Characterization and Gasification study of Lignocellulosic Garden waste

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Highlights

- Characterization of lignocellulosic biomass and their mixture
- Intrinsic kinetics for CO_2 gasification.
- Effect of catalyst.
- Formulation of semi empirical model

1. Introduction

In order to fulfill the increasing demand of energy, it is good to use the renewable energy resources as they are available in plenty, and don not create burden on atmosphere. Gasification is already an established technology, and further research is in progress on various aspects, such as improving the quality of syngas, reducing tar content, developing some semi-empirical kinetic models, or solving the problem of waste management by gasifying low end feedstock such as solid waste. The energy generation by gasification of garden and agro-waste is expected to significantly reduce problems of disposal.

The gasification process is preceded by de-volatilization steps, which also result in production of syngas, and gasification is carried out on the char remaining. The char produced from gasification is dependent on several properties like nature of parent biomass, pyrolysis process etc. [1]

In this study four types of dry leaves are collected from the road side, of IIT-B campus. They include jackfruit, mango, eucalyptus and raintree. These leaves were pyrolysed to produce char and then used for the gasification study.

2. Methods

The dry leaves collected were washed to remove the upper layer of soil and dried to carry out the further experiment. Characterization of the dried leaves powder was carried out as shown in table 1. The dry powder was pyrolysed in fixed bed reactor system, by heating the leaves in nitrogen atmosphere, process was continued till the pyrolysis gases stop coming out. The experiments on intrinsic kinetics were carried out in a TGA; char samples (50-90 µm) in the form of thin layer on the mouth of crucible were subjected to reaction conditions. The temperature range 700^0-1000^0C was chosen so that, transition temperature can be determined which changes the profile from chemical reaction regime to diffusion controlled regime [1]. To understand the effect of inorganics, a potassium salt was added from 0 to 40% (w/w) by impregnation method. The biomass species were mixed in various proportions and their reactivates were compared at 800^0C, in CO_2 environment.

Table 1. Characterization of Biomass.

	Ultimate Analysis (Wt. %)					Proximate Analysis (Wt.%)			Calorific value (MJ/kg)	Biomass Composition (Wt.%)		
	C	H	N	S	O	Volatile	Fixed carbon	Ash		Cellulose	Lignin	Hemi-cellulose
Jackfruit	37	4	0.7	<1	38	61	18	19	16	25	19	3
Mango	42	5	0.4	<1	42	65	24	11	18	11	40	29
Eucalyptus	51	7	1.2	<1	34	78	17	5	20	14	37	23
Raintree	52	7	2	<1	34	78	17	5	22	19	24	38

3. Results and discussion

The gasification rates of four biomass chars are as shown in fig.1a. It may be observed that eucalyptus is the fastest reacting species as compared to others. This differences in rates are attributed to differences in char structures and varying inorganic contents. The analysis of minerals shows the presence of potassium content higher in eucalyptus and silica content high in jackfruit. The potassium is known to act as catalyst for biomass thermochemical conversions, while silica inhibits the rate, as it tends to form the agglomerates [2-4]. The presence of alkali minerals form the active sites (inorganic), which also facilitate the reaction Even though jackfruit has more organic active sites, the presence of silica slows the reaction down as it tends to capture the carbon and does not allow to react further. This is supported by the fact that there is 9% of unreacted fixed carbon in jackfruit ash even after a long time of reaction.

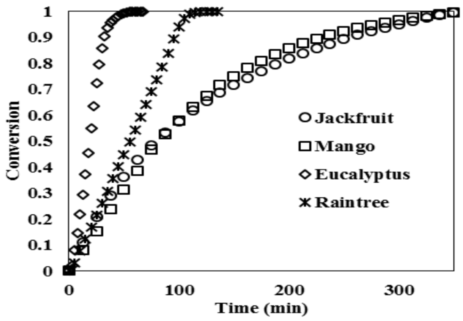

Figure 1a. Conversion vs time curve for CO_2 gasification at 800^0C for various leaf litter char.

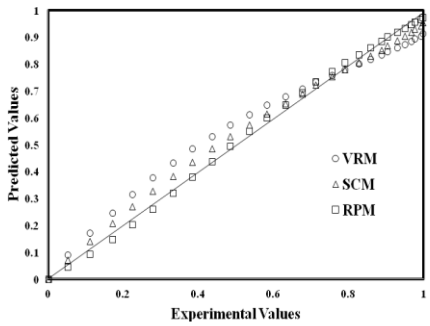

Figure 1b. Experimental vs. Predicted values for Eucalyptus char at 800^0C.

The catalytic effect of inorganic content was also observed in the intrinsic kinetics, as there is an increase in number of sites available for reaction. The rate increases with increase in catalyst loading over a range of 0-40% loading. However, adding catalyst has other limitations as it results in an increase in the ash content and increased cost. On mixing two biomass materials in various proportions, we observed that the rate lies between the rates of individual species. The kinetic parameters for gasification reaction were determined using three kinetic models: Volumetric Reaction Model (VRM), Shrinking core Model (SCM) and Random Pore Model (RPM). The RPM and SCM models were found to explain the experimental data well (see fig. 1b). Semi-empirical model is formulated for these biomass species by incorporating the mineral concentration ratios as a parameter, in order to account for the ash content. This additional parameter in the proposed model is useful to understand the role of inorganics in gasification process. [4]

4. Conclusion

Four types of biomass were studied, and the difference in their reactivities was observed which was mainly due to inorganic contents. The presence of silica slows the reaction down as it tends to form a complex with carbon, while the presence of more potassium enhances the reaction rate. Intrinsic kinetics was thus modeled using the known gas-solid reaction models of which RPM and SCM models were found to explain the data reasonably well for all the materials. .

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Keywords
Biomass; Gasification; Intrinsic kinetics; Pyrolysis; Inorganic content; TGA.