

Pyrolysis of Sugarcane Trash for the Production of Bio-Oil

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Abstract— Sugarcane Trash has been identified as an alternative feedstock to obtain fuels via pyrolysis in an auger reactor (2 kg/hr) in presence of inert medium at atmospheric pressure. Influence of pyrolysis temperature in the range of 400-600 °C on bio-oil yield investigated. Results indicated that a maximum bio-oil yield of 56.2 wt % was obtained at a temperature of 500 °C. The bio-oil yield reduces when the temperature increased from 500 °C to 600 °C, whereas the gas yield increased. Raw and dehydrated bio-oil obtained by pyrolysis was characterized by pH, density (ASTM D4052), water content (ASTM D6304), viscosity (ASTM D445) and heating value (ASTM D240). The analyses revealed that density, viscosity and water content was quite high while energy content was very low (60 % less) compared to that of conventional gasoline and diesel. Due to presence of oxygenated compounds (e.g., acetic acid, ketones, phenol and cresols) in bio-oil, it exhibited acidic nature. According to these results, bio-oil from sugarcane trash can be used as fuel after appropriate up gradation treatment, e.g. deoxygenation.

Keywords— Pyrolysis; Biomass; Energy recovery

I. INTRODUCTION

Biomass is considered to be prospective sources of renewable energy. It is composed of cellulose, hemicellulose and lignin, which could upgrade with the help of thermo-chemical processes: combustion, gasification and pyrolysis [1]. Thermo-chemical conversion of Biomass into liquid fractions known as bio-oil has been widely studied in recent years. It mainly comprises of bio-oil production by decomposing biomass at different pyrolysis conditions and characterisation of bio-oil with various instrumental techniques [2-5].

Among the main biomass residues from sugar production are sugarcane bagasse and sugarcane trash. Sugarcane agro industry produces around of 530 kg of solid residues (on a 50% mill-wet basis) for each milled ton of cane [6]. Sugarcane bagasse has been the principal fuel used around the world in the sugarcane agro industry because of its well-known energy properties [7]. Conversely, most of the sugarcane trash is usually burnt in the field due to lack of proper techniques. Besides the loss of organic matter, burning of crop residues also causes atmospheric pollution due to the emission of toxic gases, e.g. methane and carbon dioxide. Moreover, due to its low digestibility, only a small percent (3% wt.) can be included in the cattle rations. Thus, it can be routed to pyrolysis for the production of bio-oil. Thermal decomposition of sugarcane trash and bagasse leads to

formation of liquid oil, gas rich in hydrogen and charcoal in the temperature range of 450 - 500°C in a fixed and fluidized bed reactor, respectively[8, 9].

In light of the above discussion, the aim of the present work was to recover energy contents of sugarcane trash. Thus, an environmental issue attached with so-called waste has been addressed for a profitable outcome.

II. EXPERIMENTAL

A. Materials and Samples Preparation

Sugarcane trash was obtained from local sugarcane farm located near Bardoli, Gujarat, India. It was freed of physical impurities, dried for 24 hours at 110°C, ground, sieved to 300-600 µm size, and stored in a desiccator. Its density, heating value, moisture and carbon content was 340 kg/m³, 18.5 MJ/kg, 5% and 50.4 %, respectively

B. Equipment: Pyrolysis in an auger reactor

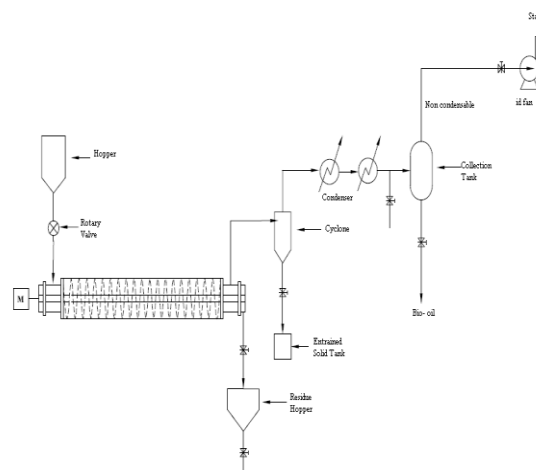


Fig 1. Schematic diagram of auger reactor (2 kg/h)

The auger-fed pyrolysis reactor used in this work is depicted in Fig.1. The feedstock was first added to the hopper from where it was fed with rotary type volumetric feeder into the auger reactor at a rate between 30-100 gm/min. The auger was inside a mild steel tube with 150 cm length and 20 cm diameter heated electrically at a rate of 15°C/min. The resulting gases along with entrained residue were passed through the cyclone separator. Purified gases were cooled to

bring about liquid (bio-oil) fractions in a series of condensers. The yield of liquid was typically determined by weighing the liquid collected in condensers known as raw bio-oil. Dehydration of raw bio-oil was carried out by heating at 100 °C to recover aqueous and lower boiling fractions. The residue was continuously received in a receiver at the other end of the reactor. The volume of gas produced was measured by subtracting the weight of liquid and residue from the each run, and the error was within $\pm 5\%$. Some of the runs were repeated to check the reproducibility of the results.

C. Product analyses

Bio-oil obtained by pyrolysis of sugarcane trash was weighed and subjected to following analyses.

C.1. pH

C.2. Density (ASTM D4052)

C.3. Water content (ASTM D6304)

C.4. Viscosity (ASTM D445)

C.5. Heating value (ASTM D240)

III. RESULTS AND DISCUSSION

A. Product yield and effect of temperature

TABLE I. PRODUCT YIELDS BY SUGARCANE TRASH PYROLYSIS

Temperature (°C)	Yield of products (wt %)		
	Bio-oil*	Gas	Char
400	48.50	15.20	36.30
500	56.20	18.50	25.30
600	40.40	39.50	20.10

* Including 10-15 % aqueous phase in bio-oil

Table I shows a typical product distribution observed for the pyrolysis of sugarcane trash at different temperatures, e.g., 400°C, 500 °C and 600 °C. Mass balance was within $\pm 5\%$ due to leakages and the evaporation of lighter products during the run. Table 1 indicates that an increase in reaction temperature from 400 °C to 500 °C increase in the yield of bio-oil while further increment of temperature, e.g., above 500 °C reduce the yield of bio-oil. At higher temperature, conversion of high molecular weight liquid fraction to lighter gaseous fraction enhanced and considerable gasification at temperature above 500 °C with significant loss of liquid fraction was observed. Higher yield (56.20 %) of bio-oil obtained at 500 °C was to be considered optimum temperature [8] reported the similar yields of sugarcane trash derived bio-oil. At 500 °C, early stage condensation of volatile products might not occur on the surface of char due to sufficient volatility of these volatile products. These products were condensable to produce reasonable liquid yields. Similar trend of product distribution observed during the pine pyrolysis in an auger reactor [10]. The liquid fraction showed two separate phases. Organic (bio-oil) (density 1045 kg/m³) and aqueous (density 1190 kg/m³). Liquid fraction have aqueous content of typically 10-15 % of the bio-oil mass. Highest yield of bio-oil obtained at 500 °C (Table I) was used for the further characterization.

B. Physical properties

TABLE II. COMPARISON OF PHYSICAL PROPERTIES OF BIOMASS/PLASTIC CO-PYROLYSIS OIL

Pyrolysate liquid	pH	Density (g/mL)	Viscosity (cSt at 40°C)	Water (wt%)	Calorific value (MJ/kg)
Raw bio-oil	3.0	1.04	4.50	15	15.25
Dehydrated bio-oil	4.0	1.25	60.50	3 ppm	18.60

Table II summarizes the pH value, density, viscosity, water content and calorific value for raw and dehydrated bio-oil. The pH value of bio-oil was observed to be highly acidic. Dehydration leads to increased acidity due to removal of aqueous phase at 100 °C. Degradation of hemicellulose, cellulose and lignin presents in biomass produced oxygenated compounds (e.g., acetic acid, ketones, phenol and cresols) which exhibit acidic nature of bio-oil. Moreover, density increased for dehydrated bio-oil, which is higher than that of gasoline (770 kg/m³) and diesel (867 kg/m³). The viscosity of pyrolysis oil has been very high because of some of the lignin-derived chemical constituents. However, use of additive, e.g. 10 wt % methanol or additive mixtures, e.g. water with methanol or preheating of fuel before atomization reduced the viscosity of bio-oil [11]. Water content of the raw bio-oil was 15%, resulting from the moisture content of the original feedstock and the product of dehydration during pyrolysis reactions. Dehydration favors significant reduction of water content of raw bio-oil. In contrast to raw bio-oil, calorific value could be improved by 18 % for dehydrated bio-oil. However, energy content of raw bio-oil is very low compare to conventional gasoline and diesel (60 % less). It might be due to the presence of large amount of oxygenates and aqueous phase in bio-oil. Thus, bio-oil needs to be upgraded by lowering the oxygen content. Various researchers have investigated different up-gradation techniques, e.g., hydro-deoxygenation, catalytic cracking, emulsification, steam reforming, esterification and reactive rectification [12].

IV. CONCLUSIONS

The yield of bio-oil was found to be increased upon increasing the temperature from 400 °C to 500 °C, whereas further increment of temperature, (e.g. above 500 °C) reduce the yield of bio-oil. At higher temperature, reduction in bio-oil occurs due to formation of gaseous fraction at the expense of liquid fraction. Due to presence of oxygenated compounds (e.g., acetic acid, ketones, phenol and cresols) in bio-oil, it exhibited acidic nature. Density and viscosity of bio-oil is quite higher while energy content is very lower (60 % lesser) than conventional gasoline and diesel. Energy content of raw bio-oil could be improved with dehydration due to removal of aqueous and lower boiling fractions. According to these results, bio-oil from sugarcane trash can be used as fuel after appropriate up gradation treatment, e.g. deoxygenation.

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