Preparation Process of Thumba Biodiesel and Analysis of Fuel Testing: A Review

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Abstract— An expanding interest of fossil fuels has being a critical issue for us. The current assets of fossil fuel are waning step by step rapidly. Biodiesel might be a decent source or substitute for fossil fuel in future. Next couple of decades fossils fills will be depleted. The energies which depend on petroleum assume an exceptionally critical part in the improvement and development of the commercial ventures, transportation, agricultural field and numerous other human necessities segment. Furthermore, petroleum fuels are likewise contaminating nature and making issue to human beings and in addition society moreover. Therefore, there is a need of exploration for optional fuels, Researcher shown that the biodiesel is a decent option fuel for this problem of pollution and limited fossil fuels. In India, there are different feedstocks available, which can be utilized for the creation of biodiesel. Thumba (Citrullus colocyntis) oil is non-edible oil made by thumba seeds which is generally found in Rajasthan locale and Gujarat. As this oil is non-edible so we can be for creation of biodiesel. In this paper a review on production of biodiesel from Thumba seed oil (Citrullus colocyntis) and fuel testing methods by different researchers are described. Transesterification process is mainly used for preparation of biodiesel in which methanol and potassium hydroxide used as catalyst for conversion of oil in to the biodiesel. The properties of this Thumba Bio-diesel are evaluated and it is found that the these properties of Bio-diesel are practically identical to the diesel fuel and can be utilized as optional fuel with better performance ,emission and combustion compared to conventional diesel fuel and it will play very important role for overall economic development. Thumba seed biodiesel preparation is optimized with different parameters by various researchers. The parameters that impact the transesterification of triglycerides are molar ratio of oil to methanol, concentration of catalyst, time required for reaction, temperature and free fatty acids content of oil. Researchers observed that Thumba methyl ester (TME) can used as an economical feedstock for biodiesel generation which is equivalent to fossil fuel according to ASTM. The emissions (CO, CO2, HC, NOx, and Smoke Opacity) are compared with different experiments.als. The maximum break thermal efficiency (BTE) achieved with low concentration blends of TME. As the concentration of TME increased in biodiesel-diesel blends, there is reduction in BTE. The exhaust gas temperature also increases with increase is TME concentration. It is found that emissions of biodiesel based fuel are less pollutant than pure diesel except the CO2 and NOx emissions. The outputs of all experimental results shows that TME is an ideal alternative to the diesel fuel, which gives in better performance and improved emission characteristics.

Key words: Thumba Seed Oil; Thumba methyl ester; Transesterification; Biodiesel; Emission

I. INTRODUCTION

The depleting reserves of fossil fuel, with increasing demand for diesel and uncertainty in its availability is considered to be the important trigger for many initiatives to search for the alternative source of energy, which can supplement or replace fossil fuels. In the last two decades, research has been directed to explore renewable plant-based fuels and plant oils. The raw material being exploited commercially by the biodiesel countries constitute the edible fatty oils derived from rapseed, soybean, palm, sunflower, coconut, linseed, etc. [1]. The transesterification process for production of Thumba oil methyl ester has been analyzed by researchers and the various process variables like temperature, catalyst concentration, amount of methanol and reaction time have been optimized with the objective to maximize yield. The optimum conditions for transesterification of Thumba oil with methanol and KOH as catalyst were found to be 60°C reaction temperature, 6:1 molar ratio of Thumba oil to methanol, 0.75% catalyst (w/woil) and 1 hour reaction time [2]. The use of biodiesel leads to the substantial reduction in PM, HC and CO emissions accompanying with the imperceptible power loss, the increase in fuel consumption and the increase in NOx emission on conventional diesel engines with no or fewer modification. And it favors to reduce carbon deposit and wear of the key engine parts. Therefore, the blends of biodiesel with small content in place of petroleum diesel can help in controlling air pollution and easing the pressure on scarce resources without significantly sacrificing engine power and economy. Thumba biodiesel can be used as an extended to diesel fuel, which would results in better performance and improved emission characteristics [3, 4].

Bio-diesel is an alternative ecofriendly diesel fuel. Keeping this in view, an attempt has been made through the experiment of Thumba blended biodiesel on CI engine in laboratory and analyzes its properties and characteristic compare with other biodiesel oils [5]. Biodiesel blended B10, B20 and B30 of thumba shows it gives better performance and lower emissions [6]. Many researchers and scientists had tried out different types of fuels namely compressed natural gas (CNG), liquefied petroleum gas(LPG), hydrogen, and alcohols. The vegetable oils and alcohols (methanol and ethanol) are favorable renewable liquid fuels. Alcohols are not suitable for diesel engines due to their low cetane number. The poor volatility and low octane number make vegetable oils unsuitable for spark ignition (petrol) engines. One possible solution to this problem is the use of bio-diesel [7]. Citrullus Colocynthis schard (Thumba) oil is a best source as a raw for biodiesel production [8]. Thumba seeds contain about 50% oil which can be exploited. Some physical and chemical properties of oil obtained in South Western region of Nigeria [9]. Biodiesel can be prepared by, dual step catalyzed process by using crude Citrul-lus colocynthis oil (CCO). In these two ionic liquids were synthesized and evaluated as pre-catalyst for the FFA-esterification first step [10]. The C. colocynthis is available in India, Pakistan, Middle Eastern, Iran, Israel, and Afghanistan. Citrullus colocynthis (L.) Schrad. (Cucurbitaceae), a species related to watermelon, is a nonhardy drought-resistant perennial herbaceous vine, originally from tropical Asia and Africa, now widely distributed in the Saharo-Arabian phyto geographic region in Africa and the Mediterranean region. The species is characterized by its angular and rough stems, rough, deeply 3–7 lobed leaves of 5–10 cm, and solitary pale yellow flowers. Each plant can produce about 15–30 round (7–10 cm) fruits, green with yellow stripes, with small (6 mm), smooth, brownish seeds [11]. Profiles of non-conventional oil extracted from Citrullus colocynthis (L.) Schrad seeds were evaluated and compared with conventional sunflower seed oil [12].

The fuel properties of EOME measured met both the ASTM D6751 and EN 14214 biodiesel standards, with the exception of lower oxidative stability. The fatty ester composition and fuel properties of EOME are comparable to those of conventional biodiesels from soybean, sunflower and safflower oils. The viscosity behavior of EOME and its blends with diesel fuel (at 25 °C, 40 °C and 55 °C) is pseudo plastic and Newtonian in nature [13]. The thumba plant has wide range of traditional medicinal uses [14]. CFD analysis of biodiesel fuel combustion is carried out using ANSYSFLUENT R14.5 software to study the effect of blending ratio on the combustion characteristics in compression ignition (CI) engine and parameter such as in-cylinder pressure, temperature, heat release rate, etc. [15]. Thumba (Citrullus colocyntis) has huge capability for biodiesel production. The most important feature of this Thumba is that it grows in the form of climbing plant in sandy soil with in a six month crop cycle [16]. The optimum combination of feasibility of four factors namely low percentage thumba biodiesel diesel blends, compression ratio, injection pressure and injection angle on single cylinder variable compression ratio diesel engine are find out using Taguchi method and grey relational analysis[17]. Production process of biodiesel using low frequency ultrasound energy (28.5 kHz) and conventional mechanical stirrer method is compared which shows advantages of new method [18].

Experimentation on the performance, emission and combustion characteristics of diesel engine using Thumba oil methyl ester and blends with diesel shows the ability of thumba oil biodiesel as a fuel [19]. Thumba biodiesel satisfies the important fuel properties as per ASTM specification of biodiesel. Engine works smoothly on thumba methyl ester with performance compared to diesel operation [20]. The byproducts as like oil cake and glycerol have very good commercial value which can reduce the cost of biodiesel [21]. Low concentration blends of methyl ester of thumba up to 30% by volume with diesel can be used successfully and satisfactorily with no major reduction in engine performance [22]. Experiments are carried out by using dual biodiesel blends and compared it with diesel fuel characteristics. [23] Biodiesel synthesized from Citrullus colocynthesis schard by applying homogeneous catalyst, sodium methoxide and investigates the synthesized citrullus methyl ester for performance and emission of engine [24]

A. Objectives:

The objectives of the present review are:

1) To explore the possibility of Thumba methyl ester (TME) by using Thumba oil.
2) To study the various methods of biodiesel preparation.
3) To study the different properties of Thumba oil and TME.
4) To compare engine performance, emission and combustion testing data of biodiesel blends with respect to pure diesel oil.
5) To investigate suitability of thumba biodiesel blend in terms of Production of methyl ester.

B. Thumba oil as a potential feedstock for biodiesel production:

Use of edible oil to produce biodiesel in India is not practical in view of a big gap in demand and supply of such oils in the country. Increased pressure to augment production of edible oil to meet the demand has also put limitation on the application of these oils for production of biodiesel. In this review Citrullus colocyntis (Thumba) oil, a non-edible vegetable oil considered as a potential alternative fuel for CI engines, has been chosen to explore its possibility for use as fuel oil. C. colocyntis is known as Indrayan, Bitter Apple, bitter gourd Chitrapala, ground melon, Handhal or Dellaa El-Wad. It is a native of Turkey and also found in many parts of Asia and Africa. In India it mainly grows in rain fed parts of Rajasthan and Gujarat. The plant is in the form of a creeper and grows well in sandy soil. The plant has annular and rough stems, rough leaves which are 3–7 lobed and 5–10 cm long in middle. Flowers are monoelcious and have yellow round fruit. The flowering season is in between May (start of monsoon) and August. It grows along with main crop of bajara and hence does not require any special care. The oil of this plant is locally called as Thumba oil. The plant is mainly used as cattle feed by farmers. It is also used as laxative and anti-inflammatory drug. Raw Thumba oil is presently consumed in large quantities by the local soap industries. Its soil binding capacity is of considerable significance and it has a potential to yield around one million tons of the oil rich seeds from the arid districts of Rajasthan [2]. Biodiesel derived from Thumba oil and its blends with mineral diesel is a potential feedstock in coming days. The Thumba is a wild plant and does not produce any harmful effect like jatropha curcas seed if it consumed by animal or human being. Biodiesel produce from thumba seed oil also yield comparable results with petroleum diesel [4, 5].

II. PRODUSTION OF TME

Researchers and scientists developed different methods for biodiesel production from different bio fuels. A brief review of these methods has presented here. Before going for biodiesel production to finding the properties of oil is important. The properties of Thumba oil determined by various researchers are given in following table. Most of the researchers reported that the production of biodiesel is more when the process used a catalyst. The recently developed biodiesel production technologies are power ultrasound, hydrodynamic cavitations and supercritical methanol processes. Hydrodynamic Cavitations is a cheaper alternative and requires approximately a half of the energy that is consumed by the conventional mechanical stirring method. In hydrodynamic cavitations method mixing of two phases of reaction is carried out by cavitations conditions, produced by pressure variation.

Sr No.	Researcher→ Properties ↓	Chavan et al. [8]	Oluba et al. [9]	Yasir et al. [10]	Nehdi et al. [12]	Solomon et al. [13]	Sivakumar et al.[19] Praveen et al.[20]	Vandana et al. [22]
1	Density (gm/cc@20^{0}C)	.0.927	.93	0.927	0.907	0.90253	0.930	0.905
2	Viscosity Cst@40^{0}C	40.2	--	35.20	19.99	31.52	31.52	31.52
3	Calorific value Mj/kg	37.42	--	--	--	39.37	39.78	39.78
4	Cetane number	--	--	--	--	--	45	45
5	Flash point ^{0}C	225	--	--	--	--	112	201
6	Fire point ^{0}C	--	--	--	--	--	122	
7	Pour point ^{0}C	--	--	--	--	--	6	-5
8	Free fatty acid (%)	--	--	--	1.57	0.49	--	<1
9	Cloud point ^{0}C	3.5	--	--	--	--	--	--
10	Saponification value (mg KOH/g)	184	--	--	204.63	204.44	--	--
11	Carbon residue (%wt)	1.51	--	--	--	--	--	--
12	Acid value Mg KOH/gm	2.3	3.5	1.9	3.14	0.98	--	--
13	Iodine value mg iodine/gm	--	110	107.4	123.31	114.46	--	--
14	Molecular wt. g/mol	--	--	--	875.21	874	--	--

Table 1: Physico-chemical Properties of Thumba oil:

When the liquid passes through the orifice plate (single or multiple holes), the velocities at the orifice increase due to the sudden reduction in the area offered for the flow, resulting in the decrease in the pressure. If the velocities are such that their increase is sufficient to allow the local pressure to go below the medium vapor pressure under operating conditions, cavities are formed. The vegetable Thumba oil of is filtered to remove impurities. It is heated up to 110 ^{0}C in order to remove water content of oil to avoid soap formation and allowed to cool up to room temperature. Methyl alcohol (CH3OH) with a molar ratio of 1:4.5 and sodium hydroxide (1% by weight of oil), are mixed and stirred till sodium hydroxide is dissolve in alcohol. This liquid mixture is mixed with vegetable oil and supplied to the feed tank of hydrodynamic cavitation reactor test rig. The pump of hydrodynamic cavitation reactor is started and whole mixture is allowed to pass through orifice hole to generate the favourable cavitation conditions. During the reaction the temperature of mixture is kept between 45 and 55 ^{0}C. After 45 min the process is stopped and the mixture is collected in a bucket. It can be observed that for all the orifice plates, around 80% yields are obtained within 30 min. The yield increases with increase in the number of holes and afterwards it remains more or less constant for all type of orifice plates [1].

The experimental setup included 250 ml glass three necked batch reactor equipped with a reflux condenser, a mechanical stirrer and a thermometer, immersed in a constant-temperature bath. 100 g Thumba oil was taken in the reactor and placed in the water bath at the desired temperature. Different weight percentage of Methanol and Potassium Hydroxide (KOH) were mixed and added to oil in the reactor at the prefixed temperature. After the required time, mixture was transferred to a separating funnel, allowing glycerol to separate by gravity for overnight. After removing the glycerol layer, washing of methyl ester was done with lukewarm water to remove catalyst, methanol and glycerol residuals. The raw biodiesel after successive washing was heated to 100°C in an open vessel to remove any water particles. Biodiesel production from Thumba oil using KOH as catalyst was carried out and it was found that KOH can be utilized as a catalyst for biodiesel production without any difficulty. It was also found that excessive catalyst concentration results in formation of soap and can also cause emulsion formation during purification of biodiesel. The optimization of major process parameters such as molar ratio (oil to alcohol), catalyst concentration (w/w), reaction temperature and reaction time was also carried out. The physic-chemical properties of TME are find out by different researchers are listed out in following table.

Sir No.	Researcher → / Properties ↓	Pal et al. [1]	Ashish et al. [2]	Yasir et al. [10]	Solomon et al. [13]	Rajesh et al. [15]	Sharma et al. [16]	Pal et al. [18]	Sivakumar et al. [19] Praveen et al. [20]	Vandana et al. [22]	Kumbhar et al. [23]	Gujar et al. [24]
1	Density gm/cc@20 ^{0}C	0.89	0.88	0.88	0.884	0.88	0.87	0.89	0.88	0.88	0.891	0.872
2	Viscosity Cst@40^{0}C	5.86	5.3	3.14	3.91	4.664	4.32	5.86	5.86	5.86	5.3	5.10
3	Calorific value Mj/kg	--	39.798	--	--	--	37.00	38.24	39.37	39.37	42.5	37.5
4	Cetane number	--	--	60.8	53.66	--	--	--	53	53	52	41.5
5	Flash point ^{0}C	>66	187.5	169	142	--	91	>66	91	174	174	164
6	Fire point ^{0}C	--	195.5	--	--	--	110	--	110	--	187.5	171
7	Moisture %	0.05	--	0.012	0.023	--	--	0.05	--	--	_	0
8	Ash content % wt	--	--	--	--	--	--	--	-	--	0.1%	--
9	Pour point ^{0}C	--	-8	--	--	--	7.2	--	--	-8	--	--
10	Free Fatty Acid %	--	--	--	--	--	--	--	--	0.48	--	--
11	Sulphur content ppm	<100 ppm	--	--	--	--	--	<100	--	--	--	--
12	Cloud point ^{0}C	--	-1	--	0.5	--	4.5	--	--	--	--	--
13	Boiling point ^{0}C	--	--	--	--	691.69	321	--	--	--	--	--

Table 2: Physico-chemical Properties of Thumba Methyl Ester (TME)

The combination of process parameters giving optimum biodiesel yield was found to be 6:1 molar ratio of methanol to oil, 0.75% KOH (w/woil), 60°C reaction temperature and 1 hour reaction time [2]. Biodiesel production with molar ratio 8:1, KOH were 0.75wt%, temperature 65 ^{0}C, reaction time 90 minutes were used and testing of parameters as per ASTM 6751 standards. The process variables that influence the transesterification of triglycerides, such as catalyst concentration, molar ratio of methanol to raw oil, reaction time, reaction temperature, and free fatty acids content of raw oil in the reaction system were investigated and optimized [8].

A 96.7% FFA conversion was achieved at the optimal conditions at 130 ^{0}C, and 600 rpm agitation rate for 2 h. In the second step, KOH-transesterification reaction of the esterified CCO was performed at 60 ^{0}C, 6:1 mole ratio of methanol: oil, and 600 rpm in a reaction system containing 1.0 wt% of catalyst for 50 min. The final yield in 98.8% revealed that the process proposed for novel CCO in this study led to a tolerable biodiesel, meet-ing the ASTM requirements for its utilization as a fuel [10]. The transesterification of thumba oil via methanol in the presence of sodium methoxide was performed and the resulting Thumba oil methyl ester (TME) was tested for its fatty ester composition, fuel properties and rheological behavior (at 25 °C, 40 °C and 55 °C). [13] It has been observed that there is higher yield in case of 6:1 molar ratio as compared to 4.5:1 molar ratio. It may be because of alcohol using for 6:1 molar ratio is more than that of 4.5:1 molar ratio. The yield for 0.5% KOH is less as compare to 0.75% and 1% KOH in both the cases. It may be because of 0.5% KOH is not sufficient to enhance the reaction. The maximum yield obtained is 97.82 at 1% KOH for 6:1 molar ratio [16].

III. IMPACT OF THUMBA MYTHYL ESTER ON ENGINE CHARACTERISTICS

A. Performance of TME:

Engine performance for various parameters such as torque, brake power, specific fuel consumption, and brake thermal efficiency are explained by researchers. The main aim of this experiment is to investigate the suitability and effect on performance of blending of biodiesel in comparison to diesel fuel. The comparison of biodiesel blends and pure diesel exhibit similar variations in performance parameters for wide range of engine speeds. The trends for variations of performance parameters using blending do not shown any sign of deterioration as compared to pure diesel. In fact, brake thermal efficiency improves significantly for blending of B-30 which encourages the possibility of further investigations for higher blending [1]. It was found that low percentage blend of Thumba biodiesel with diesel (B10) yielded highest thermal efficiency, least BSEC and low Exhaust gas temperature for all loading conditions. It is because of presence of oxygen in biodiesel and additional lubricity provided by the biodiesel which results in better combustion [4]. All blends tested, brake specific fuel consumption is found to decrease with in-crease in BHP. Blend, B10 of all biodiesel yield better results as compared to other blends [5]. Variation of performance parameters for wide range of engine speed is similar for biodiesel blends of Thumba with pure diesel. Break thermal efficiency improves significantly with increase in percentage of biodiesel blending [6]. There is increase in brake thermal efficiency for all the blends as the load increases. The 40% Thumba oil methyl ester and 60% diesel blend showed a 2% increase in brake thermal efficiency when compared to that of diesel [19]. The variation of brake power with respect to load for blends indicates that brake power increases simultaneously with load for various blends. The speed is kept constant for all the blends. As the load increases, BSFC drops simultaneously when the speed is constant. The BSFC decreases down with load significantly [21]. The engine performance is better or optimized with TME20 and the compression ratio is at CR19 [22]. At CR 18 BTE, BSFC and BP of all blends of Thumba biodiesel showed better performance than other compression ratios [23, 24].

B. Emissions from TME:

Comparison of opacity shows that Thumba biodiesel is relatively less pollutant as compared to pure diesel. 100 % Thumba biodiesel is found to exhibit lowest smoke emissions in comparison to other test fuels. As the proportion of biodiesel was increased in the biodiesel-diesel blend, emissions like smoke density, CO and HC were found to decreases. Maximum concentration of NOx was found to be for 100 % Thumba biodiesel [1, 4, 6]. The reduction in NOx, hydrocarbons and carbon monoxide emissions were observed Thumba oil methyl ester and its diesel blends along with increased smoke emissions compared to those of diesel [19]. The emissions such as CO, HC, CO_2 of B100 of Thumba biodiesel showed less emission percentage/ppm, and for NOx emissions of B10 and B20 of Thumba biodiesel showed less emission ppm. [23, 24]

C. Combustion of TME:

The in cylinder pressure, temperature, instantaneous heat release, cumulative heat release, indicated mean effective pressure, indicated power and indicated thermal efficiency predicted by the model for diesel and various blends of diesel and thumba biodiesel are analyzed using ANSYS-FLUENT R14.5 and it is observed that, the analysis of in-cylinder pressure-crank angle history and heat release analysis indicates similar combustion stages for both diesel and thumba biodiesel blends and no objectionable combustion feature such as knocking were observed. Thumba biodiesel blends had lower heat release rate compared to diesel during premixed combustion phase. The peak of heat release rate for diesel during premixed stage is about 35.03 % and during mixing stage is about 1.09 % higher compared to B20. The heat release for thumba biodiesel always starts nearly 2º to 3º crank angle earlier compared to pure diesel. The model predicts a higher in-cylinder pressure and temperature for the thumba biodiesel blends during combustion as compared to pure diesel. It is also observed that with the increase in blending ratio the peak in-cylinder pressure increases. The peak pressure for B30 is nearly 1.05% higher than B10. A stable and smoother engine operation was observed thumba biodiesel blends [15]. The results of the study revealed that combination of factors and their level comprising of a blend consisting of 30% thumba biodiesel (B30), a compression ratio of 14, an injection pressure of 250 bar and an injection angle of 20º produced maximum multiple-performance of a diesel engine together with minimum multiple-emissions from the engine. The low cetane number of Thumba oil methyl ester prevented the use of 100% replacement of diesel [17, 19].

IV. CONCLUSIONS

Bio-diesel is non-toxic and degrades four times faster than diesel. Its oxygen content improves the bio-degradation process. The lending of Thumba oil biodiesel with diesel fuel increases efficiency of engine. It is safer to handle and store. Oxygen content of bio-diesel improves the combustion process and decreases its oxidation potential. The uses of bio-diesel can extend the life of diesel engine because it has more lubricating property than petroleum diesel fuel. Thumba oil biodiesel Provides a domestic, renewable, and potentially in exhaustible source of energy with energy content close to diesel fuel. Bio-diesel obtained from Thumba oil produces favorable effects on the environment. Biodiesel prepared from Thumba oil is compared for its fuel properties and viscosity behavior. The observed fuel properties follow both the EN 14214 and ASTM D6751 standards with the exception of oxidative stability. By comparing the properties of Thumba oil methyl ester and its performance, emission and combustion characteristics it can be concluded that Thumba oil appears a good substitute in biodiesel production.

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