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Production of First and Second-Generation Biodiesel for Diesel Engine Operation: A Review

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ABSTRACT

Researchers are looking at alternative cleaner technologies to fulfill the rising need for greener fuels. For this reason, alternatives like bioethanol and biodiesel have become commercially available. Renewable fuels are classified as either "first generation," "second generation," or "third generation" depending on the feedstock used in their manufacture. Over the past decade, society's reliance on first-generation biofuel feedstocks has created an inbuilt rivalry between food and fuel. Second-generation biofuel feed-stocks, such as non-edible agricultural waste products, energy crops, and crop residues, have been illuminated by emerging technical prospects. Technologies for producing biofuels have been proposed and developed in multiple stages, with first-generation technologies being the most developed. In several nations, including the United States, corn grain is used as feedstock in bio-refineries. There is a risk that food and fuel prices will rise as a result of the usage of edible materials in crops like corn. Second-generation biofuel manufacturing technology that utilizes crop residues has been developed to deal with this kind of problem. This study investigates and evaluates the economic viability and environmental sustainability of the proposed solution for the production of second-generation biodiesel.

1. Introduction

The expansion of the human population and the rise of industrialization have led to the depletion of fossil fuel reserves and an increase in the price of petroleum over the past few decades. This has resulted in an ongoing rise in the consumption of petroleum on a global scale. However, the burning of fossil fuels is the primary source of emissions of greenhouse gases, resulting in pollution of the atmosphere and an increase in global warming [1]–[4]. The use of biodiesel as an alternative source of fossil fuel has been shown in previous studies to reduce airborne emissions of harmful pollutants like carbon monoxide and nitrogen oxides (NOx), Sulphur oxides (SOx), hydrocarbons and particulate matter, as well as those that cause haze, acid rain, and global warming by depleting the ozone layer [5]–[8]. Researchers have been motivated to develop new concepts and products as a result of the growing demand for the usage of biodiesel [9], [10]. Biodiesel properties specifications, such as kinematic viscosity, flash point, cloud point, pour point, and cetane number, have been issued by standardization bodies like the American Society for Testing and Materials (ASTM) and European Standards (EN) as guidelines for the biodiesel production to enable commercial viability in a climatic variation [11].According to the ASTM 6751, biodiesel is a fuel that is defined as being made of mono-alkyl esters of long chain fatty acids and can be generated from either vegetable oils or animal fats . As a result of the fact that it possesses the same physico-chemical properties as traditional fossil fuel, it is capable of completely or partially replacing fossil diesel fuel in compression ignition engines [12], [13] .

When biodiesel used to be made from edible sources such, soybean oil [14] corn oil [15] , palm oil [16] and sunflower oil [17] , it posed food security issues because of the competition in the supply chain practically in emerging countries [18]. Consequently, the shift from edible oil to non-edible oil has created several prospects for the utilization of waste cooking oil (WCO) in the production of biodiesel that is of a grade that is comparable to that of the currently available biodiesel [19]–[21]. On the other hand, biodiesel-powered diesel engines were shown to have significantly greater levels of NOx emissions and significantly reduced levels of engine performance [22]–[24]. In general, the majority of research have come to the conclusion that a mixture of biodiesel and diesel fuel ranging from 5 percent to 20 percent volume may meet all of the demands placed on the engine without requiring any engine change [25]–[27]. Furthermore, researchers discovered an upward trend in NOx emissions as well as brake specific fuel consumption (BSFC) [28], as well as a lower brake thermal efficiency (BTE) [29] for biodiesel-based fuels as compared to diesel fuel when used in diesel engines. The outcomes that were obtained were ascribed to the negative properties of biodiesel, which included a higher flash point, lower heating value, and a higher density and kinematic viscosity in comparison with diesel fuel. As a result, atomization and combustion were not as effective with biodiesel [30]–[33].

The other cause of pollutants to the atmosphere is the diesel engines. They are deemed as the primary contributor to the release of heavy pollutants into the atmosphere, despite the fact that they play an essential part in both on-road and off-road transportation systems [34]–[37]. In the context of the current study, compression ignition (CI) is chosen to be the medium of experiment of the proposed biodiesel [38]–[40]. The reasons behind selecting such engine are their excellent efficiency and relatively low cost, they are utilized frequently in long-distance transportation, public transportation, and sea transportation [41]–[43]. In addition to this, the CI engine can be utilized in fields such as the production of electricity and the operation of construction machinery. The energy density of diesel fuel is 38.6 MJ/L, which is higher than the energy density of gasoline fuel, which is 34.2 MJ/L [44]. The availability of non-edible oil is a crucial component that affects the rate at which biodiesel is produced, and this is a direct result of the location of the production facility [45]–[47]. The recycling of waste cooking oil can help prevent oil from being carelessly dumped into waterways, which can cause water contamination and make the treatment process more difficult [48]. However, due to the fact that WCO is composed of triglycerides and free fatty acids, its utilization in the production of high-quality biodiesel might be rather difficult [49]. According to findings from earlier research, the manufacture of biodiesel from triglycerides by means of the transesterification process over different additives can be achieved [50].

Various previous studies indicated that the oxygenated additives are highly helpful for reducing the viscosity and density of fuels that contain a combination of biodiesel and diesel. These additives also increase the amount of oxygen that is present in biodiesel [51]–[55]. The overall characteristics of the fuel are altered when it is blended with these additives. The value of BSFC is diminished when oxygenated additives such as ethanol, DEE, DMC and others are present. Furthermore, by mixing oxygenated additives with diesel and biodiesel fuel, emissions of all kinds, including carbon monoxide, carbon dioxide, hydrocarbons, and smoke, can be cut down significantly [56]–[60]. In reality, numerous studies examine the potentiality of waste cooking oil as a valuable source of producing biodiesel. However, the finding of these studies indicated different results. These contradictory results indicated that there no one source or method fit all types of biodiesel production, thus, there is a need to conduct more studies to obtain biodiesel by utilize more effective, cost-efficient and friendly- environment method [61].Increasing the efficiency of the fuel utilized in CI engines, which are the most common type of engine, while also reducing their CO2 emissions per kilometer travelled is an attractive goal. Biobutanol, hydrogen, methanol, ethanol and dimethyl-ether are just some of the alternative fuels and energy sources that are now being considered as promising area of investigation [62], [63] [64]. Whilst the highly cost of diesel oil related to the traditional energy use have been well documented, the utilization of biodiesel production from waste cooking oil as a renewable resource is poorly understood [65]–[68]. The main scope of the current study is that it the study focuses on the utilization of waste sunflower oil, waste cotton oil, and waste corn oil to produce biodiesel, the study does not focus on other biomass resources. Second, the study concentrates on CI engines only in terms of performance and emissions. Third, the location and source of waste cooking oil is Iraq, thus, it is difficult to generalize the results to other country. Renewable sources of energy are absolutely necessary for the continued existence of civilization [69]–[72]. Find and optimal techniques to decrease environmental effects generated from dumping waste cooking oil is a paramount significance that the present study seeks to achieve. The farmers will benefit from this study because it will inspire them to pay more attention to their farms and produce more rice, which has the potential to be used as a sustainable source of renewable energy. By helping policymakers and providing them with a clear perspective of how the country may benefit from this renewable resource, it could be good for them. In the future, the usage of biodiesel at an incredible price and with a huge profit margin would be a helpful renewable resource. This would result in decreased oil prices for the general population. The current experiment has the potential to expand the domain knowledge of renewable resources by offers valuable information to conduct additional research in this area of knowledge. Considering that lignocellulosic materials make up the majority of the readily available, inexpensive non-food materials from plants, "plant biomass" as it is used to describe second-generation biofuels primarily refers to these types of materials. However, due to a number of technical obstacles that must be removed before their full potential can be realized, the manufacturing of such fuels is currently not cost-effective [73] [74]. A prospective source of material for fuels and raw materials, plant biomass is one of the planet's most abundant and untapped biological resources. Plant biomass can be burned to generate heat and energy at its most basic level. However, using plant biomass to make liquid biofuels has a lot of potential [75]–[79]. The generation of biofuel from agricultural waste, however, may only provide a percentage of the rising demand for liquid fuels. This has greatly increased interest in using specific biomass crops as a feedstock for the production of biofuels [80]. Cellulosic ethanol and Fischer-Tropsch fuels are examples of 2nd generation biofuels. Even though pilot and demonstration facilities are being established, the production of second-generation biofuels is currently non-commercial [81]–[84]. These second-generation biofuels are therefore expected to dramatically reduce CO2 output, not compete with food crops, and certain varieties may even improve engine efficiency. When industrialized, second-generation biofuels could be more affordable than regular gasoline and diesel, making them the most practical source of renewable, low-carbon energy for the transportation sector [73], [85].

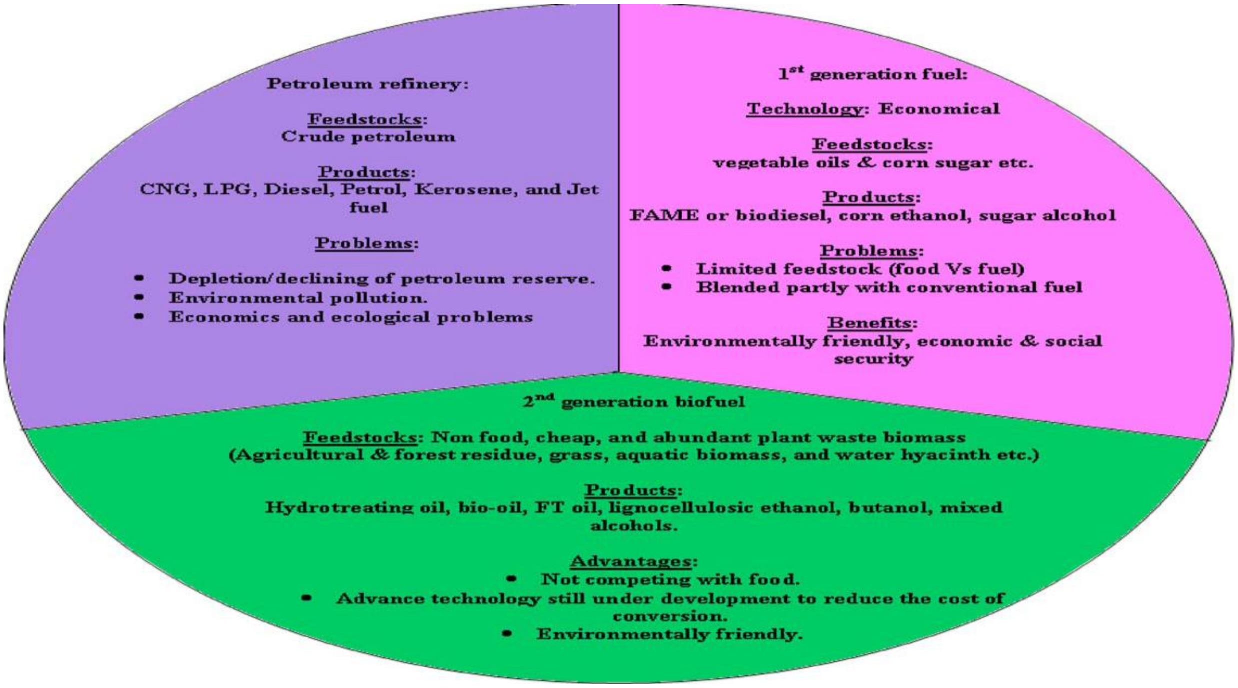

Figure 1: First- And Second-Generation Biofuels Are Compared To Petroleum Fuel [85].

As a result of the numerous advantages and disadvantages of first-generation biofuels, as illustrated in Fig. 1, and the evident advantages of second-generation biofuels.

Continuous biodiesel production and advancements in the development of cleaner fuel with a lower environmental effect and cost than fossil fuels are critical. Advanced research is needed to reduce the cost of biodiesel production and enhance the yield of biodiesel. The possibility of combining vegetable oils or animal fats with waste oils should be investigated. The research should also concentrate on developing low-cost emission reduction techniques. An expanding topic of research is the development of a technology to improve non edible oil-to-fuel conversion efficiency for various generation feedstocks.

2. What is the Distinction Between First- and Second-Generation Biodiesel?

When it comes to biofuels, there are two types: first generation biodiesel and second-generation biodiesel. The two forms are distinguished by the material from which the biodiesel is made.

First-generation biofuels are made from field crops such as wheat, maize, sugar beet and cane, and rapeseed. Rapeseed oil is largely utilized for biodiesel in Europe.

Second-generation biofuels are made from residual and waste materials from industries and households, for example. There is also a lot of used cooking oil and slaughterhouse waste [86].

3. First Generation Bio-Diesel:

The substantial rise in oil prices over the previous decades has also made liquid biofuels cost-competitive with petroleum-based transportation fuels, resulting in a surge in research and production around the world. The three primary types of first-generation biofuels utilized commercially are biodiesel (bio-esters), ethanol, and biogas of which worldwide considerable quantities have been generated so far and for which the manufacturing method is termed 'established technology. Biodiesel is a diesel alternative that is made by trans esterifying vegetable oils, residual oils and fats, and modest engine modifications; it can also be used as a full substitute. Bioethanol is a gasoline alternative, and it can completely replace gasoline in so-called flex-fuel vehicles. It is produced by fermenting sugar or starch. Bioethanol can also be used to make ethyl tertiary butyl ether (ETBE), which blends better with gasoline. Biogas, also known as bio methane, is a fuel that may be utilized in gasoline vehicles with minor modifications. It can be made via anaerobic digestion of liquid manure and other digestible material. It is challenging to employ agricultural food crops for the manufacture of biofuels because of the trend toward rising demand for edible oils. There are various crops that could be used as industrial crops on underutilized land to produce biodiesel [27]. According to the European Academies' Science Advisory Council report, biodiesels are classified into four generations. Feedstock sources are the most important aspect in the first through third generations of biodiesel, whereas synthetic biological technology is the driving force behind the fourth generation of biodiesel. The feedstock for the first generation of biodiesel is edible oils. The use of edible feedstock for biodiesel production was common at the start of the biodiesel era. Crop availability is a significant advantage of first-generation feedstocks. The critical disadvantage of employing these feedstocks for biodiesel production is that the cost of food goods rises, affecting the food supply. Furthermore, the adaptation to environmental conditions, expense, and limited cultivation field are challenged in creating biodiesel from edible feedstocks. Because of these drawbacks, biodiesel consumers were forced to seek alternative sources [87]**.**

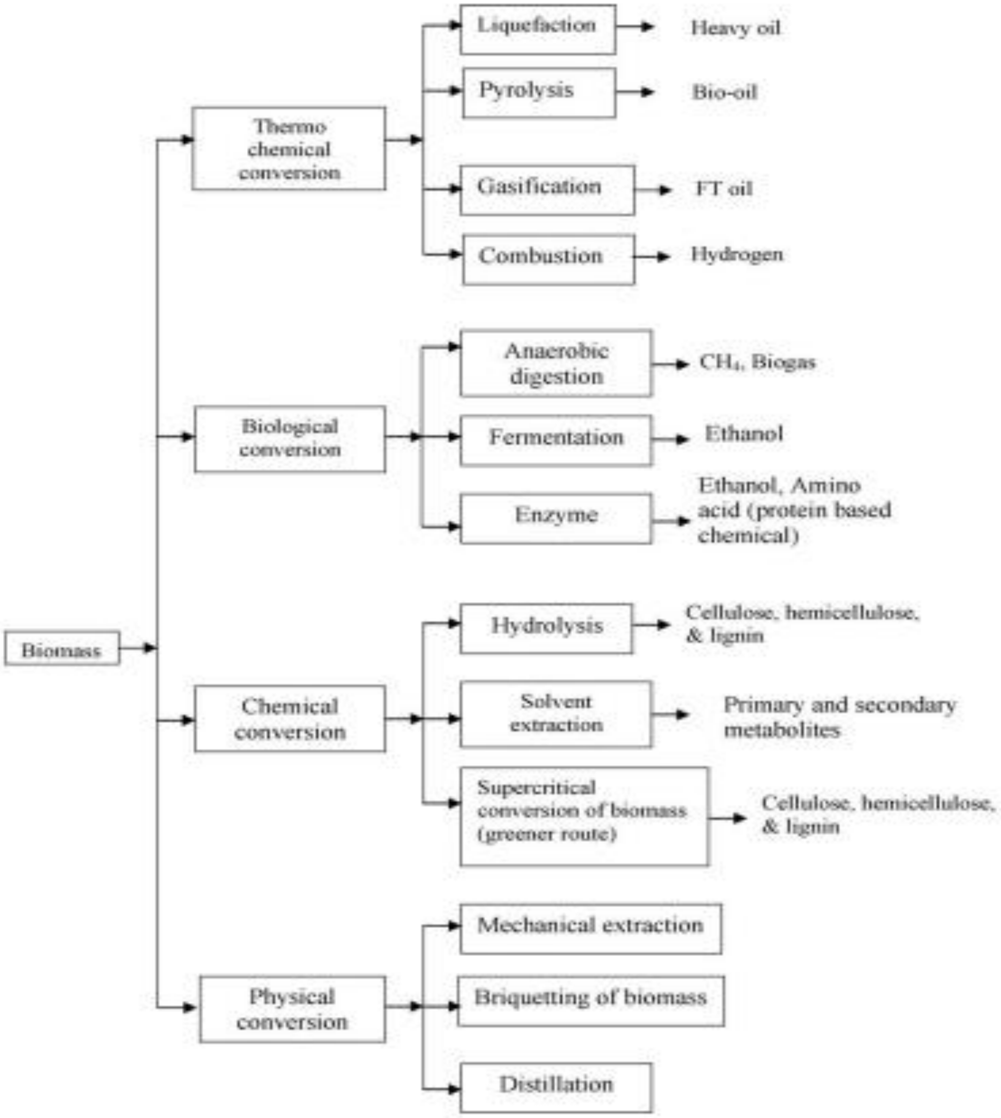

Figure 2: Methods of Converting Biomass [88]**.**

Oilseed crops with such multiple applications can be developed so that the biomass they produce can be used to create a variety of bio products [89]. In this regard, a whole-crop bio refinery example, as shown in Fig. 2, has been discussed with a focus on the integrated utilization of Jatropha in India, in an effort to support the production of sustainable biodiesel while also using its solid residues for the production of other valuable chemicals and its lignocellulosic biomass for the production of second-generation biofuels. for example, using palm kernels in Indonesia and Malaysia [90].

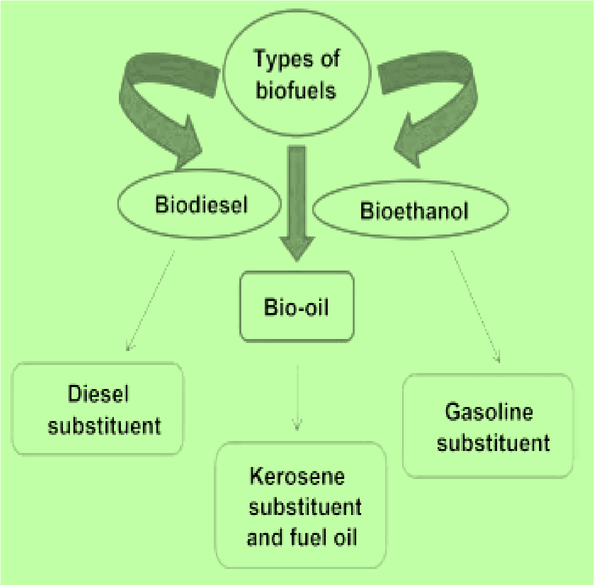

Figure 3: Various Biofuels Can Replace Fossil Fuels [89].

4. Second Generation Bio-Diesel:

A source must not be acceptable for human consumption in order to qualify as a second-generation feedstock. Specifically developed inedible energy crops, farmed inedible oils, agricultural and municipal wastes, waste oils, and algae are examples of second-generation biofuel feedstocks. Nonetheless, cereal and sugar crop feedstocks are utilised in second-generation processing processes. When assessing the feasibility of using biomass as an energy source, land usage, current biomass industries, and related conversion technologies must all be taken into account [91][92].

Second generation biofuels are made from biomass in a more sustainable way that is carbon neutral or even carbon negative in terms of CO2 concentrations. In the context of biofuel production, the word "plant biomass" refers primarily to lignocellulosic material, which accounts for the vast bulk of the inexpensive and abundant nonfood resources available from plants [93]. At the moment, producing such fuels is not cost-effective due to a number of technical challenges that must be overcome before their full potential can be realized. Plant biomass is one of the world's most plentiful and underutilized biological resources, and it is viewed as a viable supply of material for fuels and raw minerals. Plant biomass, in its most basic form, can simply be burned to generate heat and energy. However, there is a lot of potential in using plant biomass to make liquid biofuels. Plant biomass is largely made up of plant cell walls, with polysaccharides accounting for 75% of the total. These polysaccharides constitute a valuable source of potential sugars, and even in typical food crops like wheat, the stems contain as much sugar as the grain's starch. Many crop leftovers, such as straw and wood shavings, have yet to achieve their potential as sugar feedstocks for biofuel generation. However, producing biofuel from agricultural byproducts might only meet a percentage of the growing demand for liquid fuels. This has sparked a lot of interest in using dedicated biomass crops as feedstock for biofuel production [94]–[96].

5. Biodiesel Production

In comparison to diesel, the alternative fuel known as biodiesel offers a significant number of benefits due to its high potential efficiency. The use of biodiesel offers a number of benefits over diesel in comparison [97], [98]. To begin, biodiesel is not only non-toxic and biodegradable, but it also has a low impact on the natural world around it, making it an eco-friendly fuel. A study by examined the effects of additives on the combustion, performance, and exhaust emissions of a biodiesel-fueled direct – injection [99]–[103]. The study mentioned that despite the fact that biodiesel offers a number of benefits, it also has a number of drawbacks, including a high viscosity, a low heating value, and a high quantity of nitric oxide emissions [25] [26]. Consequently, the behavior of biodiesel can be significantly influenced by the addition of additives. In order to improve the various properties of biodiesel, a wide variety of additives, including those based on metals, antioxidants, cetane improvers, oxygenated additives, and many more, are utilized.

6. Methods of Biodiesel Production

Both animal fat and vegetable oil can be utilized in the production of biodiesel. Some vegetable oils are edible and are used for cooking purposes; consequently, these vegetable oils are cultivated for mass production purposes [104][105]. Other vegetable oils, on the other hand, are not edible and cannot be used for cooking purposes due to the negative effects on human health; consequently, these vegetable oils are not cultivated for mass production purposes [106]. Because of the terrain and the climate, Iraq is home to a diverse array of non-edible vegetable and spice plants, including sunflower, cotton, linen, and corn. There is a lot of potential in the biodiesel extracts from such non-edible vegetable oils for alternative fuel. A study by has reported the main steps of biodiesel production regardless of the biodiesel resources as it can be seen through the following figure.

7. Transesterification

Alcoholic’s, also known as transesterification, is “a chemical reaction that creates esters and glycerol”. This reaction takes place in the presence of a catalyst and involves the presence of triglycerides and alcohol in a specific proportion. The transesterification reaction is comprised of three separate reversible events that occur in sequence. The glycerides are converted into glycerol and an ester is created at each stage of the process [107]–[109].

The basic function of a catalyst is to speed up a reaction so that it can be completed in a shorter amount of time. This is accomplished by increasing the reaction rate. Several scholars have looked into a wide variety of catalysts with regard to transesterification. A study by scrutinized the technique of preparing methyl esters from non-edible oils with a high free fatty acid (FFA) content required a two-step transesterification procedure. The study subjected Used Cooking Oil (UCO) and Jatropha oil to an investigation in which the influence of critical parameters such as the reaction temperature, catalyst concentration, methanol-to-oil molar ratio and reaction time was evaluated and compared.

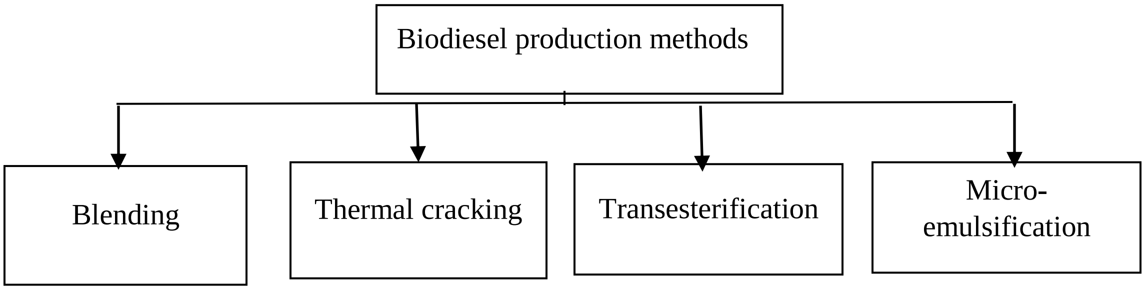

Figure 4: The study unveiled that transesterification is the most popular process since its low cost and high yield.

8. Compression Ignition (CI) Engines

Compression ignition (CI) engines, named for Rudolf Diesel, is a type of compression-ignition internal combustion engine in which the higher temperature of the air in the cylinder causes the ignition of the fuel. As a result of their great thermal efficiency and low cost, compression ignition (CI) engines and diesel fuel are extensively utilized for long-distance transport by land, sea, and construction equipment. Despite this, the pollutants produced by CI engines continue to be a source of concern for both humans and the environment [110]. The most pressing question facing researchers in the modern era is how to successfully cut down on emissions from engines [111]–[114]. Researchers investigated the potentiality of CI engine and exert efforts to alleviate such engine emissions issues. For instance, a study by investigated utilization of simulation method to test Dimethyl ether (DME) blending in different rations with diesel fuel and apply on CI engine. The results indicated that the simulation method is an effective approach to indicate DME's impact on emission reductions.

9. Performance of CI Engine Parameters

9.1 Brake Thermal Efficiency (BTE)

There have been numerous researches on the performance, combustion and emission characteristics of biodiesel and biodiesel blends in literature. different studies examine brake thermal efficiency as an indicator of engine performance [115]–[117]. On the other hand, because biodiesel has a lower calorific value than diesel fuel, the heat produced during the combustion process of biodiesel-fueled engines is less than that of diesel fuel-fueled engines. Biodiesel generated less heat and had a higher density than diesel fuel, which resulted in a lower value of BTE than diesel [118], [119]. There has been investigation on additives and the effects that they have on BTE. A study by found that the addition of Al-Mg additions resulted in a one percent improvement in BTE value when blended with Jatropha biodiesel (100 percent). Another study by revealed that when blended with BHA additives, the percentage of BTE produced was enhanced by 0.92 percent; when blended with BHT additives, the percentage of BTE produced was increased by 0.37 percent. According to the findings of the evaluations, the addition of additives to biodiesel of the second generation is the most effective method for enhancing the combustion performance and lowering emissions. Another study by showed that the diesel engine that was run on graphene oxide JME-GO nano-fuels resulted in a 17% increase in the brake thermal efficiency in comparison to the engine that ran on clean Jatropha methyl ester (JME) fuel.

9.2 Brake Specific Fuel Consumption (BSFC)

In the past, a number of different experiments were carried out to investigate the qualities of the engines that were powered by biodiesel either on its own or in combination with diesel. It has been observed that the brake specific fuel consumption (BSFC) rises alongside an increase in the proportion of biodiesel included in blends. Because of its lower calorific value, biodiesel requires a greater quantity of fuel in order to generate the same level of power as an engine that is powered by diesel [120], [121]. As a result, the BSFC is seen more often in engines that are driven by biodiesel or its blend. Under some circumstances, a diesel engine fueled by diesel or biodiesel will use more fuel. Researchers studied the effects of additives on the consumption of several kinds of biodiesel. For example, a study by investigated pongamia methyl ester (25 percent) was blended with mineral diesel (75 percent) in a variable load constant speed diesel engine and its effect on the engine's behavior. With the addition of aluminium oxide nano-particle (Al2O3), three test fuel blends were generated, namely: B25, B25 + 50ppm Al2O3, and B25 + 100 ppm. They found that the blend with 100 ppm of nano additive produced better BTE results and had lower BSFC values than the blend that did not contain nano additive. Additionally, when nano additive was employed, there was a reported increase in the peak cylinder pressure (Pmax), the heat release rate (HRR), and the amount of NOx emission.

9.3 Hydrocarbon Emission

In internal combustion engines, unburned fuel can emit hydrocarbon emissions. These emissions can be harmful to the environment. Particularly, inefficient combustion or unburned diesel fuel are the primary causes of HC emissions from compressed ignition engines. One of the many effective research areas is on finding ways to cut down on emissions of hydrocarbons. Numerous studies reported the rate of emissions when they use different types of biodiesel fuel. For example, a study examined the combustion, performance, and emissions of DI engines powered by diesel/biodiesel blends and the optimization of biodiesel production parameters using a mixture of sunflower and soybean oil. To carry out this experiment, diesel/biodiesel blends of D50B50 (50 percent diesel–50 percent biodiesel), D70B30 (70 percent diesel–30 percent biodiesel) and D30B70 (30 percent diesel–70 percent biodiesel) were created to run a single cylinder engine. The findings showed that the reduction of HC emissions from diesel fuel, D30B70 achieved the greatest decrease of 4.18 percent. Another study by indicated that the utilization of certain additives resulted in a reduction in hydrocarbon emission. As an illustration, in pure Jatropha biodiesel, the quantity of hydrocarbons will decrease by 76% if magnesium is included in with the other additives. To reiterate, if the percentage of hydrocarbon emissions from the Jatropha biodiesel blend containing cobalt oxide was reduced to 52 percent,

10. Research Design

Research design refers to the delineation and phases of methods that will be used in the current study. Figure 5 indicates the phases of the experiment. The present study considers the following points as criteria to examine the potentiality of biodiesel. These criteria are cost (raw material to production process), yield, fuel properties, engine emissions and engine performance. After obtaining the three-waste cooking oil raw materials the phases of experiment start with transesterification. The three-biodiesel produced from the transesterification process. Each one will be blended with diesel fuel in the proportion 25% from biodiesel and 75% from traditional diesel. In fact, the previous literature referred that 5 to 20 percent of biodiesel is optimal proportion when add to traditional diesel. However, there are contradictory in the previous studies findings, thus, the present study will employ 25% of biodiesel as a proportion of biodiesel with the diesel. On the other hand, recent studies reported the potentiality of using waste cooking oil produced from linseed. Thus, the present study will utilize such waste cooking oil. Figure 5 shows the phases of the experiment.

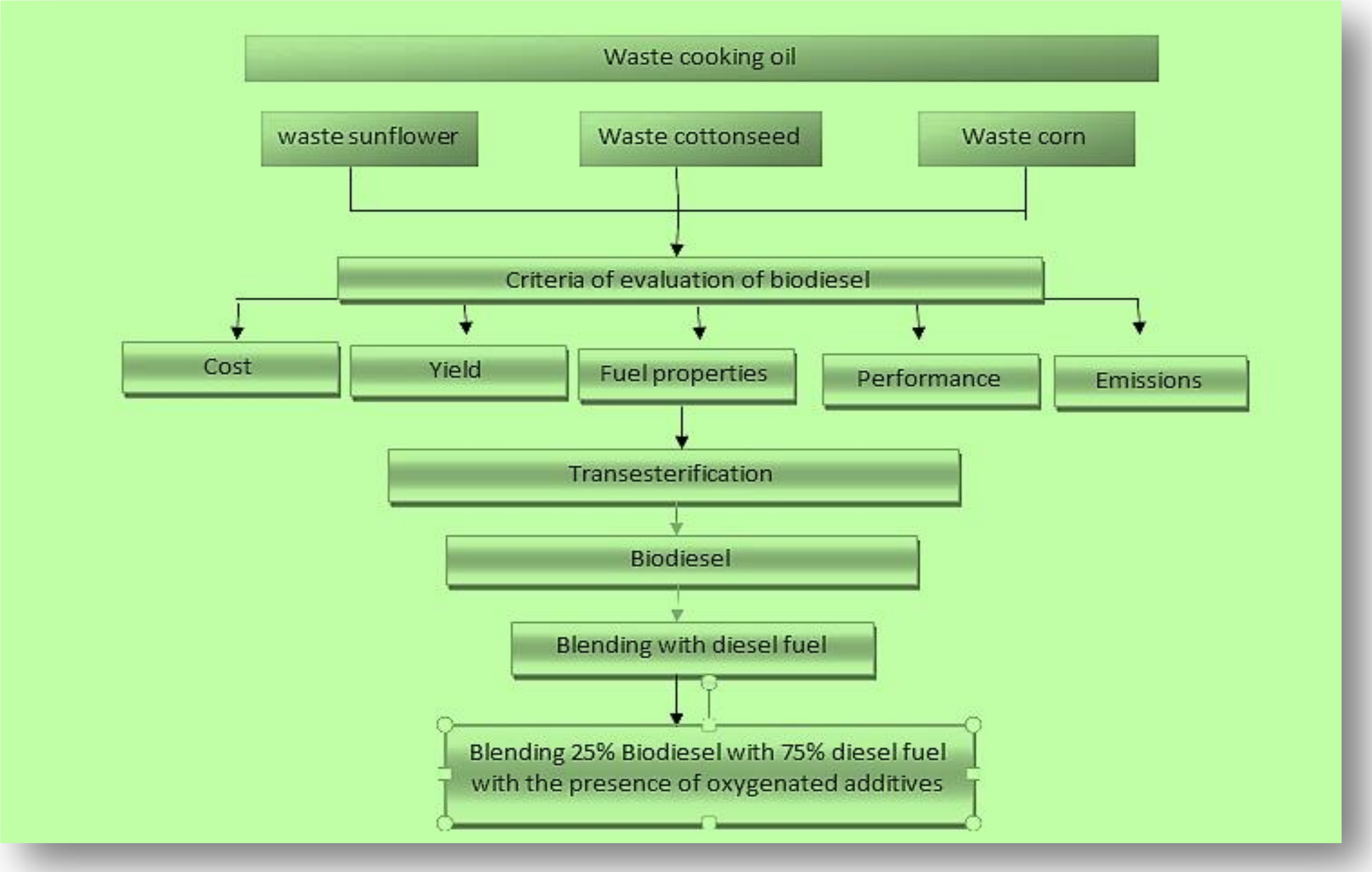

Figure 5: Phases of Biodiesel Production

Conclusion

The best method to produce second-generation biodiesel is to use transesterification of non-edible oils or used cooking oils. The best catalysts used so far are base catalysts such as sodium hydroxide and potassium hydroxide, but it is very difficult to separate them and use them again. There are better and less expensive ones, and they can also be used and separated again, and they are nano-catalysts. Most of the alcohol can be used to produce the second-generation biodiesel, but the best of them is methane for oils that have low free fatty acid (FFA), and methanol is better to use in the production of biodiesel than a raw material with high free fatty acids (FFAs) and contains animal fats. While it's no secret that conventional energy sources like diesel come with hefty price tags, little is known about how to put leftover cooking oil to use as a sustainable fuel source in the form of biodiesel. The primary focus of this research is on biodiesel production from waste sunflower oil, waste cotton oil, and waste maize oil; it does not examine the usage of any other biomass resources. In addition, the research solely looks at CI engines and considers their efficiency and pollution levels.

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