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PRODUCTION, APPLICATION AND FUTURE DEVELOPMENT OF BIODIESEL

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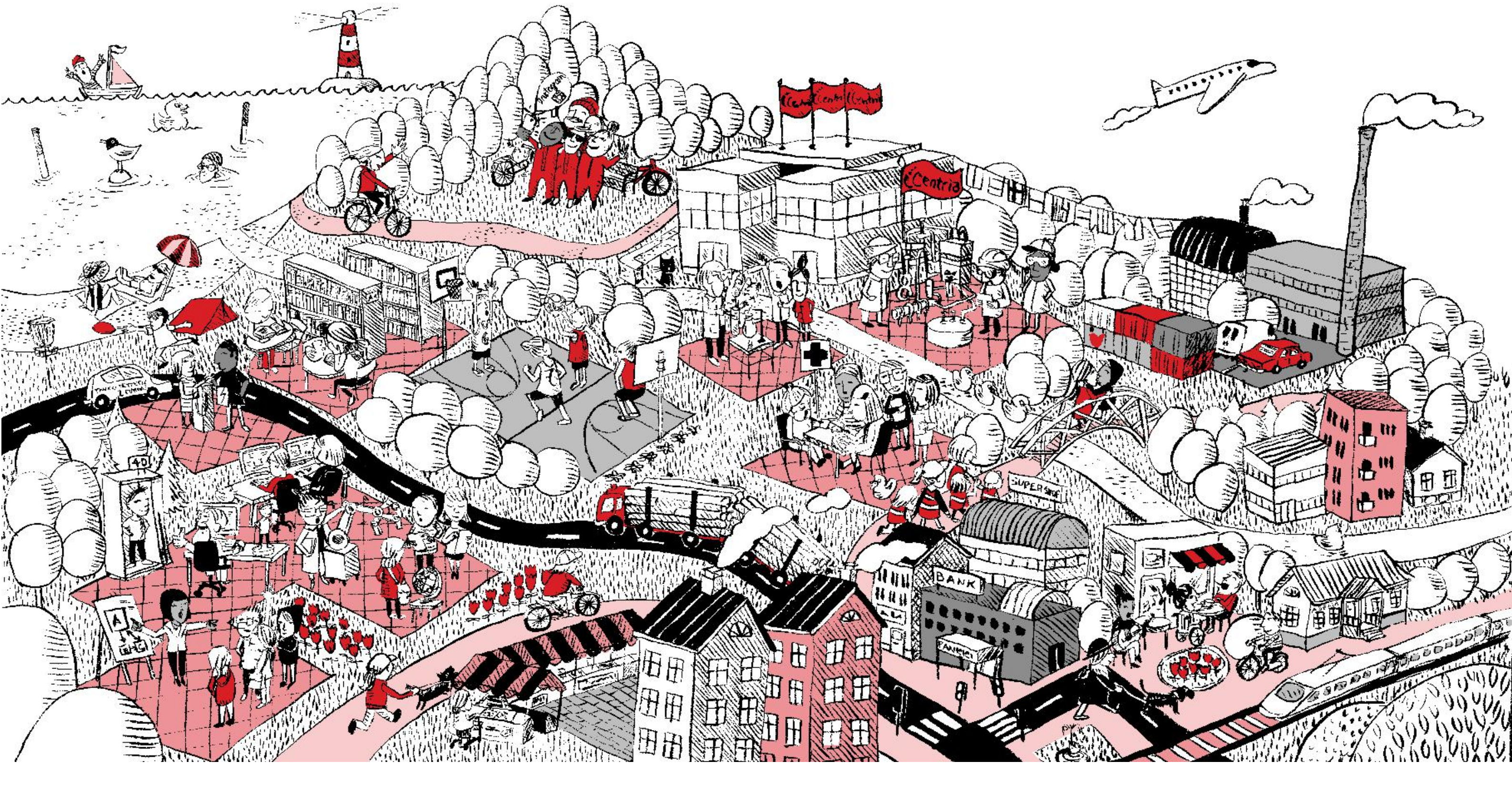

ABSTRACT

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Biodiesel has made great progress in production and application with the development of time. Biodiesel has better performance and less environmental pollution than conventional petrochemical diesel oil. Biodiesel is a clean diesel, which can be extracted from biomass. It can be said that biodiesel is inexhaustible, which is more in line with the development route of energy at the present stage. At present, all countries in the world, especially the developed countries, are devoted to the research of efficient and environmentally friendly energy, and have achieved great results. This thesis embarks from the six points, the purpose is to further analyze the possibility of biodiesel to replace disposable non renewable energy, and through the analysis of the biodiesel research progress at present stage, and the market prospect of biodiesel raw materials and products analysis, to explore whether biodiesel can gain their energy consumption market in the future.

Key words
Biodiesel, fatty acid methyl ester, ester, raw materials, development, cetane number

CONCEPT DEFINITIONS

List of abbreviations

FAME

Fatty acid methyl ester

SRCA

Ultra-near critical alcoholysis process

CO

Carbon monoxide

PM
Particulate matter

BTE
Brake specific heat efficiency

BSEC
Brake specific energy consumption

BSFC
Brake specific fuel consumption of engine

HC
Hydrocarbon

ABSTRACT
CONCEPT DEFINITIONS
CONTENTS

FIGURES

TABLES

1 INTRODUCTION

Traditional energy refers to have mass production and extensive use of resources, including coal, petroleum, natural gas. The energy that has been widely used over a long period of time belongs to the traditional one-time non-renewable energy. They are in the EARTH's crust that was formed ten million years later. The disposable non-renewable energy regeneration in the short term is impossible, so people have an energy crisis. Take oil resources as an example. According to relevant data, since 2015, crude oil consumption has been more than 70% higher than the proven reserves of new crude oil in same year. By 2019 it had risen to 80%. (China Petroleum News Center 2020.）The consumption rate of crude oil is much higher than that of the newly discovered crude oil. Since 1990, the world has consumed more conventional oil than it has discovered, and new proven reserves of crude oil have fallen from 50 billion barrels per year of conventional oil in the 1970s to 4.2 billion barrels per year in 2016. From 2013 to 2019, the average new proven oil reserves are only 6 billion barrels per year, which is nearly nine-fold less. (China Petroleum News Center 2020.) At this rate of development and consumption, petroleum energy may not be able to keep pace with human progress in the near future.

According to a survey report, (Bossert & Bartha 1985, 75 — 77) oil has not only affected the environment, but now it should be described as harmful to the environment. The harm of oil and gas is shown in three aspects. First, oil and gas pollute the atmospheric environment, combustion generates chemical smog, carcinogens and greenhouse effect. Second, it pollutes the soil. After oil enters the soil, it will destroy the soil structure, disperse soil particles, and reduce the permeability of the soil. It is rich in reactive group energy that binds to inorganic nitrogen and inorganic phosphorus and restricts nitrification and dephosphorylation, thus reducing the content of available phosphorus and nitrogen in soil. (Bossert & Bartha 1985, 75 — 77) The third problem is groundwater pollution. Oil pipeline leakage pollutes underground water sources. Toxic substances can enter the food chain system through crops, and may eventually harm human beings. And most of these disposable non-renewable energy will harm the environment. With the development of industry, the environment deteriorates. At this time, people need a kind of energy that can gradually replace these one-time non-renewable traditional energy to meet the needs of human development, and at the same time to meet the needs to minimize the harm to the environment, so renewable and better performance of bioenergy began to enter the field of vision of people.

Biodiesel is a clean diesel, which can be extracted from biomass. It can be said that biodiesel is inexhaustible, which is more in line with the development route of energy at the present stage. At present, all countries in the world, especially the developed countries, are devoted to the research of efficient and environmentally friendly energy, and have achieved great results. The research on biodiesel in China started late, but developed rapidly, and some technologies have reached the advanced level. Therefore, biodiesel has been recognized by all countries and is actively studied by all countries. With the passage of time, the status of biodiesel in energy will become important, so the future development prospects of biodiesel can be seen. (Jie, Randall, Yu, Garyr & John 2010, 525 – 530.)

This thesis starts from six aspects. The purpose is to further analyze the possibility of biodiesel to replace disposable non renewable energy, and through the analysis of the biodiesel research progress at present stage. By analyzing the market prospect of biodiesel raw materials and products, this thesis discusses whether biodiesel can occupy a place in the future energy consumption market.

2 INTRODUCTION TO BIODIESEL

Biodiesel is a typical green energy, is one of the biofuels. Biodiesel has good environmental performance, engine starting performance and fuel performance. Biodiesel has many kinds of raw materials, renewable and other characteristics. Many studies have confirmed that no matter what kind of diesel engine (small, light, large, heavy) or tractor, after burning biodiesel, hydrocarbons are reduced by 55%－60%, particulate matter is reduced by 20%－50%, CO is reduced by more than 45%, and polycyclic aromatic hydrocarbons are reduced by 75%－85%. (Vyas, Verma & Subrahmanyam 2010, 1－9.)

2.1 Biodiesel concept

Biodiesel, known as sunshine fuel, is a long-chain fatty acid mono-alkyl fat, which is prepared from animal and plant oils, various waste oils and microbial oils by lipogenic reaction with short-chain alcohols (such as methanol and ethanol). It is an oxygen-containing clean fuel. The concept of biodiesel was first proposed by German engineer Dr. Rudolf Diesel in 1985. It refers to the use of various animal and plant oils as raw materials, and methanol or ethanol and other alcohols through cross-esterification reaction modification, so that it can eventually be used as a fuel for internal combustion engines. (Costa , Silva & Ferreira 2020, 157.)

2.2 The raw material for biodiesel

Vegetable oils and animal fats with certain structural symbols of fatty acid glycerides (i.e., triglycerides) are commonly used as feedstocks for biodiesel. Biodiesel refers to the fatty acid methyl ester or ethyl ester formed by the ester conversion of vegetable oil, animal oil, waste oil or microbial oil and methanol or ethanol. Vegetable oil, animal oil, waste oil or microbial oil can all be used as feedstock for biodiesel. Vegetable oil includes peanut oil, soybean oil, rapeseed oil, cottonseed oil, sunflower oil, linseed oil. Animal fat including lard, butter, fish oil, sheep fat. Waste oil refers to the inedible animal and plant fats produced in the production and operation activities of the catering industry and the food processing industry. Waste oil can be seen everywhere in various restaurants.

Microbial oils, also known as single cell oils (SCO), are produced by microorganisms such as yeast, chlorella, molds, bacteria and algae under certain conditions using carbohydrates, hydrocarbons and ordinary oils as carbon and nitrogen sources, assisted by inorganic salts. These are the raw materials for biodiesel, which can be recycled indefinitely, and in huge quantities. (Tamilalagan, Singaram & Rajamohan 2019, 11371-11386.)

2.3 Principle of biodiesel production

FAME have the formula R-$COOCH_3$, where R is a hydrocarbon group, which can be either saturated or unsaturated. Biodiesel is long chain fatty acid methyl ester or ethyl ester, is a mixture, there is no fixed formula. According to the degree of saturation of the carbon chain, FAME is divided into unsaturated FAME with double bond and saturated FAME without double bond and triple bond. The fatty acid carbon chain of the FAME here is generally between 12 and 22, mainly the saturated and unsaturated FAME of 12-18, which can have side chains and other groups such as hydroxyl groups on the carbon chain. FAME is the product of transesterification of fats with methanol, and it can also be the esterification product of fatty acids from fats with methanol. (Vyas et al. 2010,1－9)

Because waste animal and plant oil is a high acid value oil with many impurities and high content of free fatty acids and water. It is used to prepare biodiesel. If alkali is used as catalyst, the free fatty acids in the waste oil with high acid value will be saponified with alkali. If concentrated sulfuric acid, p-toluenesulfonic acid and other acid catalysts are used, the dehydration esterification reaction between free fatty acids and methanol is easy to occur, while ester exchange reaction between fatty acid glycerides and methanol almost does not occur. Therefore, a catalyst is used in the production process. Under the action of catalyst, the ester exchange reaction between waste animal and plant oil and methanol was carried out. In the transesterification reaction between oil and methanol, 1 mol of oil fat reacts with 3 mol of methanol to produce 3 mol of methyl ester and 1 mol of glycerol as shown in chemical equation (1). If the fat contains fatty acids, the fatty acids will also transesterification with methanol. In the esterification reaction of fatty acids with methanol, 1 mol of fatty acids reacted with 1 mol of methanol to produce 1 mol of methyl ester and 1 mol of water as shown in chemical equation (2). The two reactions proceed simultaneously. (Leung, Wu & Leung 2010, 1083−1095.)

$$\begin{array}{lccccccc}
CH_2OCR_1 & & & & CH_2OH & & R_1COOCH_3 & \\
\quad | & & & \text{catalyst} & \quad | & & & \\
CHOCOR_2 & + & 3CH_3OH & \rightleftharpoons & CHOH & + & R_2COOCH_3 & (1) \\
\quad | & & & & \quad | & & & \\
CH_2OCOR_3 & & & & CH_2OH & & R_3COOCH_3 &
\end{array}$$

$$R\text{-}COOH + CH_3OH \rightleftharpoons R\text{-}COOCH_3 + H_2O \qquad (2)$$

3 PRODUCTION OF BIODIESEL

At present, the main preparation methods of biodiesel include direct mixing, microemulsion, transesterification and pyrolysis. The direct mixing method is to mix animal and vegetable oil with traditional diesel oil in a certain proportion. This method has some shortcomings, such as high viscosity, perishable and incomplete combustion. Microemulsion method is a microemulsion made by mixing animal and vegetable oil and emulsifier. By mixing two kinds of immiscible liquid and ionic or non-ionic amphoteric molecules into a colloid equilibrium system, this method solves the problem of high viscosity of animal and vegetable oil. Pyrolysis method is under the condition of rapid heating and ultra-short reaction time. The organic molecules of waste oil can be broken into short chain molecules quickly, and the carbon formation and gas production can be reduced to the minimum. Fuel oil can be obtained maximally by pyrolysis, and the biodiesel obtained is close to ordinary diesel oil. However, similar to microemulsion method, its production cost is high, and there are not many related studies and applications. (Gerhard 2006, 823 – 833) FIGURE 1. shows some of the methods used to produce biodiesel.

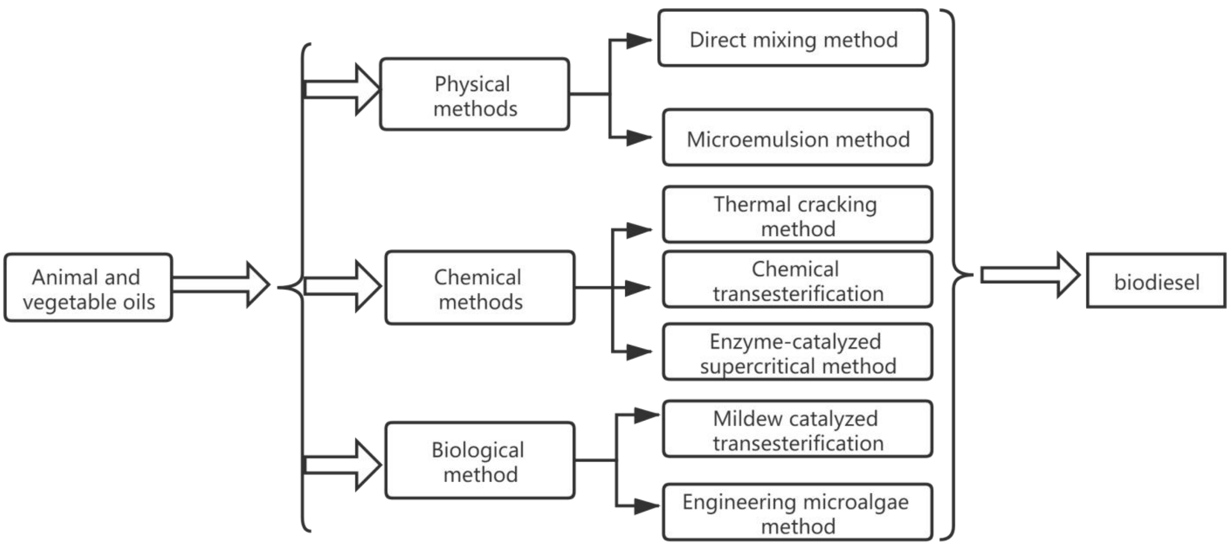

FIGURE 1. Methods of producing biodiesel from animal and vegetable oils (Adapted from Gerhard 2006, 823 – 833)

With the development of science and technology, the preparation technology of biodiesel is also making continuous progress. Scientists have developed three generations of biodiesel. The raw materials of these two generations of biodiesel have expanded from the first generation of animal and vegetable oils, waste cooking oil. to the third generation of non-lipid biomass microorganisms. The technology for the preparation of biodiesel is also improving. (Oh, Hwang, Kim C, Kim JR & Lee 2014, 320 – 333.) The following table shows the development of the technology for the preparation of biodiesel. The table describes several aspects of the first to third generation biodiesel (TABLE 1).

TABLE 1. The development process of biodiesel preparation technology（Adapted from Oh et al. 2014, 320 – 333.）

Type	**The raw material**	**Technology**	**Product**	**The development situation**
First generation biodiesel	Animal and vegetable oils,food waste oils and low molecular alcohol	Ester exchange method	Fatty acid low alcohol ester	It has the characteristics of low sulfur content and renewable raw materials. Has entered the large-scale industrial production
Second generation biodiesel	Animal and vegetable oils	Catalytic hydrogenation	Liquid aliphatic hydrocarbon	It is closer to conventional diesel in terms of structure and performance. The preparation technology realizes industrialization
Third generation biodiesel	Non-greasy biomass and microbial	Biomass gasification culture and extraction of microbial lipids	Mixed gas microbial grease containing CO, H2, CH4	In the experimental stage, developed countries such as Europe and the United States have been in the forefront of the world in the research of catalysts and gasification devices

As acid-base catalysis and SRCA are the most mature methods in biodiesel production, and the following two methods are introduced. Acid-base catalysis is divided into homogeneous catalysis and heterogeneous catalysis. Homogeneous catalysis is mainly acid catalysis and base catalysis, commonly used acid and base catalysts H_2SO_4, HCl and NaOH, KOH, CH_3ONa, CH_3OK. The traditional homogeneous catalysis method has many problems such as side reaction, emulsion and serious pollution. (Vicente, Martínez, Aracil 2004, 297–305.) On the other hand, heterogeneous catalysts can better solve the problem of separation of catalyst and product and reduce the pollution of waste catalyst and water solution to the environment. At present, heterogeneous catalysts mainly include resin, clay, molecular sieve, composite oxide and sulfate. (Pinzi, Leiva, Lopez, Redel & Dorado 2013, 126 – 143.) SuperCritical Method is abbreviated to SRCA. Supercritical methanol (SCMEOH) transesterification method is a new method put forward in recent years. Its outstanding advantages lie in fast reaction speed, high conversion rate, simple product and low raw material requirements. Therefore, it has received wide attention, but high temperature and high pressure operation is its shortcoming. At present, the ultra-near critical alcoholysis process (SRCA-I) developed by the China Research Institute of Petroleum and Chemical Technology has been applied on an industrial scale of 60,000 tons/year, and its improved SRCA-II process technology is undergoing pilot test. The process does not use catalyst, reacts under the pressure of 6.5 Mpa to 8.5 Mpa, and has strong adaptability to raw materials. The oil with high acid value can be processed directly without deacidification pretreatment. The product conversion rate is above 96%, the quality can meet the Chinese national standard (GB/T 20828-2007), and the glycerol concentration of by-product can reach 80%. (Shimada, Watanabe & Sugihara 2002,133-142.)

3.1 The production process of biodiesel

The molecular formula of the ideal diesel substitute is generally expressed as $C_{19}H_{36}O_2$. But using the waste edible oil as raw material to react with methanol generated is mixed fatty acid methyl ester. Its chemical composition is lauric acid methyl ester, nutmeg acid methyl ester and methyl palmitate, methyl stearate. So the lower boiling point fatty acid methyl ester must be equally separated from the higher boiling point glyceride by a vacuum distillation system. In the distillation process, the free fatty acids that remain in the fatty acid methyl ester will also be taken out, making the fatty acid methyl ester value of the steam higher. (Helwani, Othman, Aziz, Kim & Fernando 2009, 1 – 10.) Through the experiment. It was found that the free fatty acid would react with the metal brine, resulting in the precipitation of metal soap. The chemical equation is shown in (3). Metal soaps can recover metal salts and fatty acids through acidification. The chemical reaction equation is shown in (4). The process of producing biodiesel by acid-base heterogeneous catalysis is shown in FIGURE 2.

$$MSO_4 + 2RCOOH^{-} \rightarrow (RCOO)_2M \downarrow + SO_4^{2-} + 2H^{+} \quad (3)$$

$$(RCOO)_2M \downarrow + H_2SO_4^{-} \rightarrow MSO_4 + 2RCOOH \quad (4)$$

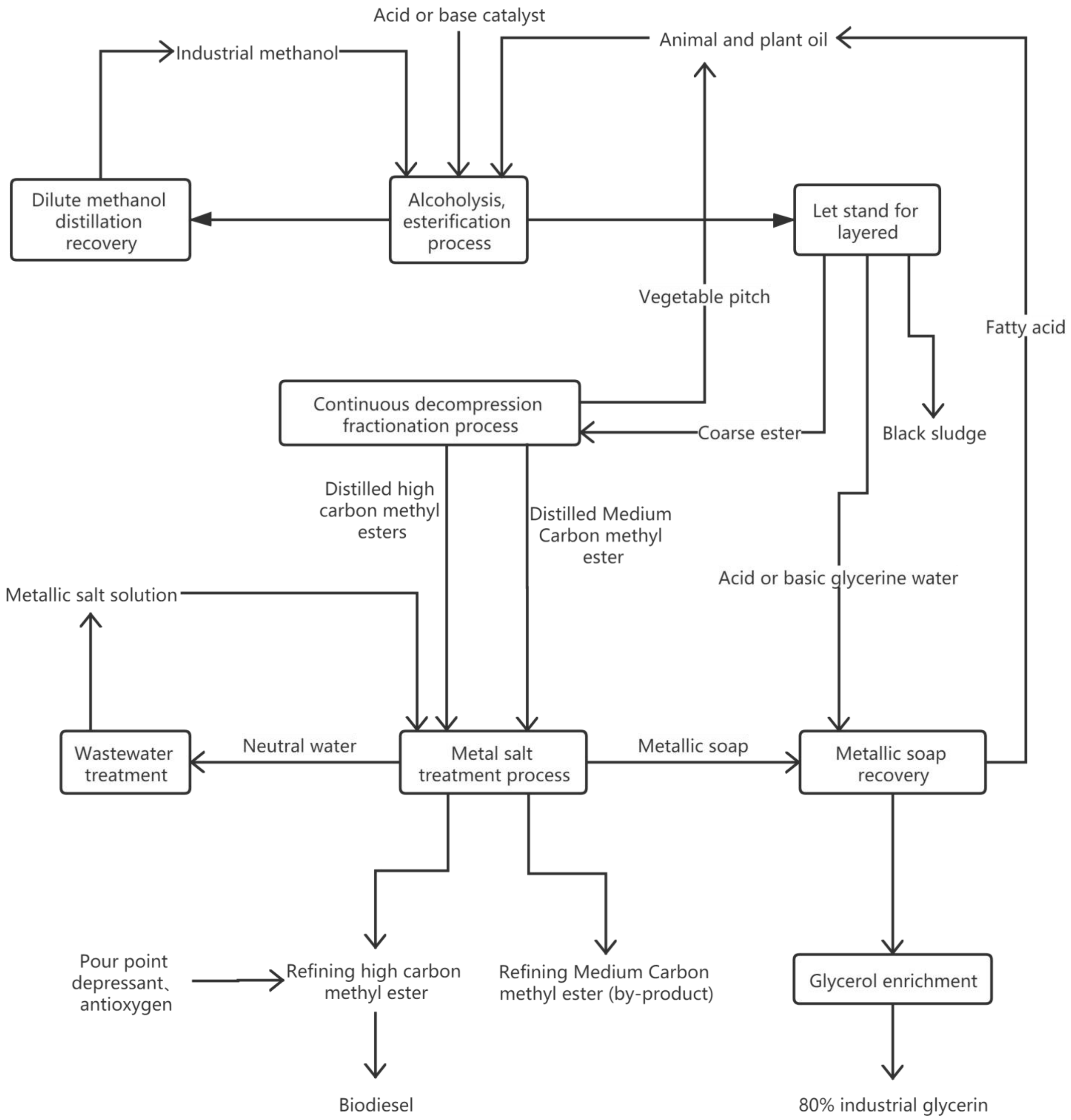

FIGURE 2. The process of producing biodiesel by acid-base heterogeneous catalysis (Adapted from Zabeti, Wan & Aroua 2009, 770 – 777.)

Supercritical transesterification can solve the problem that the reaction product and catalyst are difficult to separate. This method has a relatively low requirement on raw materials, and can convert free fatty acids and oils with high water content into biodiesel. Thus improving the yield to a certain extent. The supercritical fluid can be used as the co-solvent of oil and methanol, which greatly increases the reaction rate. There is no saponification reaction in the reaction process, and the separation and purification process of the product is simple. The disadvantage is that the reaction needs to be carried out under high temperature and pressure, and the energy consumption is relatively high. (Ilham & Saka 2016). FIGURE 3. shows the process flow chart of supercritical process (SRCA).

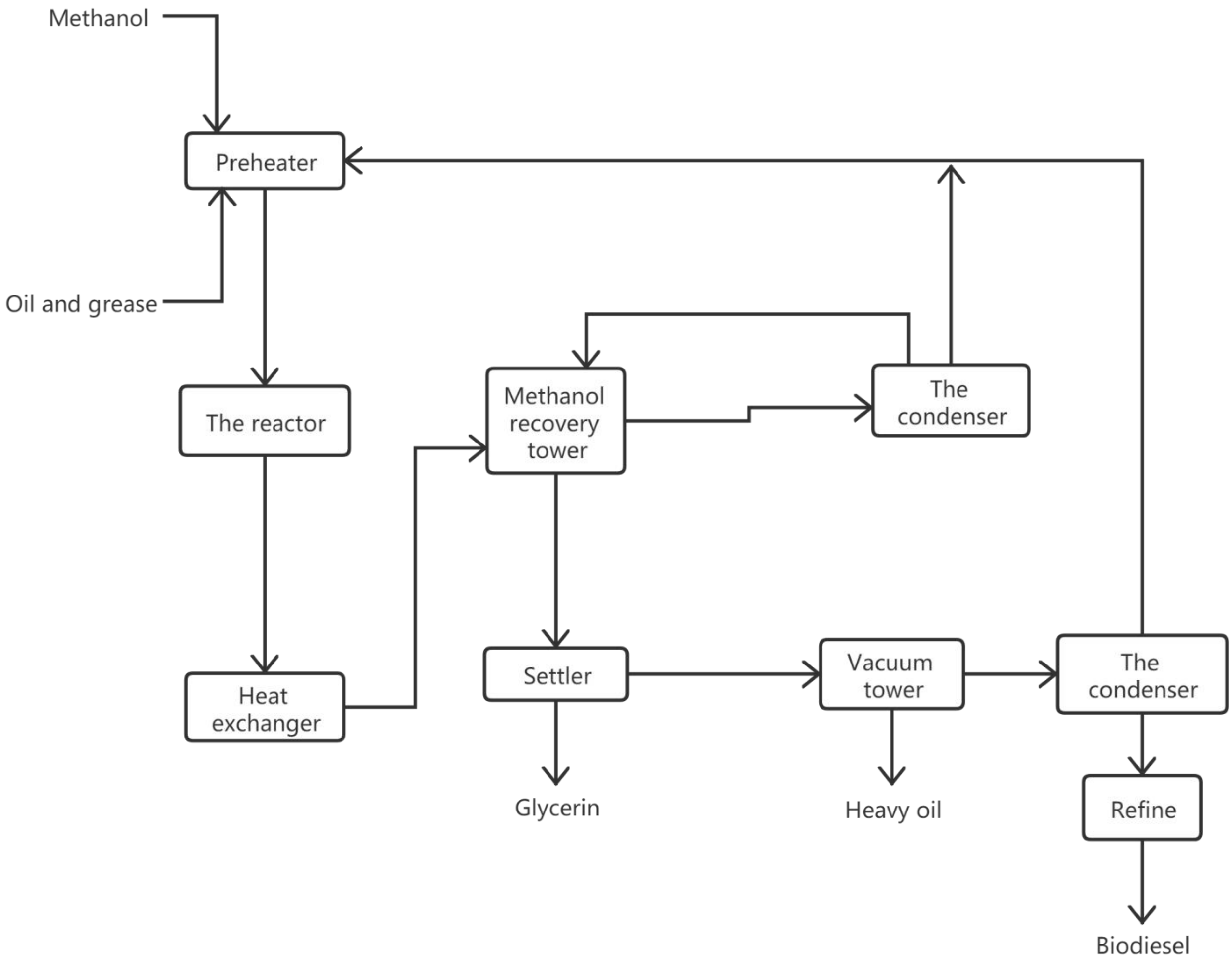

FIGURE 3. SuperCritical Method (SRCA) process for the production of biodiesel (Adapted from Ilham & Saka 2016)

3.2.Equipment for the production of biodiesel

This thesis mainly introduces acid-base heterogeneous catalysis method and supercritical transesterification method in the production process of biodiesel. These two methods are the first generation biodiesel technology, also known as transesterification method. The first generation of biodiesel technology is the earliest research, and also the most known method and technological process . Although the biodiesel technology so far have two generations of technical innovation, but in many large factories, the first generation of biodiesel technology is still in biodiesel production on a large scale . The second generation of biodiesel are put into production but on a smaller scale and technology is not mature relative to the first generation . The third generation of biodiesel technology research needs to be improved at present. (Zabeti, Wan & Aroua 2009 ; Ilham & Saka 2016.) TABLE 2. will show the production equipment of these two methods.

TABLE 2. Equipment for acid-base heterogeneous catalysis and supercritical transesterification

(Adapted from Zabeti, Wan & Aroua 2009 ; Ilham & Saka 2016.)

Acid-base heterogeneous catalysis	
Esterification of alcoholysis	Condenser, reaction tank, agitator, storage tank
The process of decompression fractionation	Flash evaporator, double distillation tower, metering pump, differential connecting pipe, carbon tower reboiler, medium carbon tower, bottom connecting pipe, high carbon tower, hot oil circulating pump
The process of metal salt treatment	Metal salt treatment tank, filter press, acidizing tank
Supercritical transesterification	
Preheater, reactor, heat exchanger, methanol recovery tower, condenser, settler, decompression tower	

4 ADVANTAGES OF BIODIESEL

With the development of industry, the demand for petrochemical resources has always been at a high level. The high-speed increase of people's economic level has brought people energy crisis and environmental crisis. Excess exploitation and utilization of non-renewable energy has caused damage to the ecological environment and serious environmental pollution. At the same time, industrial production is facing rising prices due to the shortage of oil resources and production costs. Today, countries around the world continue to strengthen ecological conservation and promote green and sustainable development of industrial production. Under the pressure of resource shortage, production cost increase and environmental and ecological problems, and it is urgent to choose a green and renewable alternative energy to replace petroleum and diesel. Biodiesel with its environmental protection, strong regeneration capacity, high oxygen content and full combustion of excellent performance more and more attention by various countries. (Pinzi et al. 2013, 126 – 143) Since biodiesel belongs to green energy, the following two points will explain the advantages of biodiesel and green energy, and indirectly prove the ability and potential of biodiesel to replace traditional diesel by describing the advantages of biodiesel.

4.1 Advantages of biodiesel

Biodiesel has strong environmental protection characteristics. Compared with petrochemical diesel, biodiesel has low sulfur lead content, and can greatly reduce sulfur dioxide and sulfide emissions after use. The data showed that sulphur dioxide and sulphide emissions could be reduced by about 30 %. Under the catalysis of the catalyst, the pollutant emission of biodiesel can even be reduced by more than 60%. Biodiesel does not contain aromatic compounds which can cause pollution to the environment. (Earley, Earley & Straub 2005.) The harm of exhaust gas to human body is lower than that of petrochemical diesel. Meanwhile, biodiesel has good biodegradation characteristics. Compared to petroleum diesel, toxic organic compounds in diesel exhaust emissions is only 10%, particulate matter is 20%, carbon dioxide and carbon monoxide emissions is only 10%, index number can reach

Europe Ⅲ emissions exhaust emissions standards. (Yusuf, Kamarudin & Yaakub 2011, 2741–2751.) The emission reduction of biodiesel compared with diesel combustion tail gas is shown in TABLE 3.

TABLE 3 . The emission reduction of biodiesel compared with diesel combustion exhaust (Adapted from Ulusoy, Arslan & Tekin 2018, 396 – 404.)

Emissions	**B100**	**B20**
CO	-48%	-12%
PM	-48%	-12%
Ozone-destroying substance	-50%	-20%
hydrocarbons	-67%	-20%
Carbonate compound	-97%	-20%
Polyaromatic hydrocarbons	-80%	-13%

Biodiesel has excellent combustion performance. The cetane number of biodiesel is higher than that of diesel. The cetane number is a quality index to measure the fuel performance of the fuel in the compression ignition engine. So biodiesel has better combustion performance. The fuel has better combustion resistance when used, so the engine with higher compression ratio can be used to improve its thermal efficiency. Although the calorific value of biodiesel is lower than that of diesel, the oxygen content of biodiesel is higher than that of petrochemical diesel, up to 11%, because the oxygen element contained in biodiesel can promote the combustion of the fuel. The amount of oxygen required in the combustion process is less than that of petrochemical diesel, and the combustion is more sufficient than that of petrochemical diesel. Therefore, the thermal efficiency of the engine can be improved, which can make up for the loss of power to a certain extent. (Ulusoy et al. 2018, 396 – 404.) Comparison of performance indicators between biodiesel and ordinary diesel is shown in TABLE 4.

TABLE 4. Comparison of performance indexes between biodiesel and common diesel (Adapted from Ulusoy et al. 2018, 396－404.)

Project	Biodiesel	Traditional diesel
Flash point / ℃	130	60
Cetane number	≧56	≧49
Sulfur content / %	≦0. 001	≦0. 2
Kinematic viscosity (40℃)/(mm2/s)	1.9－6.0	2.0－4.0
Combustion power /% (diesel = 100%)	104	100

Compared with fossil diesel, biodiesel has better low-temperature engine start-up performance, and the cold filter point reaches -20℃. Moreover, the kinematic viscosity of biodiesel is higher than that of ordinary diesel, which means that the lubricity is better than that of ordinary diesel. Good lubricity can reduce the friction loss of the engine oil supply system and cylinder liner, increase the service life of the engine, thus prolongs the service life of the car and reduces the production and maintenance cost. Biodiesel can be used in combination with fossil diesel in a certain proportion to reduce fuel consumption, reduce the pressure of traditional diesel and reduce exhaust pollution. Due to the flash point higher than that of fossil diesel biodiesel, flash point is an important performance index, combustible gas is used to describe a source caused by liquid fire, the lowest temperature higher than 100 ℃, flash points of biodiesel is far higher than that of ordinary diesel oil, biodiesel so high flash point to ensure the transport, storage, use in biodiesel security more than the ordinary diesel oil in the process. (Altıparmak, Keskin, Koca & Guru 2007, 241－246.) Biodiesel greatly reduces the risk of transportation, storage and so on. Increase the security of energy transportation. Biodiesel has high moisture content, which can reduce the viscosity of the fuel during combustion, thus improving stability and suitable for low-temperature engines. In terms of safety, cetane number is an important index to judge the anti-knock performance of diesel combustion from the aspect of anti-knock performance. The larger the cetane number, the more sufficient the combustion and the better the anti-knock performance. The cetane number of biodiesel is higher than that of ordinary diesel, so it can be seen that the anti-explosion ability of biodiesel is higher than that of ordinary diesel. From the perspective of raw material, biodiesel raw material sources are extensive and renewable, and its resources will not be exhausted like oil and coal. From an economic point of view, systems that run on biodiesel require less investment to upgrade, with no need to change the engines, refueling equipment, storage equipment and maintenance equipment that run on diesel. In addition, biodiesel has good biodegradability and is easy to be decomposed and used by microorganisms in the environment. (Canakci & Van 2003, 937– 944)

4.2 Biodiesel as Green Energy

Green energy is clean energy, which refers to the energy that does not emit pollutants and can be directly used in production and living, including nuclear energy and renewable energy. The definition of clean energy is the technology system of clean, efficient and systematic application of energy. There are three implications. First, clean energy is not a simple classification of energy, but refers to the technology system of energy utilization. Second, clean energy emphasizes not only cleanliness but also economy. Third, the cleanliness of clean energy means that it meets certain emission standards. Green energy includes ocean energy, solar energy, wind energy, hydrogen energy, biological energy, geothermal energy, water energy, nuclear energy and flywheel energy storage. Green energy is combined with environment, and different green energy is used in different areas according to local conditions. Nowadays, various countries have used green energy to reduce the pressure of traditional energy, and are still developing green energy. (Atabani, Silitonga, Badruddin, Mahlia, Masjuki & Mekhilef 2012, 2070 – 2093.)

Biomass refers to all kinds of organisms formed by photosynthesis, including all animals, plants and microorganisms. The so-called biomass energy is the energy form of solar energy stored in biomass in the form of chemical energy, with biomass as the carrier. It comes directly or indirectly from the photosynthesis of green plants and can be converted into conventional solid, liquid and gaseous fuels. It is a renewable energy and the only renewable carbon source. Biomass energy has always been an important energy for human survival. Biomass energy is the fourth most consumed energy by humans, behind coal, oil and natural gas. (Jie et al. 2010, 525 – 530) It plays an important role in the whole energy system. Relevant experts estimate that biomass energy is very likely to become an integral part of the future sustainable energy system. By the middle of the next century, all kinds of biomass alternative fuels produced by new technologies will account for more than 40% of the global total energy consumption. All countries in the world are striving to develop green energy. In addition to nuclear energy, these renewable energy is in line with today's energy development path. After three generations of technological progress and development, biodiesel may become the main force of green energy in the near future and contribute to the sustainable development of human energy. (Jie et al. 2010, 525 – 530)

5 CURRENT RESEARCH AND APPLICATION OF BIODIESEL

EU biodiesel capacity in 2006 exceeded 6 million tonnes, while production will reach 4.2 million tonnes. Between 2007 and 2010, EU biodiesel production maintained an annual growth rate of 33.9%. That is, 5.62 million tons, 7.53 million tons, 10.08 million tons and 13.5 million tons respectively, equivalent to an average annual increase of 2.325 million tons. To meet rising demand for biodiesel, the EU will need to grow more oil crops such as rapeseed while still importing large amounts of palm oil and rapeseed oil. (Souza, Seabra & Nogueira 2017, 455 – 478.) Compared with other countries, on the one hand, research and development of biodiesel in China started relatively late, the system research began with the Chinese Academy of Sciences "five-year" key scientific research project: "Research And Application Of The Fuel Oil Plant Technology", the study completed The Jinsha River Watershed Fuel Oil Plant Resource Survey And Cultivation Technique Study, and established a small seed of tung tree planting ShiFanPian 30 hectares. Since the early 1990s, Changsha New Technology Research Institute and Hunan Academy of Forestry began to cooperate in the research on energy plants and biodiesel. During the “Eighth Five-Year Plan” period, the process and combustion characteristics of methyl grease fuel oil from light bark tree oil were studied. During the “Ninth Five-Year” Plan period, the national key scientific research project "Vegetable Oil Energy Utilization Technology" was completed. On the other hand, the biodiesel industry develops at a fast speed, and various aspects of the research have achieved phased results, some of the scientific research results have reached the international advanced level. The research content involves the distribution, selection, cultivation, genetic improvement, processing technology and equipment of oil plants. It can be predicted that in 2-3 years, China's research in this field will make breakthrough progress and reach the practical level. (China Petroleum News Center 2020.)

5.1 Research progress in three aspects of biodiesel

Now the technology for producing biodiesel is maturing. At the present stage, people gradually focus on the improvement of biodiesel, how to better use biodiesel and its application. (Ashok 2019, 173) The following is the latest research progress of biodiesel in many aspects.

Research progress of biodiesel mixed with other fuels (diesel oil, petroleum, ethanol). Kashif ur Rehman used 10% and 20% biodiesel mixed with diesel to prepare biodiesel-diesel blended fuel. Experiments were carried out at different fuel injection time (FITS) and fuel injection pressure (FIPS). The results showed that with the increase of FIPS and FITS, The BSFC of biodiesel blends increased. (Kashif ur Rehman 2018,173). Y.H. Teoh mixed MOB biodiesel with diesel for the test. It is found that the torque and braking power of diesel engine decrease when MOB blend fuel is used in diesel engine compared with pure diesel fuel. In addition, the experimental data of mixed fuel combustion show that the use of mixed fuel also increases the BSFC and decreases the BSEC of the engine. (Teoh & Alabdulkarem 2019,136) Yanuandri Putrasari carried out experiments on 5%-20% gasoline-biodiesel mixed fuel by using GCI engine. The experimental results show that the thermal efficiency of the engine burning biodiesel-gasoline mixture fuel is affected to a certain extent. Compared with pure biodiesel, when the injection timing is maintained at 18-35 Ca BTDC, the thermal efficiency of the engine burning the mixed fuel is reduced. The thermal efficiency of the engine is improved when the fuel injection timing is 55-65 Ca BTDC. (Yanuandri & Ocktaeck Lim 2017,189) B.Ashok mixed n-pentanol and Cime biodiesel to prepare five Cime mixed fuels, B90P10, B80P20, B70P30, B60P40 and B50P50, and carried out combustion tests under various experimental conditions. The study found that the thermal efficiency of the Cime blend was up to 30% higher than that of pure biodiesel. The BTe value of B90P10 is about 27%, which is slightly lower than that of pure diesel. The BSFC of Cime blends increased from 4.2% to 27.3% compared to pure diesel. It is also found that when the ratio of n-amyl alcohol is more than 40%, it will cause a certain negative effect on engine performance. It can be seen that the addition of n-butanol helps to improve fuel consumption. (Ashok 2019, 173)

The research progress of biodiesel in automotive material corrosion is very fast. Copper and its alloy are important components of diesel engine accessories. Copper alloys are more susceptible to biodiesel corrosion than black alloys and aluminum alloys. At present, the corrosion rate is mainly calculated by measuring the mass change, and the corrosion rate of biodiesel is measured by the characterization methods such as scanning electron microscopy/energy dispersion spectroscopy (SEM/EDS), X-ray diffraction (XRD), X-ray photoelectron spectroscopy (XPS) and Fourier transform infrared spectroscopy (FTIR). It was found that the corrosion of waste oil biodiesel, lard biodiesel, palm oil biodiesel and peanut oil biodiesel mixed with 0# diesel in different proportions was slightly different on copper plates. When the proportion of catering waste oil biodiesel is more than 50%, the corrosion grade of copper sheet will exceed the national standard. This indicates that biodiesel prepared from different feedstock oils has different corrosivity to metal materials due to their physical and chemical properties, and rancidity is the main reason for the higher corrosivity of biodiesel than that of mineral diesel. (Ganapathy , Gakkhar & Murugesan 2011, 4376–4386) Aquino, Hernandez & Chicoma (2012) assessed the corrosion rates of brass and copper immersed in commercial biodiesel by natural light and temperature, and studied the degradation of biodiesel after contact with metal ions. It was found that the corrosion rate was higher under light condition, and the water content and viscosity of biodiesel increased after soaking copper and brass at 55 ℃. High temperature and has a strong catalytic effect of the presence of metal ions, exacerbated by oxidation of the biodiesel, reduce oxidation stability and avoid light and room temperature storage of biodiesel is more favourable conditions. (Aquino, Hernandez & Chicoma 2012, 795 — 807) Fazal, Haseeb & Masjuki (2011) specifically studied the influence of temperature on the corrosion behavior of mild steel in palm oil biodiesel. The experiments were carried out at room temperature, 50 ℃ and 80 ℃. The low carbon steel was statically soaked in B0 (diesel), B50 (diesel containing 50% biodiesel) and B100 (biodiesel) for 1200 hours. The corrosion characteristics were analyzed by weightlessness measurement and changes of exposed metal surface. TAN analyzer and FTIR were used to study the acidity and oxidation changes of fuel. SEM was used to detect the surface morphology, and XRD was used to detect the corrosion products. The results show that the corrosion of biodiesel on metal surface is more serious than that of diesel, and the corrosion increases with the increase of temperature. With the increase of soaking temperature, the oxidation of metal surface was enhanced, and $Fe(OH)_3$, $Fe_2O_2CO_3$ and Fe_2O_3 components were formed. The oxidation of biodiesel might further aggravate the corrosion of low carbon steel. (Fazal, Haseeb & Masjuki 2011, 3328 — 3334) Rubber materials are often used in automobile seals, shock absorbers, rubber hose products. Commonly used rubber components are nitrile butadiene rubber (NBR), natural rubber (NR), hydrogenated nitrile butadiene rubber (HNBR), acrylate rubber (ACM), fluorine rubber (FKM), ethylene propylene diene rubber (EPDM), neoprene rubber (CR), silicone rubber (VMQ). If the sealing rubber parts as fuel system are infiltrated by biodiesel for a long time, they may have physical properties such as swelling, plasticizing or volume change, or even degrade to form tank sediments, resulting in poor sealing effect or oil filter and injector blockage and other adverse consequences. Trakarnpruk & Porntangjitlikit (2008) studied the compatibility of NBR, NR, NBR/PVC, ACM, copolymer FKM and terpolymer FKM in B10 diesel fuel blend. The static immersion test was carried out at 100 ℃ for 22, 670 and 1008 h, respectively. The results showed that the properties of NBR, NBR/PVC and ACM were greatly affected, which was caused by the absorption and dissolution of biodiesel into rubber. The copolymer FKM and terpolymer FKM were fluorine-containing elastomers, and the properties had little change. (Trakarnpruk & Porntangjitlikit 2008, 1558 — 1563). Plastics and their composites are the most important lightweight materials in automobiles, which may be used in the parts of the engine such as fuel pump, fuel tank cover and feed port that can contact with biodiesel fuel. Soaked soybean oil biodiesel, jatropha curcas oil biodiesel and swill oil biodiesel on polyethylene (PE), polyformaldehyde (POM) and polytetrafluoroethylene (PTFE) three kinds of plastics at room temperature for 28 days respectively, and determined the influence of biodiesel on plastic swelling by measuring the change rate of mass, diameter and thickness. It was found that biodiesel from three different feedstocks had almost no swelling effect on PE, POM and PTFE plastics within the limit of error. (Anon 2006, 1114)

Research progress of biodiesel raw materials. Microbial lipids, as a possible raw material for cheap and efficient production of biodiesel, have attracted extensive attention. However, due to the complex operation and high cost of closed culture mode, its large-scale application has been restricted. Metschnikowia pulcherrmia is a new oleugenic yeast with strong adaptability, wide range of substrate utilization and cultivation in open system. It has great potential to replace traditional oleugenic microorganisms and realize the engineering application of wastewater and solid waste energy based on biodiesel. In 2014, Scientist took glycerol as carbon source for the first time and realized that the oil content of Metschnikowia pulcherrmia reached more than 40% on the basis of exploring the optimal growth temperature, initial pH and culture time, which proved the possibility of oil accumulation. Studies have shown that Metschnikowia pulcherrmia can utilize a variety of organic wastes such as brewery wastewater and algal hydrolysate, and has the same growth capacity as Rhodosporidium toruloides, Cryptococcus curvatus and other traditional oleoyeasts. When glucose was used as carbon source, the maximum biomass yield of 115.5 g/L could be achieved. (Abeln & Chuck 2019, 3200－3214). The oil yield of Metschnikowia pulcherrmia is affected by many factors, such as base species, concentration, temperature, pH and nutrients. The maximum oil content of Metschnikowia pulcherrmia can be achieved by about 30%-45% under the conditions of low temperature, low pH and nitrogen limitation. The main components are palmitoleic acid (C16:1), palmitoleic acid (C16:0), linoleic acid (C18:2), oleic acid (C18:1) and stearic acid (C18:0), which are similar to the components of soybean oil, rapeseed oil and jatropha oil, so they can also be used in the production of biodiesel. In addition, Metschnikowia pulcherrmia can be cultured in an open system due to its unique biological control mode, which is beneficial to simplify the production process of traditional microbial oil and reduce oil cost. (Tamilalagan et al. 2019, 11371-11386.)

5.2 The blending use of biodiesel with other fuels

The current state of the technology is not at the point where you can just use biodiesel as a fuel without worrying about cost. The current use of biodiesel is to blend biodiesel with conventional diesel oil, petroleum and alcohol. Biodiesel is blended with diesel fuel. Because of the soluble nature of biodiesel, it is usually blended with diesel in proportion to obtain a biodiesel-diesel blend. At present, in the research of biodiesel - diesel fuel, the blending proportion of biodiesel is generally kept at 5% — 50%. Compared with pure biodiesel, the energy content per liter of the prepared fuel mixture is increased, which can greatly improve the power capacity of the diesel engine. Under the premise of ensuring the normal operation of the engine, the blending of biodiesel and diesel fuel can effectively reduce the use of fossil diesel. Biodiesel is blended with gasoline. Gasoline, as the main fuel of ignition engine, is also selected as the fuel additive of diesel or biodiesel because of its good engine performance and emission performance. (Canakci & Van 2003, 937– 944) The characteristics of biodiesel, such as high viscosity, high pour point and low volatility, lead to its poor atomization quality, and it is easy to cause the existence of local fuel-rich areas in the diesel engine during combustion. In order to improve the atomization quality, mixing biodiesel with low proportion of gasoline can reduce the viscosity of the mixed fuel, increase its volatility and improve the physicochemical properties of biodiesel-gasoline mixed fuel. Among them, the introduction of gasoline is mainly through the method of premixed injection or fumigation of fuel, so as to achieve the mixed combustion of biodiesel and gasoline. The biodiesel is blended with alcohol fuel. The common alcohol fuels in the experimental study include ethanol (C_2H_5OH), butanol (C_4H_9OH), amyl alcohol ($C_5H_{11}OH$). Compared with biodiesel and diesel fuel, alcohol fuel has the characteristics of lower density, lower kinematic viscosity, lower calorific value, higher latent heat of evaporation, higher oxygen content and better cold flow performance. (Nanthagopal, Ashok, Saravanan, Deepam, Sudarshan & Aaditya 2018, 70 – 80.) Adding alcohol to biodiesel can effectively reduce the density and viscosity of the blended fuel and improve the physical and chemical properties of the blended fuel. The high oxygen content of alcohol fuel is conducive to the full combustion of fuel in the cylinder, improve the combustion quality and reduce exhaust gas emissions. High latent heat of evaporation makes biodiesel-alcohol fuel absorb more heat in the evaporation process, reduce exhaust temperature and reduce NOx emission. (Palash, Kalam, Masjuki, Masum, Rizwanul & Mofijur 2013, 473 – 490.) Therefore, in the study of biodiesel blending, alcohol fuel as another additive fuel is widely used.

Biodiesel is blended with petroleum diesel. In many countries, the blending amount of biodiesel is 2%, 5%, 10%, 20%, 30% and so on, which are called B2, B5, B10, B20 and B30 diesel respectively. The function of biodiesel in B2 diesel is to improve the lubricity of diesel. High content of biodiesel is beneficial to reduce the emission of harmful gases and protect the environment. (Knothe 2006, 823 – 833)

5.3 Current application status of biodiesel

Biodiesel is mainly used in fuel and chemical industry. As a fuel, biodiesel is usually mixed with conventional diesel in different proportions. The hybrid diesel is then applied to a diesel engine. The use of 100% biodiesel is rare but exists. This has strict requirements for raw materials and products, such as Germany using low erucic acid, low glucosinolates rapeseed oil production. Many countries in Europe and the United States have 100% biodiesel standards, but the production cost is high, the performance is not particularly perfect and ideal, so the application is less. (Teoh, Masjuki & Kalam 2015, 96080 – 96096.) In chemical application, biodiesel can be used as low sulfur and low aromatic diesel oil lubrication additive. In order to improve the lubricity of diesel oil, it is necessary to add diesel lubrication additives. Now the lubrication additives commonly used in industry are mainly some amines, esters, acids or their mixed components. Biodiesel has good lubricity. In the United States, biodiesel has been patented as a diesel lubricating additive (US 5730029 and US 5891203). At the same time, a lot of work has been done on the lubrication promotion of biodiesel in foreign countries. In the B2 diesel used in the United States, biodiesel is actually added as a lubricating additive to the diesel. (Singh, Sharma & Singla 2019, 14867 – 14882.) Biodiesel can also be used as an industrial solvent. With the strengthening of environmental awareness of manufacturers and consumers and the improvement of their own protection awareness, environmental protection solvent has become the main direction of the development of industrial solvents. In the United States, soybean oil methyl ester is used in the following fields: cleaning of industrial parts and metal surfaces. Used as resin washing and removing agent. In addition, biodiesel-type fatty acid esters can also be used as carrier fluids for drilling mud, and Henkel has applied for several patents in the United States. Biodiesel can be used as a surfactant. Multifunctional and efficient surfactants prepared from natural renewable resources, which are easy to be biodegradable, safe to human body and environment, have become the main development direction of surfactant industry. Fat acid methyl ester is the raw material of a wide range of surfactants. From fatty acid methyl ester, a variety of surfactants can be produced, such as the production of fatty acid methyl ester sulfonate by sulfonation and neutralization, and the production of fatty alcohol by hydrogenation. Most of the world's natural fatty alcohols are produced by catalytic hydrogenation of fatty acid methyl esters. (Gude & Martinez 2018, 327–341) Biodiesel can be used as a lubricant. Derivatives of fatty acid esters are widely used in additives of automobile oil. Epoxidized fatty acid esters are used as lubrication accelerators of lubricants. The use of vulcanized biodiesel type esters and paraffin wax can improve the high pressure lubrication of lubricants. In addition, biodiesel-type esters can be directly used as lubricants for metalworking processes to produce seamless containers, or as lubricants for high shear and high speed metal rolling processes. Chlorinated or thiofatty acid esters are used as water-based lubricants for metalworking. Fatty acid esters are used as a component of pour point depressant of industrial lubricants. (Singh, Sharma & Singla 2019, 14867 – 14882.) Biodegradable plastics is a key point in the development of plastics industry in the future. One way to produce biodegradable plastics is to introduce fatty polyesters containing ester-based structures that can be degraded by microorganisms into the molecular structure of the polymers. Fatty acid esters of biodiesel type and their derivatives can be used as monomers of polymer resin. Another use of biodiesel type fatty acid esters is as plasticizers for polymer materials. At present, the production and consumption of plasticizers are mainly phthalate esters with good comprehensive performance and low price. In addition, fatty acid esters are also an important plasticizer compound, such as plasticizer used for automobile tires and elastomer stabilizer. (Yusuf et al. 2011, 2741–2751) Some countries have begun to produce biodiesel in large quantities and the biodiesel produced has already been used. Some countries are not in production and are in the experimental stage. (Souza et al. 2017, 455 – 478) TABLE 5. describes the output and application of biodiesel in some countries. As can be seen from TABLE 5, biodiesel has been put into production and used in all countries at the current stage, but it has not been promoted and used on a large scale due to the limitations of some technologies. From the current use and application of biodiesel, biodiesel performance is very good.

TABLE 5. Production and application of biodiesel in some countries (Adapted from Souza et al. 2017, 455 – 478)

Countries	Biodiesel production (10,000 tons)	Main raw materials	Biodiesel application	The proportion of biodiesel blending
Germany	200	Canola oil, soybean oil, animal fat	Diesel cars	B5—B100
France	49.2	Vegetable oil all kinds	Diesel cars	B5—B30
Italy	60	Vegetable oil all kinds	Diesel engine	B20—B100
Britain	34.5	Vegetable oil all kinds	Diesel cars	B10—B20
Austria	14	Vegetable oil, waste oil	City bus	B100
Poland	10	Vegetable oil all kinds	Diesel cars	B10—B20
Spain	7	Vegetable oil all kinds	Diesel cars	B10—B20
Japan	40	Waste vegetable oil	Agricultural machinery, buses	B30
Brazil	Driving test	Castor oil, palm oil, soybean oil	Diesel cars	B2—B5

5.4 Emission analysis of biodiesel

In order to investigate the emission performance of alternative fuel biodiesel, experiments were carried out on a supercharged and intercooled diesel engine and compared with 0# diesel . Compared with 0# diesel, although biodiesel has a slightly lower calorific value, it has less sulfur content and less aromatic hydrocarbon content. It is also oxygenated fuel, which is conducive to the full combustion of the fuel and can reduce the content of hydrocarbon (HC) and soot. (Kainar & Wang 2018, 203—208) The engine model used in the experiment is 4100QBZL, a 4-cylinder, water-cooled, supercharged, intercooled, direct injection diesel engine. TABLE 6. is the parameters of the engine. The engine exhaust gas adopts the multi-component detection system AVL FTIR I60, which can measure the transient values of more than 20 exhaust pollutants online. The concentration of particulate emissions in the exhaust gas was measured using AVL Micro Soot Sensor 483 microfume tail gas analyzer.

TABLE 6. 4100QBZL engine parameters (Adapted from Kainar & Wang 2018, 203—208)

Type	**4100QBZL**
Bore/mm	100
Travel/mm	105
Number of cylinders	4
Combustion Chamber Type	Direct injection ω type combustion chamber
Total piston displacement/L	3.298
Compression ratio	17.5
Calibration power/kW	70
Calibration speed /(r· min^{-1})	3200
Maximum torque: rotational speed /(N·m·r· min^{-1})	245 / (2000 — 2400)
Oil supply advance Angle /(° Ca)	14 ± 2

FIGURE 4. shows the variation trend of the exhaust product NOx of the two fuels with the output speed and output torque of the engine. From FIGURE 4, it can be seen that NOx content presents an upward parabola shape with the increase of speed, and reaches the lowest near 1600 r /min, mainly because the engine is in the optimal combustion state near 1600 r /min, and combustion conditions are not conducive to the generation of NOx. It can also be seen that the NOx emission of biodiesel is significantly lower than that of 0# diesel, mainly because the cetane value of biodiesel is higher than that of 0# diesel, which makes the ignition retardation period of the fuel shorter, the exothermic peak of pre-mixed combustion decreases, the temperature in the engine cylinder decreases, and the NOx emission decreases. (Shameer, Ramesh, Sakthivel & Purnachandran 2017, 1267 – 1281.)

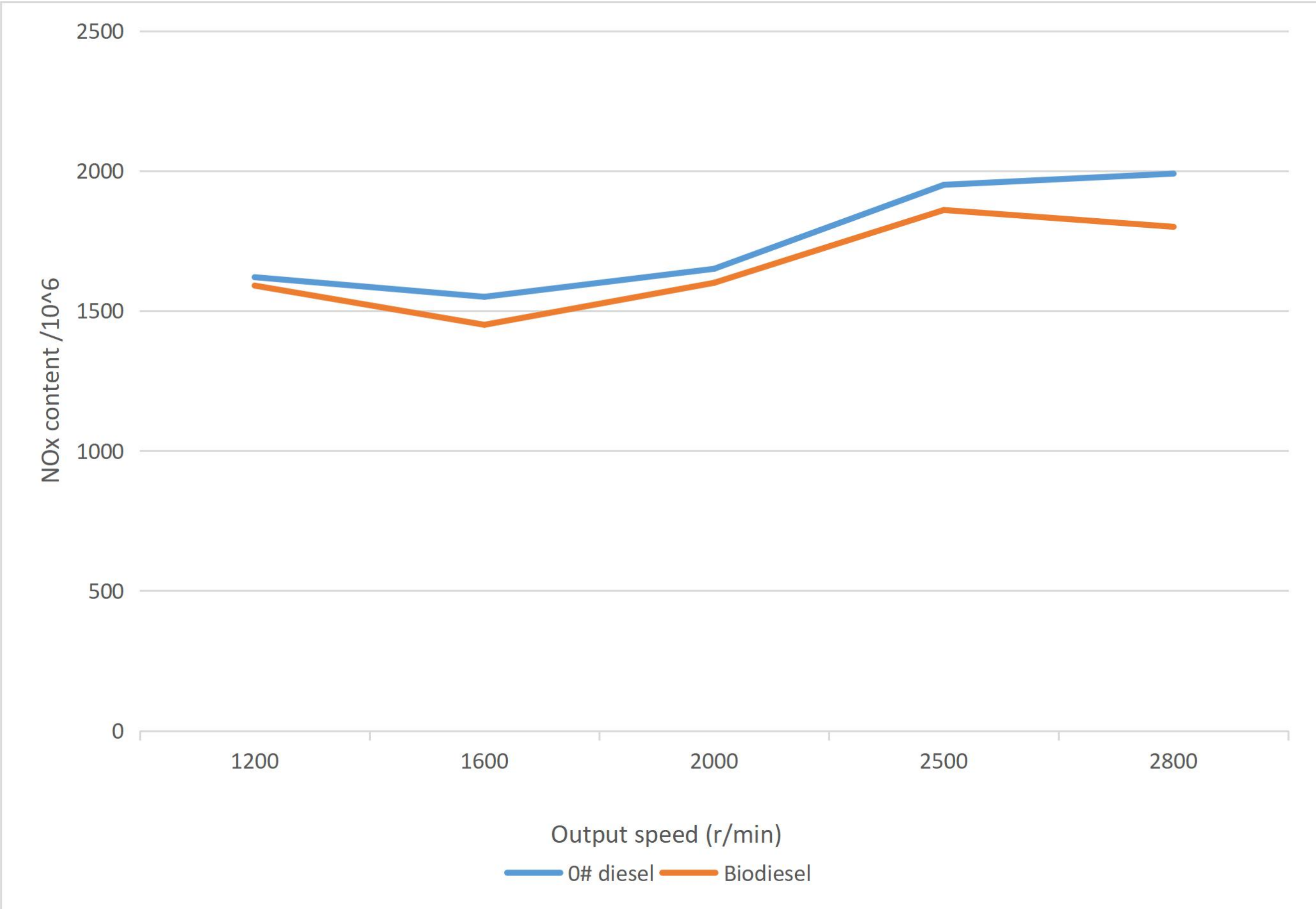

FIGURE 4. NOx emission comparison (Adapted from Shameer et al. 2017, 1267 – 1281)

As can be seen from FIGURE 5, the soot emission of the two fuels presents an upward parabola shape, because at low speed, less air enters the engine and the air flow movement is weak, resulting in uneven mixing of air and fuel, insufficient combustion, and further increasing HC content which cannot be fully burned, so the soot emission increases. At high speed, the fuel injected into the engine cylinder increases, excessive air decreases, resulting in local hypoxia in the cylinder, dehydrogenation cracking and soot content rises, with the increase of the engine speed, the combustion duration per unit cycle is shortened, so that the generated soot is discharged out of the cylinder without further combustion, so the soot emissions increase. (Kainar & Wang, 203—208) Compared with 0# diesel, the soot emission of biodiesel is reduced. This is because the molecular structure of biodiesel contains oxygen, which can further promote the full combustion of the fuel. In addition, aromatic hydrocarbon is a combination with benzene ring as structure, and its hydrocarbon mass ratio is far greater than that of alkanes, and its chemical structure is relatively stable, and it is not easy to burn. Therefore, the increase of aromatic hydrocarbon content will lead to the increase of soot emission. Considering that biodiesel contains less aromatic hydrocarbons than 0# diesel, its soot emission is reduced. (Senthil, Sivakumar & Manoharan 2015, 423－428.)

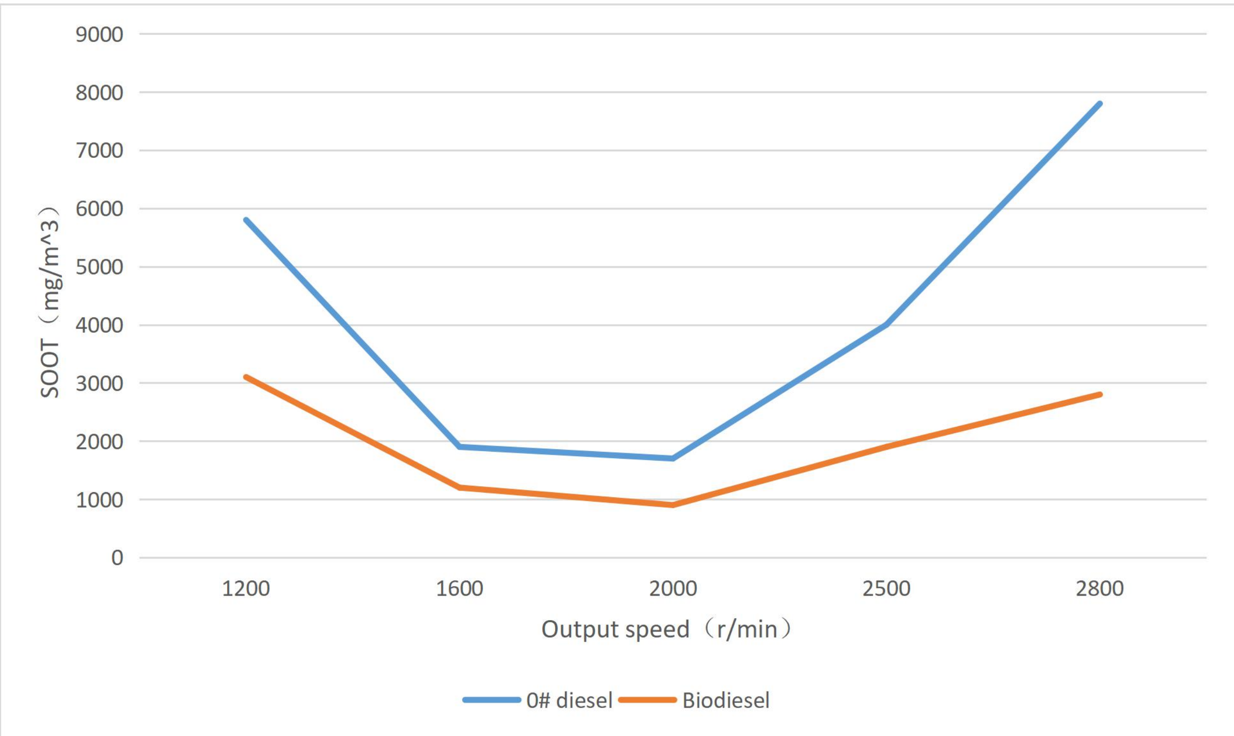

FIGURE 5. Soot emission comparison (Adapted from Shameer et al.2017, 1267－1281)

5.5 Biodiesel and conventional energy performance comparison

The main performance comparison between biodiesel and petrochemical diesel is shown in TABLE 7. The first-generation biodiesel has a high oxygen content and a low calorific value. The second and third generation biodiesel has high cetane number, similar viscosity and caloric value as petrochemical diesel, and low turbidity point, so it is an ideal alternative fuel for petrochemical diesel. (Naik, Goud & Rout 2010, 578－597.)

TABLE 7. Comparison of main performance between biodiesel and 0# diesel (Adapted from Naik et al. 2010, 578－597)

Indicators	**20℃ kinematic viscosity/ ($mm^2 \cdot s^{-1}$)**	**15℃ Density/ ($g \cdot cm^{-3}$)**	**Cetane number**	**Cloud point / ℃**	**Low heating value/(mJ $\cdot kg^{-1}$)**	**Sulfur content/ ($\mu g \cdot g^{-1}$)**	**Oxygen content / %**
First generation biodiesel	4.5	0.885	51	-5	38	＜10	11
Second generation biodiesel	2.9－3.5	0.775 － 0.785	84－99	-30 － -5	44	0	0
Third generation biodiesel	3.2－4.5		73－81	-25 － 0	43	＜10	0
0# diesel (20℃)	3.0－8.0	0.810 － 0.850	≧49			≦350	

6 THE DEVELOPMENT TREND OF BIODIESEL

First, the development of biodiesel can effectively reduce human dependence on oil resources and alleviate the energy crisis. Many countries are developing their economy so that the industry develops very fast. And that requires a lot of oil resources to be put into industrial production. As a renewable green resource, the development of biodiesel can effectively supplement the shortage of petroleum resources, improve the quality and performance of petroleum diesel to a large extent, and reduce environmental pollution. Therefore, biodiesel will be welcomed by the market in the long term. Second, with the increasing prominence of environmental problems, the state and government are increasingly aware of the importance of strengthening the construction of ecological civilization. At present, it is realizing the significance of sustainable development. It begins to promote the reform of industrial structure, and carries on the adjustment and reform in the field of bioenergy and chemical industry in China, and increases efforts to realize the transformation from processing petroleum to biomass. From the "11th Five-Year" industrial demonstration to the "12th Five-Year" industrialization and then to the "13th Five-Year”. Five great development, the country is increasing the proportion of renewable energy in national production, biodiesel as a renewable energy, is bound to be supported by the national policy. Other countries are also aware of the problem of energy shortage and environmental protection, and are making efforts to transform themselves and make a contribution to environmental protection and energy development. Biodiesel with its good market, national policy support and good performance, the development of biodiesel will have a good prospect. (Jie et al. 2010, 525 – 530)

6.1 The development history of biodiesel

The rise in oil prices in the 1970s due to the Arab oil embargo and reduced domestic oil production in the United States contributed to the emergence and development of biodiesel in the late 1980s. In 1988, Neer Company of Germany for the first time to rapeseed as raw material refined biodiesel, its main component is fatty acid methyl ester. The United States, the world's largest consumer of oil, was the one of the first countries to develop biodiesel. In 1998, the United States formulated the corresponding biodiesel standard to strictly regulate the use and production of biodiesel, and in 2002, the American Society for Testing Materials ASTM passed the biodiesel standard. (Hill, Nelson, Tilman, Polasky & Tiffany 2006, 11206 – 11210.) The development of biodiesel in China was first put forward by Academician Min Enze. The largest use of biodiesel is in Europe, which accounts for more than 5% of the refined oil market. In mid-2006, the EU produced more than 4 million tons of biodiesel. Germany has more than 300 biodiesel gas stations in 2006. France has already tested biodiesel in Renault cars, and 100, 000 km of combustion proves that biodiesel can be used in ordinary engines. Italy is by far the most widely used country in Europe for biodiesel, which is already used to heat city buses and public places such as schools and hospitals. (Souza et al. 2017, 455 – 478)

6.2 Market prospects for biodiesel

European countries have developed biodiesel technology better and faster, and European countries have begun to use biodiesel on a large scale, in many diesel cars are using biodiesel. Countries in the European region are also trying to promote the use of biodiesel and have implemented some incentive policies for biodiesel. However, biodiesel has not been widely used, and there are some reasons for this and the current technical limitations. Biodiesel is not performing well in the current market due to high production costs for technical reasons. Even with national policy support, biodiesel is still poorly represented in the market. Today, China still relies mainly on traditional petrochemical energy, most of which is imported. However, Chinese scientists are still advancing on the research road of biodiesel, and the country also attaches great importance to biodiesel. Because the development of biodiesel, an environment-friendly renewable resource, is very much in line with the path of sustainable development that China is taking. In addition, several major industries in China's petrochemical industry also focus on biodiesel. From this point of view, biodiesel has a huge market space in China. China's consumer market is one of the largest in the world, and biodiesel is in line with the current development path. No matter from the performance of biodiesel or environmental performance, biodiesel will become the most important part of the future energy. Combined with the above analysis, the future market prospect of biodiesel is very considerable. (Syafiuddin,Chong, Yuniarto & Hadibarata 2020.)

6.3 Raw material prospects

The raw materials of biodiesel are animal and vegetable oils, waste cooking oil and microbial oil. The source of raw materials is very wide and large. It can be said that the raw materials of biodiesel are inexhaustible. However, considering the high cost of these raw materials for the mass production of biodiesel at this stage, biodiesel is still at this stage if the technical restrictions are not broken, so it is difficult for biodiesel to replace the traditional fossil energy. However, in terms of the source of biodiesel raw material, the future research on biodiesel will certainly reduce the cost of raw material. In another direction, with the development of science and technology, the cultivation technology for plants is more and more advanced, and there may be the emergence of super oil crops in the future. Then the cost of biodiesel will fall even further. With the development of biodiesel technology, biodiesel can replace traditional energy. Because these raw materials are from a wide range of sources and large numbers, and oil is a necessary material for human needs. The raw material of biodiesel has a very good prospect, with the progress of science and technology will only get better and better. (Atabani et al. 2012, 2070 – 2093)

7 CONCLUSION

This thesis analyzes the research and production of biodiesel from five aspects, and uses the sixth part to analyze the future development prospect of biodiesel. It can be concluded that biodiesel meets the needs of future energy development by combining current research and production and application. The first is that the performance is more powerful than traditional energy, and biodiesel is a renewable resource, which solves the problem of energy crisis. The second problem is environmental protection. Experiments show that the NOx and soot emissions of biodiesel are far less than those of traditional diesel. The environmental performance of biodiesel can be obtained from the emission analysis. At the present stage, almost all countries are actively studying biodiesel, and the fastest and most widely used is in Europe. All these are enough to prove the status of biodiesel in green energy. In the long run, biodiesel will bring a lot of economic benefits. Once the large-scale production of biodiesel is popularized, it will not only bring benefits to the development of the country, but also provide a large number of jobs and solve a large part of the employment problem. Biodiesel has made such amazing progress in just 30 years, and in the next 20 to 30 years, biodiesel will be a new energy craze. It is completely possible that biodiesel can be used as a new energy source to replace the traditional petrochemical diesel, which has become a trend.

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