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Study on Oil Extraction From Jackfruit Seed and its Application in Biodiesel Production

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ABSTRACT

Artocarpus heterophyllus (Jackfruit), the widely cultivated and popular food throughout the tropical regions of the world and its nativity roots to a part of south and south east asia. The need for an alternative feedstock for biodiesel production due to consumption of vegetable oil for humans led to the study of jackfruit seed oil. This study includes the optimization of oil from feasible methods with respective solvents and the optimization is based on the amount of oil yield. The oil extraction process aided in this report namely, microwave oven, soxhlet extraction and mechanical shaker. The solvents used were petroleum ether, cyclohexane, methanol and ethyl acetate. The most efficient yield was obtained in microwave oven extraction process resulting in 27% of yield using methanol as solvent. The biodiesel yield obtained was about 92% by transesterification of Artocarpus heterophyllus (Jackfruit) seed oil at the following conditions: 65^{o}C of reaction temperature, 1:9 molar ratio of oil : methanol and 400 rpm of stirring speed for 120 minutes with 1 wt% of sodium hydroxide as catalyst.

1. Introduction

India was positioned fifth in largest energy consumers in the world with a high value of 4.4% (524.2 million tonnes of oil equivalent (MTOE)) of the world total 12000 MTOE of energy resources consumed (EIA Report 2012). The growth rate of demand marking a 6.8 %, is truly unachievable with the supply which increases at a compounded annual growth rate (CAGR) of only 1%. Our primary demands of energy are solved by fossil fuel such as petroleum, coal and natural gas. However, there are only 1,000 billion barrels of reserve of petroleum crude in the world and at consumption rate of 84.1 million barrels/day, there could only be some 32 years of production remaining. That is, by the year 2040, there may not be any fossil fuel available (Atabani et al 2012). Therefore, it necessitates intense research into alternative energy sources, with the implementation of more efficient, safer and eco-friendly technologies. Various possible fuel sources are being examined at present, in order to develop environmentally clean fuel.

In 2003, the Indian government declared a National Mission on Biofuels, to drive large-scale implementation of bio-fuel production (Biswas et al 2009). In this perplexed and constrained scenario, the need for the search of alternate fuel gains momentum. Bio-fuel is an effective, tested and reliable alternative fuel in this regard. The production of Bio-fuel can hardly deplete considering the fact that the Bio-fuel is produced from natural vegetation. Biodiesel is one among biofuel which can act as an alternative fuel. As biodiesel is a green fuel and its production is also eco-friendly, the production of biodiesel from *Artocarpus heterophyllus* (Jackfruit) seed was chosen in this study. *Artocarpus heterophyllus* (Jackfruit), the commonly available and widely cultivated seasonal fruit rooting its origin to western ghats in the indian sub-continent also available all over the year in Panruti, Tamilnadu. India still top charts in Jackfruit production with figures 1436 tonnes. *Artocarpus heterophyllus* (Jackfruit) seed is mostly wasted in India, about 40% of the production is left to ripe and finally wasted. The other reasons are it is a drought resistant crop with economical maintenance. Hence the present study is focused to the extraction of oil from *Artocarpus heterophyllus* (Jackfruit) seed using different solvent and finding its applications in biodiesel production.

2. Materials and Method

2.1 Materials

Artocarpus heterophyllus seed is purchased from a local jackfruit vendor at the rate of Rs 18/kg and the solvents namely, petroleum ether, cyclohexane, n-hexane, methanol and ethyl acetate are bought from Merck Specialties Private Ltd, India. The catalyst used in this study was sodium hydroxide and it was procured from SD Fine Chem Pvt. Limited, India. All the chemicals used as such without further purification.

2.2 Methods of Oil Extraction

2.2.1 Soxhlet Extractor

A soxhlet extractor apparatus is originally designed for the extraction of a lipid from a solid material. Typically, a soxhlet extraction is used when the desired compound has a limited solubility in a solvent, and the impurity is insoluble in that solvent. A soxhlet Extractor has three main sections: A percolator (boiler and reflux) which circulates the solvent, a thimble (usually made of thick filter paper) which retains the solid to be laved and a siphon mechanism, which periodically empties the thimble.

The solvent is heated to reflux. The solvent vapour travels up a distillation arm, and floods into the chamber housing the thimble of solid.

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The condenser ensures that any solvent vapour cools and drips back down into the chamber housing the solid material. The chamber containing the solid material slowly fills with warm solvent. Some of the desired compound dissolves in the warm solvent. When the Soxhlet chamber is almost full the chamber is emptied by the siphon. The solvent is returned to the distillation flask. The thimble ensures that the rapid motion of the solvent does not transport any solid material to the still pot. This cycle may be allowed to repeat many times, over hours or days. After extraction the solvent is removed, typically by means of a rotary evaporator (Model No.IKV RV-10 automatic).

2.2.2 Microwave Operation

Microwaves are form of non ionizing electromagnetic energy at frequencies ranging from 300 MHz to 300 GHz. This energy is transmitted as waves, which can penetrate in biomaterials and interact with polar molecules into materials, such as water to generate heat [Takeuchi et al., 2009]. It is the most simple process handle for extraction of oil from biomaterial simply it is uses electromagnetic microwave to induce at torque in the dipoles and thus resulting in heating of the substance.

The Jackfruit seed from which the oil to be extracted is quantified using a electronic balance and a sufficient solvent ratio is added. In this study, a seed to solvent ratio of 1:10 (30 g of crushed seed and 300 g of solvent) was taken. The mixture is kept in the microwave oven (Samsung - Model No:GW 732 KD-B/XTL) for the prerequisite time (3 min) and temperature (59.5 ^{0}C) with respect to the voltage of 300 V. Then, the intermediate is processed for solvent and oil separation. This is achieved by rotary evaporator (Model No.IKV RV-10 automatic) which runs on the principle of separation by boiling point of the respective solvent. vacuum is applied on the apparatus for productive and time shedding measures, finally extracted amount of oil is measured for its yield.

2.2.3 Mechanical Shaker

The process methodology is carried over by simple shaking and with the assurance of perfect blended mixture of solvent and feed. The instrument used for this process uses the primitive method of homogenizing the solvent and feed by mechanically shaking it for a larger time period. Through this shaking action, the components of the feed are dissolved in the solvent through the concept called selective reactivity. This is the backbone of all the extraction process which uses solvents.

The prerequisite seed is measured using to be a suitable and accurate measuring instrument. The measured seed is immersed in a solvent of 1:10 ratio in weight basis. The mixture is kept in the mechanical shaker for about 3 hours**.** Mixture is well mixed, the yielding solvent consists of dissolved oil. The obtained solvent oil mixture is filtered and the oil content is separated using a rotary evaporator. (Model No.IKV RV-10 automatic)

2.3 Bio-Diesel Production

The experiments were conducted in a 500 ml three-necked round bottom flask equipped with heating mantle, reflux condenser, digital thermometer and mechanical stirrer. Nine moles of methanol and one mole of *Artocarpus heterophyllus* (Jackfruit) seed oil were taken in a round bottomed flask. The temperature of the reactant was maintained at 65^{o}C with an accuracy of ±1°C. The temperature of the reaction was monitored by digital thermometer. To prevent the methanol loss during a reaction, a water-cooled condenser was used to condense the vapours and reflux it back into the reactor. The reaction was started by charging the catalyst about 1 wt % of sodium hydroxide catalyst and the reaction was carried out for a period of 2 hrs at 400 rpm (Rengasamy et al 2014). After the completion of the reaction, the mixture was cooled to the room temperature and transferred into a separating funnel. The crude fatty acid methyl esters (FAME) and glycerol was allowed to settle for overnight. The top layer of crude biodiesel was separated and the excess methanol was removed using rotary vacuum evaporator (Model No.IKV RV-10 automatic).

3. Result and Discussion

3.1 Efficiency of Oil Extraction

The selection of the solvent and suitable extraction methods are an important factor for any oil extraction process. The solvent selection for the extraction of oil at the initial step would be cost-effective for fuel production, without further expense required for the purification of the product. The solvent chosen should have a good extraction capacity and low viscosity to enhance free circulation. An efficient extraction requires the penetration of the solvent in to the feed and matches the polarity of the targeted compounds.

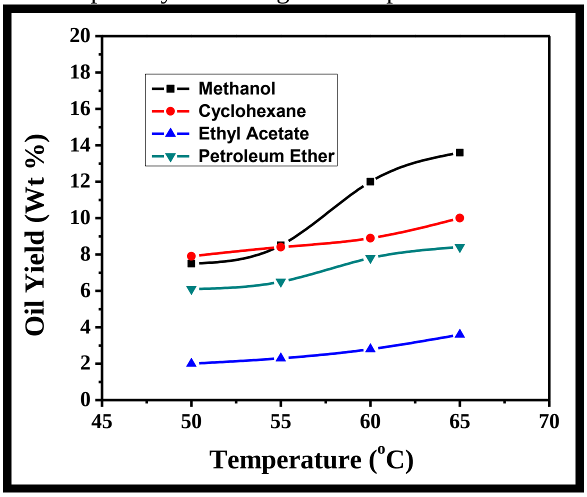

Fig 1. Effect of temperature on oil extraction using Soxhlet extractor.

The percentage of oil yield obtained for the soxhlet process using various solvents are presented in Figure 1 and 2. Figure 1 and 2 represented that the % yield of oil extracted with respect of temperature and time. From the Figure 1, the highest % of oil was obtained for all the solvent at 65 ^{0}C when compared to the other operating temperature such as 35, 45 and 55 ^{0}C for a period of 150 min. The yield of 13.6%, 10% and 8.4% was obtained for methanol, cyclohexane and petroleum ether, respectively. Hence, the optimum temperature to obtain the high yield of *Artocarpus heterophyllus* (Jackfruit) seed oil was 65 ^{0}C. Further optimisation was studied by the variations in time of extraction in soxhlet extractor and the obtained results are shown in Figure 2. For this study, the temperature was varied from 60 min to 180 min in the increment of 60 min at 65 ^{0}C. From the Figure 2, it was noted that 13.7% and 9.9 % oil was obtained using methanol and cyclohexane, respectively. The next yield was obtained about 8.5% using petroleum ether and ethyl acetate solvent yielded about 3.8 %. From the result it was concluded that methanol can act as very good solvent to extract oil from *Artocarpus heterophyllus* (Jackfruit) seed.

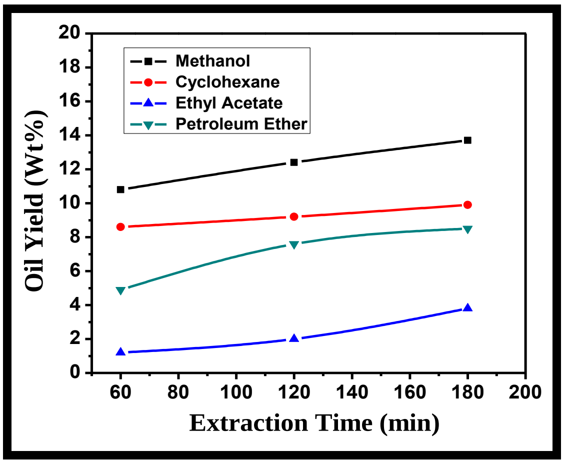

Fig 2. Effect of time on oil extraction using Soxhlet extractor.

Figure 3 used to represent the % of oil extracted using mechanical shaker using various solvents. The variability used in mechanical shaker is the time of the extraction process for the highest yield the time. From the Figure 3, it was noticed that when the extraction time increases the yield of oil increased. The yield obtained for the different solvents namely, methanol, cyclohexane, ethyl actetate and petroleum ether were 9.1%, 12.5%, 4.7% and 5.7 %, respectively for a period of 180 min. From the result it was concluded that cyclohexane can act as very good solvent to extract oil from *Artocarpus heterophyllus* (Jackfruit) seed by mechanical shaker. .

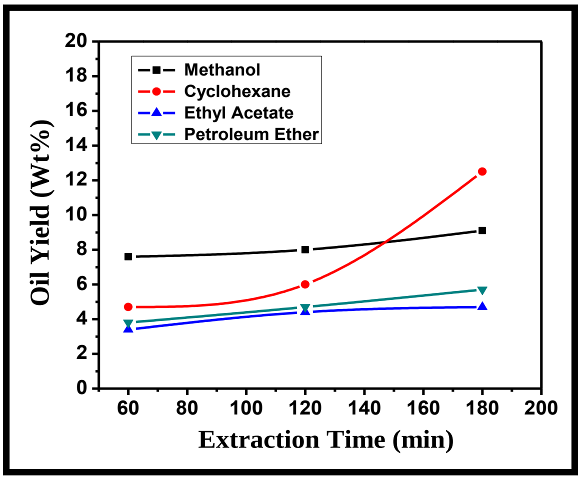

Fig. 3 Effect of time on oil extraction using mechanical shaker

Percentage of oil extraction using microwave oven method is represented in Figure 4. From the graph it was noticed that, when the extraction time increases the yield of oil increased. The yield obtained for the different solvents namely, methanol, cyclohexane, ethyl actetate and petroleum ether were 19.2%, 12.5%, 5.8% and 7.6 %, respectively for a period of 3 min. From the results, it was concluded that methanol can act as very good solvent to extract oil from *Artocarpus heterophyllus* (Jackfruit) seed in microwave oven method.

Form the experimental results, among the solvent used to extract the oil from Jackfruit seed, methanol showed higher solvent power and more selective towards the oil yield. Methanol is extensively used for oil extraction because of its high stability, low greasy residual effects, boiling point and low corrosiveness. The highest oil extraction yield of 19.8% was achieved from the microwave process using methanol as solvent and for soxhlet process the yield was 13.3%.

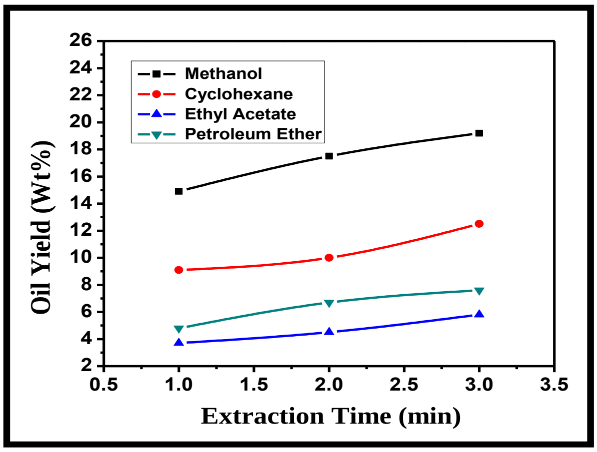

Fig 4 .Effect of time on oil extraction using microwave oven

The oil obtained by microwave oven mediated oil extraction method was undergone to the transesterification process for the production of biodiesel. The yield of biodiesel obtained for jackfruit oil using NaOH as catalyst was 92 ±1%. Then, the produced biodiesel ware characterized for their fuel properties.

3.2 Fuel Properties of Synthesized Biodiesel

3.2.1 Specific Gravity

Fuel properties of produced biodiesel from using *Artrocarpus heterophyllus* seed oil was given in Table 1. The The specific gravity is a key fuel property, which affects the mass of fuel injected into the combustion chamber. This property directly affects the engine performance characteristic because the fuel injection pump meter works on by volume not by mass. After transesterification process, the specific gravity of biodiesel was obtained about 0.891. The obtained value is very well match with the specification of biodiesel standard ASTM D6751.

3.2.2 Kinematic Viscosity

Kinematic viscosity is the most important property of biodiesel because it affects the fluidity, lubricity and atomization of the fuel. Fuels with low viscosity may not provide sufficient lubrication resulting in wear and high viscosity causes poor combustion and increases exhaust emission. The kinematic viscosity of produced biodiesel was about 5.7 mm^2/s. The obtained results are agreed well with the limits as per standard (1.9-6.0 mm^2/s). Besides, the kinematic viscosity of the conventional diesel ranges from 2 to 4.5 mm^2/s at 40 ^oC. The similar results are also obtained by Rengasamy et al, 2016. Also, the produced biodiesel may be used as fuel in existing diesel engine without any design modification.

Fuel properties	**ASTM Test Method**	**Biodiesel Specification** ASTM D6751	**Values of Produced Biodiesel**
Specific gravity at 40 °C	D4052	0.81-0.90	0.891
Kinematic viscosity at 40 °C (mm^2/s)	D445	1.9-6.0	5.7
Flash point (°C)	D93	≥ 130	178
Cloud point (°C)	D 97	-3 to 12	4
Carbon residue (% mass)	D 524	≤ 0.05	0.039
Calorific value (Cal/gm)	P 6	-	8995

3.2.3 Flash Point

The flash point is the minimum temperature at which fuel gives momentary flash on ignition under specified test conditions. It is an important parameter for storage, handling and safety of the fuel. The flash point of the produced biodiesel was about 178 °C.The minimum value of flash point for conventional diesel fuel is about 35 ^{o}C. Based on the results, the produced biodiesel was considered to be safe for storage and handling purposes when compared to the conventional diesel.

3.2.4 Cloud Point

The cloud point means that the temperature at which a sample of the fuel starts to become cloudy when the fuel is cooled under prescribed conditions. The cloud point of biodiesel produced in the present study was about 4 ^{o}C. The observed value of biodiesel matches with the specifications of ASTM. Mohamed, (2008) observed that the cloud point for jackfruit seed biodiesel produced using acid/ base catalyst was3 ^{o}C. The cloud point of conventional diesel fuel is between -10 and -15^{o}C. The result of the study suggests that the obtained biodiesel may not be used as fuel at low temperatures when compared to the conventional diesel. To overcome this problem, the suitable additives can be used.

3.2.5 Carbon Residue

Carbon residue is an indication of carbon depositing tendencies of the fuel in diesel engine. The carbon residue of biodiesel produced in the present study was about 0.039 wt%. The obtained result agrees well with the specifications of biodiesel standard ASTM D6751. The carbon residue specification for conventional diesel is 0.01 wt%. The carbon residue value of obtained biodiesel was slightly higher than that of the conventional diesel, because the biodiesel may contain inorganic impurities and biopolymers.

3.2.6 Calorific Value

Calorific value is the ability of heat generated by the unit mass of fuel. The calorific value of the produced biodiesel was reported as 8995 cal/gm. The similar result was observed by Babu and Mamila, (2008) and Ingle, (2012) for calorific value of biodiesel from castor oil.

4. Conclusion

The highest *Artrocarpus heterophyllus* seed oil yield about 19.8% was successfully obtained from microwave oven process using methanol as solvent and the following biodiesel production was successfully conducted using methanol with sodium hydroxide as a catalyst.

The properties of resulting biodiesel agreed well with the specifications of biodiesel standards ASTM D6751. Hence, the produced biodiesel can be considered as an alternative fuel to the conventional diesel.

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