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Various Types of Biodiesel as Sustainable Fuel Choices: a Review

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Abstract

The energy sources used today are non-renewable energy. Non-renewable energy, if used continuously will experience scarcity. Therefore, renewable energy sources are needed as an alternative energy. One of alternative energy source is biodiesel. Biodiesel is an alternative fuel produced from vegetable or animal raw materials. The sustainability and diversity of biodiesel feedstock sources make it an attractive option for reducing dependence on fossil fuels. The problem is that all existing natural resources have not been utilized, the potential availability of raw materials and their production, lack of knowledge about the types of biodiesel and other types of biodiesel that can be developed. This article aims to review the different types of biodiesel that are being researched and developed and increasing knowledge and becoming a reference regarding the potential of natural resources and the opportunity to develop other types based on the potential of available natural resources. The research method used is a literature review study using the Publish or Perish 8 application, on the search menu Google Scholar is selected. Article search retrieved September 19, 2023. Based on this search, 14 articles were obtained that were in accordance with this research. The research results showed that the various types of biodiesel are bintaro oil, hazelnut oil, corn oil, crude palm oil, hydrotreated vegetable oil, kapok seed oil, rubber seed oil, used cooking oil, kesambi oil and graphene nanoplatelets. Each type of biodiesel has its own advantages, while the biodiesel feedstock that has the potential to be produced in large quantities is palm oil. This research also suggests that Indonesia's natural resource potential is very large, so we can also process and develop other types of biodiesel which can be used as alternative fuel.

Keywords: Renewable Energy, Biodiesel Types, Alternative Fuel, Biodiesel Blends, Sustainable Fuel.

1. Introduction

In this day and age, the need for fossil fuels such as petroleum is increasing day by day along with technological developments. This is due to the increase in population accompanied by an increase in community welfare, which certainly has an impact on the increasing need for transportation facilities and industrial activities. Petroleum as a non-renewable energy source has begun to experience scarcity so that the price is getting higher. With the increasing price of petroleum lately, it is time for the government to start developing alternative fuels as substitutes or additives in fuel oil. Simultaneously, the extensive utilization of petroleum derived fuels leads to environmental pollution [1], [2] as a consequence of persistent emissions of various contaminants [3], [4] and poses difficulties for sustainability as demonstrated [5], [6]. To summarize, the depletion of petroleum reserves, adverse consequences of air pollution, and the potential for global warming resulting from the release of green house gases (GHG) such as carbon dioxide have prompted scientists and policymakers to explore workable and financially sustainable substitutes for traditional liquid fuels as demonstrated [7], [8]. It emphasizes the urgent requirement for alternative fuels. One alternative fuel that is considered feasible as a substitute for petroleum is fuel derived from vegetable oil or animal fat, better known as biodiesel [9], [10]. The development of biodiesel as an alternative fuel is very strategic to overcome the problem of petroleum scarcity.

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The development of biodiesel in Indonesia is very potential, considering that Indonesia is a tropical country and has abundant natural wealth and has not been perfectly utilized. In Indonesia, biodiesel research has developed since the 1990s [11], [12]. The Oil and Gas Technology Research and Development Center (LEMIGAS), the Agency for the Assessment and Application of Technology (BPPT), the Palm Oil Research Center (PPKS), the Indonesian Plantation Research Institute (LRPI), and the Bandung Institute of Technology (ITB) can be said to be the initial institutions that research biodiesel from various raw materials [13]. Indonesian researchers conducted research to produce biodiesel from various raw materials such as palm oil, used cooking oil, jatropha and other vegetable oils. The research carried out is not only basic research but also pilot-scale production, to trials on machines. Biodiesel can be mass-produced, both for domestic and foreign consumption.

Biodiesel is an alternative fuel produced from many renewable sources, such as vegetable oils, animal oils, and organic waste [14]–[17]. The difference between biodiesel and diesel is mainly in their composition. Biodiesel consists of methyl esters of vegetable fatty acids [18], [19], while diesel is a hydrocarbon [20], [21]. Biodiesel can be used pure or mixed and its use is specifically for diesel engines. Basically, there is no need to modify the diesel engine if the fuel uses biodiesel [22], [23]. The main advantage of biodiesel is that it does not contain sulfur and benzene compounds that are carcinogenic [24], so biodiesel is a cleaner fuel and easier to handle compared to diesel [25]. Biodiesel is biodegradable comes from renewable raw materials, uses energy more efficiently, can replace diesel fuel, suitable for sensitive environments and easy to use [26], can be used in diesel motors without any modification. Biodiesel is also able to reduce emissions [27]–[29] and does not add to the greenhouse effect that causes global warming [30], [31], because the carbon produced is still in the carbon cycle. Biodiesel even has a cleaning effect on fuel tanks, injectors and fuel hoses. The energy produced by biodiesel is similar to diesel, so the engine torque and horsepower produced are also similar. In addition, biodiesel produces a higher engine lubrication rate compared to diesel.

At present, the fuel for diesel motors that are being produced by Pertamina is diesel fuel oil and biodiesel fuel. In the Regulation of the Minister of Energy and Mineral Resources [32] explained that Fuel Oil type of Diesel Oil (Gas Oil) hereinafter referred to as Fuel type of Diesel Oil is fuel derived and or processed from petroleum used for diesel engines. Biodiesel (B100) biofuel type hereinafter referred to as biodiesel type biofuel is a product produced from palm oil raw materials that are processed by esterification or other processes as a mixture of diesel oil. Biodiesel type biofuels marketed domestically can be used as a mixture of diesel oil type fuel oil [33]. Diesel oil is a distillate type fuel used for diesel motors "compression ignition", which is an engine that uses a compression system that causes high pressure and heat so that it can burn diesel oil sprayed by injectors in the combustion chamber [34]. In accordance with the instructions of the Indonesian government to the Minister of Energy and Mineral Resources, the policy of mixing diesel oil with 35% Biodiesel (B35) will be enforced on February 1, 2023 [35]. In Indonesia, the potential for natural resources for biodiesel development is very large [36].

Based on the above, the problem is a lack of knowledge about other types of biodiesel that exist and can be developed, the potential availability of raw materials and production and the unutilization of all existing natural resources. Therefore, it is necessary to know the various types of biodiesel that have been studied in depth with the help of research carried out by different researchers. It is hoped that the results of this research will be useful for increasing knowledge and becoming a reference regarding the many types of biodiesel that exist and opportunities for developing other types based on the potential of available natural resources.

2. Research Methods

The research method used is a literature review study using the Publish or Perish 8 application, on the search menu Google Scholar is selected. Article search retrieved September 19, 2023. The search used the article title with the keywords diesel fuel blend and alternative fuel with a maximum result of 200 articles. Based on this search, 400 articles were obtained. Next, from 400 articles, 67 articles were selected that used the title with the keyword "type of biodiesel", then 38 articles were selected based on the exclusion of duplicates/titles with the same type of biodiesel. Furthermore, of the 38 articles obtained, the articles were taken from 2010 to 2022, resulting in 32 articles. Then, from the abstracts

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and contents of the articles, 14 articles were obtained that were in accordance with this research as show Figure 1 below.

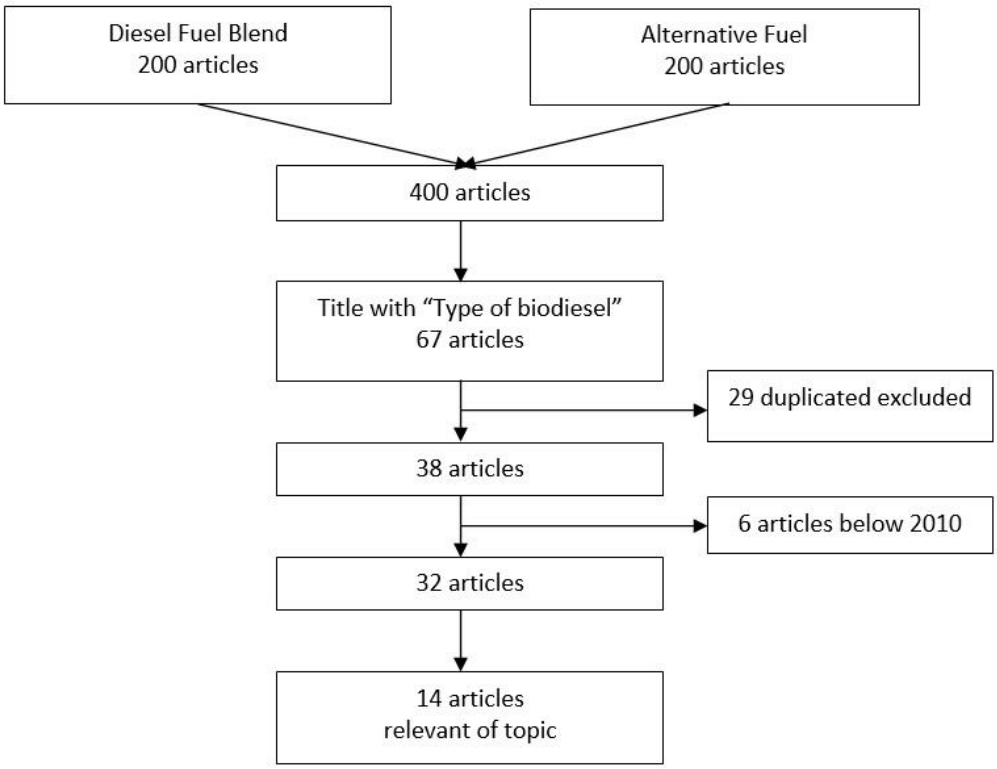

Figure 1. Schematic Diagram of the Steps of the Literature Review

3. Result and Discussion

Fuel oil commonly used in diesel motors is diesel oil, dexlite, and pertadex. These fuels are fossil fuels which are not renewable and are starting to experience scarcity. Thus, there is a need for alternative fuels as substitutes or additives for fuel oil. One alternative fuel as diesel fuel is biodiesel. The following are the types of biodiesel that are being researched and developed at this time.

3.1 Bintaro Oil Biodiesel

Bintaro (*Cerberamanghas*) is known as one of the annual plants that is widely used for greening, shade plants, city decoration and at the same time as raw material for dried flower crafts [9]. This plant can grow in extreme environments and is widely spread in Indonesia. Bintaro is a mangrove type plant , usually grows on the edge of land or coastal swamp forests or on the coast to far inland 800 m above sea level, spreading on open land and irregular places flooded by tidal water. As is known, the area of mangrove forests in Indonesia is estimated to be around 4.25 million hectares or about 17% of the area of mangrove forests in the world. This plant is not a food crop so it will not overlap with food needs. The process of making biodiesel is carried out by converting triglycerides into fatty acid methyl esters by utilizing catalysts in the transesterification process.

3.2 Hazelnut Oil Biodiesel

Indonesia is a country that has abundant natural wealth. One of Indonesia's natural wealth is the abundance of hazelnut trees. This tree can grow to a height of more than 10 meters and the trunk diameter reaches more than 50 cm and has a wide header. The hazelnut tree has a thick, brownish-gray crowed trunk with vertical stripes scattered on finely textured bark. The leaves of this plant are spiral-like with a leaf composition in the form of a single leaf. The shape of the leaves is cordatus (like a heart) with pinnate leaf bones. In general, the leaves of this plant consist of 3-5 leaves from the base of the petiole with a leaf length of ± 10-20 cm. When the leaves have a young age, the shape of the leaves is a shiny white oval that will turn shiny dark green as the leaves age. Flowers on hazelnut trees are greenish-white

in a colony with a length of up to ± 15 cm. Pecan fruit has a shape ranging from oval to round green to brownish-green with a length of ± 5-6 cm and a width of ± 5-7 cm. In general, there are 2-3 seeds in one pecan. Pecan seeds are one of the prospective sources of vegetable oil raw materials developed as biodiesel feedstock [37]. Pecan plant (Aleurites Moluccana) is a plant that has a high oil content reaching 57-69% of the total weight of hazelnut seeds. Pecan oil has flammable properties so it can be used as fuel. In addition, the oil contained in hazelnut seeds has a low level of free fatty acids (FFA) which is 0.1-1.5%.

3.3 Corn Oil Biodiesel

Corn Oil Methyl Ester (CME) belongs to the group of high-quality oils. Corn oil is of better quality than other vegetable oils. Corn oil is a refined vegetable oil produced from the extraction of corn kernels. This oil is often used for cooking, especially in deep frying techniques. Corn oil is also used for industrial purposes to cosmetic ingredients, including compositions in makeup, liquid soap, to shampoo. Even so, corn oil is best known as cooking oil which has a very high smoke point so it is called ideal for frying food to make it crispy perfectly. Corn oil is a triglyceride composed by glycerol and fatty acids. The high triglyceride composition makes corn oil also suitable for use as raw material for making biodiesel [38].

3.4 Crude Palm Oil Biodiesel

Oil palm plantations in Indonesia are very extensive and have reached a total of 5.3 million hectares (h_a) with crude palm oil (CPO) production of 11 million tons [20]. The development of oil palm plantations is still continuing and it is estimated that Indonesia will become the largest CPO producer in the world. One of the by-products of palm oil that can be developed in Indonesia is biodiesel which can be used as an alternative fuel, especially for diesel engines.

Palm oil is obtained from the processing of oil palm fruit. Broadly speaking, oil palm fruit consists of fruit fibers (pericarp) and core (kernel). Fruit fibers contain an average oil content of 56% and the core contains oil of 44%. Palm oil, like most other vegetable oils, is a compound that is insoluble in water, while its main constituent components are triglycerides and non triglycerides [39]. Fatty Acid Methyl Ester (FAME) is a type of biofuel developed by Pertamina which is currently commonly used in diesel fuel oil made from esterified Crude Palm Oil (CPO) [40].

3.5 Hydrotreated Vegetable Oil (HHO) Biodiesel

Hydrotreated Vegetable Oil (HVO) is a type of biofuel being developed by Pertamina made from Hydrotreated RBDPO [40]. Hydrotreated Vegetable Oil (HVO) is a biofuel produced through hydrogenation and hydrocracking processes using hydrogen. The hydrogenation process with hydrotreating catalysts is able to change the bonds of triglyceride compounds in vegetable oils into straight paraffinic chain hydrocarbon compounds that resemble the structure of hydrocarbon compounds in diesel. Raw materials from HVO are vegetable oils ranging from palm oil, soybean oil, corn oil, used cooking oil, and so on.

3.6 Kapok Seed Oil Biodiesel

Kapok seeds have the potential to be used as raw material for making biodiesel because they have advantages, including kapok seeds contain 40% by weight of oil, are easy to obtain, and the price is relatively cheap [41]. Kapok seed oil contains about 71.95% unsaturated fatty acids, higher than coconut oil. By looking at the content of kapok seed oil, we can take kapok seed oil as an ingredient for the manufacture of methyl ester which is a very potential material as a substitute for diesel fuel. The mixture of biodiesel from seed oil has better combustion characteristics than diesel, namely the viscosity of biodiesel is higher than the viscosity of diesel, so biodiesel has better lubrication power than diesel [42]. Higher viscosity makes it easier for the engine to spin by reducing frictional forces. In addition, biodiesel already contains oxygen in its compounds, so that combustion in the engine is close to complete and the use of fuel is more efficient. The availability of randu seeds is quite a lot and is a non-food seed, so the use of randu seeds as biodiesel is more efficient because it is no longer reused.

One of the methods used to obtain this biodiesel fuel is transesterification. Transesterification is a chemical reaction process in which oil is combined with an alcohol, usually ethanol or methanol, in the presence of a catalyst to form fatty esters and glycerol. Kapok seed oil can also be obtained through

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a methanolysis reaction. In the methanolysis process, you should use methanol with almost pure levels to prevent hoarding.

3.7 Rubber Seed Oil Biodiesel

The rubber plant is a plant of the tropics. The rubber plant has extensive roots, its taproot is able to grow through the soil up to 2 m, while its lateral roots spread along more than 10 m. Rubber plants are tree-shaped with a height of 15-25 m, upright growth type and show rhythmic growth patterns (rhythm), namely there is a growing period and a rest period that alternates in periods once in two months. Rubber plants commonly used are rubber sap and rubber seeds. Biodiesel from rubber seeds can be processed by catalyst and non-catalyst methods. The stages of the process passed by the catalyst method are pressing or extracting vegetable seeds so that rubber seed oil or also called rubber seed oil (RSO) is obtained [43]. This biodiesel can also be processed using non-catalyst methods without undergoing a "degumming" or esterification process. Transesterification is carried out in a reactor (bubble column reactor) by pumping superheated methanol into a reactor containing rubber seed oil liquid (RSO).

3.8 Used Cooking Oil Biodiesel

Used cooking oil has the potential to be used as a mixture of diesel fuel [44]. Used cooking oil has many contents in it such as water and achlorellin, achlorelin is formed from the process of glycerol hydration and forms unsaturated aldehydes. Achlorelin is formed from carbon, hydrogen, and oxygen chains, so used cooking oil can be processed into biodiesel [45]. Used cooking oil biodiesel has advantages including: it has a relatively high calorific value, the condition is still in the liquid phase so that combustion regulation is easier, not easy to explode and easy to store [46]. So far, the use of used cooking oil as a mixture of biodiesel must go through 2 reaction stages, namely: (1) esterification between fatty acids and alcohol to become esters using acid catalysts, (2) transesterification with NaOH catalysts (Base catalysts) [47]. Esterification is a reaction of ethyl ester formation by carrying out a synthesis reaction directly between carboxylic acids and alcohols. The catalyst used in the esterification reaction is an acid catalyst. Transesterification reaction is the process of breaking down triglyceride compounds in Free Fatty Acid (FFA) vegetable and animal oils using a base catalyst where one of the reagents is an ester compound. The transesterification reaction produces products in the form of fatty acids, methyl esters (biodiesel) and glycerol. Making biodiesel from a mixture of used cooking oil without treatment with diesel fuel can be done by mixing directly. Untreated cooking oil mixing is an effective technique to lower the viscosity of biodiesel.

3.9 Kesambi Oil Biodiesel

Kesambi oil is the result of extracts from kesambi seeds [48]. The oil is widely used as a treatment but not for consumption, because there are laboratory research results that state that the oil contains cyanide acid. The process to get kesambi oil is by separating the fruit flesh from the seeds, after that dry the kesambi seeds for about a full day to reduce the water content contained in the seeds. After drying, kesambi seeds are then steamed for about 1-2 hours to facilitate the extraction of kesambi oil with the seeds. After the steaming process, the kesambi seeds are then pressed with a press to extract the kesambi oil and put it in a container container.

3.10 Graphene Nanoplatelet

The application of nanotechnology has resulted in improved properties desired in diverse engineering systems. The application of this technology is a relatively new aspect of engineering that shows increased efficiency including heat transfer systems, lubrication systems, electronic systems, nuclear systems, industrial cooling systems, space systems, energy-efficient systems and storage, building heating and pollution reduction [49]. The passive technique of adding nanoparticles to base fluids has recently shown varying degrees of change in liquid properties making it an exciting aspect to be explored scientifically through further research.

Graphene is another interesting alternative fuel to consider as a fuel additive. Compared to other additives, graphene will not produce toxic emissions because the element in it is only carbon. Graphene has been introduced in many applications such as biological engineering, ultrafiltration and energy. Graphene nanoplatelets (GNP) are carbon-based rather than metal-based, so they can be an additive to

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environmentally friendly fuels [50]. Graphene nanoplatelet (GNP) has low toxicity, high energy density, and high thermal conductivity, should be able to promote the combustion of diesel fuel or biodiesel. In addition, the beneficial characteristics of graphene nanoplatelets (GNP) and related carbon nanomaterials have been demonstrated in several other applications such as in batteries, chemical sensors, heat transfer, and transparent conductors.

Based on the explanation of the types of biodiesel above, the comparison of each biodiesel can be seen in Table 1 below:

Table 1. Comparison of Each Biodiesel

No.	Type of Biodiesel	Explanation	References
1	Bintaro Oil Biodiesel	▪ The Bintaro plant is abundant in Indonesia and can grow in various environments. ▪ Bintaro oil is derived from a non-food crop, reducing competition with food sources. ▪ The transesterification process may require specific catalysts, and the availability of these catalysts can affect the overall production process.	[9]
2	Hazelnut Oil Biodiesel	▪ The Hazelnut trees are abundant in Indonesia. ▪ Hazelnut oil has a low level of free fatty acids (FFA), making it suitable for biodiesel production.	[37]
3	Corn Oil Biodiesel	▪ Corn oil is of high quality and has a high smoke point, making it suitable for biodiesel. ▪ Corn oil is widely available and commonly used in various industries. ▪ There might be concerns related to using food crops for biodiesel production, although corn oil is a by-product of corn processing.	[38]
4	Crude Palm Oil Biodiesel	▪ Abundant supply in Indonesia with extensive oil palm plantations. ▪ By-product utilization, as it uses crude palm oil. ▪ Environmental concerns related to deforestation and habitat loss due to palm oil plantations. ▪ Controversies surrounding the sustainability of palm oil production.	[39]
5	Hydrotreated Vegetable Oil Biodiesel	▪ Utilizes various vegetable oils as raw materials. ▪ Hydrogenation process improves properties resembling diesel. ▪ The production process involving hydrogenation may require substantial energy inputs.	[40]
6	Kapok Seed Oil Biodiesel	▪ Kapok seeds have a high oil content and are readily available. ▪ Biodiesel from kapok seed oil has better combustion characteristics than diesel.	[41], [42]
7	Rubber Seed Oil Biodiesel	▪ Rubber seed oil can be processed using both catalyst and non-catalyst methods. ▪ Rubber plants are abundant in tropical regions.	[43]
8	Used Cooking Oil Biodiesel	▪ Utilizes a waste product, reducing environmental impact. ▪ Relatively high calorific value. ▪ The need for multiple reaction stages in the production process.	[46], [47]
9	Kesambi Oil Biodiesel	▪ Kesambi oil is obtained from kesambi seeds, which are abundant.	[48]

		▪ The oil extraction process involves pressing and does not require complex methods. ▪ Kesambi oil contains cyanide acid, making it unsuitable for consumption.	
10	Graphene Nanoplatelet	▪ Graphene nanoplatelets are carbon-based and do not produce toxic emissions. ▪ High energy density and thermal conductivity. ▪ The application of nanotechnology in fuels may raise concerns about safety and regulatory approval.	[50]

4. Conclusion

Biodiesel is a promising renewable energy source with various types of raw materials available and can be grown easily in our country. The various types of biodiesel are bintaro oil, hazelnut oil, corn oil, crude palm oil, hydrotreated vegetable oil, kapok seed oil, rubber seed oil, used cooking oil, kesambi oil and graphene nanoplatelets. Each type of biodiesel has its own advantages, while the biodiesel feedstock that has the potential to be produced in large quantities is palm oil. This research also suggests that Indonesia's natural resource potential is very large, so we can also process and develop other types of biodiesel which can be used as alternative fuel. The development and selection of suitable biodiesel types for specific applications will be the key to success in reducing dependence on fossil fuels and their negative impact on the environment. Further research and innovation in biodiesel production is expected to continue to develop. So that research on the types of biodiesel used as alternative fuel and their impacts can continue.

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