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# A Review on *Jatropha curcas* Derived Biodiesel for Economic and Sustainable Development

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**ABSTRACT: The economic development of the country has raised the energy demand, the major part of which is derived from fossil sources such as petroleum, coal and natural gas, which have limited availability. This coupled with the stringent environmental laws, have drawn the attention of many researchers to look for alternative fuels, which can be produced from renewable feedstock. Among various options, Biodiesel has become more attractive because of its environmental benefits. In an agro economy based country like India, of the various raw materials, *Jatropha* seems to the most promising option for biodiesel synthesis. The biodiesel can be synthesize by various techniques viz micro emulsion, transesterification etc. The produced biodiesel can be used in the neat form or in the blended form with the petro-based diesel. The main issue associated with the widespread commercialization of the biodiesel is its poor oxidation stability that restrict the storage and long-term application, which to some extent can be controlled by the use of suitable antioxidants. In this paper, an attempt has been made to review *Jatropha* as a source of biodiesel production, different techniques for biodiesel production, variation of oxidation stability of biodiesel after blending with EURO-III & EURO-IV HSD, effect of various antioxidants viz BHT, BHA, DPA TBHQ, PL, and PG on the oxidation stability using Petrotest "PetroOXY(e)- VERSION: 10.08.2011" instrument. The results showed that the addition of an antioxidant to diesel fuel blends has beneficial influence on the fuel properties. Among the used antioxidants TBHQ, PG, and PL were found to be most effective and their use in diesel–biodiesel blends showed a greater stabilizing potential.**

**Keywords**: Biodiesel; HSD; Jatropha; Methyl ester Sustainable Development.

**Abbreviations**: ASTM, American Society for Testing and Materials; BIS, Bureau of Indian Standard; EU/EN, European Standard/Norms; JB, *Jatropha* Biodiesel; HSD, High speed Diesel; FAME, fatty acid methyl ester; BHT, butylated hydroxy toluene; BHA, Butylated hydroxy anisole; DPA, Diphenylamine; TBHQ, Tert-Butylhydroxyquinone ; PL, Pyrogallol and PG, Propyl-gallate.

## I. INTRODUCTION

The predicted shortage of fossil fuel encouraged the search for substitutes for petroleum derivatives. This search resulted in an alternative fuel called "biodiesel". Biodiesel is clean burning, eco-friendly, easily manufactured, nontoxic, biodegradable, Sulphur sulphurless diesel replacement fuel that can be prepared from domestic renewable resources i.e vegetable oils (edible & non-edible) and animal fats. Various edible and non-edible vegetable oils like *Jatropha curcas*, rice brain, castor oil, cottonseed oil, Mahua, Karanja, which are surplus, can be used for preparation of biodiesel. Esters of plant oils are preferred to parent oils, if used as fuels in diesel engines because esterification reduces the viscosity of oils and makes it comparable to that of diesel[1].This paper attempts to present a review on biodiesel from *Jatropha curcas* as a replacement fuel with India as focus.

## II. BIODIESEL FEEDSTOCKS

In India, the edible oils demand is higher than its domestic production and there is no possibility of diverting these oils for the production of bio-diesel. In addition, their prohibitive cost prevent their use in bio-diesel production. Under Indian conditions, therefore, only such plant sources can be considered which are non-edible and which can be grown in large scale on marginal/wastelands. Such oils should not further compete with food supplies in the long term as bio-diesel feedstocks [2].

Salunke *et al.,* [3] have stated that "Numerous cultivated as well as forest plants produce seeds that contain a significant amount of oil". However, due to the presence of toxic compounds, bitter taste, significant levels of unusual fatty acids or undesirable physical characteristics, the oils of these seeds are seldom used for edible purposes. These are generally produced on a smaller scale. Their peculiar chemical characteristics are, however, commercially exploited in the manufacture of several industrial products such as lubricants, greases, soaps, cosmetics, leather tanning, textiles, medicines, resins, nylon, plastics, adhesives, insecticides, binding materials in paints and varnishes, substitutes for common waxes, urethane foams, candles, coatings, petrochemicals, fatty acids, synthetic fragrances, electric insulations etc. Hence, although not suitable for food uses, they play an important role in industry and, thus help to release the pressure on common edible oils for nonfood uses. A few non edible oils such as linseed can be processed into edible grade products either by generic improvement or through processing into hydrogenated fat".

The most common non edible oils are listed in Table 1 with the exception of *Jatropha curcas* which now is the prominent addition to this list.

**Table 1: The common non-edible oils their source countries/region wise [3].**

| Traditional Name | Botanical Name | Countries | Utilization | |
|---|---|---|---|---|
| | | | Oil | Cake |
| Linseed | | Argentina, India Canada, USSR | Pigment binder in petrochemicals, concrete protector, stabilizer/ plasticizer for vinyl plastics. | Animal feed |
| Castor | *Ricinus communis* | China, India Brazil USSR, Argentina | Plasticizer, surfactant, cosmetics, coatings, urethane foam resins, lubricating greases, fungistactic agent, nylon 11 synthesis, synthetic fragrances and flavors, heptanoic acid, heptyl alcohol solvent, lubricants | Fertilizers |
| Mahua oil | *Bassia latifolia* | India | Soaps, wool processing, chocolate making, candles, fatty acids | Manure in sugarcane and grass field |
| Neem oil | *Azadirachta indica* | India, Pakistan, Srilanka Malaya, Indonesia, Japan, Australia | Soaps, medicines, oleic acid, stearic acid | Manure, insecticidal properties |
| Karanj oil | *Pongamia pinnata syn. P. glabra* | India | Leather tanning, lighting | Manure |
| Undi | *Calophyllum inophyllum* | India | Soaps, medicines, lubricant lighting, varnishing soaps | Manure |
| Kusum | *Schlrichera oleosa* | India, Burma, Srilanka | Medicines, lighting, hair oil, soaps fatty acids | Manure, cattle feed |
| Khakan | Sal | India | Soap making | Manure |
| Pisa | | India | Soap making | Manure |
| Kokum | | India | Vaseline for burns and injuries, soap making, lighting | Manure |
| Nahor | | India, Burma, Andamans | Burning purposes | Manure |
| Sal | Shorea robusta | India, Sumatra, Sarawak, Malaya | Substitute for cocoa butter and tallow, textile sizing, soap making | Manure, starch manufacture |
| Dhupa | | India | Candles, soaps, medicinal purposes | Manure |

Oil can be extracted from variety of plants and oilseeds. Some plants and seeds in India have tremendous medicinal value, considering such plants for bio-diesel production may therefore not be a viable and wise option. Considering all the above constraints, probable bio-diesel yielding trees in India are [4]:

— *Jatropha curcas* or Ratanjyot
— *Pongamia pinnata* or Karanja
— *Calophyllum inophyllum* or Nagchampa
— Shorea robusta or Sal

Of all the above prospective plants as bio-diesel yielding source, *Jatropha curcas* stands at the top and sufficient information on this plant is already available and also it has no significant use and hence come as an ideal raw material as biodiesel feedstock.

***Jatropha curcas*:** *Jatropha curcas* is multi purpose non edible oil yielding perennial shrub originated in tropical America and West Asia. It is commonly known as pysic nut or purging nut. *Jatropha curcas* belongs to the family Euphorbiaceae and has the tendency to produce latex and hence animals do not browse the plant. This is widespread in arid, semi-arid and tropical regions of the world.

*Jatropha* is a drought resistant perennial tree that can live over 50 years [5]. The oil content in *Jatropha* seed is reported to be in the ranges from 30 to 50% by weight of the seed and ranges from 45 to 60% wt of the kernel itself [6]. The *Jatropha* tree has several beneficial properties such as its leaves, latex and seed oil are used for medicinal applications.

*Jatropha* is grown in marginal and waste lands with no possibility of land use competing with food production. Pant *et al.*, showed that *jatropha* oil content varies depending on the types of species and climatic conditions, but mainly on the altitude where it is grown [7]. The study showed that the average oil contents in *Jatropha curcas* L. at the elevation ranges of 400-600m, 600-800m and 800-1000m were 43.19%, 42.12% and 30.66% of their seed weights respectively.

## III. SYNTHESIS OF BIO-DIESEL

The alternative diesel fuel must be technically and environmentally acceptable, and economically competitive. From the viewpoint of these requirements, triglycerides (vegetable oils/animal fats) and their derivatives may be considered as viable alternatives for diesel fuels. The problems with substituting triglycerides for diesel fuels are mostly associated with their high viscosity, low volatility and polyunsaturated character. Above problems have been mitigated by developing vegetable oil derivatives that approximate the properties and performance which make them compatible with the hydrocarbon-based diesel fuel through [8]

— Dilution
— Microemulsion
— Pyrolysis
— Transesterification

**Dilution.** Dilution of vegetable oil can be accomplished with diesel fuel, a solvent or an alcohol. Knothe *et al.*, [9] reported that the dilution of sunflower oils with diesel fuel v/v provided a fuel with a viscosity of 4.47 cSt at40°C. Although this value was greater than the maximum ASTM specification of 3.66 cSt, it was markedly less than the viscosity of neat sunflower oil (31cSt) [10]. However, it was concluded that the blend could not be recommended for long term use in diesel engine because of severe injector nozzle coking and sticking. Ali and Hanna [11] studied the effect of blending ethanol to reduce the viscocity of methyl ester of beef tallow. The scientists observed that the viscocity of tallow ester was 5.5 cSt at 30℃, where as the viscocity of diesel fuel at the same temperature was 2.4 cSt. The addition of 35% $(v/v)$ ethanol to tallow ester reduced its viscocity to 2.4 cSt. They further observed that even after the addition of ethanol, the Cetane Number of tallow ester-ethanol-diesel fuel blend was 62.5 as compared to 44 for ASTM No. 2 diesel fuel.

**Microemulsion.** Microemulsion is a system consisting of liquid dispersed with or without emulsifier, in an immiscible liquid, usually in droplets smaller than colloidal size. A micro emulsion can improve the spray characteristic due to explosive vaporization of low boiling constituents in the micelle [12]. Microemulsion can be made of vegetable oils with an ester and dispersant, or of vegetable oil, an alcohol and a surfactant with or without diesel fuel. A microemulsion of methanol with vegetable oil can perform nearly the same as diesel fuel. The use of micro-emulsion solves the problem of high viscosity associated with vegetable oil. Micro-emulsion with solvent such as methanol, ethanol, butanol etc. have been studied. The studies show that the short term performances of both ionic and non-ionic micro-emulsion of aqueous ethanol in Soyabean oil were nearly as good as that of ASTM No. 2 diesel fuel in spite of lower cetane number and energy content [13].

**Thermal Cracking (Pyrolysis).** Thermal cracking or pyrolysis is the process whereby complex organicmolecules are converted to simpler molecules by the breaking of carbon-carbon bonds in the precursors by heat in the absence of air [14]. The pyrolyzed material can be vegetable oils, animal fat, natural fatty acids and methyl ester of fatty acids. The pyrolysis of vegetable oil was initially done in an attempt to synthesize petroleum from vegetable oil. This process was applied for different vegetable oils to obtain products suitable as fuel. Upon heating the hydrocarbons upto 300-400ºC the long chain are reduced into fragment mixtures of various sizes. The viscosity of hydrocarbon depends on length of carbon chain. After pyrolysis the chain length and viscosity reduces. Thermal cracking of tung oil was studied in 1947 [15]. Tung oil was first saponified with lime and then thermally cracked to yield a crude oil, which was refined to produce diesel fuel and a little amount of gasoline and kerosene. However, the products obtained by thermal cracking are chemically similar to that of petroleum derived fuel but the removal of oxygen during the process also eradicates the environmental benefit of using an oxygenated fuel. In addition to this, the higher cost of equipment also made the process unaffordable for modest throughput [16].

**Transesterification.** Transesterification is defined as the reaction of a fat or oil with an alcohol to form esters and glycerol as given in equation below. The Lab set up for optimization of process conditions is shown below in Fig. 1. Catalyst is used to improve the reaction rate and yield. To complete a transesterification stoichiometrically, a 3:1 molar ratio of alcohol to triglycerides is needed. In practice, the ratio needs to be higher to drive the equilibrium to a maximum ester yield. Alcohols are primary and secondary monohydric aliphatic alcohols having 1-8 carbon atoms [17]. Among the alcohols that can be used in the transesterification process are methanol, ethanol, propanol, butanol and amyl alcohol. Methanol and ethanol are used most frequently, especially methanol because of its low cost and its physical and chemical advantages (polar and shortest chain alcohol). It can quickly react with triglycerides and NaOH is easily dissolved in it. The reaction can be catalyzed by alkalies, acids, or biocatalyst as briefly described below in Fig. 2.

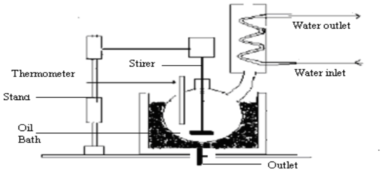

**Fig. 1.** Schematic diagram of transesterification lab reactor.

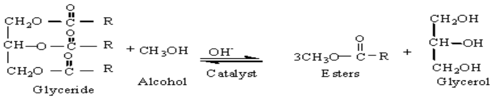

**Fig. 2.** Basic Transesterification Process.

**Acid Catalyzed Process.** If more water and free fatty acids are present in the triglycerides, acid catalyzed transesterification can be used. The transesterification process is catalyzed by Bronsted acids, preferably by hydrochloric acid, sulfonic acid and sulfuric acids [18-20]. These catalysts give very high yields in alkyl esters, but the reactions are slow, requiring, typically, temperatures above 100℃ and more than 3 h to reach complete conversion[21]. Freedman *et al.,* [18] showed that the methanolysis of soybean oil, in the presence of 1 mol% of $H_2SO_4$, with an alcohol/oil molar ratio of 30:1 at 65 ℃, takes 50 h to reach complete conversion of the vegetable oil (> 99%), while the butanolysis (at 117 ℃) and ethanolysis (at 78 ℃), using the same quantities of catalyst and alcohol, take 3 and 18 hours, respectively [18].

**Alkali Catalyzed Process.** For an alkali-catalyzed transesterification, the glycerides and alcohol must be substantially anhydrous because water makes the reaction partially change to saponification, which produces soap. The soap lowers the yield of esters and renders the separation of ester and glycerol difficult. Alkali-catalyzed transesterification is much faster than acid-catalyzed transesterification [18, 21, 22]. This reason, together with the fact that the alkaline catalysts are less corrosives than acidic compounds, industrial processes usually favor base catalysts, such as alkaline metal alkoxides [19] and hydroxides [23-26]. i.e. NaOH, KOH, sodium methoxide, sodium ethoxide, sodium propoxide, sodium butoxide and sodium & potassium carbonates [27-29]. Alkaline metal alkoxides ($CH_3ONa$ for methanolysis) are the most active catalysts, since they give very high yields in short reaction times even if they are applied at low molar concentrations (0.5 mol %). However, they require the absence of waterwhich makes them inappropriate for typical industrial processes [19]. Alkaline metal hydroxides (KOH and NaOH) are cheaper than metal alkoxides, but less active. Nevertheless, they are a good alternative since they can give the same high conversions of vegetable oils just by increasing the catalyst concentration to 1 or 2 mol%. However, even if a water-free alcohol/oil mixture is used, some water is produced in the system by the reaction of the hydroxide with the alcohol. The presence of water gives rise to hydrolysis of some of the produced ester, with consequent soap formation. This undesirable saponification reaction reduces the ester yields and makes recovery of the glycerol considerably difficult due to the formation of emulsion.

Author have studied in detail the process for the synthesis of both *Jatropha curcas* and *Pongamia pinnata* biodiesels, results of which are reported elsewhere [30, 31].

**Bio-Catalysts.** Due to their ready availability and the ease with which they can be handled, biocatalyst have been widely applied in organic synthesis. They do not require any coenzymes, are reasonably stable, and often tolerate organic solvents. The enzyme-catalyzed transesterification processes are not, yet commercially developed. An immobilized lipase was employed to catalyze the methanolysis of corn oil in flowing supercritical carbon-di-oxide with an ester conversion of more than 98%. The reaction yields as well as the reaction times are unfavorable compared to the base-catalyzed reaction systems.

The enzymatic transesterification may offers considerable advantages, including reducing process operations in bio-diesel fuel production and an easy separation of the glycerol by-product. The high cost of the enzyme is the main obstacle for a commercially feasible enzymatic production of bio-diesel fuels. To reduce enzyme associated process costs, the immobilization of fungal mycelium within biomass support particles (BSPs) as well as expression of the lipase enzyme on the surface of yeast cells has been developed to generate whole-cell biocatalysts for industrial applications [32].

**Biodiesel Specifications.** Engine manufacturers and biodiesel plants in different parts of the world use slightly different standards for biodiesel. Virtually all modern diesel engines warranties permit the use of biodiesel provided it meets certain specifications. It can be used as an additive to reduce vehicle emission (typically 20%) [33] or in its pure form as a renewable alternative fuel for diesel. The fuel quality of bio-diesel specification as per BIS 15607, and ASTM 6751 are given in Table 2.

**Table 2: Comparison of EU, BIS & ASTM Standards [34].**

| Property | Unit | EN 141214:2003 | IS 15607:2005 | ASTM D6751-02 |
|---|---|---|---|---|
| Ester content | %m/m, min | 96.50 | 96.50 | NA |
| Density at 15$^0$C | Kg/m$^3$ | 860-900 | 860-900 | NA |
| Kin. Viscosity at 40$^0$C | mm$^2$/sec | 3.5-5.0 | 2.5-6.0 | 1.9-6.0 |
| Flash point | $^0$C, min | 120 | 120 | 130 |
| Sulfur content | mg/kg, max | 10 | 50 | 15 max |
| Cetane no. | | 51 min | 51 min | 47 min |
| Water content | mg/kg, max | 500 | 500 | 0.05%vol(water& sediments |
| Copper strip Corrosion 3h at 50$^0$C | Rating | Class 1 | Class 1 | No. 3 max |
| Oxidation Stability | Hours, min (at 110$^0$C) | 6.00 | 6.00 | NA |
| Acid value | mg KOH /g | 0.50 | 0.50 | 0.80 |
| Iodine value | g/ 100g Iodine max | 120 | To report | NA |
| Methanol or Ethanol | %m/m, max | 0.20 | 0.20 | NA |
| Free Glycerol | %m/m, max | 0.02 | 0.02 | 0.02 |
| Total Glycerol | %m/m, max | 0.25 | 0.25 | 0.25 |
| Group I metal (Na +K) | mg/kg, max | 5 | 5* | NA |
| Group II metal (Ca + Mg) | mg/kg, max | 5 | 5* | NA |
| Phosphorous content | mg/kg, max | 10 | 10 | 0.001 %mass |
| Distillation Temp. (90% recovery, T90) $^0$C, max | $^0$C, max | NA | NA | 360 |

## IV. BLENDING STUDIES

As the availability of large volumes of bio-diesel, as a complete substitute of high speed diesel is still a very long term possibility, its partial replacement with bio-diesel, practically all over the world is therefore the first step in this direction. In view of this fact, experimental investigations are being carried out at various location/laboratories [35, 36] in India to study the performance and emissions of different blends (Bio-diesel and petro-diesel) in comparison to diesel alone.

Blends study with methyl esters of various non edible oils have been mostly reported in context of engine studies [37, 38]. Keeping this in consideration, author have also studied the physio-chemical characteristics of blends of *Jatropha curcas* and *Pongamia pinnata*, given below in Table 3, 4, detailed study of which is reported somewhere else [39, 40]. Considering the results of the blending study and their properties as reported in Tables 3 and 4 of *Jatropha curcas* methyl ester with Euro-III and Euro-IV correspondence diesels, it is observed that addition of both the diesels into the

*Jatropha curcas* methyl ester has a considerable dilution effect particularly on viscosity. The viscosity of the ester decreases on increasing the diesel content in the blends, Blends containing upto 80% biodiesel remain within the viscosity limit. However, the addition of methyl esters beyond B-40 concentration leads to increase in density of the blends which are in the outside limit of the requirement of maximum 0.8450 $^@$ 15ºC. Considering the other properties of the blends such as pour point, flash point, and cetane index, in relation to diesel properties requirement, their values are within the prescribed specification limits. Data shows that in both the cases the calculated cetane index values from B-20 onwards are higher than that of neat *Jatropha curcas* methyl ester. This behavior may be attributed to the synergistic effect between the compositions of the two fuels.

**Table 3: Physical and chemical properties of Euro-III correspondence diesel and *Jatropha curcas* methyl ester blends (JB+E-III).**

| S.No. | | Properties Blends | Density@ 15ºC | Kinematic viscosity@ 40ºC | Pour point$^0$ C | Flash Pointº C | ºAPI | Aniline point $^{00}$F | Cetane index |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | Euro-III HSD | 0.8243 | 2.74 | 9 | 62 | 40.16 | 127 | 51 |
| 2 | | JB-100 | 0.8885 | 4.63 | 3 | 139 | | 187 | 52 |
| 3 | | JB-20 % vol | 0.8371 | 3.14 | 9 | 65 | 37.5 | 140 | 52.5 |
| 4 | | JB-40 % vol | 0.8499 | 3.62 | 6 | 67 | 35 | 150 | 52.5 |
| 5 | | JB-60 % vol | 0.8628 | 3.91 | 6 | 69 | 32.5 | 161 | 52.3 |
| 6 | | JB-80 | 0.8756 | 4.03 | 6 | 70 | 30.1 | 175 | 52.5 |
| | | Testing methods | ASTM D 4052 | ASTM D 445 | ASTM D 97 | ASTM D 93 | — | — | — |

**Table 4: Physical and chemical properties of Euro-IV correspondence diesel and *Jatropha curcas* methyl ester blends (JB+E-IV) [39].**

| S.No. | Properties Blends | Density @ 15$^0$ C | Kinematic viscosity @ 40ºC | Pour point $^0$ C | Flash Point $^0$ C | $^0$API | Aniline point $^0$F | Cetane index (Cal) |
|---|---|---|---|---|---|---|---|---|
| 1 | Euro-IVHSD | 0.8222 | 2.65 | 12 | 63 | 40.6 | 132 | 53 |
| 2 | JB-100 | 0.8885 | 4.63 | 3 | 139 | 27.75 | 187 | 52 |
| 3 | JB-20 % vol | 0.8354 | 3.04 | 12 | 67 | 38 | 143 | 53.5 |
| 4 | JB-40 % vol | 0.8487 | 3.50 | 9 | 69 | 35.2 | 154 | 53.5 |
| 5 | JB-60 % vol | 0.8619 | 3.78 | 9 | 71 | 32.7 | 164 | 53 |
| 6 | JB-80 | 0.8752 | 4.16 | 6 | 74 | 30.17 | 176 | 53 |
| | Testing methods | ASTM D 4052 | ASTM D 445 | ASTM D 97 | ASTM D 93 | — | — | — |

## V. OXIDATION ISSUE

Biodiesel being biodegradable, allow its use in environmentally sensitive areas. However, this environmental advantage also means that the fuel is less stable, which affects storage, transportation and commercialization. Therefore, the major issues associated with the biodiesel is its tendency to oxidize. The oxidation occurs when unsaturated esters found in fatty acid methyl ester(FAME) (particularly polyunsaturated esters) comes into contact with oxygen and form peroxides which then break down and polymerize. The product from oxidation can lead to sediments formation; filter blocking, injector nozzle coking and corrosion. Additionally the end user may experience vehicle drivability deterioration such as difficulty in starting, or sudden failure during operation.

These problems are even more evident when biodiesel is blended with diesel fuel owing to difference in polarity. The oxidation of FAME is exacerbated by the presence of transition metals such as copper or iron as well impurity such as glycerol and free fatty acids. These impurities may degrade and form oxidizes byproduct which can catalyze the degradation of unsaturated esters.

There are several methods used to assess oxidation behavior of biodiesel and its blends. This include acid value, rancimat period, density, kinematic viscosity etc [41]. Some studies have reporteduse of Rancimat method [42, 43] using Metrohm instrument in accordance with EN14112 to calculate rancimat period to study the oxidation stability. Author [44, 45] have studied the oxidation behavior of biodiesel and its blend by measuring the rancimat period using Petrotest “PetroOXY(e)- VERSION: 10.08.2011” instrument made in Germany. The period was estimated accordingly the standard method ASTM-D 7545-09 “Oxidation stability of fuel”. It involves measuring the time elapsed between starting a test cycle and the breaking point (reaction stoppage time) which is defined as a pressure drop of 10% below the maximum pressure developed in the test vessel as it warms up to test temperature. Rancimat period was measured using 5 ml fuel sample in hermetically sealed test chamber. The chamber was automatically pressurized with oxygen up to 700 kPa (approximately 7 bar/101.5 psi) and heated to a temperature of 140ºC. This initiates a very fast oxidation process. As the fuel oxidizes, it consumes the oxygen in the sealed test chamber resulting in a pressure drop that is displayed. The length of the rancimat period is directly related to the oxidation stability of the fuel [46].

The rancimat test (EN 14112) has been adopted by the industry as a measure of FAME stability and FAME specifications around the world and have set limits for minimum stability requirement in order to control FAME quality.

## VI. ROLE OF ANTIOXIDANTS

The problem of oxidation has been controlled by the use of antioxidants. Several reports have been found on the stabilities of diesel biodiesel blends. Schober, Mittelbach [47] and many other researchers [48-58] have evaluated the influence of antioxidants on methyl ester on critical bio-diesel parameter. There was no negative impact on the bio-diesel fuel quality when these antioxidants were used in low concentration.

Gaurav Vohra *et al.,* [59] also mentioned that the major challenges in commercialization of biodiesel is that it is susceptibility to oxidation during storage. Author have also studied the effect of the addition of various antioxidants butylated hydroxy toluene(BHT) Butylated hydroxy anisole (BHA), diphenylamine (DPA) and tert-butylhydroxyquinone (TBHQ) on *Jatropha* Biodiesel blends, presented in Table 5, reported elsewhere [44]. The results showed that the addition of an antioxidant to diesel fuel blends has beneficially influenced most of the important fuel properties. The study revealed that with neatmethylesters and lower blends JB-5, JB-10, TBHQ was found to be most effective among all used antioxidants. The effect of BHA, BHT, pyrogallol (PL), propyl-gallate (PG), TBHQ, and DPA additive on biodiesel –diesel blend is also reported elsewhere [45]. TBHQ, PG, and PLwere found to be the most effective among all antioxidants tested, and their use in diesel−biodiesel blends showed a greaterstabilizing potential.

**Table 5: Oxidation Stability of *Jatropha* biodiesel with different concentrations of various antioxidants. (The values of rancimat periods in hours).**

| DAYS | 0 ppm | BHT 300 ppm | BHA 300 ppm | DPA 300 ppm | TBHQ 300 ppm | BHT 400 ppm | BHA 400 ppm | DPA 400 ppm | TBHQ 400 ppm | BHT 500 ppm | BHA 500 ppm | DPA 500 ppm | TBHQ 500 ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 4.2 | 4.3 | 4.32 | 4.3 | 4.34 | 4.32 | 4.32 | 4.32 | 4.38 | 4.36 | 4.36 | 4.31 | 4.42 |
| 7 | 3.7 | 3.8 | 3.8 | 3.81 | 3.91 | 3.8 | 3.81 | 3.8 | 3.98 | 3.9 | 3.9 | 3.79 | 4.11 |
| 14 | 3.2 | 3.4 | 3.38 | 3.35 | 3.45 | 3.5 | 3.36 | 3.38 | 3.51 | 3.5 | 3.44 | 3.36 | 3.65 |
| 21 | 3 | 3.16 | 3.11 | 3.07 | 3.15 | 3.18 | 3.1 | 3.11 | 3.21 | 3.2 | 3.15 | 3.1 | 3.32 |
| 28 | 2.8 | 2.9 | 2.87 | 2.85 | 2.95 | 2.93 | 2.82 | 2.86 | 2.96 | 2.9 | 2.88 | 2.88 | 3.02 |
| 35 | 2.6 | 2.75 | 2.67 | 2.73 | 2.81 | 2.75 | 2.67 | 2.68 | 2.88 | 2.73 | 2.71 | 2.68 | 2.94 |
| 42 | 2.4 | 2.5 | 2.48 | 2.48 | 2.58 | 2.5 | 2.5 | 2.5 | 2.59 | 2.5 | 2.49 | 2.5 | 2.65 |

## VII. CONCLUSIONS AND NEED FOR FURTHER RESEARCH

The petroleum-based fossil fuels has to be replaced by alternative fuel from renewable sources due to several reasons like the ever-increasing energy demand, stringent emission norms etc. Pandey *et al*., [60] also mentioned that the biofuels forms the most effective alternative fuel which gives energy security and economic development to our motherland. Modifications and additions to the conventional esterification process are required. In India *Jatropha curcas* stands at the top for the production of biodiesel. Different available technologies can be used for the synthesis of biodiesel. Among various techniques, Transesterification is the main convenient method to produce biodiesel from oil and fat feedstock.

The biodiesel produced, has similar properties of petro-diesel and meets the ASTM (US) and DIN EN (European) standards. The produced biodiesel can be used in the blended form with petro diesel as the full substitution is long term possibility. The major problem associated with the commercialization of biodiesel is its susceptibility towards environment oxidation, however to some extent it can be overcome by the use of suitable antioxidants.

In addition to synthetic antioxidants, naturally occurring antioxidants can be worked out to make the process economical and sustainable. Our group is already working on the isolation of natural antioxidants.

Since India has an agro based economic, if the cultivation of *Jatropha* is carried out more scientifically, it may turn out to be the most economical option for the biodiesel production.

**Conflict of interest.** No.

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