Kumar *et al*., 2015).

When it comes to managing these crop residues after harvest in India, the most widely practiced method till date remains to set the fields on fire. Open-burning remains the cheapest, less labor intensive and fastest method to easily discard and prepare for the next crops. The 'on-farm' burning practice employed to manage these huge volumes of crop residues emits greenhouse gases and adds particulate matter to the ambient air along with destroying the nutrients otherwise present in the crop residues. The soil quality is also damaged due to the heat generated during the burning which affects the soil ecosystem and the microbes (Chakma *et al*., 2016).

The fate of rice crop residues could be altered from being treated as waste to a resource instead. Rice crops with its high organic and carbohydrate content bears a

[Ψ] *Corresponding author; Email:* chinmay.uubot@gmail.com

potential for biogas production. Biogas is a mixture of majorly methane (CH_4) and carbon dioxide (CO_2) produced with the help of microorganisms under anaerobic conditions from several types of organic wastes from agricultural, animal, domestic as well as industrial sources (Manyi *et al*., 2013).Generating biogas could be a cost-effective, carbon neutral process where rice growing farmers could utilize the gas either for cooking or heating purposes or could further convert the calorific-rich methane to generate electricity. The aim of this research remains in determining the bio-methane potential (BMP) of rice straw and evaluate its competence as a source of energy than being discarded or burnt as waste.

2. Materials and methods

2.1. *Substrate*

Rice straw was collected from a farmer nearby in Bhubaneswar, Odisha, India. The air-dried rice straw was chopped with scissors into about 2 cm lengths.

2.2. *Dry Matter (DM) and Volatile Solids (VS) of rice straw and the inoculum*

Known quantities of sample were taken and dried in an oven at 105^{0}C. The volatile solids were quantified by combusting dried samples at 550^{0}C for 4 h (Verein Deutscher Ingenieure 2006). Samples were taken in triplicates and the average values are presented.

2.3. *Experimental Set-up for determination of biogas production from rice straw*

Anaerobic batch reactors were prepared following the guidelines of the German standard VDI 4630 (Verein Deutscher Ingenieure 2006). Borosil glass bottles with 1100 mL volume were fed with 495 mL of inoculum and were mixed with 5 g of rice straw. Reference samples were prepared by considering 5g of distilled water instead of the substrate to determine the biogas produced from the inoculum only. Wireless gas measurement system ANKOM (N1v0, 4RF2; RFS#194) was employed where the readings are transmitted to the computer every minute and the experiments were performed for 15 days. The biogas yield was calculated from the pressure values measured by the ANKOM gas systems based on Avogadro's principle and the experiments were performed in duplicates on a water bath maintained at 38^{0}C.

Table 1

Dry mass (DM) and Organic dry mass (oDM) of rice straw and the inoculum bearing active microbial consortia from an industrial biogas plant considered for batch experiments.

	Dry mass (%)	Organic Dry Mass (%DM)
Rice straw	92.5	85.8
Inoculum	7.2	66.8

3. Results and discussion

Rice straw demonstrated its competence as a suitable substrate for biogas production and as expected, the organic matter was high in the agricultural residue (Table 1).

While the references samples (i.e. pure inoculum without any given substrate) showed a cumulative biogas potential of approximately 210 mL on an average, the batch reactors with rice straw displayed an average production of nearly 894 mL (Fig. 1). A lag phase was evident in the biogas production with the rice straw. This is expected to

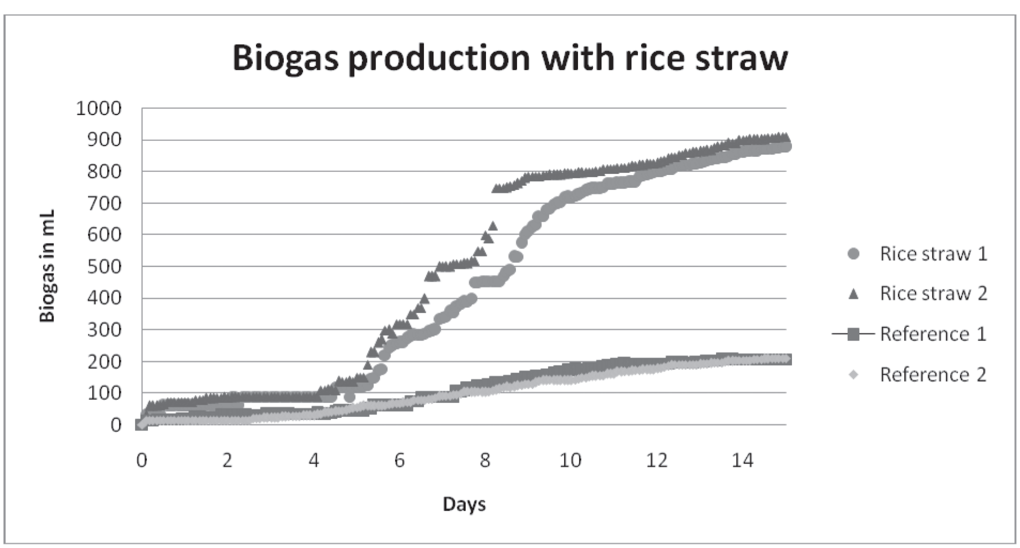

Fig.1. Biogas production with rice straw mixed with inoculum from a biogas plant (in duplicates) in batch reactors. Pure inoculum without substrates was considered as reference (in duplicates).

be due to the high lignin content (ranging between 6.4-19.4%) in rice straw and its complex and recalcitrant lignocellulosic structure containing hemicellulose (32.3-37.1%) and cellulose (25.4-35.5%) which inhibit the first phase during anaerobic digestion i.e. hydrolysis stage after which the anaerobic microorganisms sequentially convert the organic matter to methane and carbon dioxide (Jin and Chen, 2006; Chen *et al.* 2008).

The results attained in the experiments indicate a biogas potential of rice straw to generate roughly 140 mL biogas per gram fresh mass of rice straw. Considering the standard calculations that 1 m^3 biogas could generate nearly 3.2 KWh electricity (Agency for Renewable Resources, 2019), this amount of biogas could roughly correspond to a production of nearly 0.5 KWh of electricity per kg of rice straw. In other words, 1 kg of rice straw could provide electricity to power 1 bulb of 60W for nearly 8 hrs.

Climate change, pollution, energy crisis and food security remain the pressing challenges worldwide for a growing population. Agricultural activities including biomass burning, animal rearing and manure management, fermentation etc. contribute to nearly 50% of the total anthropogenic methane emissions globally.Removing the crop residues from the field and capturing and utilizing the methane instead remain an effective mitigation strategy. Utilization of organic fertilizers from the biogas reactors could improve soil fertility further contributing in maintaining food security (Mussoline, 2013). By considering the eco-friendly, zero-waste generating biogas technology from the rice stubble, farmers in India could end the practice of stubble burning and prevent the aforesaid alarming effects of such practices concerning the health of the population and environment as-well.

Acknowledgements

The authors are grateful to the Dr. Frank Uhlenhut, University of Applied Sciences, Emden, Germany for his guidance. The financial support to the first author from University Grants Commission under Dr. D. S. Kothari Post Doctoral Fellowship is gratefully acknowledged.

References

Agency for Natural Resources (2019). German Federal Ministry of Food and Agriculture. Fachagentur Nachwachsende Rohstoffe e. V. Available at https://international.fnr.de/2019.

Chakma, S., Ranjan, A., Choudhury, H.A. *et al*. (2016). Bioenergy from Rice Crop Residues: Role in Developing Economies.Clean Techn. Environ. Policy 18: 373–394 (doi.org/10.1007/s10098-015-1051-5).

Chen, Y., Cheng, J. and Creamer, K. (2008). Inhibition of anaerobic digestion process: A review. Bioresour. Technol. 99(10): 4044–4064.

Grover, D. and Chaudhry,S.(2019). Ambient air quality changes after stubble burning in rice–wheat system in an agricultural state of India. Environ. Sci. Pollut. Res. 26(20): 20550–20559.

Jin S. and Chen H. (2006). Structural properties and enzymatic hydrolysis of rice straw. Process Biochem. 41: 1261–1264.

Kumar, P. Kumar, S. and Joshi, L.(2015). The extent and management of crop stubble - Socioeconomic and environmental implications of agricultural residue burning: A case study of Punjab, India. Springer Briefs in Environmental Science. Springer India, New Delhi, India, pp. 13–34.

Manyi-Loh, Christy E. *et al*. (2013). Microbial anaerobic digestion (Bio-Digesters) as an approach to the decontamination of animal wastes in pollution control and the generation of renewable energy.Int. J. Environ. Res. Public Health 10(9): 4390–4417.

Mussoline, W. (2013). Enhancing the methane production from untreated rice straw using an anaerobic co-digestion approach with piggery wastewater and pulp and paper mill sludge to optimize energy conversion in farm-scale biogas plants. Earth Sciences. Université Paris-Est, 2013. English. ffNNT :2013PEST1185f

Verein Deutscher Ingenieure (2006). Characterization of the substrate, sampling, collection of material data, fermentation tests. Fermentation of Organic Material.Verlag des Vereins Deutscher Ingenieure, Düsseldorf, Germany.