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Research Article

STUDY OF PYROLYTIC CHARACTERISTICS AND KINETICS OF JATROPHA OIL CAKE

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Abstract: Jatropha oil cake is a by-product obtained after extracting jatropha oil from seeds. Since the applications of oil cake are limited and there is lots of scope for energy recovery from oil cake if appropriate thermochemical conversion process used. The objective of the present work was to study of pyrolysis of jatropha oil cake using a Thermogravimetric Analysis (TGA) tool. The heating rates selected for this study were 10, 20, 30, and 40°C/min. for the TGA pyrolysis experiments. Three were three stages of thermal decomposition observed for jatropha oil cake and the thermal behaviour of jatropha oil cake is briefly discussed in this paper. The maximum peak temperature recorded for tested heating rates for oil cake was 327, 335, 358, and 421°C. The Kissinger-Akahira-Sunose method was used to analyze TGA data for determining the activation energy for the pyrolysis process. The predicted average activation energy value by the KAS method for jatropha oil cake was 21.62 kJ/mol.

Keywords: *Jatropha oil cake, Thermal behavior, Pyrolysis, Kinetic analysis*

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Introduction

The jatropha oil is one of the biodiesel feedstocks used for biodiesel production. Biodiesel production from jatropha oil using the transesterification process is successfully demonstrated. The jatropha biodiesel has the potential to replace the petro-diesel fuel. The estimated diesel fuel requirement for India in the year 2020 is 93.5 million tonnes [1]. In the case of blending or 100 percent biodiesel used as fuel, a tremendous amount of jatropha biodiesel has to be produced. In other words, the massive quantity of jatropha seeds is required for this purpose, and that can be achieved through the mass cultivation of jatropha crops in the wasteland. For the transesterification process, the jatropha oil is mixed with methanol along with a catalyst to yield biodiesel and glycerol. Generally, the jatropha oilseeds are collected from the jatropha plantations and sent them to oil extraction units. The conventional/mechanical oil expellers are used for oil extraction from the jatropha seeds. After oil extraction, oil cake is collected as a by-product, and the extracted oil could be sent to biodiesel production units. The jatropha oil cake cannot be used as animal feed due to toxic components presence. An alternate suggestion for this cake is used as manure. The quantity of oil cake production is huge if jatropha biodiesel production equal to the Indian diesel demand fuel requirement. Generally, the oil content of jatropha seed is up to 60 percent [2-6]. For example, the average oil content of jatropha seed is considered as 40 percent by weight; the remaining 60 percent of solid represents jatropha oil cake. Therefore, 400 kg of jatropha oil production would generate 600 kg of oil cake if one tonne of jatropha oilseeds used for oil extraction. There is more potential to tap bioenergy from this oil cake by using an appropriate biomass conversion process. Pyrolysis process can be applied to convert the jatropha oil cake into useful products such as biochar and biooil. The necessary information about the pyrolysis characteristics and kinetics of the selected biomass is required for designing a pyrolytic reactor.

Recently, thermogravimetric analysis (TGA) is more helpful to study the thermal degradation of materials. Furthermore, the experimental data can be used to analyze the weight loss of the biomass materials with reference heating rate and also understand the reaction mechanisms as well as its kinetics. In this paper, the results of thermal behavior and kinetic analysis for jatropha oil cake using the TGA tool are briefly discussed.

Materials and methods

The jatropha oil cake was ground into a fine powder and used for the TGA experiments. The proximate analysis of jatropha oil cake was determined by following ASTM standards. The thermogravimetric analyzer (TA Instruments, USA) was used to conduct the experiments by creating a pyrolysis environment with a supply of nitrogen gas (50 ml/min.). The oil cake sample (10±05 mg) used in the pyrolysis experiments. Four heating rates selected for the TGA experiments were 10, 20, 30, and 40°C/min. For the heating rate tested, the experiment was started from ambient temperature to 900°C. All the experiments were conducted twice for confirming results and TA Universal Analysis software used for data analysis.

Kinetic analysis

TGA data were used for characterizing thermal behaviour and analyze the kinetics of pyrolysis reactions. The Kissinger-Akahira-Sunose method (KAS) was used to analyze TGA data for determining the activation energy (E) for the pyrolysis of jatropha oil cake. The following equation used in the KAS method for calculating E values.

$$Ln(\beta//T^2) = ln[(AR/Eg(\alpha)] - E/RT$$

If plot a graph for constant α values for ln (β /T^2) and E/RT, a straight line is obtained, and E can be calculated from its slope (-E/R). T- absolute temperature, Table-1 *TGA results of jatropha oil cake tested for different heating rates*

SN	Heating rate used, °C/min.	Maximum peak temperature, °C	Maximum degradation rate, %/min.	E value, kJ/mol	R^2 value
1	10	327	3.80	21.10	0.9993
2	20	335	6.10	21.75	0.9989
3	30	358	10.9	21.66	0.9991
4	40	421	13.2	21.97	0.9990

K, E-activation energy, kJ mol^{-1}, R - universal gas constant, 8.3145 J.K mol^{-1},
B-heating rate, °K min^{-1}, α -degree of conversion in the process,
A-prepositional factor,

Results and discussion

Pyrolysis is one of the thermochemical conversion processes used for converting biomass into three products, such as biooil, charcoal/biochar, and pyrolytic gas. The selection of final products from the pyrolysis process can be desired by the reaction conditions used. It is an endothermic reaction that takes place in an inert atmosphere. The results of TGA experiments could help in understanding the changes that occurred in the biomass under pyrolysis conditions. The moisture, volatile, fixed carbon, and ash content of the jatropha oil cake were found as 8.7, 58.6, 26.5, and 6.2 %, respectively.

Thermal behaviour

A typical TG curve shows three stages of thermal decomposition of jatropha oil cake at a heating rate of 10°C/min. [Fig-1]. For all the heating rates tested, the jatropha oil cake undergoes three stages of thermal degradation. The temperature ranges for stages II for the heating rate of 10, 20, 30, and 40 °C/min. were in the range of 268-390°C, 292-440°C, 306-455°C, and 314-450°C, respectively. The weight loss for the stage I for the heating rates of 10, 20, 30, and 40 °C/min. was 17.9, 22.85, 22.49, and 21.60 %, respectively. The weight loss for stage II for the heating rate of 10, 20, 30, and 40 °C/min. was 77.14, 87.41, 77.69, and 74.26 %, respectively. The percentage of residue left at 900 for °C the heating rate of 10, 20, 30, and 40 °C/min. was 21.41, 21.92, 24.40, and 24.90%, respectively. Generally, the weight losses noticed in the stages I and II were for drying cum passive pyrolysis and active pyrolysis zone, respectively. The reason for weight loss occurred at the stage I was due to the removal of moisture present in the oil cake. Moreover, the light volatile matters in the oil cake were released outside the testing samples. The weight loss in the final stage of decomposition was low due to the degradation of lignin in the biomass materials [7-8].

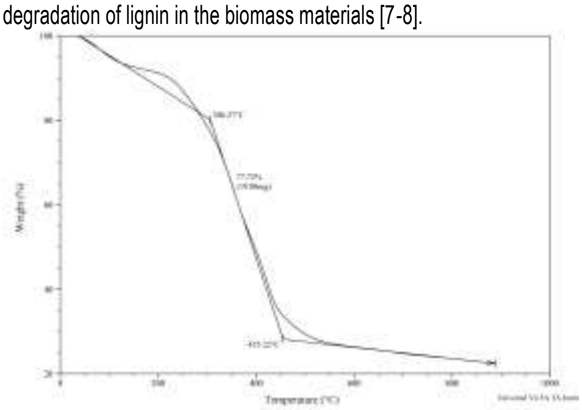

Fig-1 A typical TG curve of jatropha oil cake at a heating rate of 30°C/min.

Effect of heating rate

A typical DTG curve of the oil cake at a heating rate of 10°C/min. is shown in [Fig-2]. Three peaks appeared in the DTG curves of jatropha oil cake for all the tested heating rates. Generally, the second and third peaks appeared in DTG curve were indicate the decomposition of hemicellulose and cellulose available in the biomass [9]. A significant effect on weight loss in the biomass was noticed for the different heating rates tested. From the TGA experimental data, it was observed that shifting of peak temperature to higher values for the increased heating rate [Table-1]. The maximum peak temperature recorded for jatropha oil cake for different heating rates 10, 20, 30, and 40 °C/min. was 327, 335, 358, and 421°C, respectively. Also, the maximum degradation rate noticed for jatropha oil cake for different heating rates 10, 20, 30, and 40 °C/min. was 3.8, 6.1, 10.9, and 13.2 %/min. respectively. It was evidenced by the weight loss for stage II for the heating rate of 10, 20, 30, and 40 °C/min. was 77.14, 87.41, 77.69, and 74.26 %, respectively. The reason for this weight loss may be longer reaction time for thermal cracking of primary and secondary products for lower heating rate and vice versa. Increased heating rate results in increased release of volatile matter present in the jatropha oil cake.

Kinetic analysis

Activation energy is defined as the minimum energy amount to start a reaction [10]. the activation energy gives an idea about the nature of reactions occurs at the time of thermal decomposition of materials. The TGA results of jatropha oil cake tested for different heating rates are furnished in [Table-1]. From the table, it is observed that the average value of activation energy (E) for the oil cake was found to be 21.62 kJ/mol. The predicted E value by using the KAS method was in the range of 21.1 to 21.97 kJ/mol for the tested four heating rates used for pyrolyzing of jatropha oil cake.

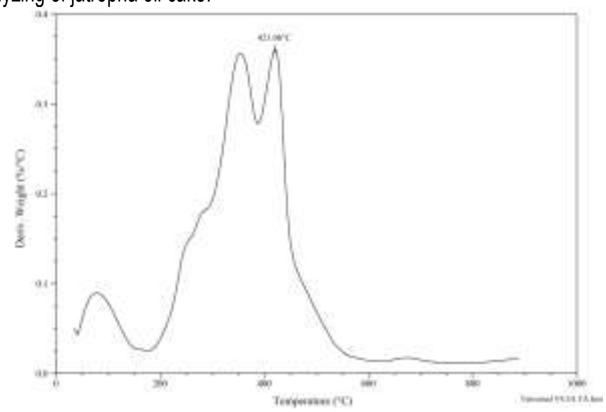

Fig-2 A typical DTG curve of jatropha oil cake at a heating rate of 30°C/min.

Conclusion

Generally, most of the developing countries are highly focused on biodiesel production from non-edible oils and lesser attention to energy recovery from its by-product utilization. We need to exploit the jatropha oil cake, so that no/little waste products will be left out at the end of the process. The TGA tool is used to simulate the pyrolysis process conditions for jatropha oil cake. Thermogravimetric curves for the oil cake showed three stages of thermal decomposition. There was more weight loss occurred in stage II, and it represents the primary devolatilization zone. KAS method was used to determine the activation energy of the pyrolysis reaction. The maximum peak temperature for heating rates of 10, 20, 30, and 40 °C/min. for jatropha oil cake was 327, 335, 358, and 421°C, respectively. The predicted average activation energy value by the KAS method for jatropha oil cake was 21.62 kJ/mol. The calculated values of activation energy by this method for tested heating rates were found to be in a closer range.

Application of research: The present study would help in understanding of thermal behaviour and reaction mechanisms for biomass materials subjected to different heating rates under pyrolysis conditions.

Research Category: Energy Agriculture

Abbreviations: TGA-Thermogravimetric Analysis

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Study area / Sample Collection: Horticultural College and Research Institute for Women, Tiruchirappalli, 62002

Cultivar / Variety / Breed name: Jatropha

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

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