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GUTTER OIL, BIO-DIESEL AND BIO-DIESEL PRODUCED FROM GUTTER OIL

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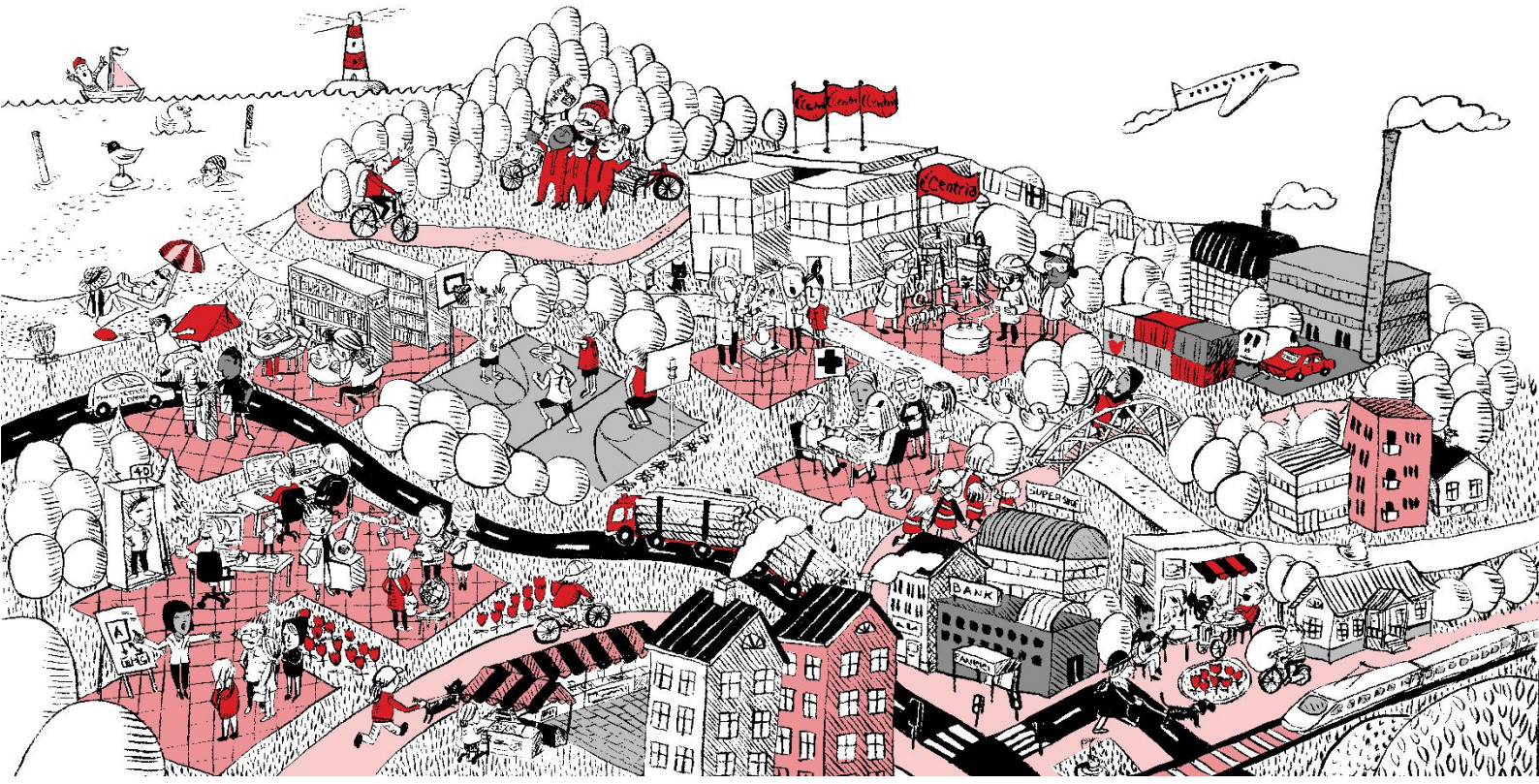

ABSTRACT

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The rapid development of national economy and the growth of population promote the rapid development of energy. The rapid development of energy will lead to serious energy problems and environmental pollution. The development of bio-diesel energy is of great significance to the current global energy structure reform, petroleum safety, transportation industry development, national economic construction, agricultural industrial structure adjustment and environmental protection. In the process of preparing biological organisms, raw materials are the most critical link, and gutter oil is one of the good raw materials. Gutter oil has complex composition, many impurities and high acid value, so it must be pretreated before the preparation of bio-diesel. Pretreatment of gutter oil has become a prerequisite for the preparation of bio-diesel. This thesis work mainly studies and introduces two mature methods in the process of bio-diesel production from gutter oil. They are respectively transesterification reaction method, special transesterification: microwave irradiation technology and hydrogenation and deoxygenation technology.

The transesterification method introduced in this thesis is to catalyze the esterification of gutter oil with low carbon alcohols such as methanol and ethanol under the condition of strong acid or strong base. The corresponding fatty acid methyl ester and ethyl ester, bio-diesel, were synthesized. Because this method is easy to control the reaction conditions, the process flow and technology are relatively mature. So it is the most commonly used method at present and can make the bio-diesel industry. However, the catalyst can only be used once. In order to improve these problems, microwave irradiation technology is introduced in this thesis. It is a more effective method to produce bio-diesel from gutter oil. Microwave irradiation can provide powerful power to reach the reaction temperature in a short time. SrO catalysts can be used in this process. This is a heterogeneous catalyst that is insoluble in any liquid solution and can be recycled. Another method is hydrogenation and deoxygenation. C_{15} ~ C_{18} straight-chain diesel alkanes, namely the second generation bio-diesel, were prepared from gutter oil by hydrogenation and deoxidation. In addition to two production methods of bio-diesel, gutter oil and bio-diesel were introduced in this paper, and the development prospect and existing advantages of bio-diesel were evaluated.

Key words
Catalyst, deoxygenation, hydrodeoxygenation, pretreatment, second generation biodiesel, transesterification, waste oil, microwave irradiation.

CONCEPT DEFINITIONS

HDO

Catalytic hydrogenation and deoxygenation of biomass oil

EN-14214

Quality standards for bio-diesel

ASTM D-975

Technical specification for diesel oil

SrO

Strontium oxide, CAS：1314-11-0

PAHs

Polycyclic Aromatic Hydrocarbons

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1 INTRODUCTION

With the traditional energy increasingly exhausted today, the research and development of renewable energy has undoubtedly become the only way to maintain human survival. Bio-diesel, derived from animal and plant fats, is one such renewable energy source. Now bio-diesel has become an effective supplement to traditional diesel in some developed countries. By mixing with traditional diesel, bio-diesel plays a positive role in saving resources and reducing pollutants.

Traditional bio-diesel is methyl ester or ethyl ester of fatty acids produced by esterification or transesterification of animal and plant fats, with its carbon chain concentrated in C_{14}-C_{18}. The carbon chain of petroleum diesel is concentrated in C_{11}-C_{22}, which is a hydrocarbon and does not contain oxygen. Bio-diesel is an ester and contains oxygen. Because it does not contain sulfur and aromatic hydrocarbons, diesel products mixed with bio-diesel can greatly reduce pollutant emissions. Bio-diesel also has good lubrication performance and high cetane value. The national standard requires the cetane value of conventional diesel not less than 45, generally between 45-50, more than 52 is rare, but the cetane value of bio-diesel is as high as 56-62. Of course, bio-diesel has some disadvantages, such as low calorific value. The calorific value of bio-diesel is only 90% of that of traditional diesel. So the fuel consumption of bio-diesel alone is higher than that of petroleum diesel, and the fuel consumption of mixed use has no obvious change. In addition, bio-diesel has poor start-up performance at low temperature. However, because of its own characteristics, bio-diesel has become the best substitute for petroleum diesel. The cooperative use of bio-diesel and petroleum diesel is the future direction of diesel application. (Zhai 2011,1364-1369.)

In this paper, the production of bio-diesel from gutter oil was studied and elaborated. The current main problems restricting the development of the second generation of bio-diesel industrialization is high cost. According to statistics, 80% of the cost of bio-diesel preparation is raw material costs. If use oil crops as raw materials in process generally high cost. So the cheap raw materials is the key to the second generation of bio-diesel. According to reports, China will generate every year only 300 ~ 5 million tons of waste oil, of which 200 ~ 3 million tons of cooking oil will be returned to the table. Because of the cooking oil contains a large number of harmful substances to human body, once were edible, will cause serious damage to human health. The best solution is to recycle. (Demirbas 2019,14-34.) Therefore, the production of bio-diesel with gutter oil as raw material has a wide range of raw

materials, which can avoid gutter oil entering the food chain and realize the resource utilization of gutter oil, thus playing a supplementary role to the shortage of fuel.

The purpose of this paper is to describe the development status, advantages and disadvantages of bio-diesel at the present stage, and introduce two mature production technologies of bio-diesel from gutter oil. This paper is divided into three main parts. The first part introduces the definition, composition, present situation, harm, treatment methods and policies of gutter oil. Secondly, in the second part, this paper briefly introduces the types, advantages and disadvantages, development and policies of bio-diesel. In the third part, the esterification reaction and hydrogenation and deoxygenation are introduced. And the advantages and disadvantages of the two methods are analyzed. In addition, the economy and environmental protection of producing bio-diesel from gutter oil are evaluated. The significance and development trend of bio-diesel will also the explained.

2 GUTTER OIL

In a broad sense, gutter oil refers to all kinds of inferior oils, also known as slop oil, derived from slop bucket. waste oil from frying is oil after many times frying, waste oil from cooking is in a narrow sense, derived from sewage of catering industry. Gutter oil in this paper refers to gutter oil in a broad sense. (Gopan, Raja & Krishna 2021, 1208-1211.) This chapter will introduce the status quo, harm of gutter oil, composition of gutter oil, policies of some countries on gutter oil.

2.1 Current status of gutter oil

Waste oil is a kind of non-edible oil of extremely poor quality and extremely unsanitary. China is a major consumer of edible oil, and a considerable part of the edible vegetable oil consumed is discarded after use. (Brandon, Cheng & Yuqi 2020.) In some aspects, the recycling of waste oil is undoubtedly a huge source of cheap biodiesel raw materials. (Gopan, Raja & Krishna 2021, 1208-1211.)

2.2 The harm of gutter oil

Gutter oil has many harms. In other words, it will lead to various diseases when people ingest it. Such as: indigestion, diarrhea, severe abdominal pain, stomach cancer and bowel cancer.

A series of chemical changes such as rancidation, oxidation and decomposition of animal and plant oil will occur after being polluted. Arsenic is one of them. Once people use "gutter oil" with a large amount of arsenic, it will cause symptoms such as indigestion, headache, dizziness, insomnia, fatigue and discomfort in the liver area. (Zhang & Jiang 2017.)

The production process of "gutter oil" is doomed to be unhygienic. Once the waste oil reaches the intestine, a large number of harmful microorganisms will enter the intestine, such as bacteria and fungi, can cause diarrhea in some cases. A series of gastrointestinal diseases such as nausea and vomiting in others. (Zhang & Jiang 2017.)

"Gutter oil" is a mix of sewage, garbage and detergent. It is extracted in the open air by underground workshops, and is unable to remove bacteria and harmful chemicals. It is an undisputed fact that all

"gutter oil" contains serious lead levels, and the consumption of food made with such levels can cause severe abdominal cramps, anemia, toxic liver disease and other symptoms. (Zhang & Jiang 2017.)

The refining process is the cause of gutter oil toxin. "Gutter oil" is refined and processed from slops and waste oil collected from hotels and restaurants to remove foul odors and flow into the edible oil market. Oil and waste contain aflatoxin and benzo pyrene, both of which are carcinogens and can lead to cancer of the stomach, bowel and kidney, as well as cancer of the mammary gland, ovary and small intestine. (Zhang & Jiang 2017.)

2.3 Composition of gutter oil

Triglycerides are the main ingredients in cooking oil, and arsenic and lead levels in gutter oil generally exceed the standard. The same is true for harmful impurities such as aflatoxin and benzopyrene. In addition, compared with ordinary cooking oil, the specific components of gutter oil contain a lot of exogenous trace pollutants. (Zhang & Jiang 2017.)

2.3.1 Acid content of gutter oil

Before introducing the acid content of gutter oil, need to understand what the acid content is. In chemistry, acid content means the number of milligrams of potassium hydroxide (KOH) required to neutralize 1 gram of a chemical substance. The acid content is a measure of the number of free carboxylic acid groups in a compound (such as a fatty acid) or a mixture. The typical measurement procedure is to dissolve a known sample in an organic solvent. Phenolphthalein solution can be used as a color indicator in the process, and potassium hydroxide solution of known concentration can be used for titration. (Gad, Hashim, & Mohaned 2021.)

Acid content can be used as the index of oil deterioration degree. When the oil becomes rancidity, triglycerides will be decomposed into fatty acids and glycerol, resulting in an increase in acid content. There are many international standards related to acid content detection methods. For example, ASTM D974 and DIN51558 are for the acid content detection of mineral oil and bio-diesel. For the acid content detection of bio-diesel, EU standards EN 14014 and ASTM D664 are widely used in the world.

According to EN 14214 and ASTM D6751, the acid content (mg potassium hydroxide /g oil) of bio-diesel should be less than 0.50 mg KOH/g. (Gad, Hashim & Mohaned 2021.)

The acid value of gutter oil is high, so pretreatment of its acid value is the key to biodiesel production. The main components of fatty acids in gutter oil are shown in TABLE 1. It can be seen from TABLE 1 that the composition of fatty acids in gutter oil is basically similar to that of other animal and plant fats. But there are differences in specific values. Gutter oil has many problems, such as complex composition, poor volatility, poor mixing effect with air and easy thermal polymerization. (Liang, Liu & Xu 2013.)

TABLE 1. Fatty acid composition of waste oil. (adapted from Liang, Liu & Xu 2013.)

Fatty acid% Raw material	⩽ Sour %	C14:0	C16:0	C16:1	C18:0	C18:1	C18:2	C18:3	⩾C18
Waste oil	0	1	23	1	10	50	15	0	0
Colza oil	0	0	12	0	1	10	15	10	60
Soya-bean oil	0	0	4	0	4	23	55	7	1
butter	0	2	27	2	25	40	2	0	2
lard	0	1	25	2	14	46	10	0	3

2.3.2 Harmful substances in gutter oil

The source of gutter oil is complex, which contains many toxic and harmful substances and is difficult to remove. The detected toxic and harmful substances mainly include aflatoxin, benzo pyrene, heavy metals and others. (Zhang & Jiang 2017.)

Aflatoxin($C_{17}H_{12}O_6$) is a compound containing an oxanaphthalone (coumarin) and a difuran ring. Among them, the former is related to carcinogens, while the latter is the basic toxic structure. (Zhang & Jiang 2017.) Twelve types of aflatoxins have been detected. Namely B1, B2, G1, G2, M1, M2, P1, Q, H1, GM, B2A and toxol. Alatoxin is mainly composed of coumarin and difuran ring, in which B1 is a derivative of dihydrofuran oxanone, and M1 is a metabolite derived from aflatoxin B1 through hydroxylation in vivo. (Zhang & Jiang 2017.) Aflatoxin is a highly toxic substance that can damage human and animal liver tissue. In severe cases, lead to liver cancer and even death. The most common in spoiled foods is aflatoxin B1, which is also the most toxic and carcinogenic. Long-term

consumption of gutter oil is equivalent to long-term intake of aflatoxin, which can lead to diseases such as stomach and bowel cancer or cancer of the breast, ovary and small intestine. (Zhang & Jiang 2017.) The chemical structure of aflatoxin is shown in FIGURE 1.

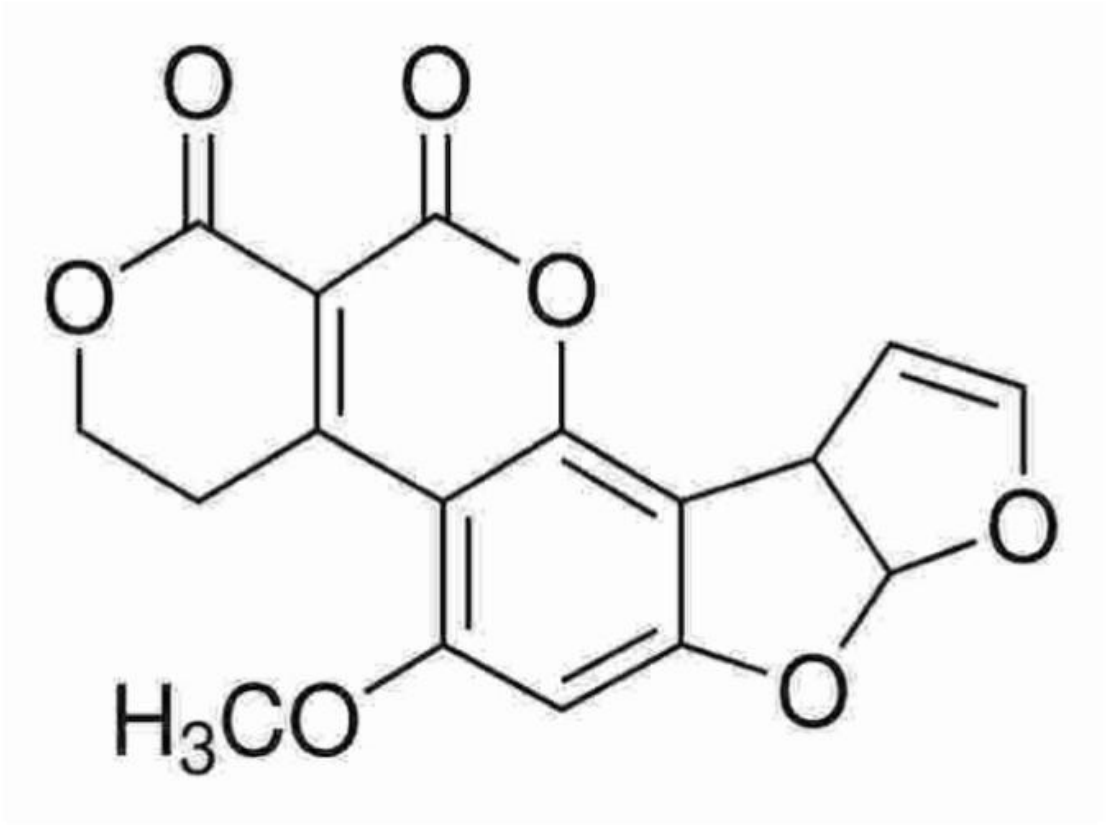


FIGURE 1. Aflatoxin. (adapted from Zhang & Jiang 2017.)

Benzopyrene($C_{20}H_{12}$) is a representative of 18 PAHs and is the most toxic of the benzene series. The most important reason why gutter oil is poisonous is that it contains a large amount of benzopyrene. Benzopyrene is found mainly in gutter oil and oil refining, and is produced by repeated use of oil used to fry food. (Zhang & Jiang 2017.)

Benzopyrene itself can not be carcinogenic directly, only through enzyme activation has a high carcinogenicity. Benzopyrene is widely found in the atmosphere and water environment, and has no correlation with the content of other polycyclic aromatic hydrocarbons. Long-term living in the air environment containing Benzopyrene will cause chronic poisoning. Experiments show that benzopyrene is carcinogenic, teratogenic and mutagenic, combustible when exposed to open fire and

high heat, and poisonous gas is released by high heat decomposition. (Zhang & Jiang 2017.) The chemical structure of benzopyrene is shown in FIGURE 2.

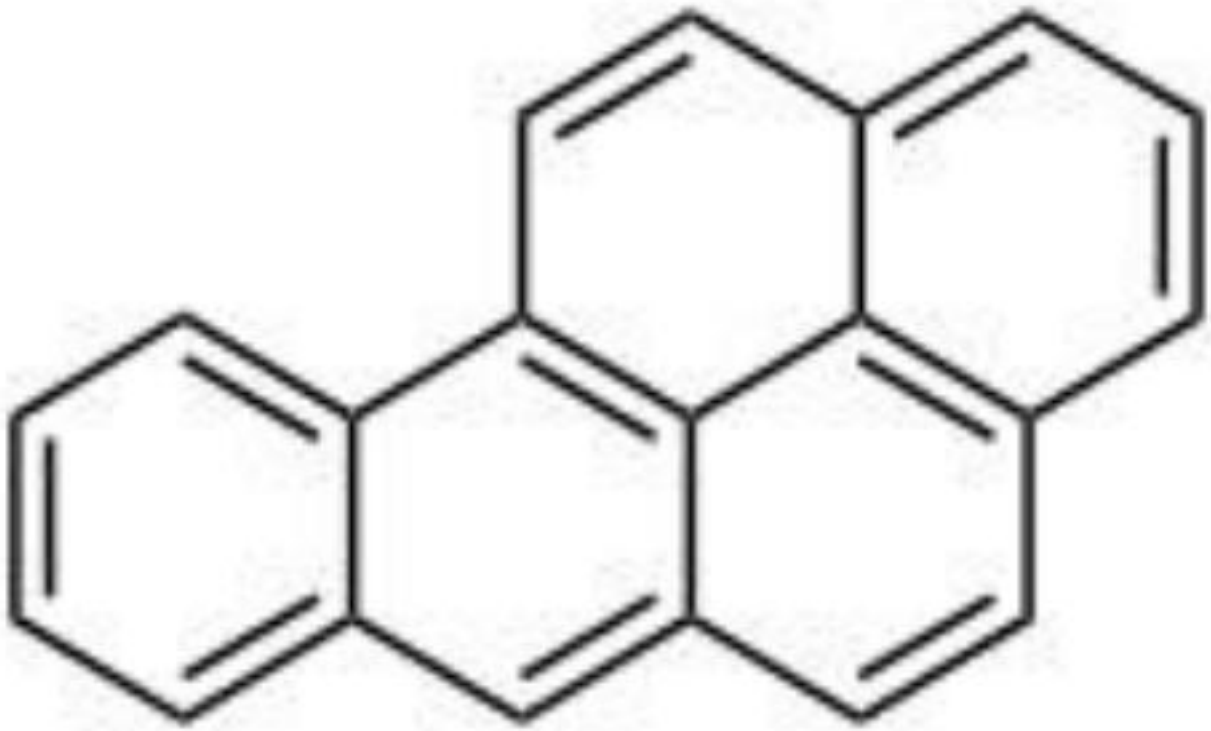


FIGURE 2. Benzopyrene. (adapted from Zhang & Jiang 2017.)

Heavy metals refer to metals with a specific gravity of more than 5. Such as gold, silver, copper, iron and lead. Heavy metals in the human body excessive, will cause chronic poisoning. Proteins, enzymes and other substances in the human body can react with heavy metals, making them inactive and accumulating in some organs of the human body, causing chronic poisoning. Heavy metals can also interfere with the normal physiological function of the human body and harm human health. Under normal circumstances, the heavy metals in the cooking oil will exceed the standard, and the consumption of such cooking oil will cause diseases. (Zhang & Jiang 2017.)

2.4 Policies on the management of gutter oil

There are many substances harmful to human health in the gutter. In order to prevent gutter oil from entering people's food and dining tables, gutter oil should be treated and used reasonably and

efficiently. Many countries have issued many regulations on the gutter oil. This chapter will introduce the specific policies of some countries.

2.4.1 China's policy on gutter oil management

The government cracked down on the illegal production and sale of edible oil. The government urges all localities and departments to make edible oil supervision an important part of food safety rectification. The focus is on urban and rural areas and the suburbs of cities. Relevant departments carefully investigate and clean up black spots in illegal production of waste oil. The task is to find out the source of raw materials and sales channels of edible oil. In response to discovered problems, black spots are banned and illegal and criminal acts are severely cracked down. (Zhang, Zhang & Qiu 2017, 708-715.)

In cities, mining areas, scenic spots and other catering industry centers as key areas, food production or small workshops, small restaurants, food stalls, hot pot restaurants and school canteens, corporate canteens, collective canteens, etc. are the main targets. The government has strengthened the verification of edible oil purchase records, and investigated and punished the edible oil purchased from illegal channels and processed foods with waste edible oil. (Zhang, Zhang & Qiu 2017, 708-715.)

2.4.2 Management policy on gutter oil in Japan

Japan has strict management policies on gutter oil. First, the Japanese government collects gutter oil at high prices. Second, to immediately add completely inedible hemp oil to prevent it from being reprocessed and sold. Professional companies process recycled gutter oil into biodiesel that can be burned by garbage trucks. With the help of public opinion, Japanese society attaches great importance to food hygiene and safety. If an enterprise is caught using gutter oil, besides being severely punished by the law, it will surely go bankrupt due to the loss of customers, which has curbed this phenomenon to a certain extent. (Zhang, Zhang & Qiu 2017, 708-715.)

2.4.3 U.S.policy on the management of gutter oil

According to the Environmental Protection Department of the United States, gutter oil is forbidden to be poured into sewers, and household oil waste and kitchen waste must not be mixed together and

must be disposed of centrally. While the U.S. government has no mandatory recycling requirements for kitchen waste, states have detailed regulations for cooking oil, and the collection of cooking oil is integrated with local government recycling programs. (Zhang, Zhang & Qiu 2017, 708-715.)

3 BIO-DIESEL

Bio-diesel refers to fatty acid methyl or ethyl esters formed by ester conversion of vegetable oil, animal oil, gutter oil or microbial oil and methanol or ethanol. Also other bio-products beside fatty acid alcohol esters can called bio-diesel. Vegetable oils generally include rapeseed oil, soybean oil, peanut oil, corn oil, cottonseed oil and the like. Animal oils generally include fish oil, lard, tallow, mutton and others. (Gopan, Rajan & Krishna 2021, 1208-1211.)

Bio-diesel is a typical "green energy", with good environmental performance, good engine starting performance, good fuel performance, a wide range of raw material sources, renewable and other characteristics. Vigorously developing bio-diesel has important strategic significance for sustainable economic development, promoting energy substitution, alleviating environmental pressure and controlling urban air pollution. (Gopan, Rajan & Krishna 2021, 1208-1211.)

3.1 An overview of bio-diesel

Bio-diesel, also known as fatty acid methyl ester, is obtained from plant fruits, seeds, plant tube milk or animal fat oil, waste edible oil and others as raw materials, and through esterification reaction with hexamethylene (methanone, ethanol). As a kind of renewable energy, bio-diesel has become a hot research topic due to its outstanding advantages such as high cetane number, non-toxic, sulfur free, renewable and biodegradable. (Li & Zhong 2006.)

Bio-diesel has some obvious advantages in that it is low in sulfur. It can reduce sulfur dioxide and sulfide emissions by about 30%. Bio-diesel has good lubrication performance, which can reduce the wear of fuel injection pump, engine cylinder and connecting rod, and extend its service life. Bio-diesel has good fuel performance, and its safety in transportation, storage and use is better than that of ordinary diesel. In addition, bio-diesel is a kind of renewable energy, and it is also a kind of biodegradable energy. Moreover, bio-diesel has a wide range of raw materials, such as rapeseed oil, cottonseed oil, soybean oil, peanut oil, corn oil, lard, butter, algae oil, waste oil of catering industry and others. (Li & Zhong 2006.)

3.2 Types of bio-diesel

At present, bio-diesel has developed into the third generation. This chapter will introduce the definition, advantages and disadvantages of the first generation, the second generation and the third generation bio-diesel respectively.

3.2.1 First generation bio-diesel

The first generation of bio-diesel was made from edible oil. Such edible oils include palm oil, soybean and rapeseed oil. The advantage of the first generation of bio-diesel is that it is a renewable energy, easy to produce, usually through the transesterification process, and is an environmentally friendly energy source. However, the disadvantage of using edible oil to produce bio-diesel is the competition between food and bio-diesel resources and the scarcity of land. (Bhikuning, Sugawara & Matsumura 2020, 11-19.)

3.2.2 Second generation bio-diesel

The raw materials of second-generation bio-diesel are not limited to edible oil. Lignin benefits, cellulosic biomass plants, waste oil and agricultural residues can all be used as raw materials for the second generation of bio-diesel. The advantage of the second-generation bio-diesel is that there is no competition from food crops, a large amount of land is not required, and the resources are renewable and environmentally friendly. However its disadvantages are high production cost and high processing technology requirements. (Bhikuning, Sugawara & Matsumura 2020, 11-19.)

3.2.3 Third generation bio-diesel

Third-generation bio-diesel is made from oleaginous microorganisms such as fungi, algae and bacteria. The benefits of third-generation bio-diesel are no conflict between land and food, high accumulation in lipid cells, and environmentally friendly. Its disadvantages are large scale of production and high cost. (Bhikuning, Sugawara & Matsumura 2020, 11-19.)

3.3 Application of bio-diesel

Bio-diesel mainly refers to fatty acid methyl esters or fatty acid ethyl esters. Bio-diesel currently has many application fields and directions. Bio-diesel can be used not only as a fuel, but also as a raw material or intermediate for chemical products, such as industrial solvents, or for the preparation of surfactants. This chapter respectively introduces the three main uses of waste oil as fuel and the five main uses of waste oil as chemical chemical products or chemical intermediates. At the end of this chapter, the advantages of waste oil and the policies of various countries are analyzed.

3.3.1 Bio-diesel as fuel

Compared with petroleum diesel, bio-diesel has many advantages, such as high cetane number, low sulfur content, no aromatics, high flash point, good lubrication performance and fast biodegradation. (Liang, Liu & Xu 2013.) When bio-diesel is used as a fuel, it can be used as 100% bio-diesel, which have strict requirements for raw materials and products, such as Germany with low erucic acid and low sulfur glucoside of rapeseed oil production, the product can meet the euro Ⅲ emission requirements. Several countries in Europe and the United States have 100% bio-diesel standards. (Liang, Liu & Xu 2013.)

Another use is to mix with petroleum diesel. In addition to China, some countries commonly used bio-diesel blending amount are 2%, 5%, 10%, 20%, 30%, etc., respectively known as B2, B5, B10, B20 and B30 diesel. The function of bio-diesel in B2 diesel is to improve the lubricity of diesel oil. The higher bio-diesel content is beneficial to reduce the emission of harmful gases and protect the environment. At present, other countries do not have a separate standard for this blend of diesel, as long as 100% bio-diesel meets the corresponding standards, for example, the United States requires bio-diesel to meet ASTM D6751 standard before it can be used as a diesel blend component. (Liang, Liu & Xu 2013.)

Of course, bio-diesel can also be used as a fuel for household stoves. Bio-diesel is rarely used as a fuel in China, one of the main reasons is that national standards have not yet been enacted and are currently being developed by the Research Institute of Petrochemical Technology. In addition, the various bio-diesel manufacturers generally have their own enterprise standards, such as the standard Q/LYZY01-2002 developed by Fujian Zhuoyue New Energy Development Company. (Liang, Liu & Xu 2013.)

3.3.2 Bio-diesel as a chemical product or chemical intermediate

Bio-diesel can be used as a lubricating additive for low-sulfur and low-aromatic diesel. The use of poor lubricity of diesel will increase the wear of the pump, prone to accidents. 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. Bio-diesel has good lubricity. The United States has used bio-diesel as a diesel lubrication additive patent. (US 5730029 and US 5891203.) At the same time, other countries have done a lot of work in the aspect of bio-diesel lubrication facilitation. In the B2 diesel used in the United States, bio-diesel is actually added as a lubricating additive to the diesel. (Brandon, Cheng & Yuqi 2020.)

Bio-diesel can also be used as an industrial solvent. Industrial solvents are playing a more and more important role in various industrial fields. At the same time, their pollution to the environment has become the focus of people's attention. 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. Environmental protection industrial solvents require high flash point and ignition point, low toxicity, low content of volatile organic compounds, low odor, easy degradation and others. Methyl esters of fatty acids derived from vegetable oils fit these characteristics. Fatty acid methyl ester has the characteristics of reproducibility, low volatile organic matter content, high flash point, easy degradation, non-toxic, strong solubility and others, and has been used as industrial solvent in some countries. At present, fatty acid methyl esters are widely used as industrial solvents in the United States. (Brandon, Cheng & Yuqi 2020.)

Bio-diesel can also be used as an industrial chemical. Fatty acid esters have a wide range of applications in industrial chemicals. These applications are usually based on various chemical structures of fatty acids, including hydroxylation, epoxidation, sulfonation/sulfonation and others, corresponding to hydroxyl fatty acid esters, epoxidation fatty acid esters, fatty acid esters sulfate/sulfonated fatty acid esters. These derivatives are not direct products of the biodiesel plant. Their production can be combined with the production of bio-diesel to improve the overall economic efficiency of the bio-diesel plant. These bio-diesel fatty acid esters and their derivatives have many uses, such as in medicine and cosmetics, a variety of fine chemicals, printing inks, magnetic recording media and others. (Brandon, Cheng & Yuqi 2020.)

Bio-diesel can also be used as a pesticide synergist to produce pesticides. This includes active components of fertilizers, pesticides, herbicides and their synergists, although fatty acid esters are not used as active components of pesticides or herbicides, but as synergists of them. In addition, fatty acid esters have other uses, such as being used with other substances as a desiccant for grains. (Brandon, Cheng & Yuqi 2020.)

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 bio-diesel type and their derivatives can be used as monomers of polymer resin. Another use of bio-diesel type fatty acid esters is as plasticizers for polymer materials. The function of plasticizer is to improve the flow performance of thermoplastic plastics, is the largest type of plastic additives used. 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. (Brandon, Cheng & Yuqi 2020.)

3.4 Advantages of bio-diesel

Bio-diesel has excellent environmental protection characteristics. Bio-diesel is low in sulphur and can reduce sulphur dioxide and sulphide emissions by about 30%, 70% with catalysts. Bio-diesel does not contain aromatic alkanes which cause pollution to the environment and its exhaust gas is less harmful to human body than petroleum diesel. Tests have shown that the use of bio-diesel can reduce the air toxicity by 90% compared with ordinary diesel. Because bio-diesel has high oxygen content and less smoke when burned, carbon monoxide emissions can be reduced by about 10%, 95% with a catalyst. (Sun,Zhao & Liu 2019.)

At the same time, bio-diesel has high biodegradability. (Sun,Zhao & Liu 2019.) It has good lubrication performance, which can reduce the wear rate of fuel injection pump, engine cylinder and connecting rod, and prolong its service life. (Sun,Zhao & Liu 2019.) It has good safety performance. Bio-diesel, due to its high flash point, is not classified as hazardous and therefore has obvious advantages in transport, storage and use. (Sun,Zhao & Liu 2019.) Bio-diesel has good fuel performance. Bio-diesel has high cetane number and better combustion performance than ordinary diesel. The combustion

residue is slightly acidic, which can prolong the service life of catalyst and engine oil. (Sun,Zhao & Liu 2019.) It is renewable. Unlike petroleum resources, bio-diesel as a renewable energy source, its resources will not run out. As the carbon dioxide emitted during the combustion of bio-diesel is much lower than the carbon dioxide emitted during the production and combustion of traditional diesel, bio-diesel is a kind of green diesel. (Sun,Zhao & Liu 2019.)

3.5 Policies and standards for bio-diesel in some countries

With the promotion and application of bio-diesel in the world, the standardization of bio-diesel is gradually improved. Typical international bio-diesel standard-making organizations include the American Society for Testing Materials and its ASTM series of standards, the German Standardization Association and its DIN series of standards, the European Committee for Standardization and its EN series of standards, and the Australian Standards Association and its SA series of standards. Austria promulgated the world's first bio-diesel standard for rapeseed oil methyl ester in 1991, Germany and the Czech Republic in 1994, Sweden in 1996, Italy and France in 1997 and the United States in 1999, respectively. Currently bio-diesel standards have been formulated in Australia, Austria, Czech Republic, Germany, France, Italy, Sweden, the United States and others. (Abdul, Pepijn & Arun 2018, 42-59.)

The main bio-diesel production countries and regions in the world are the United States, Argentina, Indonesia, Brazil and the European Union. The United States uses soybean oil to produce bio-diesel, the Philippines uses coconut oil, and Malaysia uses palm oil. The European Union is an important region for the production of bio-diesel from rapeseed oil, and is also the main region for the production of bio-diesel in the world. In order to encourage the production of bio-diesel, the European Parliament exempted 90% of the tax on bio-diesel, legislated to support alternative fuels and differentiated taxes and subsidized oilseed production.

In 2010, Europe used about 10 million tonnes of feedstocks (translated into oil) for the production of bio-diesel, of which about 4.8 million tonnes were rapeseed oil, 2.2 million tonnes were soybean oil, 440,000 tonnes were sunflower oil and 1 million tonnes were palm oil. Europe produces 4% of its soybean oil, 86% of its rapeseed oil and all of its sunflower oil, and imports more than 98% of its palm oil from Malaysia and Indonesia. The EU consumed 13.55 million tonnes of bio-diesel in 2017 and is

expected to increase to 14.27 million tonnes in 2018, representing a 5.3% increase. (Abdul, Pepijn & Arun 2018, 42-59.)

The EU has constantly adjusted its bio-diesel tariff policy. In order to promote the positive development of the bio-diesel industry. Before 2008, the import and export of bio-diesel among EU member states was free of tariff, and the import of bio-diesel from other countries was charged a tariff of 6.5%. In 2009 the European Commission imposed provisional anti-dumping and countervailing duties on American bio-diesel. In 2015, it extended anti-dumping and countervailing duties on US bio-diesel until 2020. In 2013, the EU imposed provisional anti-dumping duties on bio-diesel from Indonesia and Argentina, with tariffs ranging from 6.8% to 10.6% on Argentine bio-diesel and 2.8% to 9.6% on Indonesian bio-diesel. On April 14, 2015, members of the European Parliament's Environment Committee signed a compromise agreement that sets explicit limits on the use of food-crop based bio-fuels in the transport sector, to be reduced to 7% by 2020. On 30 November 2016, the European Commission published a second renewable energy directive for the period 2021-2030, under which the maximum blending limit for first-generation bio-fuels based on food crops is to be reduced from 7% in 2021 to 3.8% in 2030.The directive calls for an annual reduction of 0.3 percent in the blending limit for first-generation bio-fuels from 2021 to 2025 and 0.4 percent from 2026 to 2030. At the same time, the mixing limit for second-generation bio-fuels will be raised from 1.5 percent in 2021 to 6.8 percent in 2030. (Abdul, Pepijn & Arun 2018, 42-59.)

3.6 The prospect of bio-diesel

As an important petroleum refining product, diesel oil occupies a high share in the fuel structure of various countries and has become an important power fuel. The increasing exhaustion of petroleum resources and the improvement of people's awareness of environmental protection have greatly promoted the development of alternative diesel fuel in the world. Especially in the 1990s, bio-diesel has been paid more attention by all countries for its superior environmental performance. The bio-diesel industry has developed rapidly in western countries. (Abdul, Pepijn & Arun 2018, 42-59.)

Western countries have increased their investment in bio-diesel commercialization, increasing the investment scale of bio-diesel and increasing the number of projects started. The United States, Canada, Brazil, Japan, Australia, India and other countries are actively developing this industry. The research and development of bio-diesel in China started late, but the development speed is very fast. Some of

the scientific research achievements have reached the international advanced level. The research content involves the distribution, selection, breeding, genetic improvement, processing technology and equipment of oil plants. At present, all aspects of the research have achieved phased results, which will undoubtedly contribute to the further research and development of bio-diesel in various countries. (Abdul, Pepijn & Arun 2018, 42-59.)

4 USING GUTTER OIL AS RAW MATERIAL TO PRODUCE BIO-DIESEL

A lot of bio-diesel production technologies have been studied in the laboratory, and a lot of process tests have been carried out for different raw materials. In terms of reaction, it involves physical method, chemical catalysis, biological catalysis, esterification/transesterification reaction without catalyst beyond the boundary. Of course, in terms of materials, bio-diesel can be made from fresh animal oil or vegetable oil or waste industrial oil or gutter oil. This chapter will introduce three bio-diesel production technologies using gutter oil as raw material.

4.1 Bio-diesel prepared by transesterification reaction of gutter oil

The transesterification method uses lower alcohols such as methanol or ethanol as raw materials. The condition is to carry out the transesterification reaction under the action of a strong acid or a strong base as a catalyst. The reaction produces the corresponding fatty acid methyl esters and ethyl esters, that is, bio-diesel. Because the reaction conditions of this method are easy to control, and the process flow and technology are relatively mature, it is currently the most commonly used method for the industrialization of bio-diesel. (Borges & Diaz 2012, 2839-2849.)

4.1.1 Pretreatment of gutter oil

There are a lot of impurities in the gutter oil, so it is necessary to pretreat the waste oil before transesterification to produce bio-diesel. Bio-diesel can be produced from pretreated gutter oil by transesterification reaction. This chapter will introduce the pretreatment method of gutter oil.

Gutter oil contains a lot of solid impurities such as starch, protein, fiber and dust. Water-soluble impurities such as water and salt in gutter oil contain different levels of free fatty acids based on different degrees of hydrolysis. Gutter oil also contains small molecules and microorganisms of different aldehydes, ketones, acids and other substances. Because the components contain a lot of impurities and different oily substances, the whole waste oil is a mixture of components with complex shapes. The processing idea is to purify the oil to different stages according to the different properties

of raw materials and the different purpose requirements. The bottom line is still separation and purification. (Yao 2010.)

For example, after the gutter oil is initially purified, the solid residue and water in it will be removed. The gutter oil after preliminary purification can be connected to the production line to produce bio-diesel. When the product is transformed into pure triglyceride, fatty acid methyl ester or fatty acid, it can be linked with the mature oil chemical industry at present to produce various oil chemical products suitable for it. All of these beneficial applications are based on the collection and purification of raw materials. Purification can be divided into different degrees to remove impurities according to different requirements. The schematic diagram of swill oil treatment process flow is shown in the FIGURE 3. (Yao 2010.)

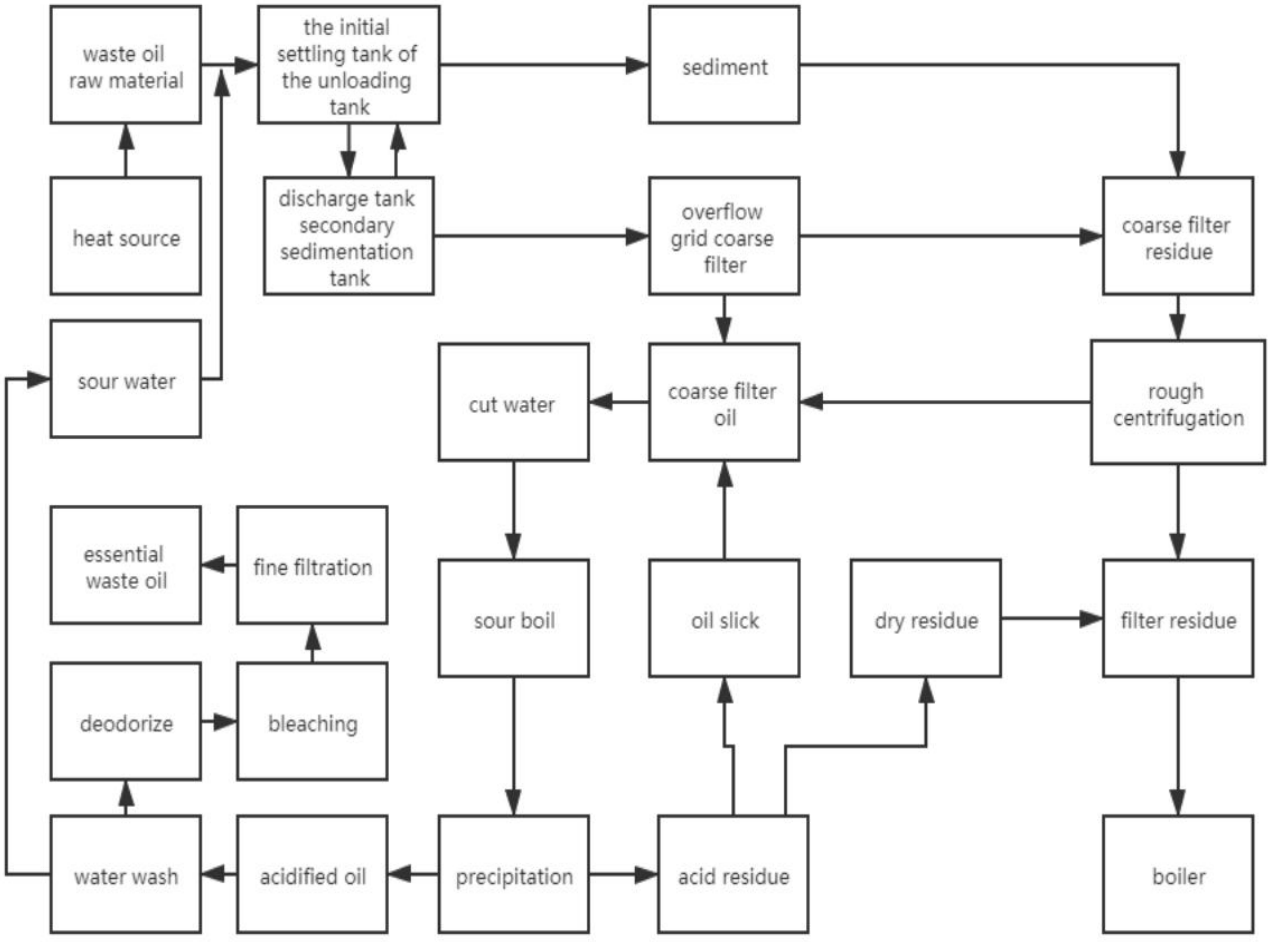


FIGURE 3. Schematic diagram of swill oil treatment process. (adapted from Yao 2010.)

As can be seen in the FIGURE 3, the waste oil feedstock is heated and first stored in the primary settling tank, where the sediment can be separated. After the primary precipitation, the oil will be transported to the secondary sedimentation tank. The crude filter oil is formed through the rough filter of the overflow gate plate. At the same time, the coarse filter residue formed in these two steps can be generated by centrifugation and put into the boiler. The crude filter oil will be boiled by acid and precipitated to form acidified oil, which will be washed, deodorized, decolorized and refined after filtration to become refined waste oil.

If used as a feedstock for bio-diesel, it only needs to be processed into acidified oil, or through fine filtration to further reduce the impurity content. Sewage produced by cutting water is sent to sewage treatment station. The water that has passed the water quality inspection can be recycled, and can generally be used for washing the ground, landscaping and others. The main pollution control processes are shown in the FIGURE 4. (Yao 2010.)

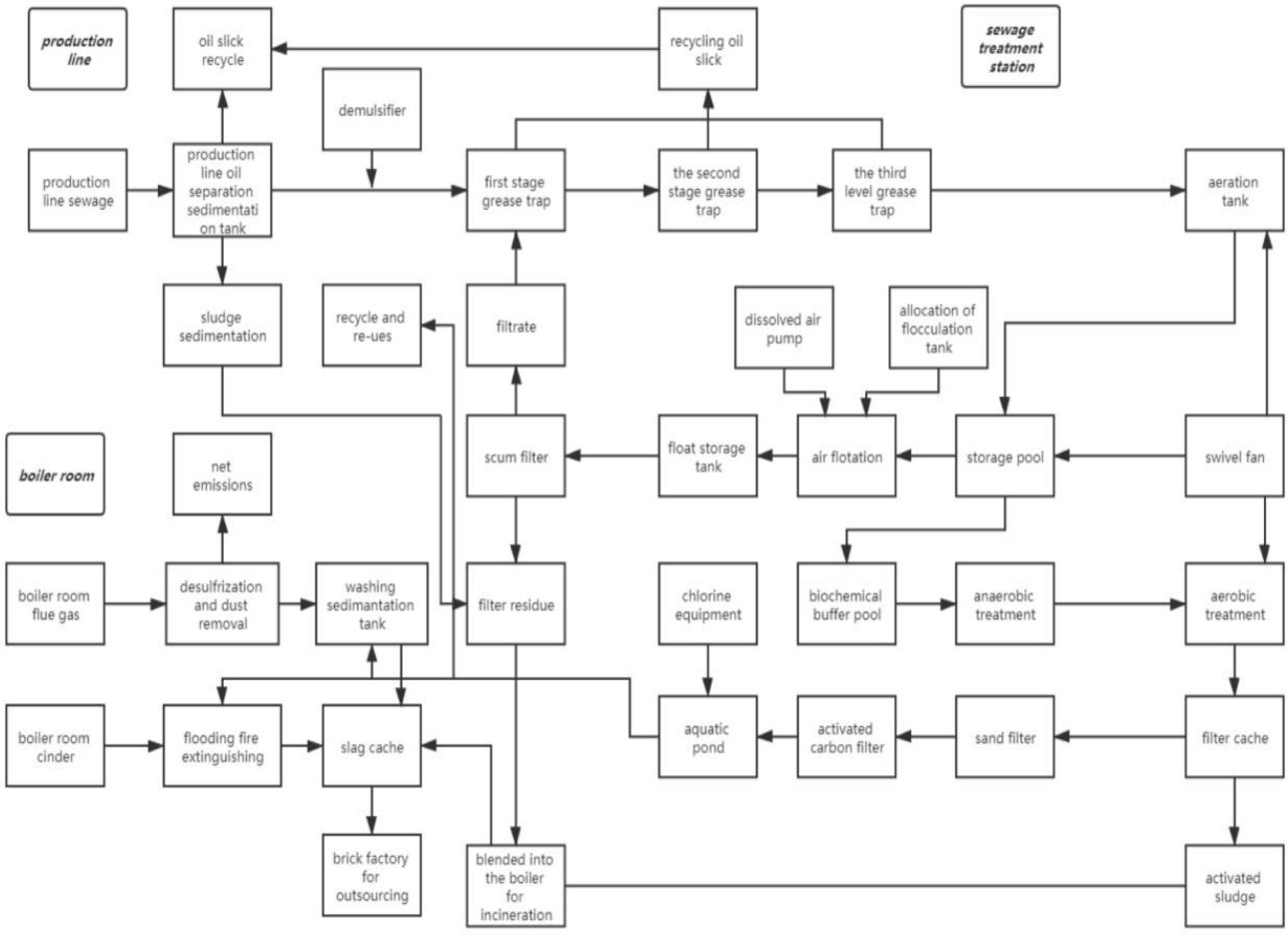


FIGURE 4. Main pollution control process flow chart. (adapted from Yao 2010.)

In FIGURE 4, the process is divided into three parts: the production line, the sewage treatment station, and the boiler room. The first is the production line. As can be seen in the process diagram, the sewage from the production line is recovered to the sedimentation tank and demulsifier is added. And then it is successively introduced into the first stage oil isolation tank, the second stage oil isolation tank, the third stage oil isolation tank and the aeration tank, and the oil slick is recovered. The filter residue produced by air floating scraping foam and scum filtration will be mixed into the boiler for incineration. The impurities after aerobic treatment or anaerobic treatment will be filtered into activated sludge mixed into the boiler incineration. In the boiler room part, the slag generated after incineration will be sold to the brick factory. At the same time, the flue gas of the boiler room which is desulfurized and dusted and the coal cinder of the boiler room which is flooded to extinguish the fire will also be cached in the slag pool and sold to the brick factory.

Regarding the collection and transportation of raw materials, in principle, a fully enclosed transportation method is used to reduce pollution along the way. Depending on the form of raw materials, the supplier can choose tank truck or box truck. The raw materials will be unloaded when they arrive at the factory. If it is a tank car, gravity flow into the discharge tank. The barreled oil transported by van can be unloaded by electric crane, and the steam heating is used to assist the oil pouring. (Yao 2010.)

Regarding the equipment for processing waste oil, the type of sedimentation storage tank must first be considered. Because waste oil has a natural stratification effect, in order to take into account raw material storage, natural sedimentation and waste acid utilization, it is recommended to build two larger oil depots, which can be used alternately or in series. It is best to choose slightly higher grade cement for pouring. There is a steam distribution pipe at the bottom which can be heated by direct steam. Leave pits on the ground for easy slag removal.An waste oil storage tank is shown in PICTURE 1. (Yao 2010.)

PICTURE 1. Waste oil storage tank. (adapted from Yao 2010.)

Regarding the type of filter, centrifugal filtration is best. The centrifugal filter device is simple to operate, sturdy, easy to remove slag, and is suitable for residual oil filtration. Centrifugal filter is easy to maintain and slightly lower in price. Suitable press cloth can be lined in the centrifuge, so it is easier to remove slag. The cleared residue can be fed into the boiler as fuel as appropriate. The centrifugal filter is shown in PICTURE 2. (Yao 2010.)

PICTURE 2. Centrifugal filter. (adapted from Yao 2010.)

Vertical storage tanks can be built for waste oil products to reduce occupation, ensure quality and facilitate loading. Due to the high melting point of waste oil, a heating coil should be installed at the bottom. Due to the natural sedimentation and classification of waste oil products, a drain valve should be designed at the bottom, and the discharge port should be a certain distance higher than the drain port, or choose 200 l ordinary waste oil drums for batch storage. Sulfuric acid tanks can be manufactured from carbon steel with distinctive markings. (Yao 2010.)

Choose suitable flow-lift pumps according to process conditions. It is recommended to use cast iron clean water centrifugal pumps and normal temperature gear pumps. If are sucking oil from the liquid surface of the low-level pool, it can also choose a suitable submersible pump. Pumps with similar functions should be of the same model as possible to facilitate maintenance or replacement. (Yao 2010.)

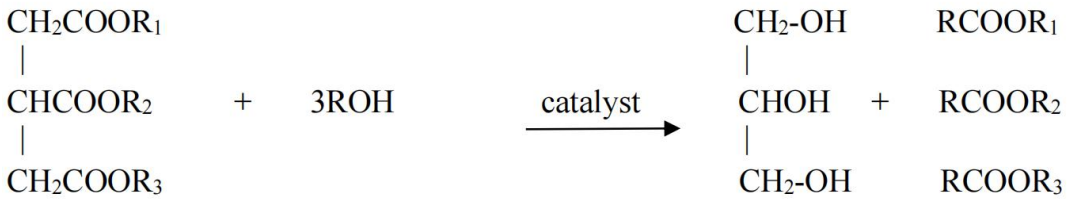
In order to reduce pollution, all of the above proposals are placed in enclosed buildings. The plant is only vented through the boiler chimney. The human operation part is equipped with fresh air inlet, and

all odorous air is discharged after being burned and purified by the boiler. Small negative pressure is normally maintained in the workshop. The transportation channel retains a bend above 90° to avoid the formation of a straight air channel, which may lead to undesirable gas diffusion. Choose a suitable location to build a sewage treatment station to facilitate sunlight and water recycling. Dangerous goods are stored in isolation. The pit type has protective cover and fence. Dangerous areas should be kept at a safe distance and clearly marked. (Yao 2010.)

4.1.2 Reaction principle

Gutter oil is a kind of waste oil in the catering industry with a high degree of corruption. Its composition is complex, consisting of a variety of animal and plant oils, and it contains a large number of solid particles, colloids, water and other impurities, among which the amount of free fatty acids is seriously out of standard. These impurities will have a certain impact on the transesterification reaction, so pretreatment must be carried out before the transesterification reaction, through impurity removal, hydration degumming, water removal and other processes. The pretreated gutter oil can be used for transesterification reaction. (Borges & Diaz 2012, 2839-2849.)

The method for producing bio-diesel from gutter oil introduced in this chapter is the transesterification reaction method. The principle of this method is to exchange alcohols such as methanol or ethanol with triglycerides, the main component of cooking oil. Use methoxy or ethoxy glycerol instead of long-chain fatty acids to break triglycerides into three-long-chain fatty acid methyl esters or fatty acid ethyl esters. So as to shorten the length of the carbon chain, reduce the viscosity of the oil, improve the fluidity and evaporation performance of the oil, to meet the requirements of use as a fuel. The reaction equation is as follows. (Borges & Diaz 2012, 2839-2849.)



4.1.3 Alkali-catalyzed gutter oil process

When alkali is used as a catalyst to participate in the transesterification process, the pretreated waste oil cannot be directly used as a raw material for the reaction. The reason is that the waste oil contains a lot of water and free fatty acids, which will undergo saponification reaction with alkali, so that the mixed solution becomes very viscous and the reaction cannot continue. (Borges & Diaz 2012, 2839-2849.)

Therefore, before the esterification reaction, pre-esterification treatment is required. The so-called pre-esterification means that in the process of preparing bio-diesel with alkali as a catalyst, the pre-treated waste oil is esterified with methanol under the action of an acid catalyst to make free fatty acids generate fatty acid methyl esters. The fatty acid methyl ester is also bio-diesel. In this way, the saponification reaction between free fatty acid and alkali can be eliminated, so that the esterification reaction can proceed normally. The reaction equation of pre-esterification is shown below. (Borges & Diaz 2012, 2839-2849.) The alkali-catalyzed gutter oil process is shown in FIGURE 5.

The reaction equation of pre-esterification is as follows:

$$RCOOH + CH_3OH \xrightarrow{\text{acid catalyst}} RCOOCH_3 + H_2O$$

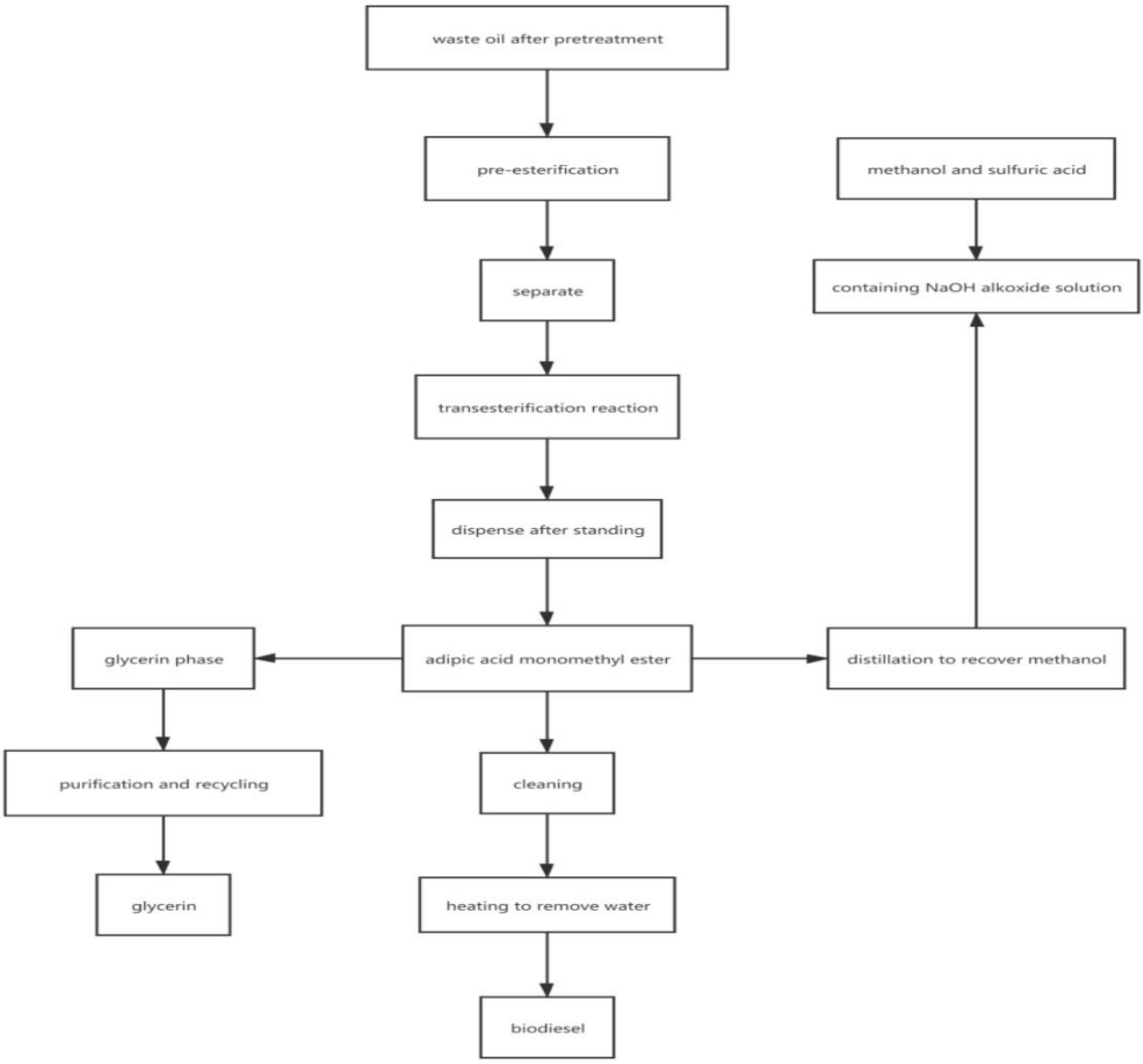


FIGURE5. Alkali-catalyzed gutter oil process. (adapted from Borges & Diaz 2012, 2839-2849.)

As the alkali-catalyzed gutter oil process can be seen in FIGURE 5. Firstly, sulfuric acid and methanol are added to the gutter oil after the pre-fatting process, and fatty acid methyl ester can be obtained after transesterification reaction and separation. The methyl esters of fatty acids produced can be used in three processes. One of the most important processes is the generation of bio-diesel after cleaning, heating and dewatering. Secondly, sulfuric acid and methanol can be distilled and recovered for the next transesterification reaction. The other direction is for the purification of glycerol. (Borges & Diaz 2012, 2839-2849.)

4.1.4 Acid-catalyzed gutter oil process

After the pre-esterification, the alkali catalytic reaction procedure is the same as the acid catalytic procedure. The process of acid catalysis is simpler than that of alkali catalysis because there is no need for pre-esterification treatment. The acid catalyzed gutter oil process is shown in FIGURE 6. (Borges & Diaz 2012, 2839-2849.)

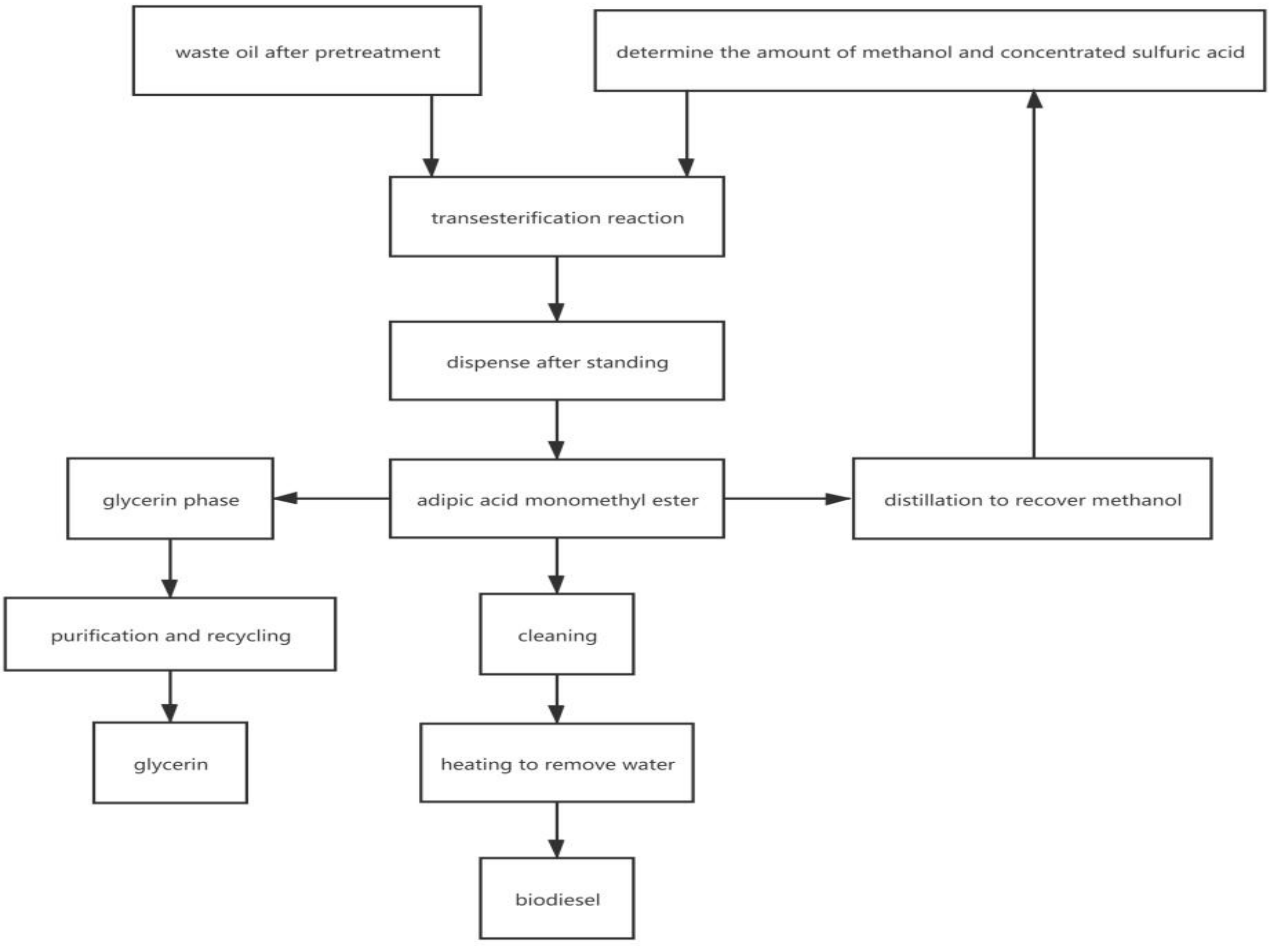


FIGURE 6. Acid-catalyzed gutter oil process. (adapted from Borges & Diaz 2012, 2839-2849.)

As acid-catalyzed gutter oil process can be seen from FIGURE 6. In the acid-catalyzed gutter oil process, the pretreated gutter oil will be transesterified with methanol and concentrated sulfuric acid. Fatty acid methyl ester was obtained after standing and separation. The methyl esters of fatty acids produced here also serve three purposes. The most important use is also for direct cleaning and heating dewatering to produce bio-diesel. Another use is to purify and recycle into glycerol. In the final use, the methanol is recovered by distillation and reused for the next transesterification reaction. (Borges & Diaz 2012, 2839-2849.)

4.1.5 A special transesterification reaction: Preparation of bio-diesel by microwave irradiation

In the transition process, acidic or alkaline catalysts are common processes for bio-diesel production from gutter oil. However, the catalyst can only be used once. High response time is a requirement of transition technology. In order to improve these problems, this study used microwave stimulation method to prepare bio-diesel from waste oil. Microwave irradiation can provide powerful power and reach the reaction temperature in a short time. The SrO catalyst is a heterogeneous catalyst that is insoluble in any liquid solution, so it can be recycled. (Picky,Teng & Ming 2015,84-91.)

The following data were taken from an experimental thesis by Ricky Priambodo, Teng-Chien Chen and Ming-Chun Lu et al. (2015) : "Novel Technology for Bio-diesel Production from Cooking and Waste Cooking Oil by Microwave Irradiation".

In this study, the best conditions are commercial SrO, reaction time 40-180 seconds, reaction temperature around 80℃, methanol to oil ratio of 6, and microwave power output of 1000W. Under these conditions, the conversion rate of bio-diesel to waste oil reached 93%. According to ASTM D6751 and EN14214 standards, the specifications for preparing bio-diesel meet the required limits. In short, current research shows that derivative fuels have the potential to become diesel substitutes, and because of their qualifications, they can be used in engines without major modifications. (Picky,Teng & Ming 2015,84-91.)

In this study, taking advantage of the fast reaction time, the possible use of microwave heating and the inherent advantages of using a heterogeneous catalyst, it will be possible to develop a very fast and simple method for producing bio-diesel from gutter oil with high efficiency.

4.1.6 Advantages and disadvantages of producing bio-diesel by transesterification of gutter oil

Esterification reaction method has rapid reaction and high conversion rate, but the catalyst used is liquid, and the subsequent separation process is complex, which requires the removal of a series of impurities such as catalyst, alcohol, by-product glycerol and others. (Werkmeister , Faulstich & Russ 2011, 1867-1874.)

The removal process of impurities is very complex and will produce a large amount of waste acid and waste alkali, causing serious environmental pollution.In the subsequent process, a multi-step washing method is needed to purify the bio-diesel products, which requires a huge amount of water. (Werkmeister , Faulstich & Russ 2011, 1867-1874.)

4.2 Bio-diesel prepared by hydrogenation and deoxidization of gutter oil

In this chapter, another method is introduced to produce bio-diesel besides transestrification, hydrogenation and deoxygenation. The method of hydrodeoxidation introduced in this chapter is to use the hydrodeoxidation device and NiMOW / γ -Al2O3 catalyst to make bio-diesel from gutter oil.

4.2.1 Reaction principle

Gutter oil contains a large number of unsaturated bonds in fatty acid composition. In the process of hydrogenation and deoxygenation, unsaturated fatty acids are first hydrogenated and saturated. The saturated fatty acids were deoxidized and decarbonized at the time of ester bond fracture under the action of catalyst. Fatty acids remove H_2O, CO_2 and CO in the form of deoxygenation or decarbonization to produce the target product, bio-diesel. The normal alkanes generated in the reaction process are isomerized to generate the corresponding isomeric alkanes. (Li,Zhang & Shen 2017,80-83.) The main reactions occurring during the hydrotreating of triglycerides is shown in the FIGURE 7.

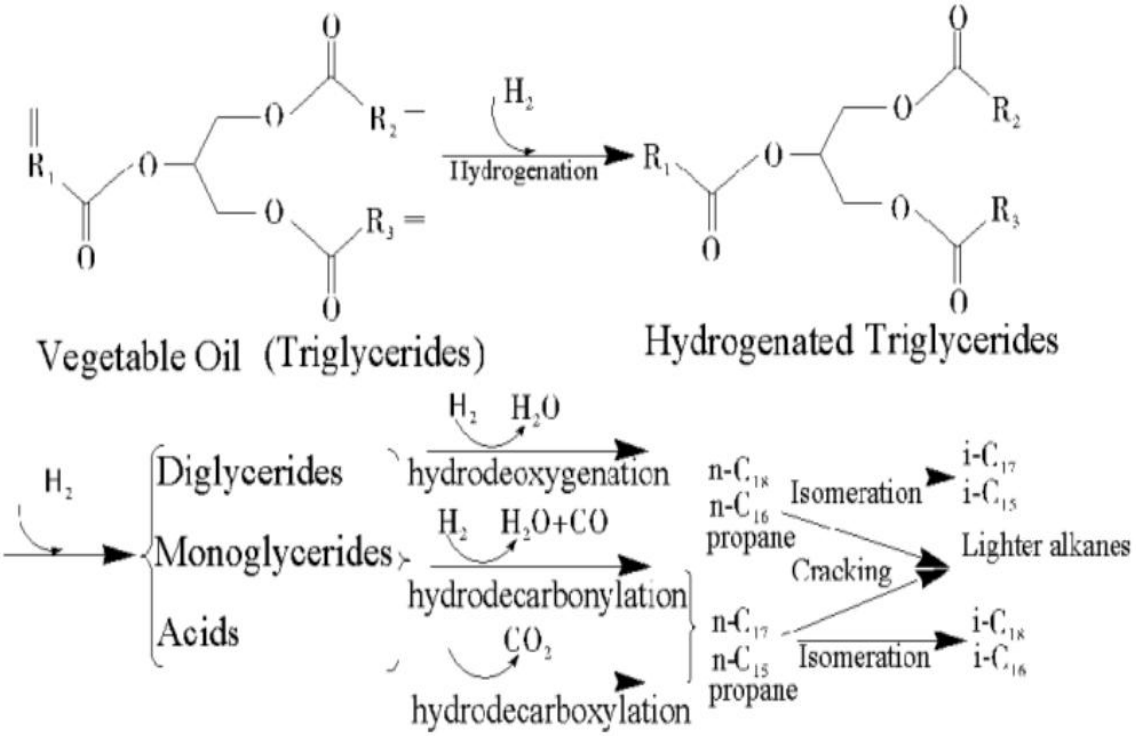


FIGURE 7. Main reactions occurring during the hydrotreating of triglycerides. (adapted from Hamed, Faisal & Wan 2018, 7-27.)

4.2.2 Conversion efficiency and products

Bio-diesel was prepared by hydrogenation with NiM_OW / γ -Al_2O_3 as catalyst, the conversion rate of hydrogenation to bio-diesel. This chapter refers to the experimental report "Preparation of the Second Generation Bio-diesel by Hydrodeoxygenation of Waste Oil" published in Guangdong Chemical Industry in June 2017 by Liaoning Shihua University. In this chapter, the experimental reported data will be used to illustrate the conversion rate of hydrogenated bio-diesel.

The subject of this chapter is the production of organic compound biodiesel after hydrodeoxygenation of gutter oil under catalyst NiM_OW / γ -Al_2O_3 conditions. The product gas chromatogram can be observed in the gas chromatogram. liquid organic matter is the main form of n - C_{15} ~ C_{18} are alkanes, plus a small amount of i - C_{15} ~ C_{18} isomerization alkane, C_{19} ~ C_{22} alkanes and the carbon chain length less than the light hydrocarbon, as well as other intermediate of C_{14}. Can be seen from the liquid alkane distribution in organic matter are four kinds of alkanes 70.36 wt % of the liquid phase organic

matter. (Li,Zhang & Shen 2017,80-83.) The chromatogram of distillate oil from hydrodeoxygenation of waste oil is shown in FIGURE 8.

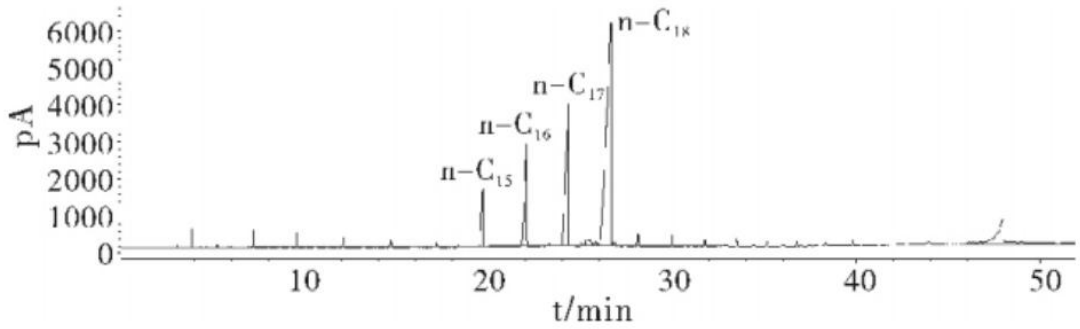


FIGURE 8. The chromatogram of distillate oil from hydrodeoxygenation of waste oil. (adapted from Li, Zhang & Shen 2017, 80-83.)

(The reaction conditions were as follows: reaction temperature 360 ℃, reaction pressure 5.0MPa, LHSV = 1.0 h^{-1})

It can be seen from the table below that the diesel produced by the reaction has a high cetane number and can be used as an additive to improve the cetane number of petrochemical diesel. The bromine value of oil obtained by hydrogenation reaction was significantly reduced. The acid does not change much. (Li,Zhang & Shen 2017,80-83.)

Bromine value is an index to measure the content of unsaturated hydrocarbons in organic matter. The number of grams of elemental bromine consumed by a 100-gram sample is called the bromine value, and the number of milligrams of bromine consumed by a 100-gram sample is called the bromine index. The higher the bromine value or the bromine index, the higher the content of unsaturated hydrocarbons in the sample, that is, the higher the degree of unsaturation. In the production of oil products, this value is used as an important indicator to measure the stability of oil products. In some chemical production, such as long-chain alkylation reaction, it can also be used to roughly estimate the conversion rate of the product. (Majhi, Pugazhenthi & Shukla 2010,128-146.) The cetane number data is shown in TABLE 2.

TABLE 2. Cetane number data. (adapted from Li,Zhang & Shen 2017,80-83.)

Oil type	Density(g/cm^{-3})	Cetane rating	Viscosity(40℃)/(mm^2*s^{-1})	Bromine value(mgBr*g^{-1})	Acid(mgKOH*g^{-1})
Gutter oil	0.91	-	76.00	1.07	1.50
Product oil	0.76	＞60	4.92	0.53	1.48

The NiMoW/γ-Al_2O_3 catalyst has a high hydrodeoxidization activity. When the reaction temperature is 380 ℃, the pressure is 5.0 MPa and the liquid time space velocity is 1.0 h^{-1}, the deoxidation rate of the gutter oil is high, the reaction hydrogen consumption is low, and the yield of diesel oil reaches 84.63%. (Li,Zhang & Shen 2017,80-83.)

4.2.3 Advantages and disadvantages of producing bio-diesel by hydrogenation of gutter oil

According to the above reference experiments, it can be concluded that the bio-diesel produced by hydrogenation has a higher cetane number. When the reaction temperature is 380 ℃, the liquid pressure is 5.0 MPa and the time and space velocity is 1.0 h^{-1}, the reduction rate of gutter oil is high, the reaction hydrogen consumption is very low, and the yield of diesel oil and gutter oil reaches 84.63%. (Li,Zhang & Shen 2017,80-83.)

5 CONCLUSION

In view of the limitation of traditional fossil energy and the increase of global environmental pressure, many countries in the world have realized the importance of new energy and renewable energy. And take action politically, economically, and technically. A series of technologies that are conducive to accelerating the development of new energy and renewable energy have emerged. The production of bio-diesel is one of the important technologies. The production and use of bio-diesel not only helps to reduce dependence on fossil fuels, but also helps to reduce external dependence.

This thesis first introduced the gutter oil and bio-diesel. For gutter oil, the characteristics, hazards, uses, treatment methods and policies of some countries were introduced. For bio-diesel, the types, characteristics, production methods, policies and standards of some countries were introduced.

Two methods of bio-diesel production from gutter oil are mentioned in this thesis are esterification reaction and hydrogenation and deoxygenation technology. In the introduction module of esterification reaction, can know that this method has simple steps and considerable yield, but the disadvantage is that there are many by-products. This technology brings relatively large pollution, for example, in the production process will use acid or base as a catalyst, these residual acid or base will bring some pollution. About the esterification reaction method, this paper also introduces a special esterification reaction method: microwave radiation technology. The technology uses microwave radiation and a special recoverable catalyst (SrO) to replace the acid-base catalyst. The advantage of this technology is that there is no need to worry about environmental pollution caused by the catalyst. Esterification is still the mainstream technology in many countries. Another method is hydrogenation and deoxygenation. The biggest advantage of this technology is high efficiency and high conversion rate. However, the disadvantage is that the technology is difficult to master. Due to the need to control the reaction temperature, space time and other factors, the production difficulty and operation complexity are higher than the traditional esterification reaction technology.

Generally speaking, this thesis first elaborated the harm of gutter oil. But it also explained that gutter oil can be used to produce bio-diesel. This idea can not only treat the gutter oil which is harmful to human beings, but also produce bio-diesel which is beneficial to the environment. Then, the two methods of producing diesel from gutter oil introduced in this thesis are both mature and widely used technologies. The bio-diesel prepared by these two methods has reached the standards of some countries. Both can be used as diesel fuel directly or as a mixture of diesel fuel. Developing bio-diesel

will not only help countries reduce their dependence on fossil fuels. It will also help reduce environmental pollution and better protect fossil fuels. Bio-diesel contains almost no sulfur and aromatic hydrocarbons, has a high cetane number, good lubrication performance, convenient storage and transportation, and good degradation performance. It is a clean and renewable source of energy. It is a typical "green energy". The vigorous development of bio-diesel has many positive implications. It can promote sustainable economic development. It can also promote energy substitution, alleviate environmental pressure and control urban air pollution.

REFERENCES

Abdul,R., Pepijn,P. & Arun,K.V. 2018. A review on sustainable microalgae based biofuel and bioenergy production: recent developments. J Clean Prod. 2018(181),42–59.

Annisa,B., Ryunosuke,S. & Jiro,S. 2020. Investigation of spray characteristics from waste cooking oil, bio-hydro fined diesel oil (BHD)and n-tridecane in a constant volume chamber. Mechanical Engineering Department, Trisakti University.

Azcan,N. & Danisman,A. 2008. Microwave assisted transesterification of rapeseed oil. Fuel, 87(17),1-8.

Bhikuning, A., Sugawara,R. & Matsumura,E. 2020. Investigation of spray characteristics from waste cooking oil, bio-hydro fined diesel oil (BHD)and n-tridecane in a constant volume chamber. Case Studies in Thermal Engineering, 21(2020),11-19.

Borges,M.E.& Diaz,L. 2012. Recent developments on heterogeneous catalysts for biodiesel production by oil esterification and transesterification reactions: A review. Renewable and Sustainable Energy Reviews. 16(2012),2839-2849.

Battaglini,A., Lilliestam,J. & Haas,A. 2009. Development of SuperSmart Grids for a more efficient utilisation of electricity from renewable sources. Journal of Cleaner Production, 17(91),1-8.

Demirbas,A. 2019. Progress and recent trends in biodiesel fuels. Energy Conversion and Management. 2009(50),14-34.

Duan,J.Z., Han,J.X. & Sun,H.2012. Diesel-like hydrocarbons obtained by direct hydrodeoxygenation of sunflower oil over Pd/Al-SBA-15 catalysts. Catal Comm. 2012(17),76–80.

Edwin,G.V., Nadia,M. & Mohand,T. 2012. Assessment of liquid fuel (bio-oil) production from waste fish fat and utilization in diesel engine. Applied Energy, 100(2012),249-257.

Gad, M.S., Hashim, A.M. & Mohaned, M.A. 2021. Effect of oil blends derived from catalytic pyrolysis of waste cooking oil on diesel engine performance, emissions and combustion characteristics. Energy, 223 (2021)

Gan,C., Mengni,Z. & Yijun,C. 2020. Preparation and evaluation of lignite flotation collector derived from waste hot-pot oil. Full Length Article.

Gopan,N.S.,Rajan,V.A. & Krishna,R.B. 2021. Review of Bio-diesel production from waste cooking oil and analyze the IC engine performance. Materials Today: Proceedings, 37(2021),1208-1211.

Hamed,P., Faisal,A. & Wan,M.A. 2018. Atmospheric hydrodeoxygenation of bio-oil oxygenated model compounds: a review. J Anal Appl Pyrolysis, 33(11),7–27.

Liang,S., Liu,Z. & Xu,Ming. 2013. Waste oil derived biofuels in China bring brightness for global GHG mitigation. Department of Civil and Environmental Engineering, University of Michigan.

Li,J.T., Zhang,X.Y. &Shen,J. 2017. Preparation of Second Generation Biodiesel via Hydrodeoxygenation of Waste Oil. Guangzhou Chemical Industry, 45(12),80-83.

Liu,Y.Y., Rogelio,S.B. & Murata,K. 2011. Hydrotreatment of vegetable oils to produce bio-hydrogenated diesel and liquefied petroleum gas fuel over catalysts containing sulfided NiMo and solid acids. Energy Fuels. 25(46),75-85.

Majhi A.,Pugazhenthi G & Shukla A. 2010. Comparative Study of Ultrasound Stimulation and Conventional Heating Methods on the Preparation of Nanosized γ －Al2O3. Industrial & Engineering Chemistry Research, 17(9),128-146.

Niraj,S.T. & Kiran,D.P. 2021. Biodiesel from waste cooking soybean oil under ultrasonication as an alternative fuel for diesel engine. Materials Today: Proceedings, 43(2021),510-513.

Olatunji, O. & Akinlabi, S. 2020. Biodiesel production from palm olein: A sustainable bioresource for Nigeria. Heliyon, 6(4), 2405-8440.

Ricky,P., Teng,C. & Ming,C. 2015. Novel Technology for Bio-diesel Production from Cooking and Waste Cooking Oil by Microwave Irradiation. Energy Procedia, 75(2015),84-91.

Shuang,C., Guilin,Z. & Caixia,M. 2019. Green and Renewable bio-diesel produce from oil hydrodeoxygenation: Strategies for catalyst development and mechanism. Renewable and Sustainable Energy Reviews, 101(2019),568-589.

Sugiura K., Yamatani S. & Onodera T. 2009. Ecofeed, animal feed produced from recycled food waste. 45(3), 397-404.

Suppalakpanya,K., Ratanawilai S.B. & Tongurai,C. 2010. Production of ethyl ester from esterified crude palm oil by microwave with dry washing by bleaching earth. Applied Energy, 23(5),6-9.

Veriansyah,B., Han,J.Y. & Kim,S.K. 2012. Production of renewable diesel by hydroprocessing of soybean oil: effect of catalysts. Fuel. 94(5),78-85.

Wang, H. 2015. Study on utilization of waste starch in food waste. Wuhan: Wuhan Institute of Technology.

Yao,D.Y. 2010. Pretreatment of swill oil and gutter oil.

Zhai, X.P. 2011. Advances in Second Generation Biodiesel Prepared by Hydroprocessing of Oils and Fats. Petrochemical Technology, 40(12),1364-1369.

Zhang, H.M., Zhang,Y. & Qiu,Y.M. 2017. Has government intervention effectively encouraged the use of waste cooking oil as an energy source? Comparison of two Chinese biofuel companies. Energy, 140(2017),708-715.

Zhu,H.L., Luo,W. & Peter,N.C. 2016. Wood-derived materials for green electronics, biological devices, and energy applications. Chem Rev, 116(93),05-74.

Zhang,Z., & Jiang,Y.J. 2017. Robust optimization on sustainable biodiesel supply chain produced from waste cooking oil under price uncertainty. School of Transportation, Southeast University.