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Short Communication

Enhanced biogas production from rice straw by selective micronutrients under solid state anaerobic digestion

Madhuri Narra [a,*], Velmurugan Balasubramanian [a], Anil Kurchania [a], Bhim Sen Pathak [b], Murari Shyam [a]

[a] Sardar Patel Renewable Energy Research Institute, P. Box No. 2, Vallabh Vidyanagar 388 120, Gujarat, India
[b] Energy Consultant, KC-5, Ghaziabad, Uttar Pradesh, India

HIGHLIGHTS

- Biomethanation of RS at 25% solid loading for production of green fuel and manure.
- Enhanced biogas yields by addition of selective micronutrients.
- Simple and faster process requires <85% water as compared to conventional process.

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ABSTRACT

Biomethanation of rice straw (RS) was studied in a batch mode at high total solid content (TSC) of 25% in outdoor pilot scale digesters. Performance was monitored for over six months by supplementing Nickel and Cobalt 15 and 10 mg kg^{-1} RS to each of mesophilic and thermophilic digesters for 35 and 21 days retention time (RT), respectively. The average biogas production from mesophilic and thermophilic digesters were found varying 310 and 396 L kg^{-1} TS, respectively. The corresponding figures for the control digesters were 225 and 270 L kg^{-1} TS. Around 37 and 46% higher biogas production was recorded by supplementing the micronutrients in mesophilic and thermophilic digesters, respectively. Methane content in biogas was 57–59%. Matured compost had nitrogen, phosphorus and potassium contents of 1.0–1.2, 1.3–2.2, and 1.2–2.1%, respectively. The results demonstrated that the present process is faster, requires less than 85% water and produces green energy in addition to manure in less time compared to conventional process.

1. Introduction

Global annual production of RS is estimated to vary between 740.95 and 1111.42 million tons. India and China alone contribute nearly half of the world's output (Amith et al., 2016). Although there are few traditional ways for RS utilization such as using it as animal feed, organic fertilizer, providing energy for household cooking, heating, as well as feed stock for paper industry, major proportion of the RS is burnt in the field itself. Burning of surplus RS in the open fields leads to wastage of energy and poses environmental and health threats to the public by releasing greenhouse gases (Gadde et al., 2009). Therefore, RS which is now burnt after harvest to clear the land for the next crop is the most promising source of biomass for distributed power generation through anaerobic digestion.

Biogas can be produced from RS by microorganisms under anaerobic conditions as it contains cellulose and hemicellulose (Song et al., 2012). Anaerobic digestion of RS is a green technology since it provides a better alternative for waste utilization as well as for reducing greenhouse gas emissions (Murphy and Power, 2009). Solid state anaerobic digestion is when the solid content of the feed stocks to be digested is greater than 15% (Li et al., 2011). It has processing and technical advantages over liquid anaerobic digestion currently used for producing biogas. A thermophilic temperature is more suitable for solid state anaerobic digestion than a mesophilic one as the former produces more biogas and shortens the start-up period without significant increase in energy consumption for heating up (Li et al., 2011). Many researchers have attempted anaerobic digestion of crop residues at low solid loading but owing to low gas production rate and a few other problems, these are not being exploited for large-scale biogas generation at low temperatures (Zhang and Zhang, 1999). Our earlier study reported that biogas can be produced from RS at high solid loadings (>25%) and

* Corresponding author.
E-mail address: madhuri68@gmail.com (M. Narra).

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thermophilic temperature (Narra et al., 2016). The biogas potential of residues can be accelerated by supplementing them with desired levels of selective micronutrients. However, information on micronutrient supplementation for biogas generation from crop residue is very limited (Mussoline et al., 2013). In pursuit of the above, a study was carried out to investigate the effect of micronutrients on biogas generation from RS at high solids concentration using outdoor pilot scale digesters at mesophilic and thermophilic temperatures.

2. Methods

2.1. Substrate and inoculum

RS (Gujarat Sattar-a local variety) was collected from nearby local farmers during the harvest, transported and stored near the plant. Sufficient straw required for feeding the plant for six-eight months was stored. RS was chopped to 2–3 cm size using chaff cutter and stored at room temperature. Compost was collected from the core of the heap of cattle dung kept for composting in the field. Cattle dung slurry was collected from a large capacity biogas plant operated in normal conditions. Micronutrients were obtained from commercial sources and were of analytical grade. Castor cake was purchased from a local market.

2.2. Biomethanation of rice straw in mesophilic and thermophilic digesters

2.2.1. Outdoor mesophilic and thermophilic digesters

The present study was carried out using the existing outdoor digesters fabricated with mild steel (MS) capable of taking in 250 kg of RS per batch. Total volume of each digester was 4.5 m^3. Both the digesters consisted of an insulted MS trough, a MS platform, a common gas storage unit and necessary pump and piping. The digesters were insulted with a 5 mm thick glass wool to prevent heat loss. Additionally, the thermophilic digester was provided with a jacket with water inlet and outlets for hot water circulation to maintain the digester temperature at 50 °C. Heating system was provided to maintain and circulate the hot water to thermophilic digester. The digesters were also provided with a water jacket with a lid around the top to prevent gas leak and to provide anaerobic condition, a lid with hinges at the bottom for easy opening and closing of the reactor and a platform over the trough for easy inspection and loading of the reactor (Fig. 1).

2.2.1.1. Batch operation

RS and inoculum were characterized for its physicochemical characteristics as described earlier (Narra et al., 2014) (Table 1). Initially, the outdoor digester for mesophilic anaerobic digestion was charged with 200 kg of RS (TS-90%), 870 L cattle dung slurry (TS-11%), 31 L water and 15 mg of nickel per kg of straw. Likewise the thermophilic batch digester was charged 200 kg of RS (TS-90%), 145 kg of compost (TS-62%), 735 L of water and 10 mg of cobalt. Mesophilic digester was operated at ambient conditions for 35 days RT while thermophilic digester was operated at 50 °C for 21 days RT. TSC was maintained at 25%. The dosage of nickel and cobalt addition was decided by the laboratory findings. Subsequent batches were operated in the same manner except that digested material (DM) after the batch operation was used as inoculum. The final average composition of feed material in mesophilic and thermophilic digester consisted of 200 kg of RS (TS-90%), 410 kg of DM (TS-21%), 454 L of water, 15 mg of nickel, 27 g castor cake and 200 kg of RS (TS-90%), 460 kg of DM (TS-19%), 410 L of water, 10 mg of cobalt, 27 g castor cake, respectively (Table 2). Substrate to culture (S/C) ratio 2:1 was maintained on dry weight basis. Straw, water and culture were mixed thoroughly prior to feeding into the reactor. Simultaneously a control reactor was also commissioned with the same materials excluding the respective

Table 1
Characteristics of RS and DM.

Parameters	RS	DM	
		Mesophilic	Thermophilic
TS, % of wet weight	90.00 ± 1.41	21.00 ± 1.35	19.00 ± 1.02
Moisture, % of wet weight	10.00 ± 1.41	79.00 ± 1.35	81.00 ± 1.02
VS, % of dry weight	83.00 ± 1.30	59.00 ± 1.42	50.00 ± 1.21
Carbon, % of dry weight	37.20 ± 1.52	24.87 ± 1.26	25.70 ± 1.19
Nitrogen, % of dry weight	0.70 ± 1.39	0.82 ± 1.28	0.93 ± 1.23
Phosphorus as P_2O_5, % of dry weight	0.95 ± 1.27	1.12 ± 1.04	1.20 ± 1.27
Potassium, as K_2O% of dry weight	1.11 ± 1.31	1.29 ± 1.28	1.35 ± 1.31
C/N ratio	53.14 ± 1.45	30.32 ± 1.27	27.63 ± 1.21

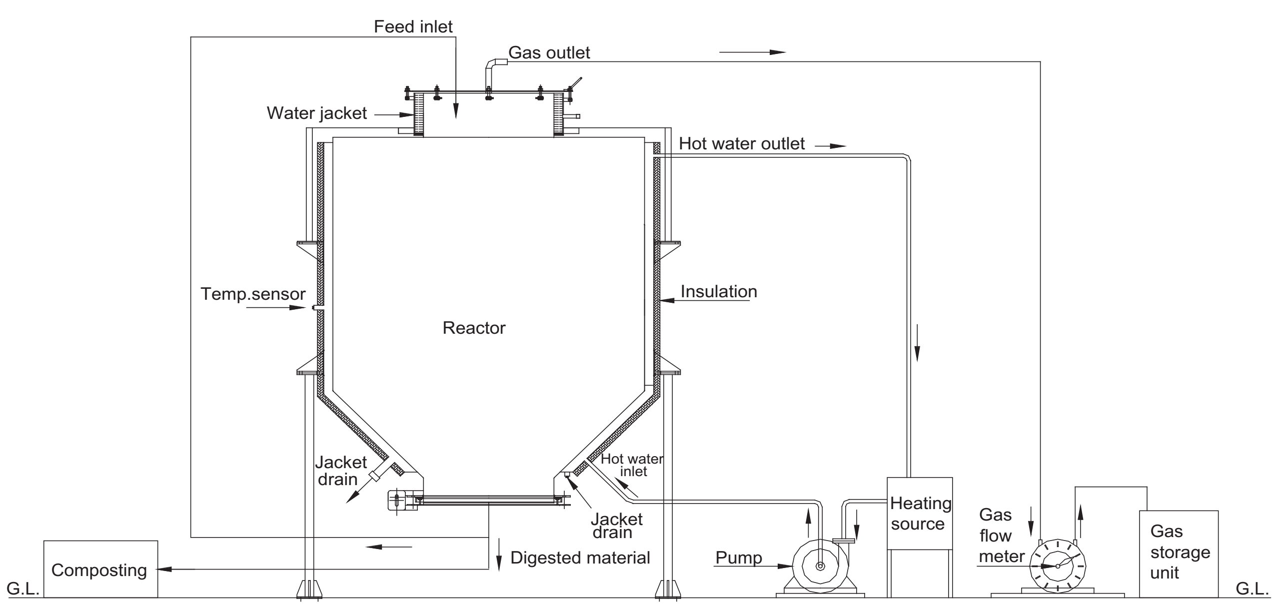

Fig. 1. Schematic diagram of batch anaerobic digester.

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