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Jatropha curcas as a renewable source for bio-fuels—A review

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ABSTRACT

Fatty acid methyl ester derived from renewable lipid feedstock is popularly known as biodiesel, the substitute for petroleum based diesel fuel. The non-food oils such as Jatropha (*Jatropha curcas*), Karanja (*Pongamia pinnata*), waste cooking oil, by-product of vegetable oil refineries are the cheap feedstock for cost-effective production of biodiesel. Jatropha may be one of the most promoted oilseed crop throughout the world due to higher oil yield, suitable fatty acid composition of the oil, adaptability to diverse agro-climatic condition and low gestation period. The current article discusses the updated research and development initiatives undertaken for the study of chemical composition of Jatropha oil, techniques for synthesis of biodiesel using homogeneous catalyst, heterogeneous catalyst, enzymes (lipases) and non-catalytic supercritical process to obtain Jatropha based biodiesel satisfying ASTM 6751, EN 14214 and IS 15607 specifications.

Contents

1. Introduction

The increasing demand and price of crude petroleum as well as increasing level of green house gases in the atmosphere has driven the research interest for the development of alternative fuels from plant origin. Since the last two decades, bioethanol and biodiesel

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have gained the interest as alternative liquid fuels respectively to substitute gasoline and diesel. The current interest is to develop liquid fuel i.e. biodiesel for transportation and make it economically viable without affecting the food demand. The fuels derived from non-food sources are known as second generation biofuel. The second generation biofuel includes biodiesel from non-edible oil sources such as Jatropha (*Jatropha curcas*), Karanja (*Pongamia pinnata*), waste cooking oils, by-products of vegetable oil refineries, microalgal oil, etc. and ethanol from agricultural residues and wastes. Out of these, the non-edible oils obtained from seed bearing trees such as Jatropha and Karanja are the potential feedstock for biodiesel. Jatropha has been attracting the attention for its easy adaptability in tropical and subtropical climates in marginal and non-agricultural areas, although good environmental condition shows better crop performances and productivity. The hardy plant having rapid growth, ease of propagation and low gestation period are the advantages for selecting Jatropha as a source of vegetable oil feedstock for biodiesel. The Jatropha plant produces seed containing 27—40% non-edible oil [1], which can be converted to biodiesel to meet international biodiesel specifications. The current article focuses on the updated research and development undertaken on biodiesel production from Jatropha oil.

2. Properties of Jatropha oil for synthesis of biodiesel

2.1. Physico-chemical properties of Jatropha oil

The physico-chemical properties of Jatropha oil has been reported in the literature [2–7] and listed in Table 1. The free fatty acid (FFA, as oleic acid) of crude Jatropha oil ranges up to 15% [8], and sometimes up to 54% as reported by Payawan et al. [9], which are far beyond the limit of 1% maximum for the synthesis of biodiesel in laboratory scale using KOH or NaOH as catalyst. The limit of FFA is 0.1% maximum as specified by Lurgi and Desmet Ballestra for production of biodiesel in industrial scale to ensure the product to satisfy EN 14214, IS 15607 and ASTM 6751 specifications. Upon storage of Jatropha oil, the hydrolysis of triglyceride occurs as a result and the FFA increases fast [8]. The high FFA content Jatropha oil needs pretreatment steps for making it suitable for conventional alkali catalyzed transesterification for industrial scale biodiesel production. The iodine value and saponification value of oil are indicative of the structure of fatty acid such as the degree of unsaturation and chain length of fatty acid in triglyceride respectively. Both the iodine value and saponification value determine the cetane number of product biodiesel. The cetane index of product methyl ester is related to the iodine value and saponification value [10] as per Eq. (1), whereas cetane index is indicative of cetane number [11] as per Eq. (2). The average molecular weight MW_{Oil} of the oil can be calculated from the saponification value (SV) as per Eq. (3) [12], which is further used for stoichiometric calculation for transesterification reaction.

$$CI = 46.3 + \frac{5458}{SV} - 0.225 \times IV \quad (1)$$

$$\text{Cenate number} = \text{Cetane index} - 1.5 \text{ to } +2.6 \quad (2)$$

$$MW_{Oil} = \frac{3 \times 56100}{SV} \quad (3)$$

2.2. Fatty acid composition of Jatropha oil

The fatty acid composition of an oil is one of the important characteristics apart from the chain length and degree of unsaturation which are indicative of the physical state of the oil and biodiesel, cetane number and also cold flow properties such as cloud point, pour point, cold filter plugging point (CFPP) and cold soak filtration test (CSFT) of biodiesel. The fatty acid composition of Jatropha oil has been reported in the literature [4–5,7,13–15] and summarized in Table 2. The unsaturated fatty acid in Jatropha oil ranges from 77% to 83%, and the cold flow properties of product biodiesel is dependent on the extent of unsaturation in the oil. Palmitic acid and stearic acid are the major saturated fatty acids in the oil. The variation in the percentage of fatty acid composition of Jatropha oil as listed in Table 2 is due to the diverse agro-climatic condition for Jatropha cultivation.

3. Production of biodiesel from Jatropha oil

The straight vegetable oils have been studied as fuel in compression-ignition engines. The poor performance of the fuel had been observed since the vegetable oils have high viscosity and low volatility. The fuel qualities of vegetable oils may be improved by various processes such as dilution, micro-emulsion, pyrolysis and transesterification. The process of transesterification of vegetable oil is widely adopted for converting it to fuel. Vegetable oils are transesterified with a short chain alcohol i.e. methanol to produce fatty acid alkyl ester in order to reduce the density and viscosity of the oil and improve other fuel qualities. The process of biodiesel synthesis is the chemical transesterification of triglycerides which also consists of esterification of free fatty acids present in the vegetable oil feedstock, and in general the overall process is known as alcoholysis. The stearic hindrance is limited in all molecules involved in the biodiesel synthesis, and the reaction mechanism may be classified as Su-AC-B (following A_N+D_N mechanism, also referred to as $B_{Ac}2$) [16]. The transesterification of vegetable oil with methanol is catalyzed either by an acid, alkali, enzyme or heterogeneous catalyst to give rise to fatty acid methyl ester (biodiesel) as the product and crude glycerol as a by-product. The factors affecting transesterification of vegetable oil are alcohol to oil molar ratio, catalyst type, reaction temperature, rate of mixing and purity of the reactants. The process is also uncatalyzed in supercritical fluid (SCF) mediums such as supercritical states of methanol or ethanol. The product of vegetable oil transesterification is allowed to stand, such that biodiesel forms the upper layer and crude glycerol as lower layer. Crude glycerol is separated either by gravity separation or by centrifuge. The upper biodiesel layer contains methanol, catalyst, traces of soap, glycerol and other impurities. The crude biodiesel is subjected to post-transesterification processes for removing the impurities, washing and drying to obtain the final biodiesel. Table 3 lists the fuel quality of biodiesel as specified by ASTM 6751, EN 14214 and IS

Table 1
Physico-chemical properties of Jatropha oil.

Sl. no.	Properties	Ref. [2]	Ref. [3]	Ref. [4]	Ref. [5]	Ref. [6]	Ref. [7]
1.	Free fatty acid (as oleic, %)	1.5–19	2.67	0.62	2.23	22.6	5.1–6.3
2.	Iodine value (gI_2/100 g)	93–107	96–105	102	103.62	100.1	103.6
3.	Saponification value (mgKOH/g)	188–196	196–200	197	193.55	208.27	193.0
4.	Unsaponifiable matter (%)	0.4–1.1	–	0.4	–	–	–