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# Economic feasibility of non-edible oils as biodiesel feedstock: A brief review

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**Abstract**

Continuous usage of rapidly depleting natural fossil fuel reserves and increased emissions of carbon in atmosphere has prompted increased research efforts on sustainable and renewable energy resources as alternative to fossil fuels. Feedstocks have undergone some drastic changes since the early attempts at biofuels production. Till today, global scientific researchers are focusing on exploration of sustainable feedstocks having desired physiochemical characteristics and percentage yield of fatty oils. The balance between food and biofuels demand is what keeps the relatively simple process of growing feedstocks and producing biofuels from being substantially cheaper than fossil fuels. Therefore, present review is an attempt to briefly compile four different non-edible seed crops (*Jatropha curcas* L., *Pongamia pinnata* L., *Ricinus communis* L. and *Azadirachta indica*) having maximum potential to produce biodiesel along with their growing conditions and areas of maximum growth. Some economic aspects and statistical data about its environmental impacts is also provided indicating its utilization, importance and per barrel cost in different countries all over the world.

**Keywords:** Biodiesel, *Jatropha curcas* L., *Pongamia pinnata* L., *Ricinus communis* L., *Azadirachta indica*

**Full length article** **Corresponding Author*, e-mail: farwa668@gmail.com

## 1. Introduction

Rapidly changing global climatic conditions because of uncontrolled human activities and imbalanced ratio of energy production and energy consumption has led to greater emphasis on overwhelming energy crisis issues and situations being faced now-a-days. Similarly, continuous depletion of existing energy resources such as fossil fuels, have made it essential to work on the production of sustainable and renewable energy resources to meet the global energy demands. The large-scale production of biofuels such as bioethanol, biogas and biodiesel could be looked upon as an appropriate alternative to not only solve the energy crisis but to maintain constantly increasing energy prices in Asian countries. A number of advanced technologies like hydrogen fueled vehicles, hybrids, plug-in electrics, biofuel and compressed natural gas, are being considered as a solution to these problems [1]. However, bioenergy has been particularly given importance as an alternative technology because of its relatively better viability and renewability [2-3]. The ease of large scale production and cost effectiveness of the liquid biofuels has made it a reliable competitor among all other technologies being used for energy production [4-5]. Tremendously increasing utilization of biofuels all around the world has been triggered due to day by day rising energy demands, environmental concerns and also the subsidies, incentives and other facilities being provided to promote it. For developing countries, it may also bring extra perks in terms of generation of more employments as well as opportunities for the development of rural areas [6]. Current contribution of biofuels in total primary-energy consumption of the world is about 14 %, biomass being the major contributor which covers around 10 % of it. In underdeveloped areas, biodiversity and environment would have to bear more stress with the development and growth of biofuel industry. Globally, agricultural food crops are being used more commonly as first generation biodiesel feedstock in the biofuel market. The cost factor of biodiesel primarily depends on the choice of vegetable oil and its availability. In Europe and USA, rapeseed and soybean are typical first generation biodiesel feedstock being used. Similarly, palm oil is another prominent feedstock being utilized in South East Asia. It is generally estimated that for biodiesel production, all edible oil based feedstock used together cannot prove to be sufficient for the fulfillment of energy demands all over the world. Till 2030, a tremendous rise in biofuel production has been anticipated by international energy agency [7].

Therefore, use of different, more novel, and reliable feedstocks for biofuel production can be considered as a predictable energy replacement for petroleum-based non-renewable fuels in the long term. According to some estimates based on existing literature, the bioenergy supply potential in the world will be 110 EJ/year in 2050 and 22 EJ/year in 2100 [8-9]. An estimation has indicated that by 2020, 20-22 % of on-road diesel would be contributed by biodiesel solely in many countries such as China, India, Brazil, and Europe. Pakistan's current annual import is 8.1 million tons at approximate cost of US$ 9.4 billion. Pakistan is facing issues regarding energy deficiency as an annual growth rate of 2.05 % in population which is currently 176.4 million has been recorded in spite of the fact that it is an agricultural country with huge areas of marginal land in Punjab and Sindh provinces (45.2 million hectares). The day by day increasing energy demands and the necessity to fill the gaps of demand and supply is encumbering the economy of the country. The growing demand, safety of energy chain sustainability and security of supply are a few of the major energy challenges faced by the country. Indigenous scientists have recommended that the marginal land in Punjab and Sindh can be utilized for the cultivation of non-edible oil crops for the production of biodiesel which on the other side can create employment for the poor farmers [10-12]. After the extraction of vegetable oil from the crop, the biomass cake can be used as fodder for the livestock. Moreover, a nutrient rich (potassium, nitrogen, and phosphorus) residue obtained after the oil extraction, can be utilized for the manufacturing of bio-fertilizer on one hand and another type of energy source, "methane gas" on the other. This article is aimed to provide a review on the pros of utilization of non-edible oil as more preferable feedstock as compared to edible oil, current situation of energy sector (manufacturing) and status of consumption of non-edible feedstock for biofuel production. The biodiversity, regional distribution, biology as well as chemistry of selected non-edible feedstocks have also been discussed in this paper.

## 2. Prospects of biodiesel and Pakistan's economy

Researchers have given a report on economic analysis of biodiesel production in Spain and have also compared the price with mineral diesel which was found to be considerably high. The actual cause for this was found to be the utilization of virgin vegetable oils [13]. Several other studies have also given similar statistics [14-15]. To solve this problem, the utilization of marginal land for the cultivation of indigenous oil producing crops was proposed. In last 10 years, India has successfully grown Jatropha and utilized it for economically effective production of biodiesel [16-17]. Other countries have also tried to explore microalgae as feedstock for biodiesel production and to achieved their goals [18-19]. Pakistan, unfortunately, have remained passive in the enhancement of biofuel energy production. Pakistan's present total primary energy demand is estimated to be around 32 MTOE (million tons of oil equivalent) whereas the total primary energy supply is around 63 MTOE [20-21]. Although there appears to be a surplus of energy, it has to be noted that most of it is imported and not of indigenous origin (thereby labeling the country as being energy deficient). Moreover, a continuous increase in the consumption (5 % per annum) would ultimately result in the outrun of supply over a period of time. Pakistan has highest energy consumption in domestic, industrial, transport and commercial sectors [21-22]. Cost effective and continuous energy supply must be ensured to sustain economic growth of the country. Currently, renewable energy sources have only negligible contribution to the whole energy supplies and tones of work need to be done to bring it to the mainstream of energy supply of the country role [23-24]. The future prospects of biodiesel production in Pakistan have been discussed and published by several researchers [25-26]. Current scenario of energy demand and supply and the role of renewable biofuel production on industrial scale have been critically discussed. The economic development as well as its sustenance depends on sustainable energy supply. The import of fuel that takes large share of the country's revenue must be controlled. That is because according to the report of the Oil Companies Advisory Committee (OCAC) 2008, Pakistan was consuming around 8 million tons of diesel and 7.2 million tons of furnace oil per year. However, overall contribution of Pakistan in greenhouse gas emissions is only 0.43% of the world's total emissions. It can be suggested that cultivation of oil producing energy crops on waste or marginal lands and their utilization as non-edible feedstock for biodiesel production can solve major energy related crisis of the country and hence, can support ailing economy.

Biodiesel feedstock crops can be grown on suitable areas as 70 % of 80 million ha geographical area remains uncultivated. Preferable energy crops include: *Eruca sativa* (taramira or bitter mustard) with oil yield of 35 %, *Brassica campestris* (Mustard) with oil yield of 33 %, *Pongamia pinnata* (Sukh Chain) with oil yield of 27 %, *Ricinus* *communis* (castor bean) with oil yield of 32 % and *Jatropha curcas* [1-23-27]. The climatic conditions of Pakistan and availability of vast lands allow the cultivation of all of these plants and many other fuel crops. A summary of various oil bearing vegetation, their respective oil yield and fatty acid contents have been discussed in detail in upcoming sections. Therefore, building and nourishing biofuel producing industries is one of the most important steps that require to be taken for the development of country and also for the socio-economic stability [1-28-29].

### 3. Potential non-edible feedstock

#### *3.1. Jatropha curcas L.*

[Family: Euphorbiaceae, Common name: Jangli Errund]

*Jatropha curcas* is a tree with smooth leaves which are 10-15 cm in length and width and have 4-6 lobes and its roots are taproot and shallow which make it able to resist and even control soil erosion. These characteristics allow it to be a drought resistant plant. A single tree produces approximately 2-4 kg of seeds per year. Depending on the quality of soil, this yield may reduce upto 1kg. A research investigation has reported per hectare yield of *Jatropha curcas* to be 1590 kg/ha. Various factors control the cost affectivity of biodiesel production from *Jatropha curcas* in a particular area such as governmental policies, issues related to land acquisition and labor charges. On the basis of 500 workers working on a farmland of 1,500,000 ha an approximate amount of 2,250,000 L can be generated. Total revenue generated can be computed by taking into account the cost spent on labor. Another advantage for the cultivation of Jatropha is that it does not demand any specific fertilizer usage or crop rotation. Research is being carried out by a number of organizations for the optimization of production of biodiesel from *Jatropha curcas* feedstock in Pakistan. An appreciably high oil content of dry seeds (30 % to 40 %) and presence of anti-nutritional constituents in the oil which render it non-edible are the main factors which provide the drive for this research to be conducted. Pakistan state oil (PSO) has used its novel transesterification unit for the conversion of jatropha oil (cultivated by PSO) to biodiesel which was studied and tested for its emissions and engine performance by Nadirshaw Eduljee Dinshaw (NED) University. The results obtained have revealed that biodiesel from jatropha oil is appreciably environment friendly with least emissions of air pollutants as compared to mineral diesel as well as biodiesel from other indigenously available feedstock. But the engine performance is minutely worse than petroleum diesel. However, this can be easily overcome by maintaining the calorific value of jatropha oil [1].

#### *3.2. Pongamia pinnata L.*

[Family: Papilionoideae, Common name: Sukh Chain]

*Pongamia Pinnata* is a medium sized tree with a broad crown of drooping or spreading branches and a short crooked trunk. This tree has been introduced to the United States of America, the Seychelles, Indonesia, Malaysia and Philippines which all are humid and tropical low lands. Pongamia thrives best in humid lands where annual rainfall ranges from 500 to 2500 mm and is therefore native to tropical and sub-tropical regions. It has been grown for different purposes like its ornamental value, fuel feedstock, to provide shade, animal fodder and green manure. Recently, it is being cultivated majorly for its ornamental value as its tree has beautiful flowers and large canopy. Medicinal value of different parts of the plant (flowers, roots, and leaves) has been reported as one of the reasons of its cultivation. Another very plausible feature of this plant is that it is one of a few nitrogen fixing trees whose seeds have such high oil contents. Therefore, it must be preferred to be utilized as a biodiesel feedstock. Pongamia can bear water scarce conditions as it has the potential to adapt to extreme soil conditions (saline or alkaline). Marginal, waste, degraded or fallow lands can be utilized for the cultivation of *Pongamia pinnata* as it is tolerant to saline conditions. However, to procure appreciably good yields of oil content and growth rate of plant, humidity and drainage of land must be maintained. On lands, which are being used for cultivation of crops over long periods of time and are subjected to nutrient exhaustion, the cultivation of Pongamia can help restore the soil quality. The chemical composition of fatty acid content shows a variety and with appropriate selection of genotype, better quality biodiesel can be prepared using Pongamia as a feedstock. Optimum values of several quality parameters like cetane number, iodine value and saponification value which are according to American standards are reported to be achieved. Hence, Pongamia is proved to be a suitable non-edible feedstock to produce biodiesel. Moreover, physiology and genetics of the plant as well as propagation of legume should be further studied to ensure the success. Biosynthesis of oil is related to overall plant growth, so that must be taken into account during further research [1].

#### *3.3. Ricinus communis L.*

[family: Euphorbiaceae; common name: castor]

Castor is proved to be a considerable oil producing crop and hence biodiesel feedstock as the oil contents obtained from its seeds could be upto 50 % of their dry weight. It belongs to Euphorbiaceae family and botanically known as *Ricinus communis* L. For its valuable use in industrial, pharmaceutical and energy sector, castor has been grown all over the world for its oil since centuries. Castor plant can adapt to weather conditions of moderate temperature range and hence, tropical/subtropical in nature. Warm and temperate regions are most suitable for its cultivation. Brazil, India, China, Thailand, and USSR are largest castor producing countries while Japan, USA and USSR are known for importing it in considerably large quantities. FAOSTAT has reported India to be the rising castor producing country (0.73 Mt annual production) as it is successfully producing 60 % of the total world's castor production. While in Pakistan, some small regions of Balochistan and Punjab are reported for being utilized for cultivation of castor, whereas, vast areas of Sindh province are still left unutilized. A hectare of land can give an average yield of 1.1 ton of castor but it can be raised upto 4-5 tons if optimum conditions are provided for its growth. Hence, it can be foresighted that about 2000 kg of oil can be yielded per hectare of land. Physically, Castor oil is viscous, non-drying, non-volatile, pale yellow colored liquid while the chemical composition of castor oil consists of a variety of fatty acids along with a unique fatty acid "ricinoleic acid" that constitute about 90% of its total fatty acid content. The percentage of other fatty acids is as follows, linolenic acid 0.2 %, oleic 2.8 %, palmitic 0.7 % and linoleic 4.4 %. Industrial importance and usage of castor oil can be attributed to its several chemical properties such as, very low solidification point (−12 ˚C to −18 ˚C), high molecular weight (298), low melting point (5 ˚C) and unsaturated bonds. Although, the viscosity of raw castor oil is considerably higher than other vegetable oils used as feedstock, but the kinematic viscosity of castor oil after its transesterification is reduced to the value that it becomes comparable to other oils and become suitable for biodiesel blends. Because of the hydroxyl group of ricinoleic acid, castor oil is the only vegetable oil that can easily dissolve in alcohol without the need of higher temperature to be provided. This result in lesser energy expenditure during transesterification of castor oil. Biodiesel produced from castor oil has a flash point of 260 ˚C, iodine value of 80, heating value of 39.5 GJ/t, minimal amounts of potassium and sulphur and ash contents as low as 0.04 and 0.02 %, respectively. Castor sequesters 34.6 tons of $CO_2$/ha and has good carbon trading potential. The extraction of castor oil from a natural mutant of castor bean which has relatively lower ricinoleic acid content and higher oleic acid content, has allowed diversifying castor oil uses. Furthermore, the conversion of oleic acid into ricinoleic acid can be prevented by genetically silencing fatty hydroxylase gene that is responsible for this conversion. Hence, castor oil can be made more attractive option to be considered for biodiesel production [1].

### *3.4. Azadirachta indica*

[family: Meliaceae; common name: neem]

*Azadirachta indica* has the capacity to survive as well as to grow in the environment where temperature fluctuates over a wide range (-10 to 50 ˚C). The natural habitat of this tree ranges from South and Central America, Africa to Asia. The plant is suitable enough to grow in different kinds of soils such as saline, alkaline, shallow, or stony soils, clay and even in solid soil with very high content of calcareous mineral. An average life span of 150-200 years is recorded for this tree and the quantity of fruit produced by a mature tree is about 30-50 kg. This information allows generating approximate statistics of the seed produced, possible amount of oil that can be extracted and the quantity of cake that can be obtained. Therefore, 540,000 tons of seeds can yield 107000 tons of oil and 425,000 tons of cake. But only 25-30 % of this source of vegetable oil has been exploited by now. The light to dark brown non-edible vegetable oil extracted from the seeds of this tree has the potential to become a reliable biodiesel feedstock. Other notable usages of this oil include its use in bio-pesticides, Ayurvedic medicines and also in cosmetics.

Higher free fatty acids contents of neem oil results in the requirement of their conversion to biodiesel. Some researchers have suggested a pretreatment of crude neem oil with an acidic catalyst so that the free fatty acid content (upto 21.6 %) could be reduced upto less than 1 %. The research investigation has given a two-step mechanism and optimized reaction parameters to achieve such results. Biodiesel yield of 89% was procured by this method and the fuel quality parameters were found within the constrictions provided by American standards of biodiesel [1-30].

## 4. Biofuel and environmental concern

A reliable assessment of actual long term impact of biodiesel feedstock production on the environment is complicated. The cultivation of oil crops for feedstock generation would result in the loss of grasslands, peat lands and forests which in turn would aggravate global warming and climate change. The account of $CO_2$ generation is balanced as the quantity of carbon dioxide produced during fuel consumption would be equated through its consumption by the oil crops grown for feedstock production. As a result of biodiesel consumption, a reduction in number of air pollutants (no $SO_2$, smaller amount of CO, PAH, soot, HC and aromatic compounds) has been reported as compared to those released in the environment by the consumption of mineral based diesel. Depending on the combustion characteristics of engine, a decrease in the emission of nitrogenous compounds NOx is also recorded. The cultivation of fuel crops on marginal land areas has become a significant research area with the passage of time as the food security issues and threats to the biodiversity are being taken into account. Besides contributing to GHG emissions, biofuel-driven agricultural expansions can also lead to land-use conflicts among different stakeholders. A recent research investigation was subjected on the effect of biodiesel production (an estimated 277 million tons per year by 2050) worldwide in terms of its consequences on biodiversity and habitat losses. Demand for biofuels and the resulting impact on food prices may further indirectly affect forests and biodiversity by undermining new incentive-driven systems for environmental conservation.

## Future Prospects

Research aims at the development of crop hybrids with higher extractable oil yields with better physiochemical properties; and percentage yield of prepared biodiesel having fuel quality parameters in a range set by ASTM and EN standards for biodiesel. Use of microalgae for biodiesel production with optimized growing conditions is another probable, highly encouraged and most appreciated option, taking a step forward towards sustainable developments.

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