

Review on Second Generation Biofuel in India

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ABSTRACT

The extensive use of fossil fuels is depleting its reserve and produces harmful emission causing environmental issues. Hence, considerable attention has been given to alternative sources such as biodiesel. Currently, biodiesel is mainly produced from conventionally grown edible oil plants thus leading to a competition of usage of food versus fuel. The increasing criticism of the sustainability of first generation biodiesels (those derived from edible oils) has raised attention to the use of second and third generation biodiesels. The second generation biodiesel includes non-edible vegetable oils, waste cooking oils as well as animal fats. These are considered as promising substitute for traditional edible food crops as they neither compete with food crops nor lead to land-clearing. This study introduces second generation biodiesel in India to be used as biodiesel feedstocks. Several aspects of these feedstocks are reviewed and discussed in this paper. These aspects include different sources of biodiesel feedstocks, biodiesel conversion technology and performance and emission characteristics of second generation biodiesel.

Keywords: *Second generation biodiesel; biodiesel feedstocks; conversion technology; performance and emission characteristics*

1. INTRODUCTION

Second-generation biofuel technologies have been developed because first-generation biofuels manufacture has important limitations. First-generation biofuel processes are useful but limited in most cases: there is a threshold above which they cannot produce enough biofuel without threatening food supplies and biodiversity. Many first-generation biofuels depend on subsidies and are not cost competitive with existing fossil fuels such as oil, and some of them produce only limited greenhouse gas emissions savings. Second-generation biofuels can help solve these problems and can supply a larger proportion of global fuel supply sustainably, affordably, and with greater environmental benefits. The problem that second-generation biofuel processes are addressing is to extract useful feedstocks from this woody or fibrous biomass, where the useful sugars are locked in by lignin, hemicellulose and cellulose.

1.1 Current biofuel production

Currently the transportation sector produces about 25% of global energy-related CO₂ emissions and accounts for roughly 50% of global oil consumption (IEA, 2008b). Biofuels are seen as one of the most feasible options for reducing carbon emissions in the transport sector, along with improvements in fuel efficiency and electrification of the light vehicle fleet. For heavy-duty vehicles, marine vessels and airplanes in particular, biofuels will play an increasing role to reduce CO₂ emissions since electric vehicles and fuel cells are not feasible for these transport modes. Over the last decade, global biofuel production increased rapidly; in 2008, about 68 billion litres of bioethanol and 15 billion litres of biodiesel were produced globally almost all of which was first-generation biofuel (mainly in the form of ethanol from sugar cane and corn) (IEA, 2009b). The main obstacle for second-generation biofuels is high initial investment costs as well as higher costs for the end-product compared to fossil fuels or many first-generation biofuels. Though investments in R&D are significant in certain OECD countries, it remains uncertain when second-generation biofuels will become commercially competitive. Some companies have reported they will start commercial production therefore of second-generation biofuels within the coming years (CHOREN, 2008; POET, 2009), but they will still depend on subsidies to be economically viable for some years to come. The WEO 2009 450 Scenario projects that second-generation biofuels will not penetrate the market on a fully commercial scale earlier than 2015 (IEA, 2009a).

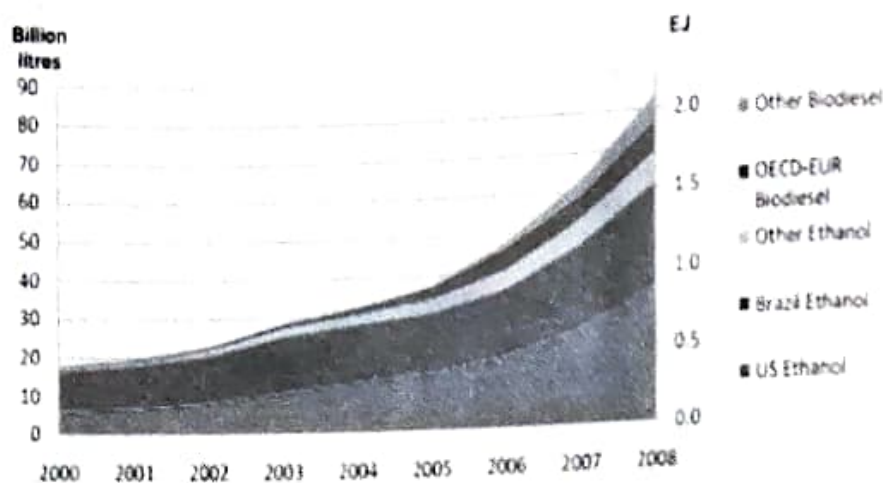


Fig: 1.1 Global biofuel production

2. LITERATURE REVIEW

2.1 GENERAL

The literature survey is carried out as a part of the project work. It contains the review of the past research about the Second generation biofuel. The past research effort will certainly guide in justifying the scope and direction of the present effort.

2.2 LITERATURE SURVEY

Saravanan et al. [2018] reviewed the key features of India's National Biofuel Policy, which aids in the regulation of biofuel production and marketing. This review summarised recent initiatives and their scope.

Abed et.al. [2019] has done work on effect of biodiesel fuel on diesel engine emission biodiesel from Jatropha, Palm, Waste cooking oil, algae had been as feedstock for biodiesel. B10 and B20 blends with diesel fuel were used on single cylinder diesel engine. From that it was observed that CO, HC, CO₂ and smoke emission were reduced as compared to diesel fuel for all blends of B10 and B20 whereas NOx emission were found higher for all blend of B10 and B20.

M. M. K. Bhuiya, et al. [2014], Second Generation Biodiesel: Potential Alternative to-Edible Oil-Derived Biodiesel. The second generation biodiesel includes nonedible Vegetable oils, waste cooking oils as well as animal fats. These are considered as promising substitute for traditional edible food crops as they neither compete with food crops nor lead to land-clearing. This study introduces second generation biodiesel to be used as biodiesel feedstocks. The aim of his experimental work was to study the Second generation biodiesel; biodiesel feedstocks; conversion technology; performance and emission characteristics.

Christine Chirat [2017], studied the Vegetal biomass, Bioeconomy, Biorefinery, Biofuels, Bioenergy and Bioproducts. The use of vegetal biomass for energy will then be discussed, with a focus on the production of biofuels. This paper will first give key figures for fossil fuel versus vegetal biomass stocks and production. The chemical composition of vegetal biomass will be described in a second part, and compared with fossil raw material.

Soni Sisbudi Harsono et al. [2015], studied the Agricultural waste, bioethanol, biorefinery, coffee pulp, fermentation and *Saccharomyces cerevisiae* of the second-generation biofuels. The research was aimed to utilize coffee wastes for producing a value added products and to reduce environmental pollution burden as well as to evaluate the potential for bioethanol production at probable optimum conditions using *Saccharomyces cerevisiae*.

Ralph E.H. Sims et al. [2010], 2nd-generation biofuels production will continue to face major constraints to full commercial deployment. The logistics of providing a competitive, all year-round, supply of biomass feedstock to a commercial-scale plant is challenging, as is improving the performance of the conversion process to reduce costs.

Jadwiga R. Ziolkowska [2014] studied Second generation biofuels with cellulosic ethanol, Biofuel feedstocks and technologies. This paper discusses various biofuels technologies and feedstocks that have a potential to emerge as prospective feedstocks for second generation biofuels production in the future on the US market.

3. Second-generation biofuel conversion routes

R&D efforts have been undertaken for different conversion routes, and so far there is no clear trend showing which technology will be the most promising future option. The two main conversion routes are:

3.1 Bio-chemical route: This process is based on enzymatic-hydrolysis of the lignocellulosic material through a variety of enzymes that break the cellulosic material into sugars. In the second step of the process, these sugars are fermented into alcohol which is then distilled into ethanol.

3.2 Thermo-chemical route: The first step in the process is the gasification of the feedstock under high temperature into a synthesis gas. This gas can then be transformed into different types of liquid or gaseous fuel, so-called "synthetic fuels" (e.g. BTL-diesel, bio-SNG).

Table-3.1 Classification of second generation biofuel from lignocellulosic feedstocks

Biofuel group	Specific biofuel	Production process
Bioethanol	Cellulosic ethanol	Advanced enzymatic hydrolysis and fermentation
Synthetic biofuel	Biomass to liquid (BTL) Fischer-Tropsch (FT) diesel, synthetic diesel, Biomethanol Heavier alcohols (Butanol and mixed) Dimethyl ether (DME)	Gasification and Synthesis
Methane	Bio-synthetic Natural Gas (SNG)	Gasification and Synthesis
Bio-hydrogen	Hydrogen	Gasification and Synthesis or biological processes

BTL-diesel and lignocellulosic ethanol are the most discussed second-generation biofuel options. Both fuels can be blended with conventional diesel and gasoline, or used pure. Another promising second-generation biofuel is bio-SNG, a synthetic gas similar to natural gas. The gas can be produced from a wide variety of biomass feedstocks and can be compressed or liquefied for use as transport fuel in modified vehicles. The biofuel yields in terms of fuel equivalent are higher in this conversion route compared to lignocellulosic ethanol and BTL-diesel.

3.2 Biodiesel Production

Trans-esterification is regarded as one of the best techniques to convert oil into biodiesel, as it has the most promising solution to the high viscosity problem among other approaches due to its low cost and simplicity. Furthermore, this technique has been identified as a widely available technique for industrialized biodiesel production due to its high conversion efficiency i.e. 60 to 90% and low cost. In transesterification process, alcohol is reacted with vegetable oil in the presence of appropriate catalyst. Generally, ethyl or methyl alcohol is used to produce ethyl or methyl esters. When the reaction is completed, two distinct layers of liquids i.e., ethyl or methyl ester and glycerine appear and they separate out as shown in Fig. 3.1.

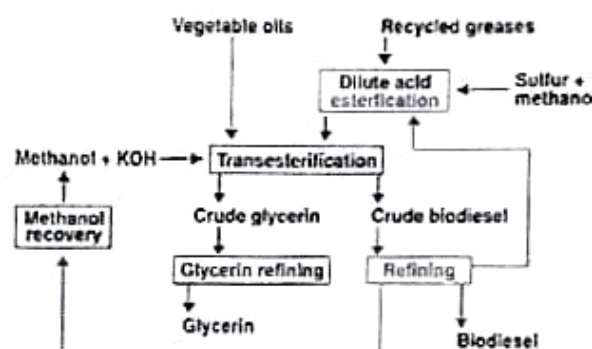


Fig.3.1: Basic Transesterification protocol

The glycerine is refined and disposed of for further use. The crude biodiesel is also refined and alcohol is separated from it which is reused in the cycle. The technology of biodiesel production includes transesterification of oils (triglycerides) with alcohol which gives biodiesel which is chemically-known as fatty acid methyl ester (FAME) as the main product and glycerol as the by-product. Fig 1.3. Basic trans esterification protocol. The triglyceride is converted step-wise into diglyceride, monoglyceride, and finally, glycerol, during which one mole of alkyl ester is removed in each step. The main Transesterification reaction variables include: methanol/oil molar ratio, catalyst concentration, reaction temperature and reaction time are optimized for high biodiesel conversion and quality. Methanol to oil ratio is varied from 3:1 to 12: 1, while catalyst concentration is varied from 0.25 % to 1.25 %. The catalysts are used in biodiesel production due to their higher kinematic reaction rates. The reaction upper temperature limit is restricted by the boiling point (65°C) of methanol and the lower limit is based on room temperature. To obtain pure methyl ester, the product is washed with hot water to separate from soap formed during reaction. The biodiesel sample is to be tested to determine the fuel quality. Fatty acid profile of the feedstock is obtained by Gas Chromatograph (GC). Fuel property test is conducted according to ASTM as well as EN test standards. The important fuel property parameters that are investigated include: cetane number (ASTM D613), kinematic viscosity (ASTM D445), density (ASTM D1298), calorific value (ASTM D240), flash point (ASTM D93), pour point (ASTM D97), cloud point (ASTM D2500), oxidation stability (EN 14112), acid value (ASTM D664), lubricity (ASTM D6079), carbon residue (ASTM D4530), iodine value (EN 14111) and sulphated ash content (ASTM D874).(1)

3.3 Biofuel production costs

Cost estimates for second-generation biofuels show significant differences depending on plant complexity and biomass conversion efficiency. Important factors include annual full-load hours of plant operation, feedstock costs and capital requirements. Accordingly, biofuel plants with a higher biomass-to-biofuel production ratio are typically able to accept higher biomass supply costs compared to less efficient plants.

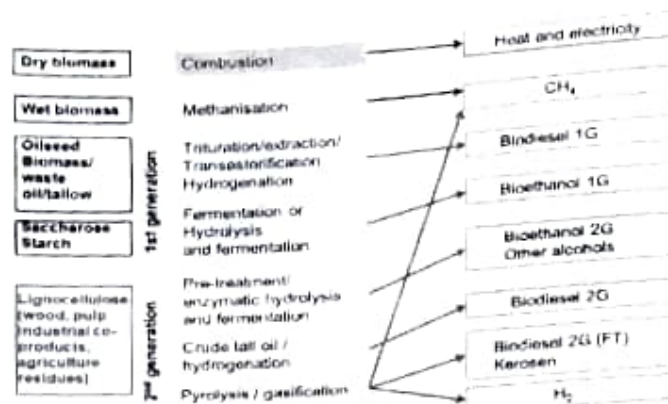


Fig: 3.2 Comparison of biofuel cost estimates in the short and long term

Figure 3.2 shows current IEA projections for short- and long-term production costs of different biofuels under two oil price scenarios. With oil at USD 60/bbl, production costs for both BTL-diesel and lignocellulosic ethanol are currently in the range of USD 0.84–0.91/lge and thus are not competitive with fossil fuels and most first generation biofuels. In the long term, however, with increasing plant capacities and improved conversion efficiencies, both BTL-diesel and lignocellulosic ethanol could be produced at significantly reduced costs. In this case, production costs are projected to be around USD 0.62/lge for lignocellulosic ethanol and USD 0.58/lge for BTL-diesel (IEA, 2009c). The estimated production prices are less than those for rapeseed biodiesel, but still more expensive than gasoline and other first-generation biofuels. With oil at USD 120/bbl, production costs rise to USD 1.07/lge for BTL-diesel and USD 1.09/lge for lignocellulosic ethanol. In the long term, prices are projected to fall to USD 0.73/lge for BTL-diesel and USD 0.72/lge for lignocellulosic ethanol. Therefore, with reduced overall costs and oil price at USD 120/bbl, second-generation biofuels could be produced at lower costs than gasoline and rapeseed biodiesel and close to the costs of corn ethanol (IEA, 2009c).

3.5 Use of vegetal biomass for energy – example of biofuels

In 2014, the world's Total Primary Energy Supply (TPES) was 13,700 Mtoe (tons of oil equivalent), of which 13.8%, or 1,894 Mtoe, was produced from renewable energy sources. The major part comes from biomass, representing 72.8% of renewable energy sources: solid biofuels/charcoal is by far the largest renewable energy (66.2% of global renewables supply), then liquid biofuels (4.1%), biogases (1.6%), and renewable municipal wastes (0.8%). The other renewable sources are hydro (17.7%), geothermal (3.8%), wind (3.3%) and solar/tide (2.5%) energies.

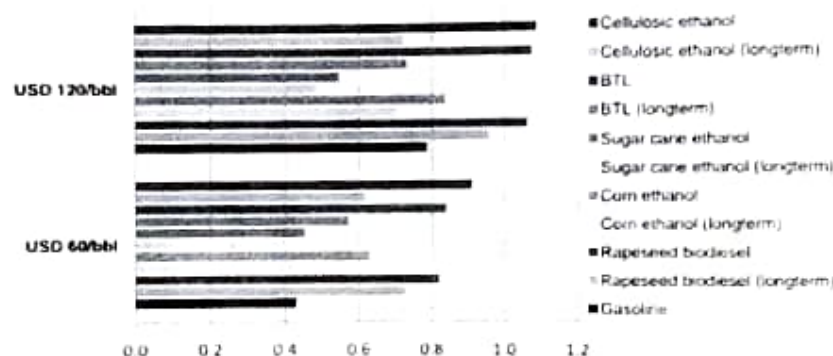


Fig: 3.3 Different current ways to produce energy and biofuels from biomass

Fig. 3.3 presents different ways that can be used to produce energy from biomass. As far as liquid biofuels are concerned, they are mainly first-generation biofuels, which means that they use edible part of plants. In the case of bioethanol, saccharose (from sugar beet or sugar cane) or starch (from maize and wheat) are used as raw material. Saccharose (which is a dimer composed of glucose and fructose) can be fermented directly to ethanol using the common baker's yeast (*Saccharomyces cerevisiae*), whereas starch, which is a polymer of α -glucose, first needs to be depolymerized into glucose using an enzymatic treatment, and then glucose is fermented into ethanol. Biodiesel is the second type of biofuel, produced from vegetal oil (e.g. rapeseed, sunflower): fatty acid methyl esters are produced by reacting vegetal oil with methanol, glycerol being the by-product of the reaction. Hydrogenation of vegetal oil is another process that can be used to produce biodiesel. In 2015, the production of bioethanol was 115.6 billion liters. About 53% of it came from maize, 26% from sugar plants (sugar cane and sugar beet), 7.5% from molasses, only a few percent from wheat, and less than 1% from lignocellulosic biomass (wood, agriculture residues). The forecast is 128.4 billion liters by 2025, 51% coming from maize, 28% from sugar plants, 8% from molasses and still less than 1% from lignocellulosic plants. Biodiesel production was 31.1 billion liters in 2015 and should increase by 33% since 2025 to 41.4 billion liters. A little more than 80% of biodiesel is produced from vegetal oil, this percentage will be about 72% in 2025. The use of other sources like waste oil and tallow to produce biodiesel will increase from 15% in 2015 to almost 25% in 2025. The % coming from lignocellulosic biomass is very small today and will be less than 0.5% in 2025.

4. Second Generation Feedstock

In recent years, oil palm, algae and *Jatropha* have been studied as potential biodiesel feedstock. They have been found to produce much higher oil yields, compared to traditional feedstock, such as soybean or rapeseed (Table 1). However, several other highly efficient feedstock bear a high potential of becoming biofuels feedstock of the future, although they have not been investigated sufficiently yet. A number of grasses like Switchgrass, *Miscanthus*, *Indiangrass*, and others have alternatively been placed in the spotlight. The particular grass chosen generally depends on the location as some are more suitable to certain climates. In the United States, Switchgrass is favoured. In Southeast Asia, *Miscanthus* is the choice. WVO have been used as a fuel for more than a century. In fact, some of the earliest diesel engines ran exclusively on vegetable oil. Waste vegetable oil is considered a second generation biofuels because its utility as a food has been expended. In fact, recycling it for fuel can help to improve its overall environmental impact.

Another prospective feedstock for biodiesel production, just emerging on the biofuels market, is *Pongamia pinnata*, also called: pongam tree, karum tree and poonga-oil tree). The tree is native to India and Australia and has a high growth rate, high drought resistance and produces oily seeds. It has low requirements in terms of irrigation and pest control, while it can also be grown on marginal lands in hot and dry climates. As pongam trees are leguminous (they fix atmospheric nitrogen), they do not require fertilizers. A single tree is said to yield 9–90 kg seed per tree, with the yield potential of 900–9000 kg seed/ha. The average oil content is 18–27.5% depending on the extraction technology the seeds can be harvested and prepared with conventional equipment used for processing tree nuts, peanuts and other crops. It has been estimated that *Pongamia* trees can generate up to thousands of gallons of biofuels from one acre, at the cost of \$1/gal (\$0.26/l) of biofuel after the oil is removed, the leftover seed cake can be used as a fertilizer or blended with soybean for animal feed.(5)

Table 4. 1 Oil yields from various biomass sources and biofuels productivity

Crop	Seed oil (%oil by wt)	Oil yield (L oil/ha year)	Land area use (m ² year/kg biodiesel)	Viscosity 40 °C (mm ² /s)
Corn	44	172	66	31
Canola	41	974–1190	12	33
Safflower	20.1	779		30
Sunflower	40	952–1070	11	-
Peanut	70	1059		22.7
<i>Jatropha</i>	20–60	1892	15	42.5
Karanj	25–40	2590		27.82
Oil palm	36	5366–5950	2	38
Microalgae	30–70	58700–136,900	0.1–0.2	36.6

4.1. Biodiesel Processing

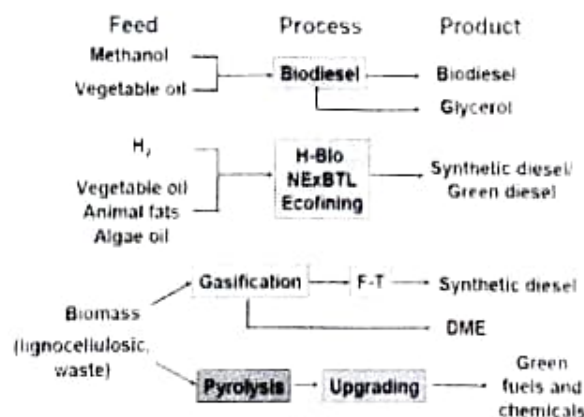


Fig: 4.1 Biodiesel Processing

A Biodiesel Processing is carried out on methanol and vegetable oil to produce Biodiesel and glycerol. Vegetable oil along with animal fats and algae oil are mixed with H₂ and processed by ecofining to produced synthetic diesel or green diesel. Biomass like lignocellulosic waste is gasified to form synthetic diesel. Same waste is pyrolysed and upgraded to form green Field and chemicals.

4.2. Second generation ethanol production

In figure 4.2 Bagasse and steam along with acid solution are pretreated and passed through filter 1, from filter 1, solid part is treated by with enzymes by pre-hydrolysis process. It is then hydrolysed and passes through filter 2 to boiler and to concentration. Liquid from filter 1 is fermented and pass to column.

5. Future perspective for second generation Biofuel

The changes and progress in the biofuels industry in recent years have shown potentials for an investment-friendly environment for new biofuels technologies. This could create a stable background for innovative biofuels technologies of the future in the long-term, where the total biofuels market would be supplied with biofuels from a balanced mix of different sustainable feedstocks. In this way, extreme natural resource overuse could be avoided, while the tradeoff conditions of food vs. fuel production could be (at least partially) solved. However, more likely only a handful of technologies and

feedstocks will prove economically viable and competitive with current traditional feedstocks, and approved to be produced on a commercial scale. As none of the second generation biofuels feedstocks has reached such a technological maturity yet, starch from corn and sugar are still dominating the ethanol production nowadays. Given the current technological development, no other second generation feedstocks are cost competitive enough to gain momentum on the biofuels market at this point of time. The problem with technological maturity relates mainly to high total costs (including experiment costs, technological costs and availability of the feedstock) that are among them also relevant factors determining the process of large-scale production. Thus, economic obstacles hinder the development of more environment-friendly technologies, as it was proved that second generation biofuels feedstocks have low direct or indirect GHG emission impacts and thus outperform conventional biofuels feedstocks

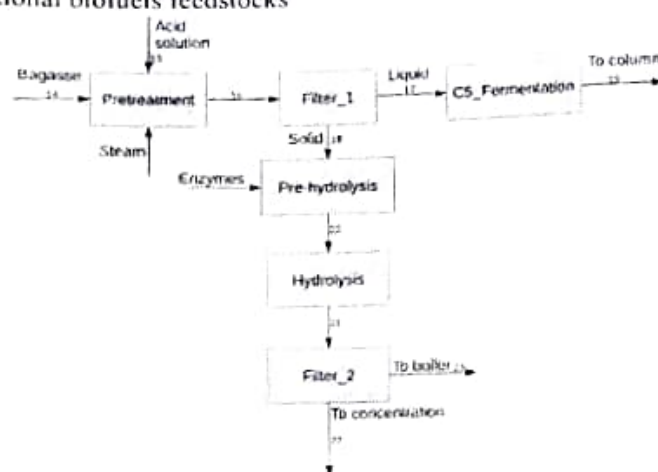


Fig: 4.2 Diagram for second generation ethanol production.

6. CONCLUSION

The second generation biofuels have become the leading raw materials for obtaining biodiesel due to an increase in world's energy demand, competition of edible oil sources for human use and biofuel production as well as environmental pollution. This paper discussed second generation biofuel, technologies, need, biodiesel processing. From study it is concluded that:

1. Next generation Biofuels can be produced from various palm sources.
2. Biomass to liquid (BTL) is an emerging bioenergy for future generation.
3. Algae and jatropha are two potential feedstocks for biofuel production.
4. Sustainable palm resources management is required to move the second generation Biofuel industry forward.
5. Development of green fuels will contribute significantly to reduction of GHG emissions and mitigate climate change.

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