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The Energy Potential of Rice Straw by the Thermal and Biological Method: A Comparative Study

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Abstract—*Rice straw (RS) contains high lignocellulosic materials which are difficult to degrade. With a low moisture content of 6% and high C/N ratio of 52.15, it is suitable for thermal decomposition. This study compares the heating values of RS by Dulong formula, Boie formula, Grummel and David formula, and Moot and Spooner formula. Results presented that the energy recovery potential is 47.31 kW/kg, 51.84 kW/kg, 44.77 kW/kg and 53.82 kW/kg respectively. Also, the study evaluates the methane potential of RS by carrying out a batch study of RS. From Biochemical Methane Potential (BMP) study results, the heating value of the methane (CH_4) generated from RS can be calculated. The results show that the CH_4 generated from the sample is 0.174 m^3/kg and the energy potential of the CH_4 produced is 8.34 kW/kg. The results indicated that the energy potential from the anaerobic digestion of RS is less as compared to the thermal decomposition of the RS.*

Keywords*: Rice Straw (RS), Lignocellulosic materials, Thermal Decomposition, Biochemical Methane Potential (BMP)*

1. INTRODUCTION

Due to the low nutrients value present in the RS, open burning of RS is preferred over animal feeding. Open burning cause many health and environmental problems [1]. With the complex lignocellulosic structure of RS, it is intricate to decompose. Thus, RS has not been chosen as a substrate for energy generation. But with abundance production and crop burning of RS which causes a greenhouse effect, RS can no longer be overlooked as an energy crop and must be used as a renewable energy source [2-6].

It is difficult to produce and utilize energy from certain biomass such as RS because of its complex lignocellulosic structure and characteristics [7]. Therefore, a proper treatment is required for the abundant RS production. Thermal decomposition is a chemical process in which heat is used for the decomposition of waste materials. Thermal decomposition processes such as gasification, pyrolysis or incineration have been widely used to biomass for energy content [8]. Particle size, heating rate and temperature can influence the products of thermal decomposition [8]. Any cheap material, with a high carbon content and low in organics, can be used as a raw material for the production of AC [9]. Thermal decomposition can be a viable solution for the RS.

Anaerobic process is a process in which organic waste is decomposed by the anaerobic microorganism under the presence of an oxygen deficient atmosphere. Anaerobic digestion is more economical and environmentally friendly as compared to the thermal decomposition [10]. AD is globally recognized as a method to control greenhouse gases and use widely for energy generation [11-13]. By AD process, around 90% of biodegradable organic compounds can be converted into biogas [14]. From previous studies, it can be clearly seen that the temperature, loading rate, design of anaerobic reactor and inoculum rate and pretreatment methods can affect the result of CH_4 yield [15-19]. However, the energy potential of the anaerobic digestion is less as compared to the thermal decomposition.

The objective of this study is to compare the thermal and biological decomposition. The heating value of the RS is first calculated on the basis of the different formula of calorific value and then the CH_4 production of RS is measured on the cumulative basis by bench scale study. The resulted heating value and cumulative CH_4 production are then used to evaluate the energy potential of RS.

2. MATERIALS AND METHODOLOGY

The RS is collected from the different rural areas on the outskirts of Delhi. The RS sample collected is then ground and place in the refrigerator before future degradation. Anaerobic sludge used as an inoculum for the seeding has been collected from the DJB waste water treatment plant near Pappankalan, New Delhi. Before BMP setup, VS, Moisture content and Ash content of the samples are determined by the standard method given by the Bureau of Indian Standards [20]. Carbon, Nitrogen, Oxygen, Sulphur and hydrogen are determined by the standard method [21]. The values of carbon, oxygen, sulphur, ash content and hydrogen are used to calculate the heating value of RS.

A bench scale BMP study has been used for the CH_4 generation. 175 mL BMP bottles is used with a working volume of 150 mL and anaerobic digestion is carried out with F/M ratio of 0.5. The substrate and inoculum are filled on the basis of VS concentration and rest of the bottle are filled with media. The bottles are tightly capped with aluminum and silicon caps for the anaerobic conditions. The bottles are placed in an incubator for a temperature of 30 ^{o} C. All the samples are running on the basis triplicate basis. Blank bottles (without any substrate) have been running parallel to the RS bottles. CH_4 production is measured on the daily basis and is collected by the inverted serum bottle method [22, 23].

3. RESULTS

Proximate and elemental analysis of RS is presented in table 1. From results, it can be observed that the RS has low moisture content of 6% and high carbon, and C/N of 42.76% and 52.15 respectively. This shows that the RS has more energy potential for thermal decomposition than anaerobic digestion.

Table 1: Proximate and elemental analysis of RS

Parameter	Weight (%) (dry)
Carbon	42.76
Nitrogen	0.82
Hydrogen	6.32
Sulphur	0.08
Oxygen	39.21
Ash	22.90
Moisture content	6.00
C/N ratio	52.15

Gross calorific values (GCV) of the RS can be calculated [24] by equation 1-4 and are shown in table 2.

Dulong formula

Q= 145.44 C + 620.28 H + 40.5 S - 77.54 (O) …. (1)

Boie formula

Q= 151.2 C + 499.77 H + 45.0 S - 47.7 (O) + 27.0 N …. (2)

Grummel and Davis formula

Q= [654.3H/ (100-A)]+424.621 [C/3 + H - (O)/8 + S/8] …. (3)

Mott and Spooner

Q = 144.54 C + 610.2 H + 40.5 S – O [65.88- {30.96(O)/ (100-A)}] …. (4)

Where, Q is the gross calorific values in Btu/lb which can be converted to kcal/kg by multiplying with a factor 0.002326. C, H, S, O, N and A represent the weight of Carbon, hydrogen, sulphur, oxygen, nitrogen and Ash present in the RS respectively. Figure 1 and 2 shows the physical characteristics of RS and inoculum respectively.

Table 2: GCV of the RS by different formula

Formula	GVC (MJ/kg)	Energy potential (kW/kg)
Dulong	16.51	47.31
Boie	18.09	51.84
Grummel and Davis	15.62	44.76
Mott and Spooner	18.78	53.82

Biodegradability can be affected by the methodology used, inoculum source, storage conditions and activity of the inoculum. Volatile solids (VS) and Ash content of the RS, and Inoculum is determined before the beginning of the experiment as shown in Figure 1 and 2. It can be observed from Figure 1 and 2 that the RS has more than thrice the VS concentration than the ash content. Inoculum has more than 2.5 times VS concentration than Ash content.

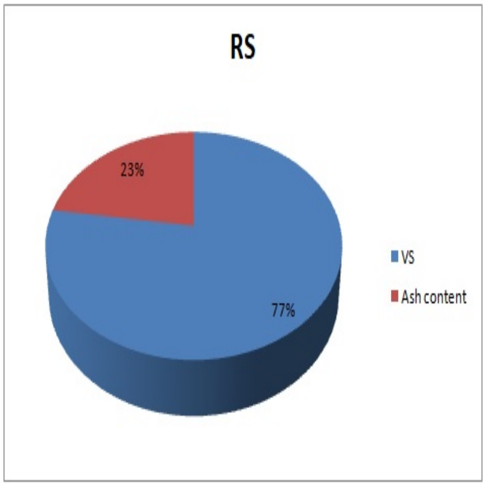

Figure 1: Physical characteristics of RS

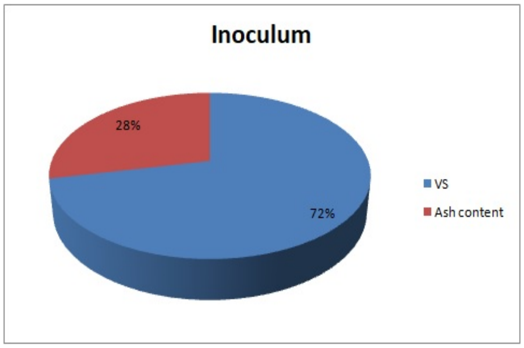

Figure 2: Physical characteristics of inoculum

A BMP study of RS has been carried out for 30 days and the CH_4 production is measured on the daily basis. The data obtained is summarized into the cumulative CH_4 production which is 0.174 m^3/kg. It can be observed from figure 3 that the RS has low CH_4 production. It may be due to the presence of lignocellulosic content which is difficult to degrade without pretreatment. Also, it can be observed that the CH_4 production is low in the initial days and then increases rapidly afterward. The energy potential can be calculated as per the MoUD manual [25]. The energy potential of RS by anaerobic digestion is 8.34 kW.

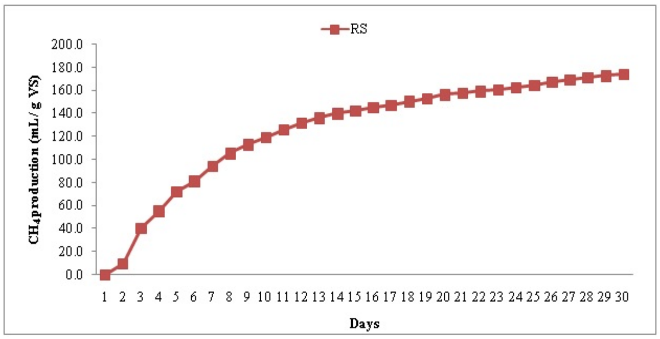

Figure 3: Cumulative CH_4 production for RS

4. CONCLUSIONS AND DISCUSSIONS

From different calorific value formula, it can be observed that the thermal decomposition of RS can have an energy potential around 50 kW/kg. CH_4 produced from the anaerobic digestion of RS has an energy potential of 8.34 kW. It can be concluded from the result that the thermal decomposition of RS has more energy potential than the anaerobic digestion of RS. This is due to the fact that the anaerobic digestion can degrade the limited amount of components present in the RS. However, in thermal decomposition, all components undergo the heating process and give more energy. Also, the lignocellulosic materials present in the RS cannot degrade by the mono digestion of RS. In case of thermal decomposition, the proper temperature can degrade the lignocellulosic matter and thus providing more energy than the anaerobic process.

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