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A Review on Renewable Biofuels and its Properties: A Promising Choice for the Production of Biodiesel

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A B S T R A C T

Natural energy resources like coal and petroleum are under extreme pressure due to the world's population expansion, which is driving up energy consumption. The twenty-first century will see more violent drought occurrences, which will have an impact on agricultural production, according to climate prediction models. Developing bioenergy feedstock as a possible alternative for the manufacture of biodiesel might be a workable solution to manage the increasing demand for energy and worldwide climate crisis without diminishing fossil fuel supplies. Therefore, this research paper concentrates on the background sources of biodiesel along with their chemical and technological features. A thorough discussion of their respective benefits and drawbacks is provided, with an emphasis on their industrial use. An overview of the alternative fuels, possible feedstocks, biodiesel production processes, characteristics and their benefits from environmental point of view are also presented.

1. INTRODUCTION

Biodiesel can be made from a wide range of edible and non-edible plants oil. Biodiesel is made in most industrialised countries from sunflower, peanut, palm oil and a variety of other feedstock's that are available in India [1]. The car industry's concentrates on performance has been sharpened due to growing fuel prices and imminent pollution laws. Furthermore, the increasing depletion of fossil fuels as a result of extensive use has compelled researchers to look for low-emission, renewable fuels. Renewable fuels such as vegetable oils, alcohols, and other biofuels have been discovered to be a viable choice in the hunt for alternative fuels. Furthermore, because the usage of biodiesel is heavily reliant on feedstock prices, lower-cost feedstock are necessary.

The biggest impediment to biodiesel's widespread commercialization is its high cost, which is primarily attributable to the expensiveness of oil feedstock. Concerns about the environment and the depletion of resources have prompted researchers to examine the accessibility of generating energy from a variety of renewable energy sources rather than non-renewable diesel fuels.

Biodiesel is trending as a burgeoning area of great interest due to rising Petroleum prices and environmental concerns about pollution occurs by automotive emissions. Existing energy sources, such as coal, oil, and uranium, may not be sufficient to fulfil rising energy demands. The globe is grappling with both the depletion of fossil fuels and the destruction of the environment. Alternative fuels have the potential to bring together environmental protection, conversion of energy, management, effectiveness and sustainable development in one package. Vegetable oil has the potential to be a viable alternative to Petroleum-based products. The cost of oil (Crude) and the rate of delivery to remote places are the two most important elements in determining its economic viability [2].

Due to increased demand and limited supply, the price of diesel will inevitably rise in the future. Biodiesel fuel is widely available, and it does not pollute the environment. Internal combustion engines have undergone extensive research and development, not only in terms of design but also in terms of finding an acceptable fuel. Biodiesel has potential as an alternative fuel for diesel engines, according to many researchers, because its qualities are extremely similar to diesel fuel. Because biodiesel has different chemical qualities than petroleum-based fuels, its combustion properties, such as gravity, viscosity and cetane number influence efficiency of engine and characteristics because it has wider choice of chemical properties than diesel fuels.

Diesel oil consumption is higher than that of gasoline. Due to the scarcity of products of petroleum and their rising costs, attempts are being made to create alternative fuels, particularly for oil such as diesel [3], as a partial substitute. Vegetable oils are renewable energy sources that are not responsible for global carbon dioxide emissions. In case of another petroleum fuel shortage, vegetable fuels might be utilised as a backup energy source, which would have positive economic effects.

Soybean, sunflower, rapeseed, coconut, cotton, Milk Sludge, linseed, and castor oil have all been attempted in various parts of the world. The ignition characteristics of vegetable oils are good due to their long chain hydrocarbon structure, but they have limitations such as carbon deposits, more density, more viscosity, less calorific value, more molecular weight, and inefficient combustion. When utilising vegetable oil in a diesel engine, these issues result in low thermal efficiency. Different ways for reducing the free fatty acids value (FFA) and vegetable oils viscosity can be employed to solve these issues. Transesterification, dilution, and cracking are three of these processes. Give an appropriate reference for these procedures.

Because there must be some similarity to conventional diesel fuel, vegetable oils, animal fats, and their derivatives such as alkyl esters are appropriate as diesel. The cetane number is the fuel parameter that best demonstrates this compatibility. Several other attributes are critical for establishing the viability of biodiesel as a fuel, in addition to ignition quality as measured by the cetane scale. Among the most essential of these qualities are heat of combustion, pour point, cloud point, and kinematic viscosity. Please provide appropriate references to clarify these features [4].

2. BACKGROUND AND SOURCES

The vegetable oils were utilized as an emergency fuel and for other uses during Second World War. Concerns about the rising use of Petroleum fuels and the possibility of resulting fuel shortages in the United States in the years following WWII sparked a dual fuel project at The Ohio State University (Columbus, Ohio), which looked into cottonseed oil and corn oil, as well as blends with conventional diesel fuel.

Brazil banned the export of cottonseed oil so that it might be used to replace imported diesel fuel. Reduced liquid fuel imports have also been observed in Argentina, forcing the commercial use of vegetable oils. Tung and various oils were utilized to make diesel fuel, lubricating oils, "gasoline," and "kerosene," the latter two by a cracking process.

Biodiesel is produced from a different source in modern times, including animal fats, leftover frying oils, and even soap stock. Geographical, climate, and economic variables all play a role in determining which vegetable oil is most appealing for use in biodiesel fuels. Soybean oil is a valuable feedstock in the United States. Rapeseed (canola) oil is used in Europe, while palm oil is used in tropical countries. Provide the appropriate references [5].

3. TECHNICAL ASPECTS

Vegetable oils have a kinematic viscosity that higher than petroleum-derived diesel fuels. More viscosity effects poor fuel atomization in the combustion chambers of the engine, which leads to operational issues such engine deposits. Transesterification, cracking and micro emulsification have all been researched as best solution of high viscosity since the late 1970s resurgence of concern in vegetable oil produced fuels. Give appropriate sources that clarify these procedures.

4. ALTERNATIVE FUELS

Compressed Natural Gas (CNG)

Natural gas is a mixture of hydrocarbons, primarily methane, that is extracted from wells or produced in conjunction with crude oil. Compressed Natural Gas is compressed (20-25 MPa) for cylinder storage fitted in vehicles due to their less density of energy for utilized as a vehicular fuel. Low noise, low maintenance, and resistance to adulteration are just a few of the benefits of CNG as an automobile fuel. That is why CNG has become a very popular alternative fuel all around the world [6].

Liquefied Petroleum Gas (LPG)

LPG is largely composed of propane and butane, with minor contents of butylene and propylene. It is a ingredient of natural gas processing or a product derived from crude oil refining. Because LPG is mainly propane, propane characteristics are sometimes used as a closely to LPG properties. Reduced pollutants, very little carbon build-up extends the engine parts life such as spark plugs and a higher-octane rating are just a few of the benefits of LPG fuel. While using LPG fuel as an engine, difficulties such as safety and handling, excessive volatility of the fuel, and so on must be addressed in the early phases of its introduction, otherwise it can cause serious damage.

Methanol

Methyl alcohol, often known as wood alcohol, can be made organically by distilling hardwoods at large pressure and temperatures of around 350°C, which is a time-consuming and energy-intensive operation [7]. With a much rating of cumulative toxicity compared to ethanol and an energy content of around 3.7 kWh per litre (roughly one-third that of gasoline), it's a less appealing alternative transportation fuel. The mixture of methanol and gasoline produces problems since they aren't completely compatible, and even a small content of water absorption by the oil effects the alcohol to segregate in the tank's bottom. Commercial additives are available, but they raise the overall fuel cost. Please provide a good reference for the methanol fuel.

Ethanol

Ethanol is a colourless with a distinct and pleasant aroma. It has a slightly sweet taste in dilute aqueous solutions, but a scorching taste in more concentrated solutions. Ethanol has been produced by fermenting sugars since prehistoric times. This technique still produces all drinks and greater than half of ethanol utilized in industry. It can be manufactured from sugarcane, corn, cassava, sugar beets, and other raw materials utilising already improved and proven technology. Ethanol can be used as a standalone car fuel, or it can be blended with gasoline to make "gasohol," or with diesel to make E-diesel. Due to the ethanol molecule contains oxygen, the engine can burn the fuel entirely, resulting in less exhaust pollutants [8].

5. ALTERNATIVE FUEL SELECTION

The following points should be care of while selecting alternative fuels:

- It should be made locally in order to reduce shipping costs and supply issues.
- For low capital investment and inexpensive maintenance, it should just require a simple production plant.
- It should only require minor engine modifications to keep the initial cost low.
- It should have the least amount of negative impact on the engine in order to decline the need for expert maintenance.

Social, ecological, economic, and technical aspects all influence the choice of a viable energy source to change Petroleum fuels. CNG, LPG, Alcohols, Biogas, Producer gas, DME and vegetable oils are gaining more attention in comparison to non-renewable fuels these days. However, due of India's enormous agro-forestry basis, bio-origin fuels might be considered appropriate alternative renewable fuels for IC engines in India. Biogas, Biomass, Producer gas, and Vegetable Oils are examples of bio-origin fuels and may be developed to have qualities similar to fossil fuels. Modern bio-energy solutions provide considerable, cost-effective, and long-term prospects to meet emission reduction targets, as well as collateral benefits resulting from the widespread availability of biomass materials [9].

6. BIODIESEL

Biodiesel is a type of alternative fuel designed specifically for diesel engines. Biodiesel is manufactured from animal fats, or it is the generic name for ester-based fuels produced from vegetable oils using a simple transesterification process. It is a drop-in biofuel, which means it may be employed in diesel engines and does not require the use of a fuel-converted diesel engine.

Uses of biodiesel in C.I. (Compression Ignition) diesel engine:

- It is utilized as an alternative for Petroleum-based diesel because it is a renewable, with a low carbon footprint and is easily biodegradable.
- Biodiesel is environmentally friendly and biodegradable.
- It has a large cetane number, which means it emits less harmful pollutants from diesel engines (80% less CO_2 and 100% less sulphur). Biodiesel has a high cetane number, which makes it easy to start in cold weather and reduces idle noise.
- Biodiesel fuel lubricating effect and can assist to enhance the diesel engine life, resulting in less wear and tear of engine parts.

7. BIODIESEL DEVELOPMENT IN INDIA

In India, biodiesel is a novel product. Vegetable oils' contribution to motor fuels in 1912 may appear modest today. However, such oil may one day overtake Petroleum products as the important source of energy. In 1970, studies revealed that the vegetable oil viscosity can be lowered using a chemical method and that it may be utilized as a diesel fuel in modern engines. It is the name given to this fuel type. It is a diesel-like substitute that can be employed in diesel engines. It lowers the country's reliance on oil demand from different countries [10].

The Petroleum price is directly linked to the cost of life for the average person. As it is a new product, it will eventually replace the Petroleum industry's product, diesel. However, in India, ongoing research on renewable sources, like vegetable oils, is ongoing in several laboratories, dating back to the early 1940s. Now, a biodiesel has been proposed to blend 5% ethanol with gasoline in eight major cities as of January 1, 2003, as Phase I, and to gradually increase this ratio to 10% and 20% of time up to 2021-2022 as Phase II [11].

The Railway used a three-pronged plan to convert oil to biodiesel on a big scale and use it in its massive road cars and locomotives. In India, awareness is only now taking shape in the form of new projects [11]. Other companies responding to these projects include Vrideshwar SSK Ltd. (Ahmednagar, Maharashtra), Mewar Sugar Mills (Jaipur), SM Dyechem (Thane, Maharashtra), R.S. Petrochemicals (Punjab), and Petroleum (Mumbai). They all believe that the Indian government should provide incentives to mitigate the Greenfield area risk.

8. VEGETABLE OILS

Vegetable oil can be produced from different plant sources that are made on a large scale or in rural locations under different conditions. The main edible oils that have been successfully tested in the diesel engine are sunflower, soybean, peanut, Soybean, and others. Scientists and researchers are being drawn in a new path by encouraging outcomes. In Paris, Rudolf Diesel utilised peanut vegetable oil fuel as a substitute to diesel when he built the diesel engine. Using direct oil of vegetable as a gasoline alternative is an option, but it requires numerous engine adjustments to ensure ongoing engine efficiency. As a result, biodiesel is a realistic choice for future needs during the transition to a clean fuel system. The fuel must be changed in order to use vegetable oils as a fuel without modifying the engine. Because engines are built to run on diesel fuel, any substitute must have similar attributes in order for engine to function properly. It is a realistic option that cannot require a significant investment in new infrastructure because distribution will be same as diesel [12].

9. PROS AND CONS OF VEGETABLE OIL

Since its inception, vegetable oil has widespread use in diesel engines. Because most oils are consistent with diesel, combining diesel engine with vegetable oil is a viable choice. Contrast to diesel, vegetable oil has a more viscosity, which can cause a variety of issues. In cold weather circumstances, if the oil is excessively viscous, it may solidify to the point where it is not flow properly into the engine, clogging injector nozzles and causing ring sticking. Minor solidification will seize the nozzle, causing the engine to run out of fuel [13]. When viscous fuel is come from the nozzle, it does not spread evenly in the cylinder and so does not combine with compressed air, resulting in huge amounts of unburned hydrocarbon emissions and less fuel performance. The inadequate oil mixing with air causes inappropriate combustion, creates a lot of smoke, and the high flash point contributes to lesser volatility. These drawbacks unsaturated vegetable oils, make it impossible for the engine to run without problems for an extended time period.

10. BIODIESEL PRODUCTION METHODS

Direct use and blending

Vegetable oils are blended directly with diesel in this manner.

The following are the benefits of using vegetable oils as a diesel fuel: It is easily compatible with diesel fuel.
- Extensive heat content,
- Availability,
- Adaptability.

The disadvantages are:
- higher viscosity,
- lower volatility,
- the presence of additional chemicals with high reactivity in unsaturated hydrocarbon chains.

Problems only occur when the running on vegetable oils for a long time, particularly with direct-injection (DI) engines. The issues are as follows:
- Fuel atomization issues,
- Black carbon deposits,
- Oil ring sticking,
- Lubricating oil formation with a gelly-like structure due to contamination by vegetable oils.

Transesterification

The vegetable oil is treated to a reaction in this procedure. The vegetable oil is reacted with methanol and catalyst (usually a base) to produce the appropriate alkyl esters of the Fatty Acids combination contained in the vegetable oil.

Methanol is commonly utilised as an alcohol in the creation of biodiesel due to the least expensive, despite the fact that other alcohols [14], such as ethanol, may produce a biodiesel fuel with superior fuel characteristics than methanol but are too expensive to employ.

Transesterification is the method by which biodiesel is made, as shown in the Fig. 1. R stands for a long hydrocarbon chain, often known as a fatty acid chain [14].

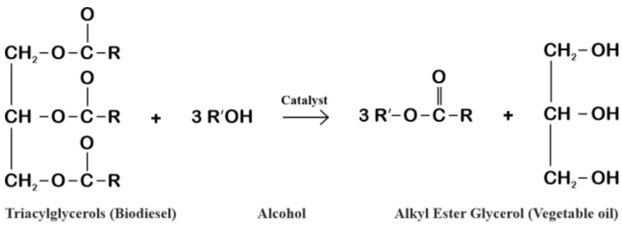

Fig. 1. Transesterification process.

Pyrolysis (cracking)

Thermal cracking or pyrolysis is the process that causes the break of the molecules by heating at high temperatures, that is, by the heating of the substance in the air or oxygen absence in temperatures superior to 450°C, forming a chemical compounds mixture with properties resemble to those of Petro diesel. Silicon oxide (SiO_2) and aluminium oxide (Al_2O_3) are two common pyrolysis catalysts (Al_2O_3).

Pyrolysis or thermal cracking equipment is expensive. Chemically, the products are identical to diesel oil. Cracking is particularly useful in situations where there is a low demand for a large amount of output and a scarcity of trained personnel. Catalytic or thermal cracking creates a combination of condensed hydrocarbons with an organic phase yield of roughly 80%. There is an aqueous phase that makes up around 5% to 10% of the whole, while the rest is made up of gases [15].

Micro emulsion

Micro emulsion with solvents like ethanol, and 1-butanol may be used to tackle the viscosity problem of vegetable oils. A colloidal equilibrium dispersion in the range of 1-100 nm generated from two immiscible liquids is referred to as a micro emulsion. It creates a liquid solution that is more thermodynamically stable than a basic emulsion or macro emulsion.

11. CHARACTERISTICS OF A VARIETY OF FUELS

The chemical properties of the fuel, such as viscosity, pour and fire points, and calorific value, are among the fuel characteristics. The following is a basic overview of these properties:

- Density or Specific Gravity
  The density is also another name for specific gravity. Biodiesel fuel has a more specific gravity than regular diesel. Biodiesel fuel has a specific gravity of 0.88, while Petroleum-based diesel fuel has a specific gravity of 0.84. This enables bio-diesel blends to be made by splash blending biofuel above diesel fuel. Blending bio-diesel with diesel is always a good idea. Due to the particular gravity, if bio-diesel is placed below and diesel fuel is added afterwards, the two will not mix.
- Kinematic Viscosity
  Viscosity is an important physical attribute. Poor combustion due to insufficient viscosity results in power loss and more smoke at exhaust [16]. Fuels with exceptionally less viscosities cannot be enough to keep the injector plungers lubricated. They can cause injector pump leakage and dribbling, resulting in a power loss when the fuel quantity provided by the injector is decreased. Higher viscosity diesel fuel is also undesirable since it enhances losses in injector pumps and injectors, lowering injection pressure which causes poor atomization.
- Flash Point
  A fuel's flash point is the temperature at which it can catch fire in the presence of a flame or spark. The flash point of biodiesel is greater than that of diesel fuel derived from petroleum. Biodiesel and its mixes are thus safer in storage than traditional diesel because they require a high temperature to ignite. The biodiesel flashpoint is roughly 160 degrees Fahrenheit, which is excessively high, however it can be reduced if the alcohol utilized in biodiesel production is not properly removed. Greater flash point fuels result in incorrect combustion in the engine. The existence of alcohol in biodiesel lowers its flashpoint, which is hazardous to engine components.
- Moisture Content or Water Content
  The presence of biodiesel in water and its blends, microorganisms are more likely to proliferate [17]. The biodiesel's solvent features can influence microbial slime to detach and clog gasoline filters, which is a frustrating condition. It has an impact on biodiesel quality. Biodiesel's standard specification is disrupted by a high content of the above attribute. It clogs the fuel filter and the fuel lines.
- Cloud Point
  Under test settings, the temperature at which a cloud appears in the fuel. As a result, fuel usage is efficient for low-temperature activities. The cloud point of biodiesel is often greater compared to diesel fuel.
- Pour Point
  Pour point is specified in Italian biodiesel requirements, but CFFP is specified in others. It is proposed that bio-diesel pour point not be specified because CFFP better correctly reflects the cold weather fuel operation. Pour point is a word that is often used for Petroleum-based diesel fuel but does not apply to biodiesel fuel.
- FFA Information
  If the oil contains a lot of water or FFAs (free fatty acids), the reaction will fail owing to saponification (defined as the interaction of biofuel with a metallic base and water), which makes separating the glycerol at the conclusion of the reaction problematic. The biodiesel amount produced will be determined by the FFA concentration of the

source oil. An extremely low FFA content (0.2) may result in a 100 percent yield [18].

- Calorific Value
  The entire amount of heat when one-unit mass of fuel is completely burned. The calorific value of a substance is the amount of energy released when it is entirely burned to a final condition and all of its energy has been released [19].
- Ash Content
  The ash content of a fuel sample determines the quantity of inorganic impurities present, such as abrasive particles and catalyst residues, and the concentration of soluble metal soaps. These chemicals are oxidised further during combustion, resulting in ash, which adds to engine deposits.

12. BIODIESEL'S ADVANTAGES

Biodiesel is a clean-burning, renewable alternative to Petroleum diesel that is manufactured in the United States. Biodiesel as a vehicle fuel enhances energy security, public health, and the environment, as well as providing safety benefits.

Increased Energy Security

Biodiesel can be generated in the United States and utilized in standard diesel engines, immediately replacing or extending the supply of Petroleum-based diesel. Before putting biodiesel in your vehicle, check with your auto manufacturer and the warranty statement on your engine. It also has a good energy balance: biodiesel includes 3.2 times the energy required to manufacture it.

Environmental and public health protection

Biodiesel in a typical diesel engine cuts exhaust pollutants significantly when compared to Petroleum-based diesel. Unburned hydrocarbons (HC), carbon monoxide (CO), polycyclic aromatic hydrocarbons and particulate matter are among the exhaust emissions regulated by bio-diesel (PM). The reductions rise as the amount of biodiesel incorporated into diesel fuel increases [20]. The best pollution reductions come from B100, but lower-level mixes can still help. B5 has been proven to reduce PM emissions by 10%, CO emissions by 11%, and unburned HC emissions by 21%.

Because the carbon dioxide emitted from biodiesel burning is compensated by the carbon dioxide trapped when growing the soybeans or other feedstock, using biodiesel reduces greenhouse gas emissions. As contrast to Petroleum diesel, B100 cuts carbon dioxide emissions by more than 75%. CO2 emissions are reduced by 15% using B5.

Biodiesel enhances engine performance

Biodiesel increases the fuel's cetane number and improves its lubricity. To keep moving parts from wearing down prematurely, diesel engines rely on the lubricity of the fuel. Sulfur in diesel fuel was decreased to 15 parts per million by federal restrictions a few years ago, reducing the lubricity of Petroleum diesel. The ASTM D975 diesel specification was changed to include a lubricity requirement; biodiesel has enough lubricity to meet this criterion at blends as low as 1%. Provide appropriate references [21].

Assisting in the provision of safety benefits

Because biodiesel is harmless, it causes significantly less environmental damage than Petroleum diesel if spilled or inadvertently released. It is also less flammable than Petroleum diesel, making it safer. Biodiesel has a flashpoint of more than 150°C, compared to 52°C for Petroleum diesel. Handling, storing, and transporting biodiesel is risk-free.

13. BIODIESEL'S BENEFITS

- Biodiesel is not harmful to the environment.
- Biodiesel is non-toxic and biodegradable.
- When compared to regular diesel, biodiesel is safer to handle.
- Biodiesel can simply be combined with regular diesel, and it can even be utilized as pure biodiesel B100 in most modern automobiles.
- Biodiesel has the potential to reduce our reliance on fossil fuels while also enhancing our energy security and independence.
- Biodiesel may be generated in large quantities in many regions of the world; the United States alone has the capacity to create more than 50 million gallons of biodiesel per year.

- When compared to normal fuel, biodiesel creates 78 percent fewer emissions during manufacture and consumption.
- Biodiesel has much greater lubricating characteristics than regular diesel, which can help to extend the life of engines.
- When compared to regular diesel, biodiesel has a shorter ignition delay.
- Because biodiesel contains no sulphur, it does not contribute to the creation of acid rain.

14. BIODIESEL'S DISADVANTAGES

- Biodiesel is currently consisting from corn, which could result in food shortages and price increases. As a result, there may be more hunger around the world.
- Biodiesel is 20 times more sensitive to water pollution than regular diesel, which can result in corrosion, rotten filters, piston pitting, and other issues [22].
- When it comes to low temperatures, pure biodiesel has a lot of issues. When compared to regular diesel, biodiesel is much more expensive.
- Biodiesel has substantially less energy than regular diesel.
- Biodiesel can produce nitrogen oxide, which can cause smog to occur.
- Despite generating substantially less damaging carbon emissions than regular diesel, biodiesel nonetheless contributes to climate change to some extent.

15. CONCLUSION

As technology advances, the fossil fuels need rises steadily and necessitates more fuel. Prospective use of petroleum and coal will decline due to the growing use of energy supplies. It is unsustainable to meet the worlds growing population. The food vs. energy dilemma is complicated by the use of first-generation crops like maize and soybeans as bioenergy sources. Similarly, the subsequent generations crops are not appropriate for producing biodiesel, especially grasses. The fact that utilizing vegetable oil from the subsequent generation might shorten the engine lifespan if it is not refined properly is one of the major issues with it.

Third and fourth generation biofuels can help with the problems associated with using first- and second-generation bio fuels, such as food scarcity, social problems and financial issues. Algal-based biofuels have enormous potential and no rivalry for food or land, and they are produced quite efficiently from a variety of algae. This is the source of third and fourth generation biofuels. Fourth-generation biofuels have shown a lot of promise recently in terms of overcoming their inherent shortcomings and satisfying the worlds expanding energy needs.

Furthermore, employing this generation of biofuels results in far fewer greenhouse gas emissions-essentially, no CO or CO_2 emissions at all. As a result, these fuels might be a viable substitute for fossil fuels. It is also advised to take into account the possible advantages of switching to more affordable, climate-resilient, and environmentally friendly energy sources by utilizing different resources. This may lessen the future demand for fossil fuels.

REFERENCES

[1] M. Balat, “Potential alternatives to edible oils for biodiesel production–A review of current work”, Energy Convers. Manag., vol. 52, no. 2, pp. 1479-1492, 2011, doi: 10.1016/j.enconman.2010.10.011.

[2] M. Ball and M. Weeda, “The hydrogen economy–vision or reality”, Int. J. Hydrogen Energy, vol. 40, no. 25, pp. 7903-7919, 2015, doi: 10.1016/j.ijhydene.2015.04.032

[3] K. Naima and A. Liazid, “Waste oils as alternative fuel for diesel engine: A review”, J. Pet. Technol. Altern. Fuels, vol. 4, no. 3, pp. 30-43, 2013, doi: 10.5897/JPTAF12.026.

[4] O.M. Ali, T. Yusaf, R. Mamat, N. R. Abdullah and A. A. Abdullah, “Influence of chemical blends on palm oil methyl esters’ cold flow properties and fuel characteristics”, Energies, vol. 7, no. 7, pp. 4364-4380, 2014, doi: 10.3390/en7074364.

[5] E. Akbar, Z. Yaakob, S. K. Kamarudin, M. Ismail and J. Salimon, “Characteristic and composition of Jatropha curcas oil seed from Malaysia and its potential as biodiesel feedstock feedstock”, Eur. J. Sci. Res., vol. 29, no. 3, pp. 396-403, 2009.

[6] I. O. Ibeneme and J. O. Ighalo, “Implementation of CNG as an alternative fuel for automobiles in Nigeria: benefits and recommendations”, Int. J. Eng. Res. Technol., vol. 9, no. 7, pp. 1516-1522, 2020.

[7] C. J. Clarke, W. C. Tu, O. Levers, A. Brohl and J.P. Hallett, “Green and sustainable solvents in chemical processes”, Chem. Rev., vol. 118, no. 2,

pp. 747-800, 2018, doi: 10.1021/acs.chemrev.7b00571.

[8] D. Turner, H. Xu, R. F. Cracknell, V. Natarajan and X. Chen, "Combustion performance of bio-ethanol at various blend ratios in a gasoline direct injection engine", Fuel, vol. 90, no. 5, pp. 1999-2006, 2011, doi: 10.1016/j.fuel.2010.12.025.

[9] P. Nautiyal, K. A. Subramanian, M. G. Dastidar and A. Kumar, "Experimental assessment of performance, combustion and emissions of a compression ignition engine fuelled with Spirulina platensis biodiesel", Energy, vol. 193, p. 116861, 2020, doi: 10.1016/j.energy.2019.116861.

[10] A. W. Bhutto, A. A. Bazmi and G. Zahedi, "Greener energy: Issues and challenges for Pakistan—Biomass energy prospective", Renew. Sustain. Energy Rev., vol. 15, no. 6, pp. 3207-3219, 2011, doi: 10.1016/j.rser.2011.04.015.

[11] O. Ogunkunle and N. A. Ahmed, "A review of global current scenario of biodiesel adoption and combustion in vehicular diesel engines", Energy Rep., vol. 5, pp. 1560-157, 2019, doi: 10.1016/j.egyr.2019.10.028.

[12] M. Ball and M. Wietschel, "The future of hydrogen–opportunities and challenges", Int. J. Hydrogen Energy, vol. 34, no. 2, pp. 615-627, 2009, doi: 10.1016/j.ijhydene.2008.11.014.

[13] S. Bari, C. W. Yu and T. H. Lim, T.H, "Filter clogging and power loss issues while running a diesel engine with waste cooking oil", Proc. Inst. Mech. Eng., Part D, vol. 216, no. 12, pp. 993-1001, 2002, doi: 10.1243/095440702762508245.

[14] S. Al-Zuhair, "Production of biodiesel: possibilities and challenges", Biofuels Bioprod. Biorefin., vol. 1, no. 1, pp. 57-66, 2007, doi: 10.1002/bbb.2.

[15] J. W. Shabaker, G. W. Huber, R. R. Davda, R. D. Cortright and J. A. Dumesic, "Aqueous-phase reforming of ethylene glycol over supported platinum catalysts", Catal. Letters, vol. 88, no. 1, pp. 1-8, 2003, doi: 10.1023/A:1023538917186.

[16] R. K. Pandey, A. Rehman, and R. M. Sarviya, "Impact of alternative fuel properties on fuel spray behavior and atomization", Renew. Sustain. Energy Rev., vol.16, no. 3, pp. 1762-1778, 2012, doi: 10.1016/j.rser.2011.11.010.

[17] J. M. Suflita, D. F. Aktas, A. L. Oldham, B. M. Perez-Ibarra and K. Duncan, "Molecular tools to track bacteria responsible for fuel deterioration and microbiologically influenced corrosion" Biofouling, vol.28, no.9, pp. 1003-1010, 2012, doi: 10.1080/08927014.2012.723695.

[18] M. P. Dorado, E. Ballesteros, F. J. López and M. Mittelbach, "Optimization of alkali-catalyzed transesterification of Brassica C arinata oil for biodiesel production", Energy Fuels, vol. 18, no. 1, pp. 77-83, 2004, doi: 10.1021/ef0340110.

[19] M. T. Suryantoro, B. Sugiarto and F. Mulyadi, "Growth and characterization of deposits in the combustion chamber of a diesel engine fueled with B50 and Indonesian biodiesel fuel (IBF)", Biofuel Res. J., vol. 3, no. 4, pp. 521-527, 2016, doi: 10.18331/BRJ2016.3.4.6.

[20] A. Demirbas, "Importance of biodiesel as transportation fuel", Energy policy, vol. 35, no. 9, pp. 4661-4670, 2007, doi: 10.1016/j.enpol.2007.04.003.

[21] B. R. Moser and S. F. Vaughn, "Evaluation of alkyl esters from Camelina sativa oil as biodiesel and as blend components in ultra-low-sulfur diesel fuel", Bioresour. Technol., vol. 101, no. 2, pp. 646-653, 2010, doi: 10.1016/j.biortech.2009.08.054.

[22] A. Groysman, "Physico-Chemical Properties and Corrosiveness of Crude Oils and Petroleum Products", Corrosion in Systems for Storage and Transportation of Petroleum Products and Biofuels: Identification, Monitoring and Solutions, pp. 1-21, 2014, doi: 10.1007/978-94-007-7884-9_1.