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Experimental Investigation On Tamanu Seed Oil Methyl Ester

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Abstract: Oil crisis witnessed by the world has resulted in unprecedented stock piling of oil in most of the developed countries. Fossil fuel depletion and environmental degradation is the greatest twin challenge confronting the human race. The petroleum reserves worldwide is depleting in an abnormal speed because of the indiscriminate extraction and consumption of fossil fuel. Turning away towards utilizing alternative fuels is the only better and the most feasible way to meet the growing demand. The search for liquid fuels as an alternative to diesel is the greatest necessity of the hour. So it is very important to explore the feasibility of substitutions of diesel with an alternative fuel, which can be produced within the country on a massive scale for commercial utilization. An alternative fuels may be advantageous if only it is easily available, environment friendly and techno economically competitive. A promising option is bio-diesel that is extracted from vegetable oils. Vegetable oils, being renewable, are widely available from a variety of sources and have low sulphur contents close to zero, and hence cause less environmental damage than diesel. New energy crops are being identified which may not be used for edible purposes. In this paper, an attempt has been made to identify new non-edible tamanu seed oil which can be used as bio-diesel. tamanu seed oil fall under non-edible oil category. So using it as an alternative will not result in food versus fuel conflict. The widely used triple stage transesterification process is used for bio-diesel preparation. The properties of tamanu oil is tested in the laboratory and compared with diesel and other vegetable oils of its same category. It comes to light from the test reports that the bio-diesel extracted from tamanu seed oil will be one of a promising alternative for petroleum diesel. The density and viscosity of the tamanu Oil Methyl Ester (TOME) was found to be close to the petroleum diesel oil. All the characteristics of bio-diesel are in very close agreement with the diesel oil making it a potential fuel for the application in compression ignition engines for complete replacement of diesel fuel.

Keywords: Biodiesel, Alternate fuel, Tamanu oil, Blending, Transesterification, Extraction.

I. INTRODUCTION

The essential input for economic growth, social development, human welfare and better quality of life is energy. The major convectional energy source were the fossil fuel since their exploration, With increasing trends of modernization and industrialization, the world energy demand is also growing in a faster rate. One of the other most important problem is the environmental degradation caused because of fossil fuel combustion. Thus it is high time to switch away to some low emission alternate fuels for use in diesel engines. Vegetable oil is a promising substitute. Recently, several researchers are taking serious efforts to use different vegetable oils as fuel in existing diesel engines.

In several countries this research and development mostly involves edible oils. In a highly populated country like India, biodiesel produced from non-edible oil seeds like jatropha, pungamia, cotton seed etc. are given first preference. The present paper is an attempt to review the possibilities of using tamanu oil as biodiesel by studying the process available, fuel properties and economical analysis of tamanu oil production. There are some ancient literatures to explain that tamanu oil has been used as lamp oil in the ancient times. Thus this present work is to experimentally evaluate the possibilities of using tamanu oil which is developed from one of the easily available non-edible oil seed in India.

Biodiesel -Alternative diesel fuels

An alternative fuel is compatible only if it is easily available, environment friendly and techno economically competitive. Triglycerides and their derivatives present in vegetable oil is one of such fuel. Vegetable oil is renewable, widely available from a variety of sources

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and is also having low sulphur contents close to zero. Due to its low sulphur content it results in less environmental damage (lower green house effect) than diesel.

Chemically modified vegetable oil as diesel fuel

Utilizing neat vegetable oils as diesel fuels in conventional diesel engines may lead to a number of problems related to the type and grade of oil and local climatic conditions. The injection, atomization and combustion characteristics of vegetable oils in diesel engines are significantly different from those of diesel. The injection process is interfered by the high viscosity of vegetable oil and thus results in poor fuel atomization. Incomplete combustion occurs because of the inefficient mixing of oil with air which contributes to heavy smoke emission, and the high flash point attributes to lower volatility characteristics. These disadvantages, coupled with the reactivity of unsaturated vegetable oils, do not allow the engine to operate trouble free for longer period of time. To overcome these problems, the vegetable oils are chemically modified to biodiesel. This modified biodiesel has similar characteristics like diesel.

II. BIODIESEL

A methyl ester of fatty acids made from vegetable oils and animal fat is biodiesel. The biodiesel may be classified as edible and non-edible oil. “Rudolf Diesel” demonstrated his first diesel engine at the world exhibition at Paris in the year 1900 by using peanut oil as fuel. Soya bean oil, rice bran oil, palm oil, pungamia oil, cotton seed oil, jatropha oil, tamanu oil etc. are some major sources of biodiesel. Non-edible oil are selected mainly because there is no demand, inexpensive, renewable, more availability and not for food.

Advantages of biodiesel as diesel fuel

The advantages of biodiesel as diesel fuel are its liquid nature portability, ready availability, higher combustion efficiency, low sulphur and aromatic content, higher cetane number, high flash point, inherent lubricity and higher biodegradability. Engine modification is also not necessary. Its domestic origin also makes it advantageous as it reduces the dependency on imported petroleum.

III. INTRODUCTION TO TAMANU OIL

Tamanu tree, (Botanical name: Calophyllum Inophyllum) is generally called as Alexandrian Laurel in English.

Tamanu tree-Plant description

Coastal regions as well as nearby lowland forests are perfect for the growth of tamanu trees. A tamanu tree is 2-3 meter high, with a thick trunk covered by a rough, black and cracked bark. Its leaves are elliptical, shiny and tough. Its flowers, arranged in clusters, are spherical drupes. The grey, ligneous and rather soft nut contains a pale yellow kernel, which is odourless when fresh. Tamanu kernels have very high oil content (75%). Oil obtained by cold pressing of these kernels is greenish yellow in colour.

Raw tamanu oil processing

The oil extracted from these nuts is called tamanu oil. The nuts are cracked and the kernels are extracted. The seeds need to be Sun-dried on rocks for 1-2 months leaving it for oil formation. Kernels turn from creamy white to brown during the process. During the Sun-drying, kernels lose weight from a mean 7 gm of fresh kernels to about 4.5 gm of dry and oil-rich ones. These kernels have longer shelf life. Any moldy nuts should be discarded. The oil is then extracted by cold pressing and filtration.

Characterization of tamanu oil

The unrefined but filtered tamanu oil is dark green in colour and is used as feed stock for biodiesel production in this study. The fatty acid composition and the important properties of tamanu oil in comparison with other non-edible oils are given.

Table 1. Properties of tamanu seed oil in comparison with other non-edible oils:

Property of the oils	Tam -anu oil	Cotton	Karanja	Jatropa
Palmitic acid (%)	0	11.7	11.65	16.0
Stearic acid (%)	0	0.89	7.5	6.5
Oleic acid (%)	41.6	13.7	51.59	43.5
Linoleic acid (%)	24.3	57.5	16.46	34.4
Linolenc acid (%)	0	0	2.65	0.8
Acid value (mg KOH	44	0.1	5.06	3.8

Tamanu oil contains 24.96% saturated acids (palmitcs and stearic) and 72.65% unsaturated acids (oleic,

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linoleic and lenolenic). Saturated fatty acid alkyl esters increases the cloud point, cetane number and stability.

The free fatty acid (FFA) content of unrefined filtered tamanu oil was found to be 22%. i.e. acid value of 44 mg KOH/gm. A standard titrimetry method was adapted to determine its free fatty acid content.

The yield of esterification process and quality of biodiesel decreases considerably if acid value is greater than 4 mg KOH/gm. i.e. free fatty acid content is 2%.

Therefore, it is significant to develop any method to produce biodiesel from high acid value oil. Hence, esterification of a typical high free fatty acid type of oil, i.e. Tamanu seed oil is undertaken for this study

III. BIODIESEL FORMULATION BY AN EXPERIMENTAL SETUP

Methodology

The laboratory set up for the experiments consists of a heating mantle, a glass reaction flask and mechanical stirrer. The working capacity of reaction flask is 3 liter. It consists of three necks. One for stirrer, the others for condenser and inlet of reactant as well as for placing the thermometer to observe the reaction temperature. The final product is collected from the bottom of the flask thru a stopcock. The progress of the reaction is observed by measuring the acid value.

In course of the test, it was observed that the appropriate quality of biodiesel could be produced from tamanu seed oil in following three stages so that the physio-chemical properties were close to those of petro-diesel.

A. Zero catalyzed transesterification

The first stage removes the organic matters and other impurities present in the unrefined filtered tamanu oil. Toluene is used as a reagent for the removal.

B. Acid catalyzed transesterification

The intermediate stage reduces the acid value of the oil about 4 mg KOH/gm corresponding to a FFA level of 2% by using H_2so_4 as catalyst.

C. Alkaline catalyzed transesterification

The product of the intermediate stage (pure triglyceride) is transesterified to mono-esters of fatty acids (biodiesel) by using NaoH as alkali catalyst.

IV. Process of biodiesel production

Transesterification process:

The displacement of alcohol by another alcohol from an ester is called alcoholysis or transesterification. This is widely used to reduce viscosity of triglycerides.

Chemistry of transesterification reaction

The overall transesterification reaction is given by three consecutive and reversible equations as below:

catalyst

Triglyceride + ROH <----------------→Diglyceride + R^{1} COOR

catalyst

Diglyceride + ROH <--------------→ Monoglyceride + R^{11}COOR

catalyst

Monoglyceride + ROH <----------------→Glycerol + R^{111} COOR

The first step is the conversion of triglycerides to diglycerides, followed by the conversion of diglycerides to monoglycerides, and of monoglycerides to glycerol, yielding one methyl ester molecule per mole of glyceride at each step.

The overall chemical reaction of the transesterification process is:

CH2OCOR'''			CH2OH	R'''COOR
|		Catalyst		|
CH2OCOR''	+ 3 ROH	------>	CH2OH +	R''COOR
|				|
CH2OCOR'			CH2OH	R'COOR

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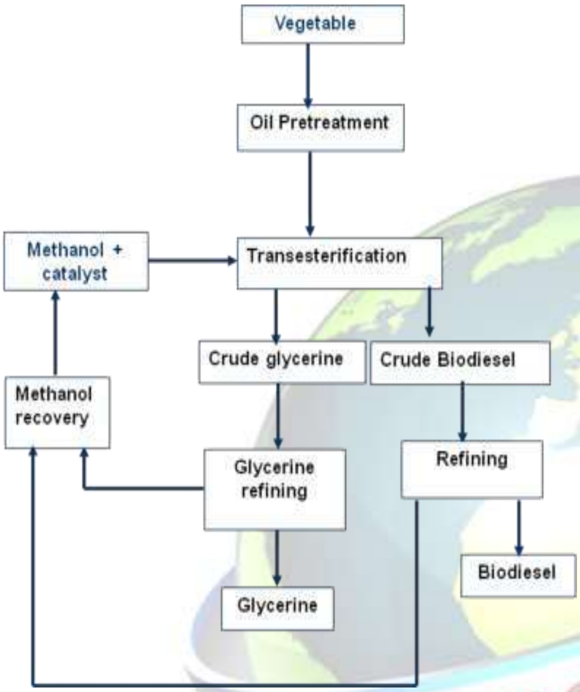
Triglyceride Alcohol Glycerol Biodiesel

Where, R^1, R^{11}, R^{111} are long-chain hydrocarbons which may be the same or different with R= - CH_3 / C_2H_5

V. BIODIESEL PRODUCTION PROCEDURE



A mechanical expeller was used to extract the raw tamanu oil in which small traces of organic matter, water and other impurities were present. These materials were creating problems in yield and in the phase separation between the glycerin and esters. This makes the pretreatment of tamanu oil a necessary step in the first stage

One liter of tamanu oil was mixed with 350 ml of methyl alcohol and 5 ml of toluene as a reagent. Toluene helps in dissolving the organic matter with methanol and separating it from the neat oil along with other impurities. Different methanol to oil ratio (0.15, 0.20, 0.25, 0.30 and 0.35) and reaction times (0.5 h, 0.10 h, 0.15 h, 0.20 h) were used to investigate for the optimization and their influence on the acid value of crude tamanu oil. The mixture was stirred in the air closed reaction flask for 2 hours at 65^0C. The heating set up should be just above the boiling point of the alcohol i.e 65^0C to accomplish the reaction. The speed of the stirrer was kept same for all test runs.
i.e. 450 rpm. The product from the first stage was allowed to settle for 1 hour and complete phase separation was visualized. The upper layer which consisted of methanol-water fraction, organic matter toluene and other impurities was separated from the lower layer. The acid value of the required lower layer is determined and found to be 18 mg KOH / gm corresponding to FFA of 9%.

Anhydrous sulphuric acid (98.4%) was used as catalyst in the acid catalyzed transesterification. Experimentally it was optimized that 0.65% by volume of the H_2SO_4 acid and a molar ratio of 6:1 gave the maximum conversion efficiency of free fatty acid value of the product of the second stage below 4 mg KOH / gm. the duration of the reaction was 4 hour.

The raw material for the final stage is the product of second step having FFA less than 2% . A molar ratio of 9:1 and the 1.5% by weight of sodium hydroxide was found to give the maximum ester yield for reaction duration of 4 hour.

After the reaction was completed the products were allowed to separate in two layers. The lower layer is separated and purified by using warm water. After washing, the final product was heated up to 70ºC for 15 min. under vacuum condition and stored for further use. This resulted in a clear amber-light yellow liquid with a viscosity similar to petro-diesel.

Table 2. Properties of tamanu oil methyl ester in comparison with diesel and blends:

Fuel blend	Viscosity	Calorific value	Flash point	Cloud point	Pour point
HSD	2.87	44	76	6.5	3
B20	2.98	44	86	7.8	2.8
B40	3.30	43	91	8.5	2.8
B60	3.61	41	96	10.6	3.2
B80	3.72	40	111	10.8	3.6
B100	4.92	39	140	13.2	4.3

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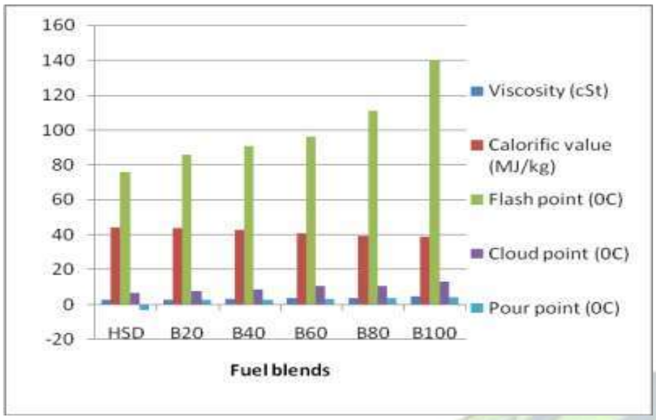

Figure 1. Properties of tamanu oil methyl ester

The physio-chemical properties of the tamanu oil, neat petro-diesel, neat biodiesel (B 100) and its blend of 20% at each step were evaluated as per the ASTM standard methods and the results are in accordance with ASTM.

The fuel properties of tamanu oil methyl ester and its different blends with diesel are shown in Table-3. It is observed that the chemical characteristics of the tamanu oil methyl ester were found to be in the close range of engine requirement.

Economics of biodiesel utilization

The major obstacle to produce biodiesel is higher cost than petroleum diesel. The actual cost will depend also on economics of scale in manufacturing and the political decision to promote biodiesel in the country.

The cost factor may also be considered taking in the view of increased rural employment opportunities, indigenous energy sufficiency and savings of foreign exchange. There would also be employment generation in storage, oil extraction etc.

The glycerin and cake would be valuable products, which further reduces the cost of biodiesel. Oil cake can be used as a raw material for production of biogas which would be a leverage to start many types of industries. Reduction of tax on biodiesel by government is one of the effective ways to bring down the cost.

VI. CONCLUSION

The density and viscosity of the tamanu oil methyl ester (TOME) obtained after triple stage transesterification was found to be in close proximity to that of petroleum diesel oil. All the blends of TOME had a higher flash point than that of diesel oil. Particularly, the 100% biodiesel also demonstrated comparatively higher flash point than petroleum diesel oil and was in safe range for storage. All the tests for characterization of biodiesel demonstrated that almost all the important properties of biodiesel are in very close agreement with the diesel oil making it a potential fuel for the application in compression ignition engines as a complete replacement for diesel fuel.

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