Production of Biodiesel through Catalytic Transesterification of Jatropha Oil

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Abstract

Depletion of fossil fuel and their effect on environment give the importance of alternative fuel or renewable fuels. It is renewable, nontoxic and sustainable energy resource. Jatropha oil is non-edible vegetable oil which is obtained from jatropha curcas plant. It is used for the production of biodiesel.

Biodiesel was produced through transesterification process. In this process 4:1 methyl alcohol to jatropha oil molar ratio was used. Mg/Al hydrotalcite was used for the production of biodiesel in reactor under different conditions. Optimum yield 87.92% of biodiesel was obtained at reaction temperature 45^{0}C at 500 rpm for 1.5 hr and catalyst wt% was 1.3%. Flash point, density, viscosity and calorific values of produced biodiesel were determined. Jatropha oil can replace the edible oil for the production of biodiesel and it can fulfill the requirement of energy in Pakistan.

Key words: Jatropha oil; Biodiesel; Transesterification; Solid catalyst

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INTRODUCTION

There are many resources for energy production but renewable biomass feed stocks are very important fuel and has potential for energy requirement in current scenario. Biodiesel is one of the best renewable fuels because it creates a minimum pollution and friendly environment as compared to other fuel oil such as rock oil obtained from crude oil (Ma and Hanna, 1999). Diesel produced from different vegetable oils and biomass can be used in diesel engine directly or mixed with crude oil petroleum diesel as a fuel at various proportions (Pramanik, 2003). Monoalkylesters are the main components of biodiesel which obtained from vegetable oil through transesterification process (such as soyabean oil, rape oil, sunflower oil and jatropha oil etc.) with alcohol (methanol or ethanol). Biodiesel are similar and sometime better Chemicals and Physical properties than crude oil petroleum diesel. Lubricating efficiency of biodiesel is better than petroleum diesel and it has lower emissions of pollutants. Due to high price of vegetable oil and expensive techniques and process such as catalyst and equipment, the production cost of biodiesel is very high. In the developed countries raw materials commercially used are vegetable oils for example rape oil, soyabean, palm oils, coconut and lineseed oils (Demirbas, 2009) which is limited in developing countries such as Pakistan, India and Sri Lanka. Using of edible oils in such countries is not possible economically for biodiesel production therefore it is banned due to limited arable land per capita. On the world level total biodiesel produced from vegetable oils is rapseed oils 83%. Sunflower oils 14%, palm oils 2% and others 1% (Gui et al., 2008). Consumption of edible oils are increasing day by day therefore it is not favorable for the production of biodiesel particularly in non-developed countries as like Pakistan, Sri-Lanka and India. Therefore, most favorable resources for the production of biodiesel are only non-edible such as Jatropha curcas L. and Chinese tallow trees. Appreciable quantity of non-edible oil is produced from these trees and they can be grown on non-cropped wastelands and marginal lands in a large-scale. Jatropha curcas L. is largely spreaded in non-cultivated in all over the world such as Africa, America, South Asia, Australia, China and India. It can grow in every kind of land. Life of jatropha plant is about 30 to 40 years. Jatropha oil has same composition of fatty acid as like edible oil but it has some toxic materials which are not suitable for cooking purpose. Jatropha seed contains the amount of oil ranges between 30 to 35% by wt. and range of oil in the core is between 35 to 55 percent. Currently, as a potential alternative crop of biodiesel, Jatropha trees were mostly grew in different provinces of China such as Guangxi and Yunnan. In future there is a potential to supply the raw feed stock for the production of biodiesel on commercial basis (Yang et al., 2010).

Currently, Annual Consumption of diesel in Pakistan is about 10 million tons 60% of which is imported. Jatropha plant can grow everywhere, saline and sandy soils. It can grow in the crevices of rocks and even on the stony soil. According to the significance biodiesel PSO (Pakistan State Oil), D.G cement and other organization in the country motivating the people to Jatropha cultivation. We can save foreign exchange as well as increased our earning by blending 10% of bio diesel. We can increase economy of whole nation especially for poor farmer communities. Therefore, Jatropha plant has been selected as economical and for production of biodiesel. PSO and D.G cement nominated *Jatropha curcas* as a suitable plant for the production of biodiesel. Practically, research work on *Jatropha curcas*has is done in different countries such as China, Sri-Lanka, India USA and Brazil, due its unique properties. One million barren or waste lands are required for plantation of jatropha, to produce 10% blend of biodiesel. PSO and other organization in Pakistan are showing the significant progress in Jatropha plantation and are leading in all aspects of jatropha plantation to application and its production.

MATERIALS AND METHODS

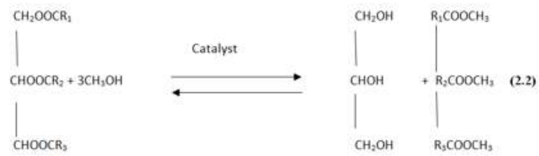
Materials and Chemicals

Nano sized solid catalyst (Mg/Al hydrotalcite) used in biodiesel production was synthesized. Jatropha oil was obtained from DG cement Dera Ghazi khan. Sulfuric acid (99% concentrated) and Alcohol (methanol) used in the synthesis were purchased from shabir synthetic store Hyderabad.

Experimental Procedure

Biodiesel production can be achieved by using two-step transesterification process (Tiwari et al., 2007).Jatropha seeds were collected from the DG Cement Factory from Dera Ghazi Khan and extracted the oil from the seed. The oil was treated in the following two step process (Deng X et al., 2010). In the first step free fatty acids were removed through esterification process by using sulfuric acid with high concentration. Took the flask and mixed 15 ml of methyl alcohol with 150 ml of Jatropha oil (4:1 molar ratio) and 3 ml of sulfuric acid. The solution of oil and alcohol was vigorously stirred at 100 rpm at 45C in a flask type reactor for 1.5 hr in a water bath. Mixture was washed by using ionic liquid of Sodium Chloride to reduce the Acid Value. Sodium chloride solution used to wash the oil and it was dried with dehydrated sodium sulphates. Then there was reduced the acid value of jatropha oil up to 0.8 mg KOH/g. The chemical reaction can be described in the following equation:

$$RCOOH + CH3 \rightarrow RCOOCH3 + H2O \qquad (2.1)$$



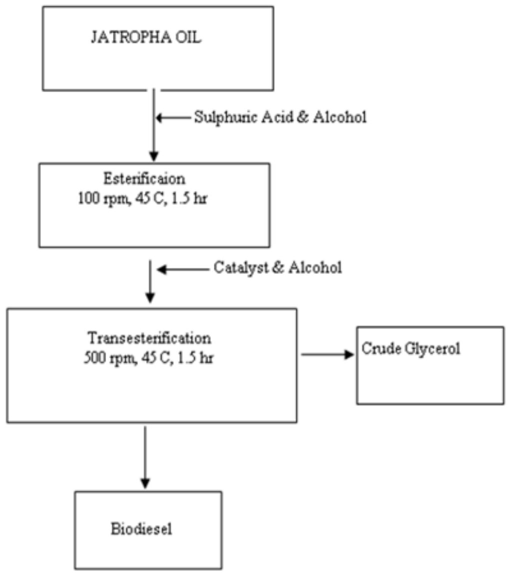


Figure 1: Flow sheet diagram of biodiesel production

Base catalytic transesterification reaction was carried out in the second step which can be explained in the following equation. Mg/Al hydrotalcite solid particles were used as a catalyst. In this reaction 1.3% hydrotalcite catalyst at 500 rpm was used at same reaction time and temperature. Process was repeated for several times and process was completed in the same flask type reactor with a stirring motor.

Production of biodiesel was determined by using the following formula;

$$\text{yield } (\%) = \frac{\text{actual weight of product}}{\text{theoretical weight of product}} * 100$$

Total amount of biodiesel were produced from reaction of jatropha oil and alcohol in actual, while theoretical weight of biodiesel was achieved when we assumed the 100 percent conversion of fatty acids present in jatropha oil. Above procedure was used to produce the biodiesel; first, methanol was mixed with catalyst in a flask and then pretreated oil was added in the sample with mechanical stirring at 500 rpm. The mixture was heated and reaction temperature was 45C by using water bath. High speed centrifugation was used to separate the catalyst. Layer of glycerol was separate by gravity separation and final product of biodiesel was achieved. Chromatographic analysis and other properties of biodiesel were determined by using different equipment's and analyzers.

RESULTS AND DISCUSSION

Jatropha oil was converted into diglyceride, monoglyceride and finally into fatty acid methyl esters and glycerin through transesterification consisted of three consecutive reversible reactions. Different techniques were used to determined different properties.

Gas chromatography analysis

Gas chromatographic analysis jatropha oil and biodiesel were carried out as the following procedure. Gas chromatographic analyzer was used for analysis of jatropha oil and biodiesel on the similar conditions. Standard biodiesel was used as a standard solution, which was dissolved in a solution of dichloromethane and prepared biodiesel for GC analysis. Oven temperature was 220 C when sample solutions were injected by a sampler. Helium was used as a career gas at a flow rate of 1 ml/min.

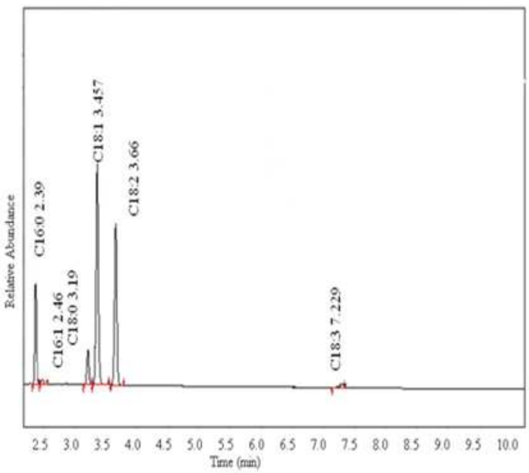


Figure 2: GC graph for crude Jatropha oil

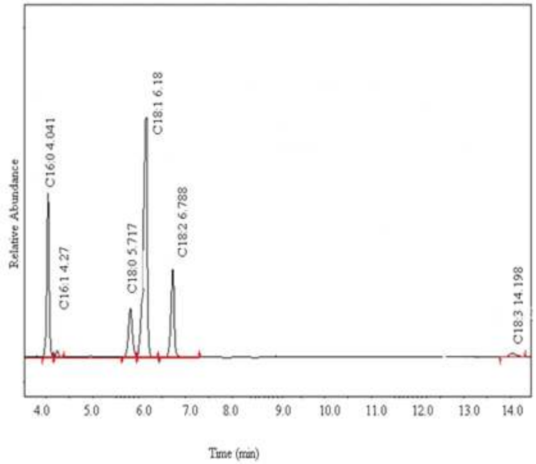


Figure 3: GC graph of Biodiesel

Methyl ester (Biodiesel) peaks were identified related to the retention times between the samples and the standard compounds. Different hydrocarbons have different percentage in a jatropha oil and biodiesel. Composition of Linolenic acid change is maximized from jatropha oil to biodiesel. Abundance of Oleic acid is maximum upto 43%.

Compositions of Jatropha oil and biodiesel are given in the following tables:

Table 1: Composition of Jatropha Oil

Components	Percentage (%)
Palmitic acid (C16:0)	14.12
Palmitoleic acid (C16:1)	0.91
Stearic acid (C18:0)	7.21
Oleic acid (C18:1)	43.11
Linoleic acid (C18:2)	27.31
Linolenic acid (C18:3)	0.07

Table 2: Composition of Biodiesel

Components	Percentage (%)
Palmitic acid (C16:0)	14.98
Palmitoleic acid (C16:1)	0.98
Stearic acid (C18:0)	7.21
Oleic acid (C18:1)	43.19
Linoleic acid (C18:2)	32.29
Linolenic acid (C18:3)	0.09

Effect of molar ratio of methanol/jatrophaoil on biodiesel yield

Yield of Biodiesel (methyl ester) was directly affected by the molar ratio of methanol/jatropha oil it was important factor which effected the production of biodiesel. Maximum yield was achieved at molar ratio 4:1 which was 87.92%. Higher molar ratio than the stoichiometry calculation resulted in a higher rate of biodiesel formation by completing the reaction. Large amount of methanol was not significant effect on yield of biodiesel. Maximum production of biodiesel (87.92%) achieved at 4:01 molar ratio of methanol/oil, which is given in the following table.

Table 3: yield of biodiesel at different molar ratios

Methanol/ oil (molar ratio)	Production of Biodiesel (%)
2:01	59.30
3:01	81.83
4:01	87.92
5:01	85.51
6:01	83.77

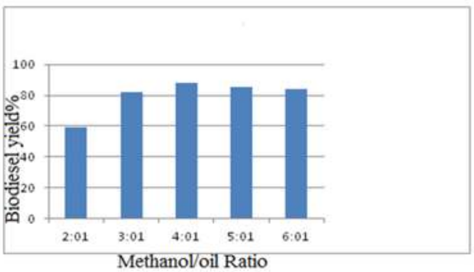


Figure 4: Effect of molar ratio of methanol/jatrophaoil on biodiesel yield %

Effect of Methanol/Oil Ratios and Catalyst Concentrations on Properties of Biodiesel

Properties of biodiesel produced by different methanol/oil ratios and catalyst concentrations were affected the parameter. Density of biodiesel was determined by measuring the sp. gravity of biodiesel through hydrometer. Density of biodiesel effected heating value and flash point of the fuel. Viscosity of biodiesel was measured by using Ubbelohde viscometer (Fraile et al., 2009). Similarly bomb calorimeter was used to measure the heating value of biodiesel. Different parameter can be explained in the following table:

Table 4: Effect of Methanol/oil ratios and concentration of catalyst on different parameter

Methanol/oil (Molar Ratio)	Catalyst (wt%)	Yield (%)	Density (g/ml)	Flash Point (^{0}C)	Viscosity (mm^2/s)	Cetane number	Calorific Value (Mj/Kg)
2:1	1.3	59.30	0.897	235	4.82	52.89	39.91
3:1	1.3	81.83	0.892	239	4.86	55.12	40.12
4:1	1.3	87.92	0.89	229	4.67	56	40.99
5:1	1.3	85.51	0.892	231	4.67	55.62	41.21
6:1	1.3	83.77	0.896	234	4.71	56.15	40.78
4:1	0.75	53.3	0.899	235	4.85	53.76	39.99
4:1	1	69.91	0.892	234	4.73	53.85	40.25
4:1	1.5	79.13	0.892	233	4.69	53.88	40.35
4:1	2	77.73	0.893	233	4.72	54.00	38.63

Different properties of biodiesel are affected by the concentration of catalyst and by changing the molar ratio of methanol/oil. According to above properties maximum production of biodiesel was achieved at 1.3% of catalyst concentration and 4:1 methanol/oil having maximum heating value.

Different properties of Jatropha oil and produced biodiesel were compared in the following table by using German Standard (DIN V 51606; 1997)

Table 5: Comparison of Properties of Jatropha oil and biodiesel

Parameter	Jatropha oil	Biodiesel	German Standard (DIN V 51606;1997)
Density (gm/ml)	0.905	0.89	0.875-0.900
Flash Point (^{0}C)	237	229	≥100
Fire Point (^{0}C)	241	235	-
Viscosity (mm^2/s)	26.3	4.67	3.5-5.0
Cetane number	52	56	≥49
Calorific value (Mj/Kg)	39.92	40.99	-

CONCLUSIONS

Due to energy crises and reducing the resources of petroleum oil Biodieselis getting more and more attention in the world particularly in Pakistan. Environmental pollution and emission of gases from petroleum diesel is a major problem. Therefore, Biodiesel is attractive and environment friendly biofuel. Monoalkyl ester of vegetable oil is known as biodiesel. Due to higher cetane number of Jatropha oil and required no modification in diesel engine and is more efficient for diesel engine. Jatropha oil was used for the production of biodiesel. It is nonedible vegetable oil and getting more and more attention because it can be cultivated in barren area. Importing cost of petroleum diesel can be reduced by biodiesel production through jatropha oil. Jatropha plant cultivated once and its production start after one year up to forty years. It can produce seed from 40 tons to 52 tons per acre. For the production of biodiesel from Jatropha oil was studied by catalytic transesterification with methanol, effective catalyst was Mg/Al hydrotalcitenano sized solid base catalyst.

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