



## Full Length Article

# Co-pyrolysis of sugarcane bagasse and low-density polyethylene: Influence of plastic on pyrolysis product yield



Ashish Dewangan, Debalaxmi Pradhan\*, R.K. Singh

Department of Chemical Engineering, National Institute of Technology Rourkela, Odisha 769008, India

## HIGHLIGHTS

- Co-pyrolysis of SCB/LDPE significantly improved the quality of fuel obtained.
- The maximum liquid product yield obtained was 52.75% at 500 °C with 1:1 SCB/LDPE ratio.
- The calorific value of SCB/LDPE co-pyrolysis oil was 40 MJ/kg which was better than that for SCB pyrolysis oil and almost equal to that of conventional fuel.
- Co-pyrolysis resulted in decreases of oxygen percentage from 33% to 15.06%.

## ARTICLE INFO

### Article history:

Received 1 February 2016

Received in revised form 3 June 2016

Accepted 1 August 2016

### Keywords:

Co-pyrolysis

LDPE

Sugarcane bagasse

Pyrolysis oil

## ABSTRACT

The aim of this study was to investigate the effect on plastic during co-pyrolysis with biomass. Pyrolysis of sugarcane bagasse (SCB), low density polyethylene (LDPE), and their mixtures of different ratios was carried out in a semi-batch reactor with varying temperatures ranging from 350 to 600 °C at a heating rate of  $20 \pm 1$  °C/min. The maximum liquid product yields for the pyrolysis of SCB and LDPE obtained were 47.15% and 74.40%, respectively, whereas the maximum liquid product yield for SCB/LDPE co-pyrolysis was 52.75% at 500 °C with 1:1 blend ratio. A significant improvement of the calorific value has been observed for the co-pyrolytic oil in comparison with SCB pyrolytic oil. The results of GC–MS and FTIR analysis confirmed the interaction between SCB and LDPE during co-pyrolysis, which resulted into a decreasing amount of oxygenated compounds, phenol and acidic compounds, makes the co-pyrolysis process more favorable for the production of high calorific value fuel.

© 2016 Elsevier Ltd. All rights reserved.

## 1. Introduction

Depletion of fossil fuels has encouraged researchers to find out alternative sources of energy. It has been projected that coal reserves will be depleted by 2112 and crude oil by 2042 where world energy demand is going to escalate by 56% by 2040 [1,2]. Over the last three decades the research on renewable sources of energy has been focused on biomass (56%), followed by solar energy (26%), wind energy (11%), geothermal energy (5%) and hydropower (2%) [3,4]. Availability, economic and environmental benefits are the three most crucial factors decided proper selection of alternate energy source. In this respect, biomass has a great potential since it can be converted into all forms of fuels, solid, liquid and gas. Some of its merits include promising flexibility in production, with great abundance in diverse forms such as wood

residue, agricultural residue, dedicated energy crops and municipal solid waste. Pyrolysis is the most frequently used method to prepare bio-fuel as it can give as high yield of liquid fuel as 75% with moderate operating conditions [5].

Despite the fact that pyrolysis oil being environment friendly, the fuel characteristics render the pyrolysis oil inefficient for its direct application as fuel because of its low combustion efficiency, low calorific value and high water content as reported by several researchers [5–8]. Also, the problems of corrosion and stability issues have been identified due to high level of oxygen. Therefore, upgradation of bio-oil is a necessary step to overcome the challenges in its application [9]. Some of the most commonly used upgradation techniques are catalytic cracking and hydrodeoxygenation. Catalytic cracking is a cheaper technique but the major challenges faced during the process are high coke production (8–25%) and poor quality fuel [10]. Hydrodeoxygenation produces high hydrocarbon fuel but, at the same time, the process is very complex and costly due to the need of costly equipment.

\* Corresponding author.

E-mail address: [debalaxmichemical@gmail.com](mailto:debalaxmichemical@gmail.com) (D. Pradhan).

Simplicity, effectiveness and economy are the three crucial factors which needs to be considered while developing a technique for the production of synthetic liquid fuel. Co-pyrolysis is the most promising technique which can meet the aforementioned criteria, at the same time reducing the volume of the waste and environmental concerns as the waste is usually used as one of the feed. Many studies have shown improvement in the quality and quantity of bio-oil without any improvement in the process. The key feature of this technique is the synergistic effect between biomass and plastic which occurs during the process. Literature portrays cracking process of polymer waste into useful lower molecular weight compounds that could be utilized as fuels or chemicals [11].

Thus, co-pyrolysis of biomass and plastic produces a more stable and homogeneous pyrolysis oil than blending of individual oils, which is impractical as oil from biomass is polar in nature and the mixture of oil is found to be unstable since it undergoes phase separation after a short interval of time.

Hugo et al., carried out slow pyrolysis and vacuum pyrolysis of bagasse [12]. They produced maximum char of highest calorific value by slow pyrolysis and bio-oil with less water content by vacuum pyrolysis. However the HHV of bio-oil obtained from sugarcane bagasse is 23.5 MJ/kg which is less than the HHV of petroleum fuels.

Montoya et al. studied the effect of temperature, biomass feed rate, carrier gas flow and feed particle size on the yield of products during fast pyrolysis of sugarcane bagasse [13]. The highest yield was obtained at 500 °C with nitrogen flow of 50 L/min and feed size range of 0.425 to 0.6 mm with 72.94% of bio-oil. They concluded that the yield increases due to heating severity and decreases due to entrainment of small particles. Nevertheless the obtained bio-oil has low heating value due the presence of oxygen when inert particles of larger diameter are used.

Abnisa et al. showed that by adding the same ratio of polystyrene (PS) in the pyrolysis of palm shell the liquid yield was increased to about 61.63%, whereas for individual pyrolysis of palm shell the yield was obtained 46.13% [14]. Also, these authors stated that the heating value of co-pyrolysis oil increased to three times that of individual palm shell pyrolysis oil. Co-pyrolysis of pine cone with different plastics such as PP, LDPE, and PS has been proposed by Brebu et al. [15]. From their result they concluded that the energy content of co-pyrolysis oil was comparatively more than that of single pyrolysis of pine cone alone. In addition, co-pyrolysis of biomass with bioplastic, also provides the positive contribution in pyrolysis product yield. Cornellsen et al. described the co-pyrolysis of willow with different bioplastics such as polylactic acid, polyhydroxybutyrate, corn starch, potato starch, biopearls, solanyl and eastar was used among them PHB showed great potential for improving the quality and quantity of co-pyrolysis oil [16].

Significance of plastic with biomass during co-pyrolysis makes the positive effect because plastic like polymer is a higher hydrogen rich product and the liquid product obtained from pyrolysis of plastic has a calorific value close to calorific value of conventional fuel which is around 40 MJ/kg [17]. This is one of the reason that addition of plastic in the pyrolysis of other type of biomass can make a positive contribution stated by different researchers around the studies. However, solid waste plastic is a cheaper hydrogen-rich feedstock with economic and environmental advantages [18].

The motivation for the current research specify that the upgrading techniques like co-pyrolysis of biomass with plastic have lot of advantages. The basic need of plastic as a co-feed in biomass pyrolysis is that, biomass is a hydrogen deficient feedstock which is one of the most important reasons for the low bio-oil yields. Therefore co-feeding with some hydrogen rich feedstock can be helpful in improving the quantity and quality of oil yield. Waste plastic are mainly formed by the polymerization of olefins with H/C ratio of 2, which means they are proper feedstocks for

conversion with biomass [19]. The oil obtained by co-pyrolysis of SCB and PR studied by Perez et al. shows the minimum oil yield and forming unstable emulsion with feedstock of 15% PR. Increasing feedstock to 50% gives a stable emulsion but a carbon residue of 9%. In addition, the presence of oxygenated compounds was observed and increase in viscosity caused by PR limits its application in fuels [20]. This influences the study of sugarcane bagasse co-pyrolysis with alternate feedstocks which overcomes the above limitations and improves the properties and yield of the oil. Waste LDPE was found to be suitable which enhances the oil properties when mixed with SCB in co-pyrolysis. LDPE has higher H/C ratio, high calorific value and less oxygen content which makes it appropriate alternate for mixing with sugarcane bagasse in co-pyrolysis [17]. In another instance Panda and Singh [21] have reported a complete study on the thermocatalytic degradation of LDPE waste to suitable hydrocarbon fuel therefore LDPE, has been used as one of the components for co-pyrolysis in the present work.

As a consequence, the proposed work based on pyrolysis of LDPE and SCB mixture has been carried out in a semi-batch reactor in the temperature range of 350–550 °C and varying SCB and LDPE ratios of 9:1.3:1, 1:1, and 1:3 at a heating rate of  $20 \pm 1$  °C/min. Co-pyrolysis of SCB/LDPE was investigated with the aim of increasing the oil yield with improved quality. The oil obtained under suitable conditions has been characterized for its physical and chemical properties.

## 2. Materials and methods

### 2.1. Materials and sample preparation

Sugarcane bagasse (SCB) was obtained from Sakti Sugar Ltd., Bhubaneswar, Odisha India. Low-density polyethylene (LDPE) grains were obtained from Blowing Towers Private Ltd., Rourkela, Odisha, India.

Bagasse was dried in the hot air oven at 40 °C for 24 h and ground to fine powder by using a grinder. Before co-pyrolysis, SCB and LDPE were maintained in average size range. SCB was sieved to a constant size range between 500 and 853  $\mu\text{m}$  (–18 + 30 BSS Mesh Size), whereas the average LDPE grain size was  $\sim 2$  mm in diameter.

The compositional analysis of feedstock SCB and LDPE was done on the basis of proximate and ultimate analysis. Proximate analysis was carried out by standard procedure described by the ASTM D3172-07a method to identify the moisture, volatile matter, fixed carbon and ash content of the feed. The percentage of carbon, hydrogen, nitrogen, oxygen and sulphur in the feedstock was determined using CHNSO Elemental Analyzer by Variael CUBE, Germany.

The calorific values of the SCB, LDPE, and bio-oils were obtained through a bomb calorimeter (Model: Parr 6100 EE digital bomb calorimeter). The sample ( $0.5 \pm 0.05$  g) was placed inside the bomb and burned in the presence of oxygen with an increment of  $\pm 0.01$  °C to determine the HHV (higher heating value) as per the ASTM D 4809-95 method.

Thermogravimetric analysis (TGA) of SCB and LDPE was carried out individually using the SHIMADZU model DTG-60/60H. Approximately, 10–12 mg of the sample was taken in an  $\text{Al}_2\text{O}_3$  crucible and heated up to the final temperature of 600 °C with 20 °C/min heating rate. The inert atmosphere was created by flowing pure nitrogen gas at around 40 mL/min flow rate in replacement of the air present in the pyrolysis zone for avoiding unwanted oxidation of the sample.

### 2.2. Experimental setup: co-pyrolysis in batch reactor

Co-pyrolysis of sugarcane bagasse and LDPE was carried out in a laboratory scale semi-batch reactor made up of stainless steel of

Download English Version:

<https://daneshyari.com/en/article/6632821>

Download Persian Version:

<https://daneshyari.com/article/6632821>

[Daneshyari.com](https://daneshyari.com)