Review on Biodiesel Characteristics and Various Feedstocks

[1]Maulik R Acharya,
Lecturer,
Chemical Engineering Department,
1 Government Polytechnic Gandhinagar, Gandhinagar, India

Abstract : This review assesses biodiesel's role as a sustainable and renewable alternative to petroleum diesel. Produced via transesterification of plant or animal triglycerides with alcohol, biodiesel's properties are defined by its fatty acid composition, which varies by feedstock. The analysis underscores that no single feedstock is ideal; instead, sustainable industry growth requires a holistic strategy balancing technical, economic, and environmental factors. Future success depends on leveraging diverse local feedstocks and advancing catalytic and processing technologies to meet energy demands and reduce fossil fuel dependence.

IndexTerms: Bio Diesel, Feed Stock, Characteristics, Property of Bio Diesel

1. Introduction

Biodiesel is a viable alternative fuel that is chemically similar to petroleum diesel, allowing it to be used directly in existing diesel engines with little to no modification. It can be used pure (B100) or blended in any ratio, with a 20% blend (B20) being the most common. Its key advantages include a high flash point (making it safer to handle), zero sulfur content, and the absence of harmful aromatics. Biodiesel contains 11% oxygen by weight, which promotes more complete combustion. This results in significant reductions in tailpipe emissions, including visible smoke, odors, and noxious fumes. It is also non-toxic and readily biodegradable. While different alcohol esters (like methyl or ethyl) from the same oil source have similar fuel properties such as viscosity and heating value, all biodiesel shares favorable traits including superior lubricity and environmental benefits compared to conventional diesel. (3,9,11,12)

2. Important Properties of Bio Diesel

2.1. Fuel Properties of Biodiesel Oil

1. Viscosity: Viscosity measures a fluid's resistance to flow. Biodiesel's viscosity is similar to petroleum diesel, which is critical for engine operation. High viscosity, especially in cold weather, can lead to poor fuel atomization and injector problems. (3)

2. Density & Specific Gravity: Density is the mass per unit volume. Biodiesel's specific gravity (0.87–0.89) is higher than diesel. Since fuel injectors meter fuel by volume, this results in a slightly greater mass of fuel being delivered, impacting engine performance and emissions. (3)

3. Cetane Number (CN): The cetane number measures the ignition quality of diesel fuel; a higher CN means shorter ignition delay and smoother combustion. Biodiesel typically has a higher CN than petroleum diesel, leading to better combustion efficiency, reduced noise, and lower CO/HC emissions. Saturated, long-chain molecules (common in animal fats) have higher CNs. (3)

4. Cloud Point (CP) & Pour Point (PP): These define a fuel's cold-weather performance:

Cloud Point: The temperature at which wax crystals first become visible.

Pour Point: The lowest temperature at which the fuel can still flow.

Biodiesel has higher (worse) CP and PP than conventional diesel, which can limit its use in cold climates. (3)

5. Flash Point: The flash point is the temperature at which a fuel can ignite when exposed to a flame. Biodiesel has a significantly higher flash point than petroleum diesel, making it much safer to handle, transport, and store. (9)

6. Neutralization Number: This number indicates the acidity of the fuel, reflecting the presence of free fatty acids or acids from the manufacturing process. It is a key indicator of fuel quality, aging, and whether the production process was conducted properly. (9)

7. Carbon Residue: Carbon residue predicts a fuel's tendency to form carbon deposits in the engine. In biodiesel, a high carbon residue is a strong indicator of contaminants like leftover glycerides, soaps, polymers, and inorganic impurities from incomplete processing. (9)

2.2 Physical Properties

Some of the physical characteristics of biodiesel are given in Table-1.

Table1. Physical Properties of Bio Diesel (11)

Properties	Values
Specific Gravity	0.88
Viscosity @ 20 0Ċ (Centistokes)	7.5
Cetane Index	49
Cold Filter Plugging Point (Ċ)	-12
Net Heating Value (kilojoules/Liter)	33,300
Boiling Point	> 400 0F
Vapor Pressure (Mm Hg)	< 5mm Hg @ 72 0 F
Flash Point	321 0 F
Solubility In Water	Insoluble
Appearance	Light To Dark Yellow Clear Liquid
Odor	Light Musty Odor

2.3 Emission Characteristics

Biodiesel is a biodegradable and non-toxic fuel that produces lower levels of harmful emissions compared to conventional diesel. When used in unmodified diesel engines, it reduces particulate matter (PM), hydrocarbons (HC), and carbon monoxide (CO). However, it can lead to a slight increase in nitrogen oxides (NOx) emissions.

Biodiesel is the first alternative fuel to have its emissions and health impacts fully evaluated and approved by the U.S. EPA under the Clean Air Act. Life-cycle analysis shows that biodiesel generates approximately 80% less carbon dioxide and nearly 100% less sulfur dioxide than petroleum-based diesel.

The increase in NOx emissions—which tends to rise with higher biodiesel blends—is due to more complete combustion resulting from the fuel’s oxygen content. This effect can be offset using modern NOx control technologies, which are particularly well-suited to biodiesel since it contains no sulfur. Biodiesel is a biodegradable and non-toxic fuel that produces lower levels of harmful emissions compared to conventional diesel. When used in unmodified diesel engines, it reduces particulate matter (PM), hydrocarbons (HC), and carbon monoxide (CO). However, it can lead to a slight increase in nitrogen oxides (NOx) emissions.

Biodiesel is the first alternative fuel to have its emissions and health impacts fully evaluated and approved by the U.S. EPA under the Clean Air Act. Life-cycle analysis shows that biodiesel generates approximately 80% less carbon dioxide and nearly 100% less sulfur dioxide than petroleum-based diesel. The increase in NOx emissions—which tends to rise with higher biodiesel blends—is due to more complete combustion resulting from the fuel’s oxygen content. This effect can be offset using modern NOx control technologies, which are particularly well-suited to biodiesel since it contains no sulfur. (3)

Table 2 Biodiesel Emissions Compared to Conventional Diesel [11]

Emissions	B100	B20
Regulated Emissions		

Total Unburned Hydrocarbons	-93%	-30%
Carbon Monoxide	-50%	-20%
Particulate Matter	-30%	-22%
NOx	+13%	+2%
Non-Regulated Emissions		
Sulphates	-100%	-20%*
Polyciclic Aromatic Hydrocarbons (PAH)**	-80%	-13%
NPAH (Nitrated PAHs)	-90%	-50%***
Ozone Potential of Speciated HC	-50%	-10%
Life-Cycle Emissions		
Carbon Dioxide (LCA)	-80%	
Sulphur Dioxide (LCA)	-100%	

2.4. Toxicity & Safety

Biodiesel is non-toxic and poses minimal health risks. It is biodegradable, breaking down 4-5 times faster than petroleum diesel. Its high flash point (approximately 300°F) makes it significantly safer to store and handle. While it can cause mild skin irritation (less than a 4% soap solution), it is not hazardous upon ingestion. Spills can damage painted surfaces if not cleaned promptly. Critically, biodiesel exhaust does not show an increased tendency for mutagenicity. (10)

2.5 Storage & Handling

Standard diesel storage protocols apply to biodiesel. It should be stored in a clean, dry, dark environment to prevent degradation and avoid low temperatures that can cause gelling. Compatible tank materials include mild steel, stainless steel, and certain fluorinated plastics. A key consideration is biodiesel's solvent effect; it will dissolve existing deposits in tanks and pipes from previous diesel use, which may clog filters initially. Filters should be monitored closely after switching to biodiesel. (10)

2.6 Materials Compatibility

Biodiesel can degrade certain elastomers and natural rubber compounds over time. Metals such as copper, brass, bronze, lead, tin, and zinc should be avoided as they can catalyze oxidation and create sediments. Incompatible components should be replaced with aluminum, stainless steel, or biodiesel-compatible polymers. The effect is less pronounced with lower blends like B20. Most modern vehicles are already compatible, as they are designed for low-sulfur diesel**.** (10)

2.7 Solvency:

As a mild solvent, biodiesel can damage painted surfaces and dissolve accumulated sludge in fuel tanks and systems. This released sediment can then be carried into the engine, potentially clogging fuel filters and, in severe cases, damaging injectors. This is most common in older, poorly maintained systems. The issue is significantly reduced with B20 blends and typically resolves after the first few tankfuls as the system is cleaned out. (10)

2.8 Lubricity:

A significant advantage of biodiesel is its superior lubricity. Even low blends greatly enhance lubrication, reducing engine wear and extending the life of critical fuel injection system components, especially in pumps that are lubricated by the fuel itself. This property makes it an excellent lubricity additive for ultra-low-sulfur diesel, which has poor inherent lubricating properties. (10)

3. Biodiesel Feed Stocks:

Biodiesel's versatility stems from its ability to be produced from a wide array of biological sources, which are categorized as feedstocks. These feedstocks are broadly divided into four main groups, each with its own advantages and challenges. (5)

3.1 Virgin (Pure) Vegetable Oils:

This category refers to oils extracted from crops specifically grown for fuel production.

Common Crops: Rapeseed (canola) in Europe and soybean in the Americas are the dominant industrial-scale sources due to high oil yields and established agricultural infrastructure.

Promising Alternatives:

Mustard: A drought-resistant crop that can be grown in rotation with wheat.

Palm Oil: Extremely high yield per acre, but its cultivation is controversial due to its link to deforestation and habitat destruction in tropical regions.

Jatropha: A non-edible shrub that grows on marginal, arid land, minimizing competition with food crops.

Hemp: A fast-growing plant with a high biomass yield.

Algae: Considered the future of biodiesel by many, as it can produce extremely high oil yields per acre, can be grown on non-arable land (including in wastewater or seawater), and consumes carbon dioxide. (5)

3.2. Waste Vegetable Oil (WVO):

This is used cooking oil recovered from restaurants, food processing plants, and households.

Advantage: It is a recycled waste product, making it a very cost-effective and environmentally friendly feedstock that doesn't compete with food supplies or require new land use.

Challenge: It requires extensive filtering to remove food particles and water before it can be converted into biodiesel**.** (5)

3.3 Animal Fats:

These are by-products of the meat rendering and fishing industries, providing a valuable use for waste that would otherwise need to be disposed of.

Sources: Include tallow (beef fat), lard (pork fat), chicken fat (yellow grease), and oils left over from the processing of fish oil for dietary supplements.

Property: Biodiesel from animal fats often has a higher cetane number and better stability but also a higher cloud point (it solidifies at warmer temperatures), which can be a drawback in cold climates. (5)

4. Novel and Experimental Feedstocks:

Research is continuously expanding the possible sources for biodiesel, aiming for greater sustainability and lower costs.

Sewage Sludge: As mentioned, companies are pioneering the use of nutrient-rich wastewater to cultivate oil-producing algae. This solves two problems at once: it treats waste and produces fuel. The algae consume the nutrients in the sewage, and are then harvested for oil extraction. (5)

Key Production Process: Thermal Depolymerization (TDP)

This is a broader, more revolutionary process than traditional transesterification (which is used for the oils and fats listed above).

Function: TDP is a patented process that uses heat and pressure to mimic the natural geological processes that create petroleum. It can break down almost any carbon-based waste material—including non-oil feedstocks like plastic waste, tires, paper pulp, animal by-products, and sewage—and convert it into light crude oil.

Significance: This technology has the potential to create biodiesel and other fuels from a vast range of waste streams, effectively turning trash into valuable energy while reducing landfill burden. It greatly expands the definition of what can be considered a "feedstock" for biofuel production. (5)

5. Classification of Bio-diesel Resources [5]

Class-I: Bio-diesel From Oil Seeds

Category A – Conventional Cultivated Oil Yielding Crops

Rape Seeds, Ground Nut, Sesame Seeds, Rocket Seeds

Category B – Non Conventional Cultivated Oil Yielding Crops

Sun flower, Soybean, Safflower

Category C – Industries Based Crops

Linseed, Castor beans, Cotton seeds

Category D – Wild Plant Resources

Pongame tree, Olive tree, Hemp oil, Oat seeds, Milk Thistle, Carthamus seeds, Jatropha

Class-II: Bio-diesel From Waste Oils

Categories of Class-II Resources

Straight Vegetable Oil (SVO), Waste Vegetable Oil (WVO), Animal Fats

The selection of plant sources for biodiesel in India is governed by key principles. To avoid competition with food supplies, feedstocks must be non-edible and capable of large-scale cultivation on non-arable land. Furthermore, plants with significant medicinal value are considered unsuitable. Therefore, the most feasible options are specific trees that align with these requirements.

Table 3 Prospective Feedstock in India (15)

Name	Botanical Name	Oil Content (%)
Neem	Azadirachta indica	20
Karanja	Pongamia pinnata	27-39
Kusum	Schleichera	34
Pilu	Salvadora oleoides	33
Ratanjot	Jatropha curces	30-40
Mahua	Madhuca indica	35
Bhikal	Prinsepia utilis	37
Undi	C.inophyllum	50-73
Thumba	C.colocynthis	21
Sal	Shorea robusta	20
Nahor	Mesua ferrea	45
Jojoba	S.chinensies	-
Kamala	Mallotus phillipines	-
Kokam	Garcinia indica	-
Rubber Seed	Hevea Brasilensis	-

5. In-Depth Analysis of Biodiesel Feedstocks and Characteristics

Biodiesel stands as a pivotal renewable alternative to petroleum diesel, but it is not a monolithic fuel. Its identity is fundamentally shaped by its biological origin. The choice of feedstock is the most critical decision in the biodiesel value chain, as it dictates the fuel's chemical properties, economic viability, environmental impact, and overall sustainability.

5.1 The Feedstock Spectrum: A Trade-Off Between Yield, Cost, and Ethics

The evolution of feedstocks from first to third generation represents the industry's ongoing quest to resolve the "food vs. fuel" debate and improve ecological footprints.

5.1.1 First-Generation Feedstocks: The Established Giants

These crops benefit from mature agricultural supply chains, high oil yields (especially palm oil), and well-understood processing techniques. This makes them economically competitive and readily available for large-scale production. The core controversy lies in their impact on global food markets, land-use change (e.g., deforestation for palm plantations), and high-water consumption. Their sustainability is often questioned unless strict certification schemes are followed.

5.1.2 Second-Generation Feedstocks: The Sustainable Workhorses

These sources are the cornerstone of sustainable biodiesel production. They add value to waste streams (used cooking oil, animal rendering by-products) or utilize marginal, non-arable land for non-edible crops like Jatropha and Karanja. This eliminates competition with food production and reduces waste disposal problems. Their primary technical hurdle is the high Free Fatty Acid (FFA) content. FFAs react with alkaline catalysts used in standard transesterification to form soap, which complicates the reaction and reduces biodiesel yield. This necessitates an extra pre-treatment step (acid-catalyzed esterification) to convert FFAs into biodiesel before the main reaction, adding complexity and cost.

5.1.3 Third-Generation Feedstocks: The Future Potential

Microalgae represent a quantum leap in potential productivity, capable of yielding 10-100 times more oil per hectare than terrestrial crops. They can be grown on non-arable land using saline or wastewater, do not require pesticides, and consume CO_2, making them a truly carbon-neutral feedstock. The technology is in its infancy. The major hurdles are capex and opex: achieving cost-effective cultivation (preventing contamination, optimizing growth), harvesting (dewatering the dilute algal broth), and oil extraction at an industrial scale. Significant R&D is needed to make algae-based biodiesel commercially viable.

5.2 The Critical Link: How Fatty Acid Chains Dictate Fuel Properties

The properties of biodiesel are directly governed by the structure of its constituent fatty acid methyl esters (FAMEs), which are derived from the parent oil's triglycerides.

5.2.1 Cetane Number (Ignition Quality):

Saturated FAMEs (no double bonds, e.g., from palm oil or animal fats) have straight molecular chains that pack together easily. This allows for quicker and more uniform auto-ignition upon injection into the hot combustion chamber. A higher cetane number means a shorter ignition delay, smoother combustion, reduced engine knock, and lower cold-start emissions.

5.2.2 Kinematic Viscosity (Flow Resistance):

Long-chain, saturated molecules have stronger intermolecular forces, making the fuel "thicker." Double bonds in unsaturated molecules (e.g., in soybean or sunflower oil) introduce kinks in the chains, preventing them from packing closely and reducing viscosity. Excessive viscosity leads to poor atomization, larger droplet size, incomplete combustion, carbon deposits, and increased engine wear. It must be within a strict range to ensure proper engine operation.

5.2.3 Cold Flow Properties (Operability in Winter):

Saturated FAMEs have a higher melting point. As temperatures drop, they begin to crystallize and solidify, forming a gel that can clog fuel filters and lines. Unsaturated FAMEs have much lower melting points. This is the primary technical drawback of many biodiesels. A fuel like palm biodiesel can have a cloud point above 10°C (50°F), making it unusable in temperate climates without blending or additives. This creates a fundamental trade-off: feedstocks that give a high cetane number (good) also result in poor cold flow (bad).

5.3.4 Oxidative Stability (Shelf Life):

The double bonds in unsaturated FAMEs are chemically reactive sites susceptible to attack by oxygen in the air. This leads to autoxidation, forming peroxides, acids, and insoluble gums that can degrade fuel quality. Fuels high in polyunsaturated fats (e.g., linolenic acid in soybean oil) degrade quickly, forming sediments that can plug fuel filters and injectors. Oxidative stability is inversely related to cold flow properties—oils that remain liquid at low temperatures (unsaturated) are less stable. Antioxidant additives are often essential.

5.4.5 Flash Point (Safety):

The flash point is determined by the volatility of the fuel. Biodiesel molecules are larger and heavier than those in petroleum diesel, meaning they vaporize at much higher temperatures. A high flash point (typically >130°C for biodiesel vs. ~52-96°C for diesel) means the fuel is much less likely to form flammable vapors at room temperature. This is a major safety benefit for storage, handling, and transportation**.**

6. Conclusion:

In conclusion, biodiesel can be produced from a wide array of feedstocks, offering significant flexibility. Nevertheless, each source entails distinct trade-offs between benefits and drawbacks. Crucially, the fatty acid profile of the feedstock fundamentally shapes the properties of the resulting biodiesel, directly affecting its performance, handling requirements, and storage stability. Moving forward, the industry's focus is on refining production methods to better accommodate non-edible and waste-derived feedstocks. This shift aims to boost sustainability and address the challenges associated with first-generation sources.

References

1. Anjana Srivastava, Ram Prasad “Triglycerides-Based Diesel Fuels” Renewable & Sustainable Energy Reviews 4 (2000) 111-133 Received 20 May 1998;
2. Ayhan Demirbas “Progress And Recent Trends In Biofuels” Progress In Energy And Combustion Science 33 (2007) 1–18,
3. Ayhan Demirbas “Biodiesel Production Via Non-Catalytic SCF Method And Biodiesel Fuel Characteristics”, Energy Conversion And Management 47 (2006) 2271–2282
4. B.K. Barnwal, M.P. Sharma “Prospects Of Biodiesel Production From Vegetable Oils In India” Renewable & Sustainable Energy Reviews 9 (2005) 363–378
5. Clean Power (Pvt.) Ltd. “A Project Of Alternative Energy Development Board (Aedb) Government Of Pakistan” Issue: 01 July, 2005
6. Fangrui Ma, Milford A. Hanna “Biodiesel Production: A Review” Bioresource Technology Bioresource Technology 70 (1999) 1- 15 ,
7. Hideki Fukunda, Akihiko Konndo And Hideo Noda “Biodiesel Production By Transesterification Of Oils" Bioscience And Bioengineering Accepted September 2001, http://www.jstage.jst.go.jp/article/jbb/92/5/405/_pdf
8. J.M. Marchetti, V.U. Miguel, A.F. Errazu “Possible Methods For Biodiesel Production” Renewable & Sustainable Energy Reviews (2005) 1-12
9. L.C. Meher, D. Vidya Sagar, S.N. Naik “Technical Aspects Of Biodiesel Production By Transesterification - A Review” Renewable & Sustainable Energy Reviews 10 (2006) 248–268,
10. S Biswas, N Kaushik & G Srikanth “Biodiesel: Technology & Business Opportunities – An Insight” Technology Information, Forecasting and Assessment Council (TIFAC) Department of Science & Technology, New Delhi,
11. http://www.techbizindia.com/Article1.pdf
12. http://www.cpcb.nic.in/diesel/contents0902.htm
13. http://www.feezol.com/astm.htm
14. http://en.wikipedia.org/wiki/Biodiesel#Historical_background
15. http://www.tifac.org.in/news/Bioenergy_1.htm