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Review Article

Biodiesel Production: Agricultural and Economical Aspect in India

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Abstract: The production of biodiesel attracts attention from scientists and researchers as of its tremendous applications and commercial use. It becomes important as of its eco-friendly nature, too, as it is biodegradable and non-polluting. The advantages of using petro-diesel with biodiesel lie in diminishing air pollution, encouraging the domestic supply of fuel, and creating new opportunities in agriculture. The production of biodiesel provides an alternative for agriculture as well as the industry. Focusing on short-duration annual crops that can generate fuel and oil seed crops provides numerous opportunities for small farmers. The intention of biodiesel concerns for creation and fortification of the environment. It is economically beneficial in several ways, namely by creating new jobs in the food and farming industries. Biodiesel fuel is eco-friendly and replaces petro-diesel. Previous studies showed that pollutants such as CO, CO_2, SO_X, HC, PAH, PM, and others can be reduced by using blended and pure biodiesel. However, the emission of NO_X increases by using biodiesel. Biodiesel also provides a means to recycle CO_2 which is mainly responsible for global warming. Biodiesel has been produced using plant oils such as Jatropha oil, Cottonseed oil, Pongamia oil, Palm oils, Rapeseed oil, and Castor oil. Such oils are converted to biodiesel through transesterification. We investigated the potential of Jatropha oil as a source of biodiesel. Biodiesel has become an eco-friendly and alternative fuel with many aspects in industrial use. When the use of biodiesel becomes more popular than petroleum fuel, the supply must be sufficient to meet daily needs. Therefore, the presented review article describes production, properties, agricultural benefits, marketing, and the prospect of biodiesel.

Keywords: Biodiesel, Transesterification, Economic, Agriculture, Market

1. Introduction

An extremely high and positive link between energy consumption and living standards demonstrates that energy is the most crucial component for environmental and economic growth in most countries. Most of the world's principal commercial energy supply comes from nonrenewable petroleum. Demand for petroleum has been rising steadily, at a yearly pace of 6−7% worldwide [1]. Predictions show that the remaining lifespan of the world's petroleum reserves is no more than 40−50 years [2]. The ignition of fuel causes greenhouse gas emissions, which contribute significantly to air pollution. Climate change, brought by human-caused increases in atmospheric carbon dioxide and other greenhouse gases, has detrimental effects on human well-being, the global climate, and the natural environment.

Using alternative fuels such as biodiesel is becoming increasingly popular due to increased concerns over energy security, climate change, and oil costs. As it is renewable, inexpensive, and better for the environment, biodiesel demand has steadily risen over the past few years. Comparisons between biodiesel and petroleum diesel have shown that the latter can lower carbon dioxide emissions by as much as 78%. In addition, it is comparable to petroleum-based diesel fuel in terms of engine performance. The improved lubricity, biodegradability, higher combustion efficiency, and lower toxicity are only a few of its other advantages [3,4]. A diesel engine running on biodiesel emits much less unburned hydrocarbon (HC), carbon monoxide (CO), sulfates, polycyclic aromatic hydrocarbon (PAH), nitrated polycyclic aromatic hydrocarbon (nPAH), and particulate matter than that running on petroleum diesel (PM). Even while B100 is the most effective, lower blends still significantly cut emissions. The emission of PM, HC, CO, NOx, SO_2, and CO_2 emissions in Fig. 1 decreases from B5 to B100 [5].

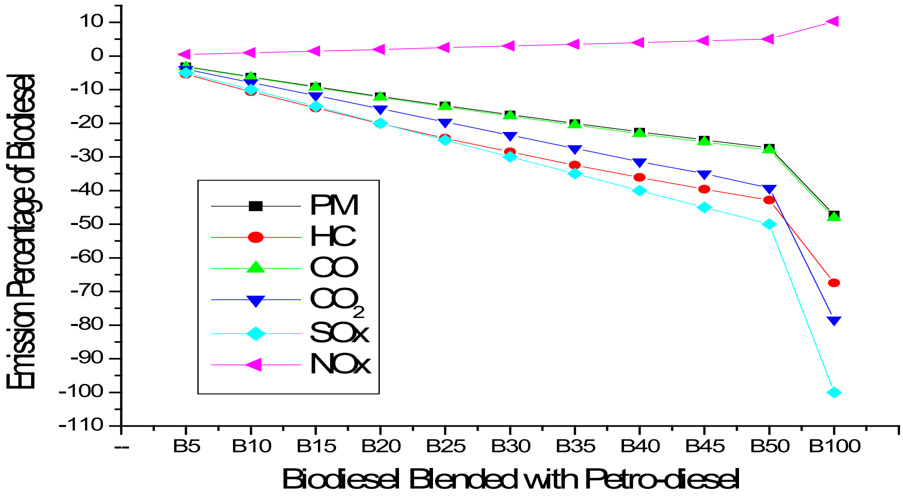

Fig. 1. Biodiesel blend to reduce PM, HC, CO, NO_x, SO_x, and CO_2 emission.

Compared to conventional fuels, biodiesel has several advantages including improved energy independence, less environmental damage, cost savings in international trade, and resolving social and economic problems in rural areas. Further, biodiesel technology is essential for emerging and developed nations. The usage of biofuels in the transportation industry is expected to increase quickly over the next decade. Biofuels are a source of nonviolent energy that any nation can use. They may be replenished and found all over the globe. The ramifications of shifting to a biofuel economy are becoming increasingly important, and policymakers need to pay close attention. The sustainable development model represents the concept of harmony among economic, social, and environmental factors [6,7]. Biodiesel is an alternative fuel that can be made synthetically from several sources, including vegetable oils, animal fats, and waste oil. Either it can be used directly as fuel in modified engines or mixed with petroleum diesel and can be used in existing diesel engines with few, if any, adjustments [8,9]. Less than 2% of the diesel used in transportation now is biodiesel globally. The environmental advantages of biodiesel have increased its popularity in recent years [10,11]. Several viable solutions exist to reduce the cost of biodiesel, including the infinite transesterification process and the recovery of high-quality glycerol as a biodiesel byproduct, both of which are made from cooking oils [12,13].

Per capita energy use varies considerably across urban and rural locations, with 75% of rural households using firewood, 10% using dunk cake, and about 5% using LPG, compared to 22% of urban households using firewood, 22% using kerosene, and 44% using LPG. The same is for home lighting. Although 89% of urban households rely on electricity and 10% on kerosene, just 50% of rural households rely on kerosene.

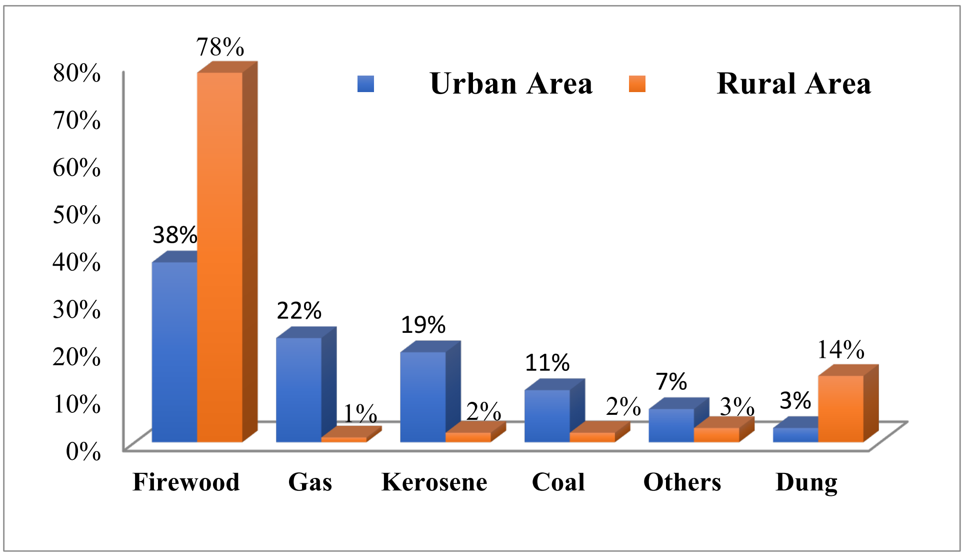

Fig. 2. India's rural and urban cooking and lighting energy landscape.

About 80% of the energy in rural areas comes from biomass, putting further stress on the area's already dwindling plant life. Women and children in rural regions spend more time collecting fuel wood as of the widespread use of ineffective chulhas (a mud stove in India) [14]. As shown in Fig. 2, wood and bovine dung (cow dung) have been used for cooking in India [15]. Increasing energy conservation, boosting energy efficiency, and expanding energy output from renewable energy sources (such as edible and non-edible oil) may undoubtedly aid India in becoming energy independent. India imports fuel mostly. Thus, the country needs to be ready to meet its future petroleum needs by enhancing the energy efficiency of its transportation strategy and vehicle technology. This goal can be attained by developing new energy sources, improving the energy efficiency of existing transportation modes and fuels, and establishing stricter standards for vehicle emissions. India's consumption pattern of diesel by transport and non-transport sectors is shown in Fig. 3.

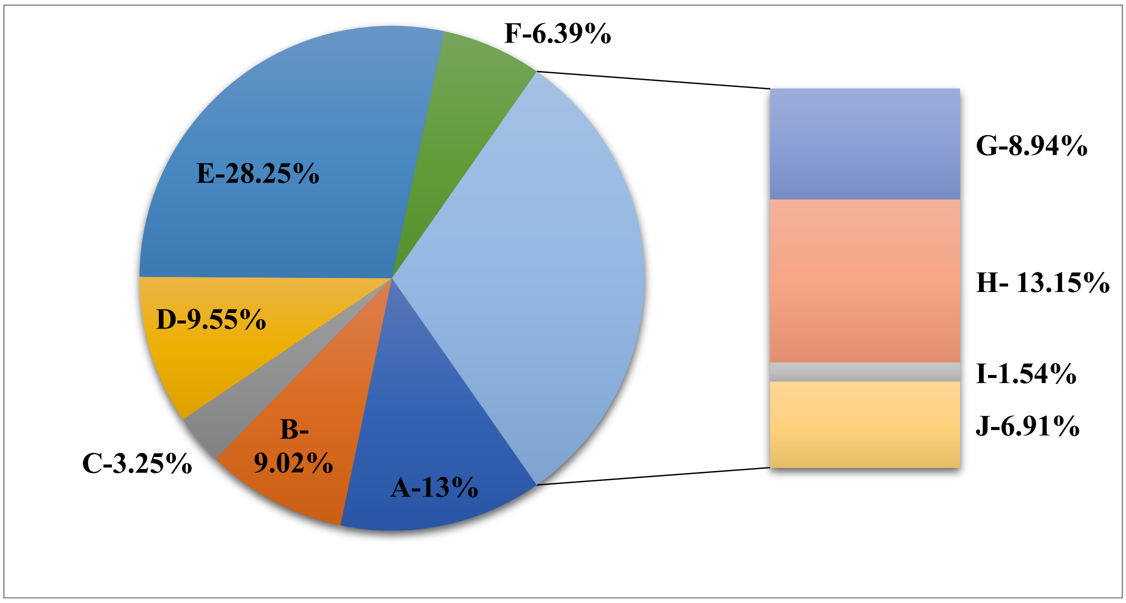

Fig. 3. India Consumption pattern of diesel by transport and non-transport sectors.

(A- Agriculture sectors, B-Industries, C- Railways, D- Buses, E-HCV/LCV, F-Three wheelers, G-Cars/USV, H-Privates, I-Mobile tours, J- Others)

Studies on the economics of biodiesel production need to precede the selection of the most cost-effective variables (such as capital cost, plant capacity, process technology, staple cost, and chemical cost) [16]. The feedstock is the primary determinant in the cost of producing biodiesel, accounting for around 75−80% of the total budget. Other significant expenses include the feedstock, the methanol, and the catalyst required for production [17]. Using a predictable process cost of USD 0.158/l for biodiesel production and projecting a feedstock cost of USD 0.539/l for refined soy oil. On average, soy-based biodiesel production is expected to cost USD 0.70/l [18]. Vegetable oil is the most viable commodity for international trade with the possibility of importation soon [19].

Economically, the viability of biodiesel production is largely influenced by feedstock cost. Still, waste vegetable oil is 2.5−3.5 times cheaper than virgin vegetable oils. Thus, it greatly cuts the overall cost of biofuel production. For biodiesel, Jatropha oil is the major option. This is relatively cheap when used for biodiesel production compared with fresh edible oil as shown in Table 1. The economic advantage of biofuel production is to add value to feedstock. There have been a few more manufacturing jobs in rural areas, and consequently, more income taxes were collected, and more capital was invested in infrastructure. It is also helpful for lowering greenhouse gas emissions and decreasing reliance on foreign oil. Additionally, it helps the agricultural sector open up a new market for American-grown food. The demand for biofuel has increased the cultivation of oil crops unsuitable for human use. The set-aside plan can be used to improve the production of biofuels by significantly increasing the output of non-food crops.

Table 1. Cost comparison of different feedstock.

Feedstock	Country	Yield hectare (Kg)	Rate/barrel (US $)
Soybean oil	USA	375	73
Rapeseed oil	Europe	1000	78
Jatropha oil	India	3000	43
Palm oil	Malaysia	5000	46

2. Literature Review

Vegetable oil as diesel fuel is not a new concept. At the Peris Exposition in 1900 [20], a scientist used vegetable oil as fuel for engines. However, a chain of issues (such as engine banging, carbon deposits, and excessive engine wear) showed that using oil directly was not optimal as the engine was suitable for the intended use. Using the transesterification process reduces these issues as it modifies the molecular structure of the oil for diesel-like properties and any diesel engine [21]. The most widespread ingredients for making biodiesel are soybean oil and yellow grease. Transesterification is utilized to create bio-diesel in India from a variety of plant oils, including Jatropha [22], castor [23], sunflower [24], cottonseed [25], and rapeseed [26]. There is no denying the need to research alternate oils. In this regard, Jatropha is among the most promising potential feedstocks [22].

2.1. Biodiesel initiatives in India

India has been working to increase energy security and reduce its reliance on imported oil for nearly a decade. In 2001, India launched a pilot program to introduce 5% ethanol blends, and in 2003, it developed a National Mission on Biodiesel to achieve 20% biodiesel blends by 2020−2021. Supply constraints, smooth oil cost fluctuations, and worldwide worry about food security have been factors in India's biofuel program's difficulties. India's December 2009 National Policy on Biofuels for biodiesel and ethanol suggests a voluntary blending objective of 20% by 2017 [26]. Figure 4 summarises the National Policy on Biofuels and provides a brief history of efforts to promote biodiesel production in India. In 2003, India took the first significant move toward establishing a biodiesel program with the launch of the National Mission on Biodiesel. The initiative planned to mandate the use of Jatropha curcas as the primary feedstock for biodiesel and reach a blending rate of 20% by 2011−2012. A little low plant called Jatropha thrives on degraded soil and yields oils that humans cannot consume. It can be a raw material for making biodiesel. Even though India is home to approximately 400 different types of non-edible oilseed crops, Jatropha was chosen for the program as it has a relatively high oil content (40 % by weight) and a short gestation period (23 years) compared to other oilseed crops [27]. A total of 17.4 million ha of degraded land would need to be cultivated with Jatropha to meet the 20% blending goal.

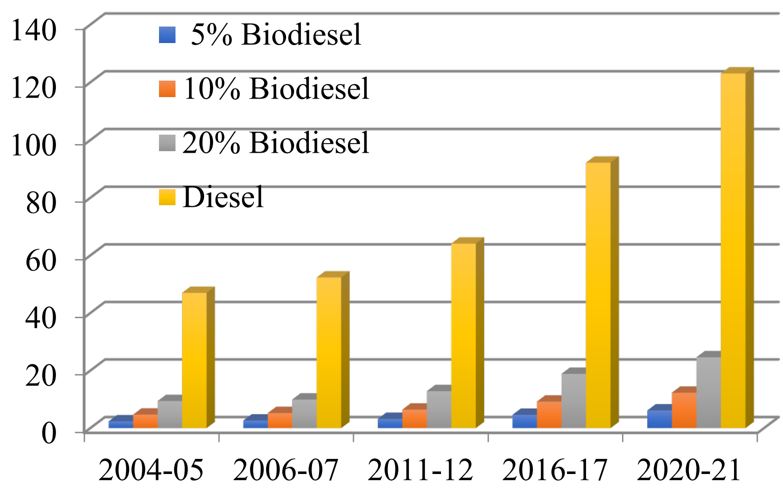

Fig. 4. Petro-diesel and Biodiesel requirement and blending target (2020-21) in India.

Phase I from 2003 to 2007, focused on research and demonstration, while Phase II from 2007 to 2012 was the implementation phase of the biodiesel program. Phase I's objective was to have 5 % of blending rate, develop 400 thousand hectares of land, and establish a research network of 42 public universities. Phase II required a 20% blending rate by 2020−2021. India was ratified with the backing of the Ministry of Petroleum and Natural Gas, responsible for the referred program [27].

2.2. Future market of biodiesel

Due to the enormous potential of the market, the biodiesel sector is expanding faster than any other sector. Over the period from 2000 to 2005, global biodiesel capacity, production, and consumption increased by an average of 32% per year. In addition, the annual growth rate is exceptionally high, coming in at 115% for capacity and 101% for demand [28]. Biodiesel's market potential can be seen in the conventional fossil fuel market size. Biodiesel cannot yet be used as a direct replacement for fossil fuels due to a lack of a suitable technical solution. A lack of non-edible oil has prompted the government to promote the growth of the biodiesel business, which in turn encourages the cultivation of crops on formerly unproductive land. Government subsidies and tax exemptions are used to increase demand [29] and the manufacturing of glycerin as the byproduct of biodiesel. Producing biodiesel requires a lot of raw glycerin, which biodiesel manufacturers traditionally sell to local refineries that purify it into medicinal-grade glycerin. As of the uptick in biodiesel production, the glycerin market has seen an influx of both crude and refined glycerin in large quantities [29].

3. Sources of Biodiesel

The eco-friendly nature of biodiesel makes it an alternative diesel fuel prepared from agricultural resources such as edible or non-edible oil. Any diesel-powered vehicle, be it a car, bus, truck, or construction machinery, can benefit from using biodiesel. Oils, both edible and non-edible, are gaining popularity as of their low environmental impact. There are more than 350 oil-bearing trees and crops identified, among which only Sunflower, Soybean, Cottonseed, Rapeseed, Peanut, and Palm are edible oils. Jatropha curcas, Cottonseed oil, Mahua, Karanja, Neem, and Simarouba glauca are either surplus or non-edible and can be used for the preparation of biodiesel [30,31]. However, there are significant challenges to implementing non-edible oils as a crop, including the lengthy maturation time and a lack of knowledge. However, annual crops such as sorghum and castor, which may be used to create biofuels, are preferable. Producing biodiesel also makes use of various other short-term multipurpose crops.

3.1. Jatropha plantation

When thinking about other sources for biodiesel, Jatropha is often one of the options that come up. There are more than 50 million hectares of unused land in India that may be used for agriculture. The shrub and toxic tree Jatropha Curcasare a member of the rosid magnoliopsid family, and its smooth grey bark is characteristic of this group. It may grow wherever in the tropics, yet as it persists on poor soil and harsh heat, the leaves survive weather and arid conditions. It grows best with an annual average rainfall of 900−1,200 mm but can survive with as little as 250 mm. Jatropha can grow to be about 4 m tall. Although Jatropha can begin producing seeds after just one year, its main output does not take off until at least four or five years have passed. It has a lifespan of over 20 years.

Table 2. Fatty acid composition of Jatropha oil.

Fatty acid	Molecular Formula	Structure	Composition (wt %)
Myristic	$C_{14}H_{28}O_2$	14:0	0.5-1.4
Palmitic	$C_{16}H_{32}O_2$	16:0	12-7.0
Stearic	$C_{18}H_{36}O_2$	18:0	5.0-9.7
Oleic	$C_{18}H_{34}O_2$	18:1	37-63
Linoleic	$C_{18}H_{32}O_2$	18:2	19-41

The entire Jatropha plant can be put to good use. Jatropha crops are used for biodiesel, biomass, fertilizer, glycerol, and medicinal and detoxified animal feed [32]. Seed yield estimates for Jatropha vary due to a lack of research data and the crop's genetic variety. The Jatropha plant is perennial and may thrive in various climates. As a result of cultivation, seed yields per hectare might fluctuate between 1,500 and 2,000 kg, which results in oil production of 540 to 680 l/ha. Jatropha oil's fatty acid breakdown is presented in Table 2 [33]. There are toxins in the seed, including phorbol esters, curcin, typsin inhibitors, lectin, and phytates. As a result, without proper purification, the seed, oil, and seed cake are inedible.

Jatropha seeds retain about 34% of their oil after being dried. It is simple to blend Jatropha oil with petroleum diesel for use in a diesel vehicle. This combines the benefits of petroleum diesel with oil unsuitable for human consumption, resulting in a win-win for the environment [34]. Using unmodified Jatropha oil or blends with a high percentage of Jatropha oil in an engine can be problematic. However, as Jatropha oil has a viscosity that is 20 to 25 times larger than the viscosity of petroleum diesel, the oil must be modified to lessen its viscosity and become appropriate as engine fuel.

3.2. Karanja (Pongania globra's)

The Karanja tree is common in nearly every corner of the vast Indian subcontinent. You can tell it is a Neem tree as of its appearance. The oil comes from a plant called Pongamia glabra, which is in the family Leguminaceae and goes by the common name Karanja seed oil. Karanja is an oil that is not fit for human consumption and has its origins in India. Geographically, it is part of the Western Ghats in India, northern Australia, Fiji, and certain parts of eastern Asia.

Table 3. Fatty acid composition of Karanja oil.

Fatty acid	Molecular Formula	Structure	Composition (wt %)
Palmitic	$C_{16}H_{32}O_2$	16:0	3.7-7.9
Srearic	$C_{18}H_{36}O_2$	18:0	2.4-8.9
Lignoceric	$C_{20}H_{40}O_2$	24:0	1.1-3.5
Oleic	$C_{18}H_{34}O_2$	18:1	44.5-71.3
Linoleic	$C_{18}H_{32}O_2$	18:2	10.8-18.3
Dosocasnoic	$C_{22}H_{44}O_2$	22:0	4.45
Tetracosonaic	$C_{24}H_{48}O_2$	24:0	1.09

Plants tolerate salty conditions and can thrive in various soil types, including stony, sandy, and clayey terrains. Karanja requires an annual precipitation of 500−2,500 mm to thrive, typical of subtropical regions. As a result, this plant species is so common. About 10 months after harvesting, the green pods turn a golden brown. The brownish-red kernels are kidney-shaped, and the pods are either flat or elliptical and measure between 5 and 7 cm in length. There have been reports of trees yielding between 8 and 24 kg of kernels. Air-dried kernels have a moisture content of around 19% and a protein content of around 17.4%. According to recent data, the annual production of Karanja oil has reached 200 million tonnes [35]. A tree needs between four and seven years to reach full maturity. Different writers report an oil content of between 30 and 33% [35]. As of its low price and easy availability, the oil extracted from the seeds is immensely popular. Table 3 [33] details the reported carboxylic acid content of Karanja oil. The entire Karanja tree is used for its therapeutic benefits, and its wood is commonly burned as a fuel source. As of the risk of insect infestation, its wood is not used in construction. However, it will be used in implements, tools, and combs for the agricultural industry.

3.3. Castor (Ricinus communis)

The Euphorbiaceae family includes the castor bean plant. It is widely accessible worldwide, including in the most remote areas. Native to eastern Africa and particularly the Ethiopian region, this fast-growing plant is non-wood fibrous. Although oilseed is a perennial plant, it is planted as an annual outside of the tropics. The seeds are the primary commodity of this crop. Up to 45% of the castor bean is made up of natural oil that dries quickly and is high in unsaturated fatty acids, making it useful in various fields, particularly the pharmaceutical industry. Castor is grown at an annual rate of 1.1 million tonnes of seed with a yield of about 0.7 metric tonnes globally. Castor seeds are mostly produced in India, Brazil, and China. About 70% of India's oil seeds come from farms in Gujarat and Maharashtra, where they are grown using just rainwater.

In the hot and humid climates of the tropics, castor plants thrive. It takes about four to five months for it to mature fully. Cotton, groundnut, arhar, green gramme, jowar, bajra, and cowpea are grown in combination with castor. Castor is also grown as a pure crop in rotation with wheat, linseed, etc. Seed yields average 1,250 kg/a, with oil yields averaging 550 l/ha. India dominates global aperient production and trade [36]. As it is soluble in alcohol and the transesterification process can be carried out at room temperature, biodiesel made from cathartic has a lower production cost compared to biodiesel made from other oils [37]. Castor oilseed biodiesel is produced in a way that allows it to meet all quality standards, including viscosity and cold filter plugging. Castor oilseed has been described as a potential alternative feedstock for biodiesel production, with experiments finding that the resulting methyl ester (biodiesel) can effectively replace petroleum diesel.

Castor has a growing season shorter than Jatropha and Pongamia, giving it a comparative advantage. Thus, spreading education about growing castor plants among farmers is crucial. Given its yearly nature, it allows farmers to readily adjust their production to fluctuating market demand [36]. For this reason, it can potentially raise the standard of living for rural dwellers who cultivate it.

3.4. Simarouba Glauca (paradise tree or lakshmitaru)

A member of the family Quasia, Simarouba Glauca is also known as the Paradise tree, the LakshmiTaru, and the Acetuno. It has been used for several purposes, and the LakshmiTaru can thrive in extreme environments. It originated in North America, yet it can also be found in many parts of India. This tree's average height is 20 m. Its trunk diameter is between 50 and 80 cm, and its lifespan is around 70 years. Its cultivation is affected by factors such as the subsoil moisture, the soil's water-holding capacity, and the rainfall distribution (about 400 mm). Simarouba Glauca needs a soil pH of 5.5−8 and temperatures between 10 and 40 °C to thrive. It grows 20−50 cm long, with brilliant green foliage, yellow blooms, and oval, elongated, purple fleshy fruits [38]. Approximately 40% of a LakshmiTaru seed is made up of a kernel. It has between 55 and 65% oil in its kernels. If plants were spaced at 5 m, annual oil production would be between 1,000 and 2,000 kg/ha. Their industrial application can benefit soaps, detergents, lubricants, and other products. The oil cake has a high %age of valuable nutrients like nitrogen (7.7 to 8.1%), phosphorus (1.07%), and potash (1.24%) and can be used as an organic fertilizer [39]. Having a melting point of around 29 °C, LakshmiTaru is a great source of fat.

Biodiesel is produced from the seeds of the LakshmiTaru tree, ethanol is derived from fruit pulps, biogas is produced from fruit pulps, oil cakes, leaf litters, undesirable branches, and other byproducts of the fruit pulps are used to generate thermal power. As determined by gas chromatographic analysis, LakshmiTaru oil contains fatty acids in a composition different from most other oils (Chemito CERES 800 plus GC). There are just triglyceride esters in Simarouba Glauca oil (96.11%). Table 4 details the fatty acid profile of LakshmiTaru (Simarouba Glauca) oil [31].

Table 4. Fatty acid composition of Simarouba oil.

Fatty acid	Molecular Formula	Structure	Composition (wt %)
Stearic	$C_{18}H_{36}O_2$	18:0	27.3
Oleic	$C_{18}H_{34}O_2$	18:1	54.6
Palmitic	$C_{16}H_{32}O_2$	16:0	12.3
Linoleic	$C_{18}H_{32}O_2$	18:2	2.3
Arachidic	$C_{20}H_{36}O_2$	20:2	1.2
Erucie	$C_{22}H_{40}O_2$	22:2	0.4
Linolenic	$C_{24}H_{48}O_2$	24:0	0.2
Heptadecanoic	$C_{17}H_{30}O_2$	17:2	0.1

4. Biodiesel Production

Tree oil does not require engine modifications before being used in farming equipment. Converting oil into biodiesel, however, improves its quality and reduces its long-term difficulties. Tree-born oil's qualities are in line with those of fuels required by the United States (ASTM D6751), Germany (DIN 51606), India (BIS), Europe (EN 14214), and Australia (AS 5830) [41]. With methanol, sodium methoxide, hydrogen chloride, and sodium hydroxide, Figure 5 depicts the unit process of biodiesel conversion in a typical batch of transesterification [42]. The weight conversion rate efficiency of the procedure approaches 95%.

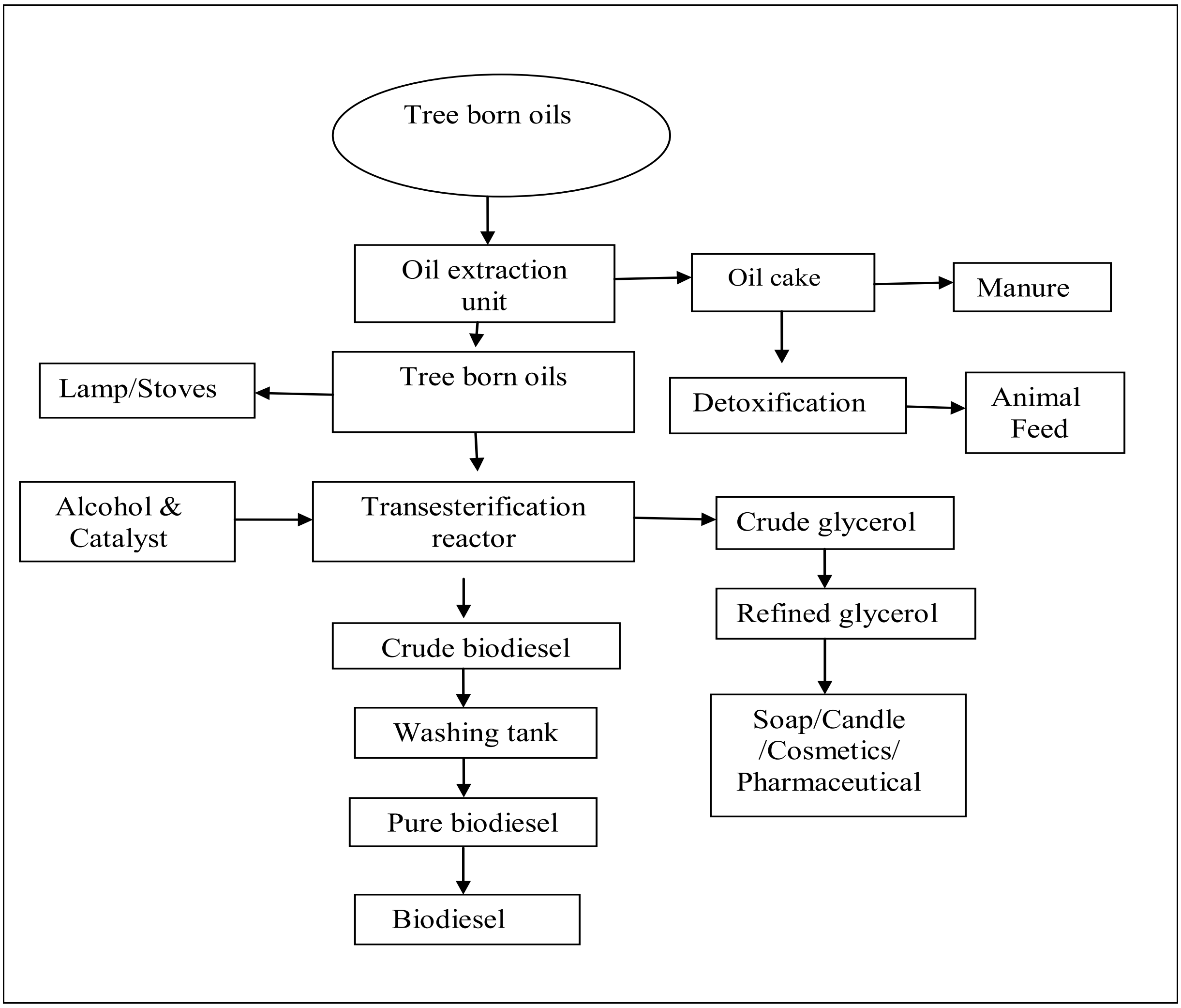

Fig. 5. Flowchart of the biodiesel manufacturing process using crude tree oils and other byproducts.

4.1. Tree-born oil co-products as biomass

The byproducts of TBOME manufacturing (Tree born oil methyl esters) have various potential uses, including as fertilizer and others. These items, together with their byproducts, are used to generate energy. Plantation yields wood, leaves, and coat with dry weights of 4,000, 2,000, and 800 kg, respectively. Another byproduct of the drilling process is Press cake, with a dry weight of 91.5 kg.

5. Result and Discussion

5.1. Characterization of Tree born oil biodiesel

Biodiesel (TBOME) is tested under established protocols to ascertain its physiochemical characteristics. Data has been analyzed with American (ASTM D6751), German (DIN 51606), Indian (BIS), and European institutions (EN 14214). Various properties have been calculated, including kinematic viscosity, flash point, pour point, cloud point, saponification value, iodine value, and acid value. Table 5 displays the results of experiments measuring biodiesel's physical and chemical characteristics (TBOME).

Table 5. TBOME (biodiesel) vs. Petro-diesel: A comparison of fuel properties.

Properties	Petro -diesel	Biodiesel
	ASTM D0975	ASTM D6751
Density at 30°C (kg/m3 or g/gL)	0.876	0.875 - 0.90
Viscosity at 40°C	1.9 -4.1	1.9 -6.0
Specific gravity (kg/m3 or gm/mL)	0.850	0.88
Flash point °C	60 -80	100 -170
Pour point	-35 to -15	-15 to 16
Cloud point	-15 to 5	-3 to 12
Acid value (mg NaOH/g)	0.35	<0.8
Iodine value	…	….
Saponification value (mg NaOH/g)	…	…
Ash content (%)	0.01	<0.02
Water content (%)	0.02	0.03

5.2. Economic scenario of biodiesel

The primary focus of the study is on the feasibility of blending biodiesel fuel with gasoline to produce fuel that is both inexpensive and less harmful to the environment. The development of the biodiesel business is a promising step toward a more environmentally friendly domestic fuel source. Since the product is still in its infancy, it has a promising future. As a result, the industry must grow in the right direction. The cutting-edge equipment will be used to establish an"oil from trees" extraction facility. The Ministry of New and Renewable Energy (MNRE) and the Confederation of Indian Industry (CII) have proposed raising the cost of biodiesel made from tree-born oil to revitalize India's biodiesel industry [43]. According to available statistics from the ministry and the Confederation of Indian Industry, the price of biodiesel made from tree-born oil has to increase from its current price of Rs 26.50 per liter. To make it sustainable and allow for suitable growth of the Indian biodiesel sector [44], the necessary procedures must be taken. If the 2020−2021 goal of blending 20% of tree-born oil-based biodiesel is met, the study predicts that India save roughly Rs. 3000 crores, earn revenue of around Rs. 5500 crore in the rural economy, and have an annual investment potential of Rs. 1700 crore. By doing so, we expect a reduction in greenhouse gas emissions of 3 MMT per year based on our findings [45].

5.3. Economical analysis of biodiesel

Policymakers face a severe challenge in addressing the cost susceptibility of petroleum fuel import due to the erratic price movements of rock oil on the international market. During the past couple of years, every available resource has been focused squarely on meeting the country's energy demands. An affordable supply of tree-born biodiesel oil for blending with petro-diesel is crucial to India's successful adoption of a bioenergy program. An important factor in ensuring the on-time implementation of the national biofuel program by 2021–2022. That demonstrates the economic necessity of replacing petro-diesel with tree-born oil biodiesel. The retail price of tree-born oil biodiesel in India is approximately Rs 30-32 per liter as shown in Table 6. The price difference may stem from the varying expense of sourcing Tree born oil seeds.

Table 6. Tentative cost of biodiesel production in Indian rupee.

Cost Component	Rate (Rs/Kg)	Quantity (Kg)	Cost (Rs)
Seed	10	3.28	32.8
Cost of collection and oil extraction	2.36	1.05	2.48
Less cake produced	1	2.23	-2.23
Transesterification cost	6.67	1	6.67
Less cost of glycerol produced	50	0.095	-4.75
Cost of Biodiesel per kg	-	-	34.97
Declared goods tax@4%	-	-	1.39
Total cost per kg	-	-	36.37
Cost of biodiesel per liter (specific gravity of 0.85)	-	-	30.91

5.4. Tree-born oil marketing mix model in the Indian scenario

5.4.1. Tree-born oil

The plant is generally cultivated for the aim of extracting biodiesel fuel and is tree-born oil seed. The seeds are the primary source by which the oil is extracted. Due to the toxic nature of tree-born oil seeds, humans do not use them. The key objective of tree-born oil seed cultivation is extracting tree-born oil. The oil content is 25−30% within the seed. The oil contains 21% soaked carboxylic acids and 79% unsaturated fatty acids. As a result of the presence of these toxic chemical components, the oil extracted from the seeds should not be used for human consumption. Fig. 6 presents the various marketing strategies used to sell Tree Born products.

5.4.2. Press cake

The byproduct of Tree-Borne Oil is typically fed to animals. In addition to being a potential source of biogas and a replacement for firewood, this byproduct is also proposed as fertilizer. For the time being, India has relied on their biogas plants. These factories are powered by cow manure. However, the biogas produced from the press cake is quicker to produce than that produced from regular cow dung. This opens up a fresh commercial possibility with the potential to create both electricity and jobs. Several remote communities now have access to a reliable and affordable power source for improvements in energy efficiency in the electricity sector. Its decaying material is a source of high-quality organic manure. According to the experiments, the best results are achieved by mixing 75% cattle dung with 25% tree-born oil cake [46].

5.4.3. Soap

Soap made from oil tree crops and plants has anti-microbial qualities and is more efficient than other plant-oil-based soaps at eliminating *S.aureus* and *E.coli*. The addition of other substances, such as essential oil, provides a soothing experience and aids in the healing of fungal skin conditions, including acne and eczema. This echoes the result that products like soap can become a viable natural option. This creates a new market for an expansive variety of soaps in the soap manufacturing industry. Soaps made from unusual ingredients such karnja, jojoba, Jatropha, castor, Lakshmi Taru, and others can expand their current market share [32].

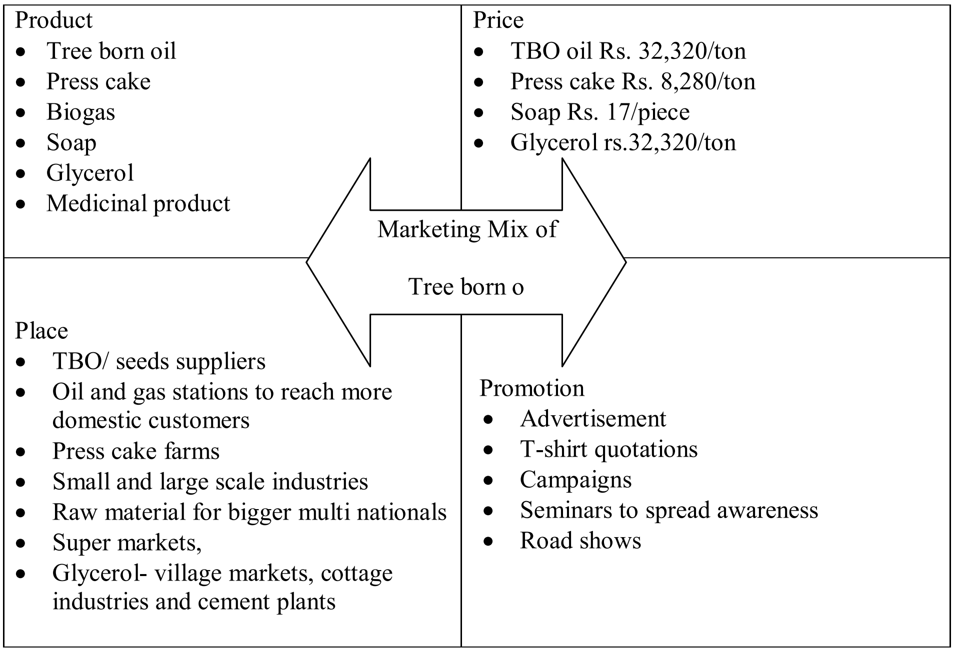

Fig. 6. Marketing mix of tree-born oil production.

5.4.4. Glycerol

Another byproduct of the biodiesel manufacturing process is glycerin. Biodiesel manufacturers sell raw glycerin to manufacturers. It is possible to refine this byproduct into a form of glycerin suitable for medicine. Cement grinding aid that includes purified glycerol results in a finer cement consistency. As a result, you can now process higher-quality cement for less money [40].

5.4.5. Medicinal product

In several countries, oil seeds derived from trees are employed in conventional folk medicine. Many secondary metabolites with potential medical use are found in the oil seeds of tree-born plants. Tree-born oils, such as those found in leaves, fruits, latex, and bark, include a wide variety of therapeutic compounds including glycosides, tannins, phytosterols, flavonoids, and steroidal sapogenins. One of the plant's possible future commercial applications is biopharmaceuticals [41].

5.4.6. Logistics and business study

Importing crude oil is a substantial cost for India and a significant contributor to the country's budget deficit. The well-established petro-diesel industry is biodiesel's biggest rival. The availability of biodiesel to the general public, on par with other fuels, is therefore of paramount importance. Biodiesel in India should have a defining characteristic that benefits the country economically and in ecological terms [44].

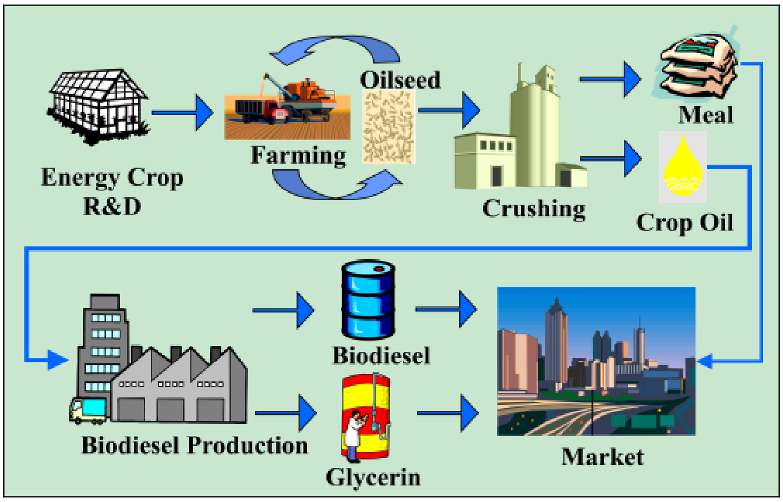

Fig. 7. Supply chain of biodiesel.

Those involved in making and consuming biodiesel cannot be separated from the petroleum business. There is a growing "petroleum-diesel" market where biodiesel fuel is blended with diesel made from petroleum. This broad assumption suggests that diesel and petroleum-based fuels must be standard for engine development. It's important to note that the engine performance and emissions of biodiesel blends like B2 to B5 (2 to 5% biodiesel in 98 to 95% petro-diesel), B20, and B100 are comparable to those of petroleum-diesel. A fun fact about the development of compression ignition (diesel) engines is that they run on peanut oil. In addition, as shown in Fig. 7, the liquid fuel industry is now operating in a market that is controlled by the petroleum industry.

5.4.7. International market scenario

According to a recent study, the global market for biodiesel fuels is expected to grow over the next decade, rising from USD 82.7 billion in 2011 to USD 185.3 billion in 2021. Although growth was expected to rise slowly throughout 2016, more substantial growth was forecasted between 2017 and 2022 due to higher oil prices, increasing mandate obligations, availability of the newest feedstocks, and the scaling from modern technology [47]. The international marketplace for biodiesel is booming. Despite severe protests by environmental organizations, the European Union Commission stipulated for agrofuel (more frequently mentioned as biofuel) blends be increased by 2020. India even aimed for a 20% blend by 2017 and Japan for a 20% blend by 2030. The worldwide production of diesel-supported plants was estimated to be 30 billion liters in 2010.

Biodiesel is a potential category of oxygenated fuels derived from sustainable biological resources such as edible oils and uses the ester structure. The term "bio-diesel" refers to replacing traditional diesel oil with a biodegradable form of fuel. Modifying the engine to use biodiesel is unnecessary as it can be used in compression ignition engines such as petroleum diesel. This keeps the same range and towing capacity as regular gasoline-powered diesel vehicles. Biodiesel is an alternative fuel made from recycled or virgin vegetable oils and animal fats. Pure biodiesel, in contrast to fossil diesel, is completely free of sulfur and aromatic compounds, making it safe for human consumption and the environment.

6. Conclusion

Renewable energy sources including biodiesel can potentially boost India's energy security and economy in the years to come. According to the research, the biodiesel industry is found to be vital to India's thriving economy. The bio-diesel industry offers numerous options for producing this promising alternative fuel. This study in biotechnology coincides with managerial and commercial opportunities in India. India will be able to advance further on the path to economic dominance. New growth by scientific research offers a wide range of agricultural products and technological advancements which can be adapted to a wide range of socioeconomic and environmental settings in rural areas.

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