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Production and characterization of pyrolytic oil by catalytic pyrolysis of Niger seed

Krushna Prasad Shadangi, Kaustubha Mohanty *

Department of Chemical Engineering, Indian Institute of Technology Guwahati, Guwahati 781039, India

HIGHLIGHTS

- Pyrolysis of Niger seed was investigated with and without the presence of catalyst.
- The yield of oil during thermal and catalytic pyrolysis was more or less similar.
- Kaolin at 8:1 ratio was more suitable to enhance calorific value of pyrolytic oil.
- CaO at 8:1 ratio was able to reduce the viscosity of pyrolytic oil.
- Pyrolytic oil contains both saturated and unsaturated hydrocarbon compounds.

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ABSTRACT

Conventional pyrolysis of Niger seed was investigated in a semi batch reactor with and without the presence of catalyst. Thermal pyrolysis yielded maximum 34.5% of oil (by weight basis) at 550 °C temperature. The catalytic pyrolysis was carried out using catalysts Al_2O_3, CaO and Kaolin at 2:1, 4:1 and 8:1 feed to catalyst ratio at this temperature. The yield and fuel properties of thermal and catalytic pyrolytic oils were compared. The results confirmed that the presence of catalysts decreased the oil yield marginally whereas enhanced the fuel properties compared with thermal pyrolysis. It was observed that the three catalysts had different effect on the fuel properties of pyrolytic oils. Among the three different feed to catalyst ratios used, 8:1 resulted in higher oil yield and thus the fuel properties were evaluated at this ratio. Kaolin at 8:1 ratio was more suitable to enhance calorific value whereas CaO at 8:1 ratio was able to reduce the viscosity of pyrolytic oil. The FTIR and DSC analysis confirmed that pyrolytic oil was a mixture of saturated and unsaturated hydrocarbon compounds.

1. Introduction

The Niger seed (*Hyoscyamus niger* L.) is one of the non-edible oil seed available in huge quantity in India and African Countries. Inga, Ramtil, Black seed and Henban seed are the additional names of Niger seed. In general, the seed is used as a feed for birds. The tree grows in waste area, sandy area, road-sides, on rubbish heaps and near old buildings, old herb gardens and particularly near the coastal areas. These seeds bear high oil content and wealthy in protein and other nutrition. The plant flowers in July and the seed are collected in the month of August [1]. Due to more oil content (35–40%) the seeds can be used as a source for the production of alternative fuel by different biomass conversion methods. Pyrolysis is one of the alternative thermo-chemical processes used to convert biomass in to bio-fuels in the form of solid, liquid and gaseous products. Among the three forms of fuel, the pyrolytic liquid is gaining a lot of attention due to its inherent advantages than other fuels. The organic rich phase of the pyrolytic liquid is known as pyrolytic oil or bio-oil. Literatures reveal that non-edible oil seeds are suitable for the production of pyrolytic oil [2–5]. However due to several draw backs of the crude pyrolytic oil such as high viscosity, acidic nature and high water content, the pyrolytic oil cannot be used as a fuel in diesel engine. It was reported that during biomass pyrolysis the use of catalyst increased the fuel quality of pyrolytic oil compared to the thermal process [6,7]. Catalytic pyrolysis increases the fuel properties by reducing the oxygen content in the pyrolytic oil in presence of some selected catalysts [6–8].

Various catalysts were used for seed pyrolysis such as zeolites, aluminum oxide, Al-MCM-41, CaO and MgO [9–14]. Zeolite is

* Corresponding author. Tel.: +91 361 2582267; fax: +91 361 2582291.
E-mail address: kmohanty@iitg.ernet.in (K. Mohanty).

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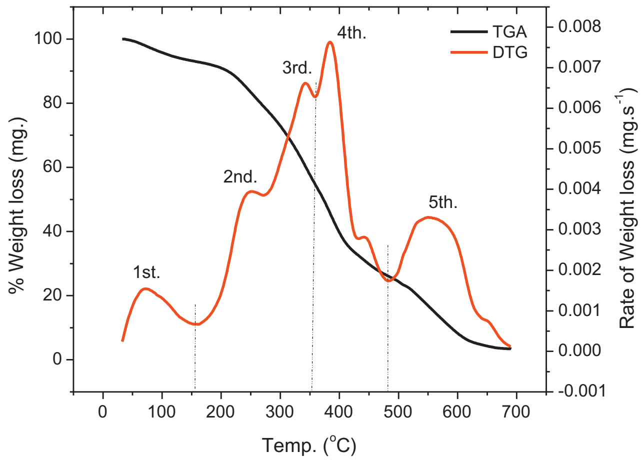

Fig. 1. TGA/DTG thermograph of Niger seed.

available in various compositions of silica and alumina. The pyrolytic liquid yield and its composition vary with the silica and alumina ratio. The zeolite catalytic cracking reactions involve the breaking of C—C bonds associated with dehydration, decarboxylation and decarbonylation of organic compounds to produce several aromatic hydrocarbon compounds [9,10]. Putun et al. [11] used aluminum oxide as catalyst and suggested that pyrolysis with less amount of catalyst increased the yield as well as quality of oil [11]. The comparison between catalytic (Al-MCM-41) and non-catalytic pyrolysis of Beta seeds confirmed that catalytic pyrolysis increased the total liquid yield and total organic compounds [12]. Literatures reveal that zeolite is one of the most suitable catalysts whose catalytic effect enhances the quality of pyrolytic oil. Kaolin is composed of silica and alumina which is quite similar to zeolite and comparably cheap also. Hence it was decided to study the effectiveness of Kaolin as a catalyst on the yield and quality of pyrolytic oil. It was reported that catalytic pyrolysis of cotton seed with MgO resulted in lower oil yield however with better quality of pyrolytic oil [13]. Catalytic pyrolysis of oil seeds with Calcium oxide (CaO) increased the yield of oil as well as enhanced the fuel properties. Moreover, it absorbs the emitted CO_2 during pyrolysis [7,14].

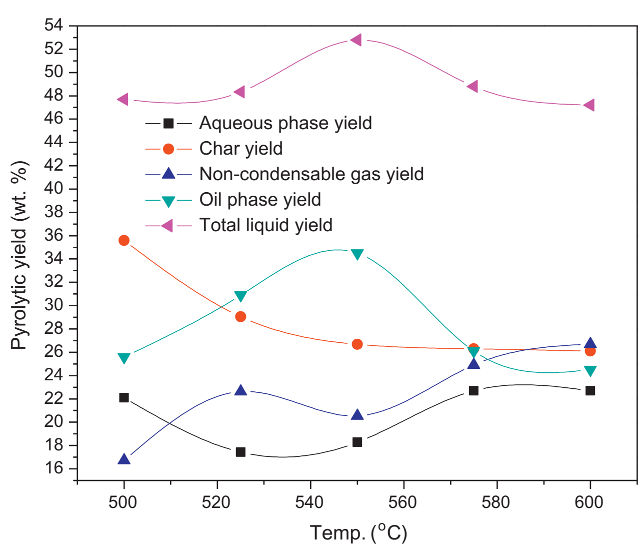

Fig. 2. Effect of temperature on Niger seed pyrolytic yield.

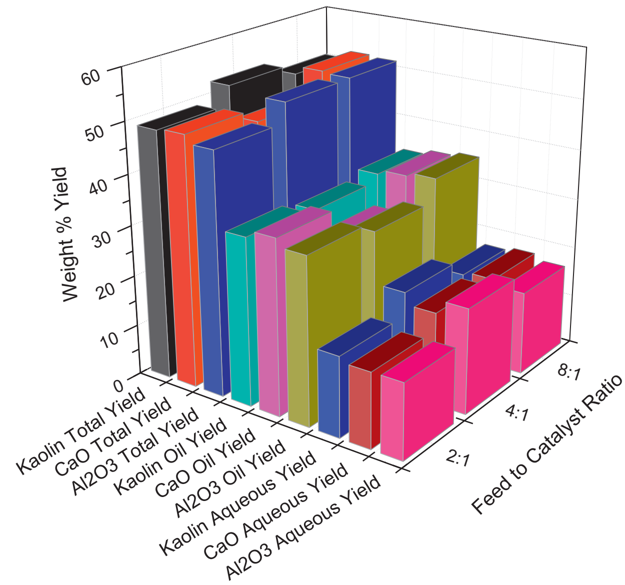

Fig. 3. Effect of catalyst on Niger seed pyrolytic yield.

Table 1
Fuel properties of pyrolytic oil.

Niger seed pyrolytic oil	pH	Calorific value (MJ kg^{-1})	Water (%)	Viscosity (cP)
8:1 CaO	9.08	35.87	14.18	9.007
8:1 Al_2O_3	8.24	35.49	13.92	19.17
8:1 Kaolin	8.01	38.72	18.14	13.135
Thermal	7.34	34.95	11.34	35.37
Diesel	–	45	–	4.57

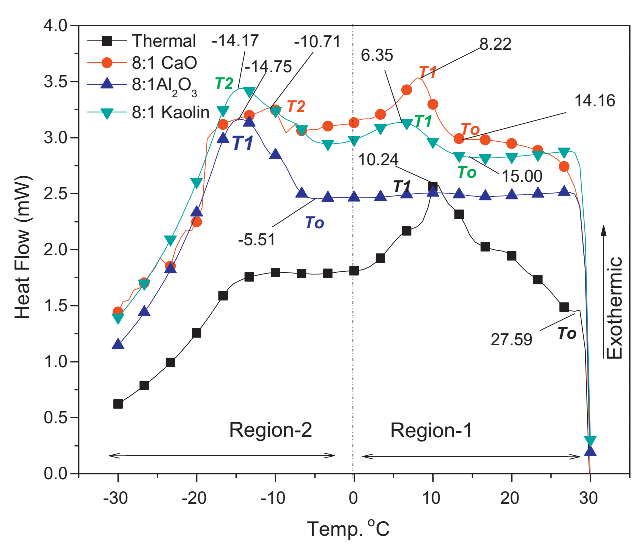

Fig. 4. DSC analysis of pyrolytic oil.

The present work was carried out to study the effect of various catalysts on the yield and fuel properties of Niger seed pyrolytic oil. Niger seed, being a non-edible oil seed is outside the food chain and contains a good amount of oil. In-situ catalyzation was carried out in a semi batch reactor using three different catalysts such as CaO, Al_2O_3 and Kaolin ($Al_2Si_2O_5(OH)_4$). The yield of thermal and catalytic pyrolytic oils is compared along with their fuel properties.