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FOOD WASTE AS A RAW MATERIAL FOR BIOFUEL PRODUCTION

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ABSTRACT

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With the development of economy, people's living standard is constantly improving. People's demand for food is also increasing. With the increase of food consumption, the production of food waste is also increasing. Therefore, the increase of food waste results in the increasing proportion of food waste in urban garbage. Compared with other waste, food waste is more difficult to deal with and more harmful to the environment. Because the treatment technology of food waste is not perfect, it may cause secondary pollution in the process of treatment. Food waste has always been a concern of people and there are many organic compounds and nutrients in food waste. This part can be used to produce biofuels to solve the current energy crisis, it can also be a good way to deal with food waste to prevent food waste from polluting the environment.

Starting from food waste, this paper introduces the definition, source and treatment of food waste. The treatment methods of food waste mainly include mixed landfill, incineration, anaerobic fermentation, aerobic composting and livestock feed. Among them, the two treatment methods of mixed landfill and incineration are banned by many countries because of their disadvantages. The following article introduces the definition, application and how to use food waste to produce biofuels. In this part, the production of biogas by anaerobic fermentation, transesterification and biodiesel, bioethanol and butanol by ABE fermentation are introduced respectively.

Key words
Anaerobic fermentation, biogas, biodiesel, biobutanol, food waste

CONCEPT DEFINITIONS

List of abbreviations

ABE	Acetone-Butanol-Ethanol
CH_2CH_3OH	Ethanol
CH_4	Methane
CHP	Combined heat and power
CO_2	Carbon dioxide
CSTR	Continuous stirred-tank reactor
H_2	Hydrogen
H_2O	Water
NH_3	Ammonia
NH_4^+	Ammonium

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1 INTRODUCTION

In recent years, with the development of economy, people's living standards have been improving. People's demand for food is also increasing. Therefore, A large number of food waste is produced, and the proportion of food waste in urban domestic waste is also increasing. The imperfection of food waste treatment leads to environmental pollution and harm to human health. In the process of food waste storage, a large number of leachates will be produced, which will increase the burden and cost of sewage treatment. Therefore, the treatment of food waste has become an urgent problem. At the same time, the global development of science technology and economy has led to the continuous reduction of energy. Most of the fuels used are fossil fuels, which are non-renewable resources. Looking for a new energy source has become the most important objective at present.

The combustion of fossil fuels will also produce pollutants, which will cause environmental pollution and harm human health. The contradiction between supply and demand of oil has become the main problem in the development of society. The main purpose of biofuels is to develop oil to replace resources and alleviate oil shortage. At present, the global demand for oil is very large, and fossil fuel resources are relatively scarce (Florinda, Carlos & Miroslava 2018). And biofuels are clean energy that can reduce pollution and improve the atmospheric environment. For example, the use of fossil fuel in the city will emission of car exhaust which is harmful to the environment. Biofuels can solve these problems. However, there are still some deficiencies in the production of biofuels. The raw material structure of biofuels is less and the supply is insufficient. The raw materials of biofuels include some crops, but if the crops are used as raw materials of biofuels, the food supply will be insufficient. Using food waste can solve this problem. The second problem is the high cost of production, but with the development of technology, the cost of production will continue to reduce. (Bian & Chen 2018)

Food waste contains a large quantity of organic matter and nutrients. Therefore, food waste is an ideal raw material for the production of biofuels. Food waste can be separated into oil phase, liquid phase and solid phase by three-phase separator. The oil phase can be used to produce biodiesel. Solid phase can be composted to produce organic fertilizer for agricultural production. Biogas is produced by anaerobic fermentation in liquid phase, which can be used for power generation or fuel. The treatment of food waste has a broad prospect. Food waste is separated and treated to produce biofuels. The purpose of this paper is to describe the source and harm of food waste, introduce the methods of biofuels and food waste conversion into biofuels. This paper is divided into two parts: the first part is to introduce the source, harm and treatment of food waste. The second part first introduces the kinds and advantages of biofuels, then introduces the methods of food waste to biofuels. The third part is to summarize the current situation of biofuels and describe the future of biofuels. (Bian & Chen 2018)

2 FOOD WASTE

Food waste refers to the perishable and biodegradable waste produced in the food processing, consumption and cleaning of schools, families, canteens, restaurants and other catering industries (Zhang 2017). Food waste is the most important kind of municipal solid waste, which is a mixture of oil, water, peel, vegetables, rice noodles, fish, meat, bone and other substances. In terms of chemical composition, the main components of food waste are starch, cellulose, protein, lipids, inorganic salts. (Wang 2005).

2.1 Status of food waste

Food waste accounts for a large part of domestic waste, and food waste is more likely to cause serious environmental pollution. Because food waste is rich in organic matter and microelements and has high water content, it is easy to cause a large number of microorganisms and pathogens. The low calorific value of food waste means that the heat released by the waste after combustion is low. People often use calorific value to measure or express the value and ability of garbage as fuel. As the moisture content of food waste is very high, the low calorific value per unit mass is about 2100-3100 kJ/ kg. When the average low calorific value of waste is higher than 3350 kJ/ kg, no combustion supporting agent is added in the incineration process, and when it is higher than 3350 kJ/ kg, waste heat can be used. In case of power generation, it is necessary to add fuel oil or coal to support combustion and increase cost. At the same time, it is necessary to control the temperature to prevent the generation of dust and other harmful substances. (Zhang, Ji & Ji 2013, 558-562)

Although food waste is very harmful to human and the environment, food waste has a high utilization value. The content of nutrition elements in food waste is high, and the main components are oil and protein. Crude fat is about 30 % and crude protein is about 20 % in dry materials, which can be used to produce biodiesel. Solid components in food waste can be composted to form organic fertilizer, which can be used for crop growth and fertilizer. However, in some countries, garbage is not treated by classification, and all kinds of garbage are mixed together, resulting in the waste of a large number of nutrients. (Gao 2019)

Food waste sources can be divided into three categories: the first is food products lost in the production phase, the second is the inevitable waste of food, the third is avoidable food waste. According to each stage of the food supply chain, Gustavsson divide food waste into five sources: agricultural production, postharvest handling and storage, processing and packaging, distribution consumption. (Jenny & Christel 2011)

Food waste contains large amount of perishable substances, which are not suitable for the existing garbage collector and transport vehicle. Due to the high-water content of food waste, it is very difficult to transport it in sealed bottles. A little carelessness will cause waste liquid to overflow from the bottles. It will be very difficult to load, collect and unload the garbage with sealed tank car. The waste liquid may leak out if the road is not smooth in the transportation project. (Bian & Chen 2018, 38-39)

The waste liquid will permeate into the nearby soil and pollute the surrounding water source and groundwater, resulting in new secondary pollution. As food waste is perishable, it will produce unpleasant and disgusting gas, which not only pollutes the surrounding air quality, but also breeds various harmful bacteria, attracts mosquitoes, flies, cockroaches and other pests, and spreads various diseases. In addition, some areas do not pay attention to environmental protection. They often use food waste as livestock feed. Some bacteria and heavy metals of waste will harm human health through livestock. (Bian & Chen 2018, 38-39)

2.2 Treatment of food waste

Food waste has the characteristics of high content of organic matter, high percentage of water, easy to corrupt and deteriorate. During transportation and treatment, toxins will be produced and the environment will be polluted. At present, the treatment methods of food waste are mixed landfill, incineration of waste, anaerobic fermentation, aerobic composting and livestock feed. With the development of social economy and the growth of urban population, the output of food waste is increasing every day, and the demand for food waste treatment is increasing accordingly. The diversity of food waste and the complexity of its ingredients make it more difficult to deal with it. However, food waste contains a large quantity of organic matter, which can be used to a certain extent. So, the treatment of food waste is very important. (Zeng 2017)

2.2.1 Mixed landfill

The mixed landfilling of food waste refers to the direct pouring of food waste into the landfill and the mixing of other household waste for landfilling. The advantages of this waste treatment method are simple treatment process, low transportation cost, low operation cost and large amount of treatment. The disadvantage is that it occupies a large number of land resources, the landfill space is limited, and it needs to be continuously built, further increasing the occupation and investment cost of land resources. Moreover, food waste has high water content and organic matter content, which will produce a large number of leachate and harmful gases in the landfill. If no protective measures are taken, it will directly affect the natural resources such as groundwater and air, and form secondary pollution, which will harm human health. This method of food waste is directly buried, in which a large number of resources and energy are not used. Therefore, although landfill treatment is one of the main treatment methods commonly used in some underdeveloped areas, it will bring serious sequelae and secondary pollution problems. With the development of regional economy, this treatment method will be eliminated in the future. (Ng, Yang & Yakovleva 2019, 248-262)

2.2.2 Incineration of waste

There is a difference between incineration and landfill technology. The energy generated by incineration of waste can be used for power generation, so that waste can be converted into resources that can be used conveniently. Although there are application precedents of waste incineration technology, many regions refuse to adopt it, and most countries do not advocate waste incineration. The advantage of incinerating waste is that the amount of incineration is large. The heat generated can be generated by turbine to generate power and realize the resource utilization of waste. The disadvantage is that there is a higher requirement for the low calorific value of waste, most of which is the high moisture content of food waste, so it is difficult to meet the requirement without dehydration. The high-water content of food waste will increase the consumption of combustion supporting agent, greatly increase the financial investment and increase the cost of treatment, which many economically underdeveloped areas cannot afford. At the same time, due to incomplete combustion, the produced gas may be discharged into the environment, resulting in secondary pollution. Therefore, whether from the perspective of technology or from the perspective of social impact, the feasibility of incineration technology for food waste treatment is not high. (Da Silva, Dos Santos & Mensah 2020, 1386-1394)

2.2.3 Anaerobic fermentation

Anaerobic fermentation refers to the treatment of solid waste by anaerobic bacteria under anaerobic conditions. Food waste can degrade organic matter and produce biogas through the microorganisms. CH_4 is the main product of anaerobic fermentation. Anaerobic fermentation technology is a new type of treatment technology, which can effectively degrade waste, lower the pollution of air and soil, and can produce bio natural gas and other energy materials. The world has paid attention to the research of anaerobic fermentation technology. (Allegue, Puyol & Melero 2020)

Anaerobic fermentation can not only deal with a large number of food waste, but also produce a large amount of biogas with a short fermentation cycle, and biogas slurry and residue can be converted into agricultural organic fertilizer. Anaerobic fermentation can be divided into medium temperature fermentation and high temperature fermentation according to different temperature. According to the fermentation stage, anaerobic fermentation can be divided into single-phase anaerobic fermentation and two-phase anaerobic fermentation. (Achinas, Krooneman & Euverin 2019, 970-978)

2.2.4 Aerobic composting

The aerobic composting process of organic waste is the microbial fermentation process of substrate. Aerobic composting technology is to use aerobic microorganisms to degrade organics under aerobic conditions. Aerobic composting technology has become increasingly mature. The process of aerobic composting can be roughly divided into three stages: the middle temperature stage is the initial stage of composting process, which is 15 ℃ - 50 ℃. Mesothermic microorganisms are more active and use soluble organic matter in compost for vigorous life activities. These microorganisms include fungi, bacteria and actinomycetes. These microorganisms are mainly based on sugars and starch. The second stage is high temperature stage. It is a high temperature stage when the temperature rises to 45 ℃. At this stage, mesothermic microorganisms are inhibited or even die, and then thermophilic microorganisms emerge. Residual and newly formed soluble organic matter in the compost continues to be oxidized and decomposed, and complex organic matter in the compost continues to be decomposed. The third stage is cooling stage. The present part is hard to be decomposed organic matter and newly formed humus. At this time, the activity of microorganisms decreases, calorific value decreases, temperature decreases, and mesophilic microorganisms dominate, and continue to decompose the remaining difficult-to-decompose organic matter. (Keng, Chong & Ng 2020)

The advantage of this process is that relatively simple technology is adopted, and products treated by aerobic composting technology can be used as agricultural products to realize waste reuse. However, aerobic composting technology is mainly used for green garbage and straw-rich waste. Although the structure of food waste contains such substances, not all waste contain such substances. In addition, composting requires a large amount of land and a long processing cycle, thus increasing the operating costs. At the same time, aerobic composting technology treatment is carried out in a non-sealed environment, and the generated odor may affect the surrounding environment, leading to secondary pollution. (Keng, Chong & Ng 2020)

2.2.5 Livestock feed

Feeding treatment mainly refers to heating food garbage by means of high temperature, frying. After drying, sterilization, salt removal and other procedures, protein feed and other substances are finally generated. The Japanese government calls the feed obtained from the innocuous treatment of food waste "Ecofeed". (Sasaki, Aizaki & Motoyama 2011, 175-180) Before using food waste to produce feed, it is necessary to silage and dry food waste. The drying methods include high temperature fermentation drying, boiling drying and low pressure drying. The purpose of drying is to reduce the moisture content of food waste to 13.5 % or less than 13.5 %. The preparation method of feed is as follows: The first step is to boil the raw material at 70 ℃ for 30 minutes or at 80 ℃ for 3 minutes before use. The second step is to use lactobacillus fermentation raw materials to ensure the safety of feed. The third step is to obtain dry feed by vacuumizing, boiling and high temperature fermentation. The above preparation process is shown in the FIGURE 1. (Sugiura Yamatani & Onodera 2009)

Figure 1. Ecofeed production process. (adapted from Sugiura Yamatani & Onodera 2009)

The advantages are that the processing technology has high degree of mechanization, small area and high resource utilization. But the risk of protein feed additives re-entering the food chain and eventually returning to the human body will be unpredictable. There have been many diseases caused by improper feed handling before. Therefore, many countries have banned this waste disposal method. (Georganas, Giamouri & Pappas 2020)

3 BIOFUELS AND BIOFUELS PRODUCTION FROM FOOD WASTE

Biofuels refer to all the fuels made from agricultural and forestry products or their by-products, industrial waste, domestic waste and other biological organisms and their metabolic excreta. Biofuels are derived from biomass and biomass is found everywhere. Therefore, the development of biofuels is significantly. In most cases, biofuels are used to refer specifically to liquid biofuels such as bioethanol, methanol and biodiesel. Because liquid biofuel products are considered the best alternative or supplement to gasoline and petrochemical products. Due to growing concerns about energy security and environmental pollution, the development of biofuels has attracted worldwide attention. (Moioli, Salvati, Chiesa, Siecha, Manenti & Laio 2018, 22-31)

The main purpose of biofuels is to develop new fuels to alleviate the energy crisis, while fossil fuel resources are relatively scarce. The contradiction between supply and demand of oil has become a major problem in the development of today's society. And biofuels are clean energy that can reduce pollution and improve the atmospheric environment. Urban air is polluted by a large number of automobile exhaust. If fuel alcohol is used, it can not only solve these problems, but also have great benefits for the automobile itself. However, there are still some shortcomings in the production of biofuels. The raw material structure of biofuels is single and the supply is insufficient. Some crops are included in the raw materials of biofuels, but if the crops are used as the raw materials of biofuels, the supply of food will be insufficient. The use of food waste can solve this problem well. The second problem is that the cost of production is high, but with the development of technology, the cost of production will continue to decrease. (Moioli, et al. 2018, 22-31)

Biofuels have become the most promising alternative fuels, among which biodiesel and fuel ethanol technologies have achieved large-scale development. In 2017, the global production of biodiesel reached 32.232 million tons. The United States, Brazil, Indonesia, Argentina and the European Union were the main countries and regions for biodiesel production, among which the EU's biodiesel production accounted for 37 % of the global production, the United States accounted for 8 %, and Brazil accounted for 2 %.Global biofuel ethanol production reached 79.81 million tons in 2017, and the United States and Brazil were the countries with the largest production of fuel ethanol, yielding 44.1 million tons and 21.28 million tons. (Ma, Tang, Wang, Sun, Lv & Chen 2019, 434-441)

At present, the global resource shortage, a large number of energy demand and serious environmental pollution, many waste treatment methods have been unable to meet the needs of emission reduction and resources. Food waste is the main component of urban organic solid waste. Although food waste has great harm, if food waste is used, it will become a good resource. It is difficult to meet the purpose of resource recovery and utilization with a single energy source of food waste. By combining a variety of resource-based methods, food waste can be processed into different products with high demand. In this way, the diversified treatment of food waste can be realized and the energy can be reused at the same time. This chapter will introduce how food waste is transformed into biogas, biodiesel, bioethanol and biobutanol. (Ma, Tang, Wang, Sun, Lv & Chen 2019, 434-441)

3.1 Biogas

Biogas technology has matured and realized industrialization. Europe is the most mature region of biogas technology, and the biogas engineering equipment in developed countries such as Germany, Sweden, Denmark and the Netherlands has reached the design standardization, product serialization, assembly modularization, production industrialization and operation standardization. Germany is currently the country with the largest number of rural biogas projects in the world. Sweden is the best country for biogas purification for automotive gas. Denmark is the most characteristic country for the development of centralized biogas project, in which centralized combined fermentation biogas project has been very mature and used for centralized treatment of livestock and poultry manure, crop straw and industrial waste, most of which adopt the mode of combined production of thermoelectric and fertilizer. (Achinas & Euverink 2016, 143-147)

Biogas is a combustible gas with methane as the main component, which is converted from municipal garbage, livestock manure, industrial organic wastewater, crop straw. Biogas includes biogas produced by poultry and livestock manure, biogas produced by crop straw, biogas produced by landfill. It is one of the most mature ways to utilize biogas in the world at present to convert biomass resources into biogas in an economical and rational way, and to process and utilize biogas in accordance with the needs of energy-using facilities at the user end. Biogas can be directly used after primary purification treatment. Biogas can be used as pure biogas after further purification, such as shallow purification or deep purification. Biogas can also be purified and converted into high value-added natural gas for efficient use. Biogas can also be used as chemical raw materials. Biogas is utilized in different ways, and the corresponding processing depth and production cost are also different, and the utilization value is also different. Generally, the higher the processing depth, the greater the cost and the higher the added value generated. The utilization modes of biogas can be divided into the following four categories: direct utilization mode of biogas, pure utilization mode of biogas, utilization mode after purification into natural gas and utilization mode as chemical raw material. (Scarlat, Dallemand & Fahl 2018, 457-472)

3.1.1 Biogas production from food waste

The production of biogas from food waste by anaerobic fermentation is a complex biochemical conversion process. The anaerobic fermentation process can be divided into three stages: firstly, the substrate, such as protein, carbohydrate and fat, is hydrolyzed into simple organic units such as amino acids, sugars and fatty acids through bacterial action, and then acidified into low-level fatty acids such as propionic acid and butyric acid through acidogenic bacteria, and then hydrogen gas and acetic acid are produced. Finally, under the metabolism of methanogenic bacteria, acetic acid and hydrogen are converted into methane. Food waste is a kind of organic waste, which is very suitable for anaerobic fermentation. According to the different moisture content, the anaerobic fermentation process can be divided into dry and wet; it can also be classified according to the temperature, which can be divided into medium temperature (about 37 ℃) and high temperature (about 55 ℃). According to the fermentation process, it can be divided into single-phase and two-phase fermentation systems. (Zhang 2017)

3.1.2 Methanogens

Methanogens are a kind of extremely anaerobic archaea, belonging to the family euryarchaeota. It mainly exists in the strictly anaerobic environment, such as human digestive system and rumen of ruminant, animal manure, anaerobic sludge and biogas reactor, lake or seabed sediment, deep oil layer and coal seam. The end product of methanogens is mainly methane gas. Methanogens are strictly anaerobic microorganisms. Before the invention of strict anaerobic technology, the research progress of methanogens isolation and culture was slow. Methanosarcina barkeri and methanobacteria formicum are the first methanogenic bacteria isolated. In the ninth edition of Berger's handbook of systematic bacteriology, methanogens are classified by phylogeny, including five major orders: methanobacteriales, methanoccales, methanosarcinales, methanomicrobiales and methanopyrales. (Wang, Liu, Han, Liu & Hu 2014, 418-425)

Most methanogens are suitable for growth in the pH range of 6.6 - 7.2, but when the pH is lower than 6.3, the reaction system will cause the accumulation of organic acids, and the methanogenic efficiency will be significantly reduced; when the pH is higher than 7.8, NH_4^+ will be converted into toxic NH_3, causing ammonia inhibition. Another important factor affecting the anaerobic fermentation of food waste is temperature. Each kind of microorganism has the most suitable growth temperature. Temperature also affects the metabolism of microorganisms in organic matter. Microorganisms need to grow rapidly at the most suitable temperature. With the rapid metabolism of microorganisms, the amount and concentration of methane produced will also be increased. According to the sensitivity of methanogens to temperature, methanogens can be divided into medium temperature methanogens and high temperature methanogens. Generally, in the experiment and industrial anaerobic fermentation, medium temperature is the best fermentation condition in most processes. (Li, Li & Ouyang 2014, 2025-2030)

Anaerobic fermentation is a kind of decomposition and digestion reaction that produces methane and CO_2 under the metabolism of methanogens and bacteria contained in food waste. Anaerobic fermentation is a complex process of microbial metabolism, mainly plays a role in the complex environmental bacteria and methanogenic archaea. Methanogens are the main bacteria that transform the products of acid producing stage (acetic acid, CO_2, H_2.) into methane. (Li, Li & Ouyang 2014, 2025-2030)

3.1.3 Single phase and two phases

The whole process of anaerobic fermentation can be divided into acid production and methane production. Because the most suitable conditions of the two processes are different, the single-phase and two-phase anaerobic fermentation in industry are divided. Single phase process and two-phase process have their own advantages. This is mainly determined by the fermentation substrate. But at present, the single-phase operation requirements and conditions are relatively easy, so most of the projects are single-phase fermentation. Because of the difficulty of two-phase fermentation, almost all of them are carried out in the laboratory. (Zhang 2017)

Two phase anaerobic fermentation is also called two-stage anaerobic fermentation. According to the different optimum conditions of acidogenic bacteria and methanogenic bacteria in the process of anaerobic fermentation, it is divided into two stages: acetic acid production stage and methane production stage. According to the different characteristics of these two stages, different fermentation reactors are developed respectively, which forms the acid production phase and methane production phase. The whole anaerobic fermentation process is to combine the acidogenic phase with the methanogenic phase. This process can avoid the mutual restriction and interference between different groups, thus accelerating the metabolism level of microorganisms and improving the anaerobic fermentation rate. (Zhang 2017)

3.1.4 Dry and wet fermentation

The solid content of dry fermentation is between 20 % - 40 %. The advantages of dry fermentation are less loss of volatile organic compounds, high content of organic compounds and strong impact resistance. The cost of pretreatment is cheap and the reactor is small. The water consumption and heat consumption are small, the amount of wastewater produced after treatment is small and the cost of wastewater treatment is relatively low. The disadvantage of this fermentation is that wet waste cannot be treated separately. The cost of the equipment used in this fermentation is high. Because of the high solid content of fermentation, it is difficult to transport and stir. (Zhai 2016)

The solid content of wet fermentation is between 10 % and 15 %. The advantage of wet fermentation is that the technology is mature and the cost of treatment facilities is low. The disadvantage of this fermentation is that the pretreatment is very complex. The workers are required to remove the scum regularly, and the water consumption is large, and the amount of wastewater is large. (Zhai 2016)

3.1.5 Temperature classification of anaerobic fermentation

In the process of anaerobic fermentation, the activity of microorganism and enzyme in the system is greatly affected by temperature, and the change of temperature will also change the hydrogen partial pressure in the system. According to the different temperature of anaerobic fermentation, it can be divided into low temperature fermentation (10 ℃ - 25 ℃), medium temperature fermentation (30 ℃ - 45 ℃) and high temperature fermentation (45 ℃ - 60 ℃). High temperature is suitable for the growth and fermentation of methanogens, but most of them are suitable for medium temperature. In the medium temperature fermentation system, the activity of microorganisms is high and the system is easy to start, but in the current research, high-temperature fermentation has attracted more attention, because in the process of high-temperature fermentation, pathogenic bacteria and other pathogenic microorganisms in the fermentation substrate can be killed, which is convenient for the resource utilization of fermentation residue. High temperature is more suitable for acid production stage, which can promote the decomposition and metabolism of organic waste and accelerate the acid production of the system, so temperature plays an important role in the selection of reaction system. (Izumi, Okishio & Nagao 2010, 601-608)

There are many kinds of methanogens in the process of biogas fermentation, and the range of temperature adaptation is also different. Some methanogens are suitable for high temperature fermentation, and the most suitable temperature is 55 ℃. The optimum temperature of some methanogens is about 37 ℃. Different temperatures are important in the growth of methanogens and biogas production. The most suitable temperature range for anaerobic fermentation is about ± 2 ℃. If the temperature fluctuation is ± 3 ℃, the anaerobic fermentation rate may be restrained to a certain extent. When the temperature fluctuation range is ± 5 ℃, the reaction system will appear obvious instability, which will reduce the gas production efficiency or stop gas production, and may cause a large amount of organic acid accumulation, seriously affect the anaerobic fermentation system, or even cause fermentation failure. Therefore, the temperature selection and control of anaerobic fermentation It's extremely important. (Izumi, Okishio & Nagao 2010, 601-608)

3.1.6 Types of anaerobic fermentation

At present, the anaerobic fermentation process can be divided into three types: sequencing batch, semi continuous and continuous. Each type is suitable for different conditions and different substrates. And each process type has its own advantages. (Sun, Liu, Zhou, Wang, Yu, & Cui 2013, 345-350)

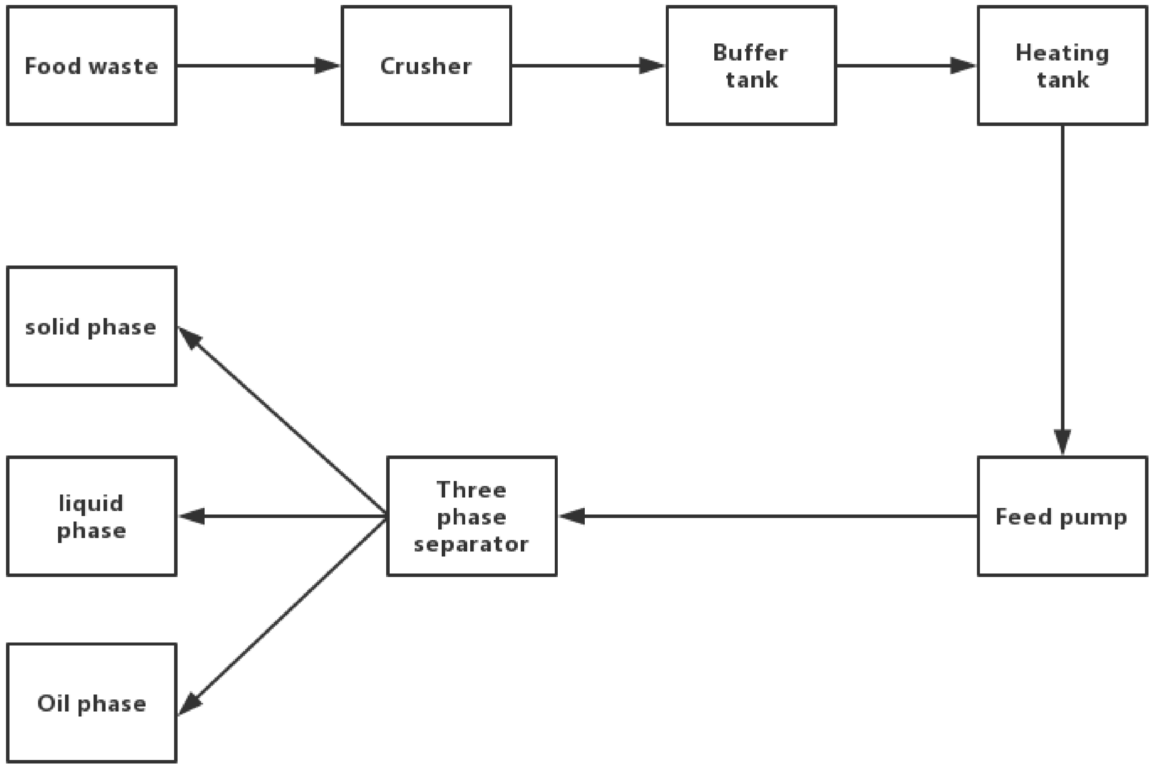
Sequencing batch anaerobic fermentation is mainly used for the fermentation of straw, cattle manure, chicken manure and municipal waste. The solid waste is placed in an anaerobic environment with suitable closed temperature. Through the role of anaerobic microorganisms, the organic matter in the waste is degraded. The process is composed of hydrolysis acid production stage and anaerobic fermentation biogas production stage. The anaerobic sequencing batch fermentation reactor consists of four stages: influent, reaction, sedimentation and drainage. The main advantages of this process are simple operation, less floor space, impact resistance, strong adaptability and good solid-liquid separation effect. The sequencing batch anaerobic fermentation is mainly solid fermentation. (Sun, Liu, Zhou, Wang, Yu, & Cui 2013, 345-350)

Single phase and two-phase semi continuous anaerobic fermentation is a combination of adding materials in stages and combining stages and continuity to jointly promote substrate fermentation. Semi continuous operation mode has higher stability and higher production efficiency than batch fermentation mode. Compared with batch fermentation, in the semi continuous fermentation process, the fermentation liquid in the reactor is discharged first, and then the fresh substrate or feed liquid is fed in the same amount, which not only replenishes the nutrition required by the microbial fermentation, promotes the growth of the microorganism, but also improves the fermentation efficiency and the output of organic acid and biogas. However, the semi continuous fermentation process is relatively complex. Generally speaking, through semi continuous fermentation, it can reduce the accumulation of by-products of microbial metabolism to a certain extent, so that the microorganism can stay in a stable environment for a long time and maintain the activity of microorganism. (Liu, Qiao & Croce 2017, 2194-2202)

Continuous anaerobic fermentation is to keep the reaction volume in a dynamic equilibrium state by continuous feeding and discharging according to the reaction type under certain conditions. Continuous anaerobic fermentation is mainly used for liquid waste such as wastewater and waste liquid or solid-liquid mixture with good fluidity. For the anaerobic fermentation treatment of a large number of liquid waste, continuous fermentation is superior to the above two types of fermentation. CSTR reactor is generally used for continuous anaerobic fermentation, This kind of reactor has advantages for liquid fermentation. The inoculum and substrate are completely mixed and fully reacted by agitation, and orderly feeding and discharging are carried out under dynamic balance. In comparison, continuous fermentation has advantages for waste with high water content and high fluidity. (He, Li, Zhao, Wu, Qu & Peng 2018, 587-598)

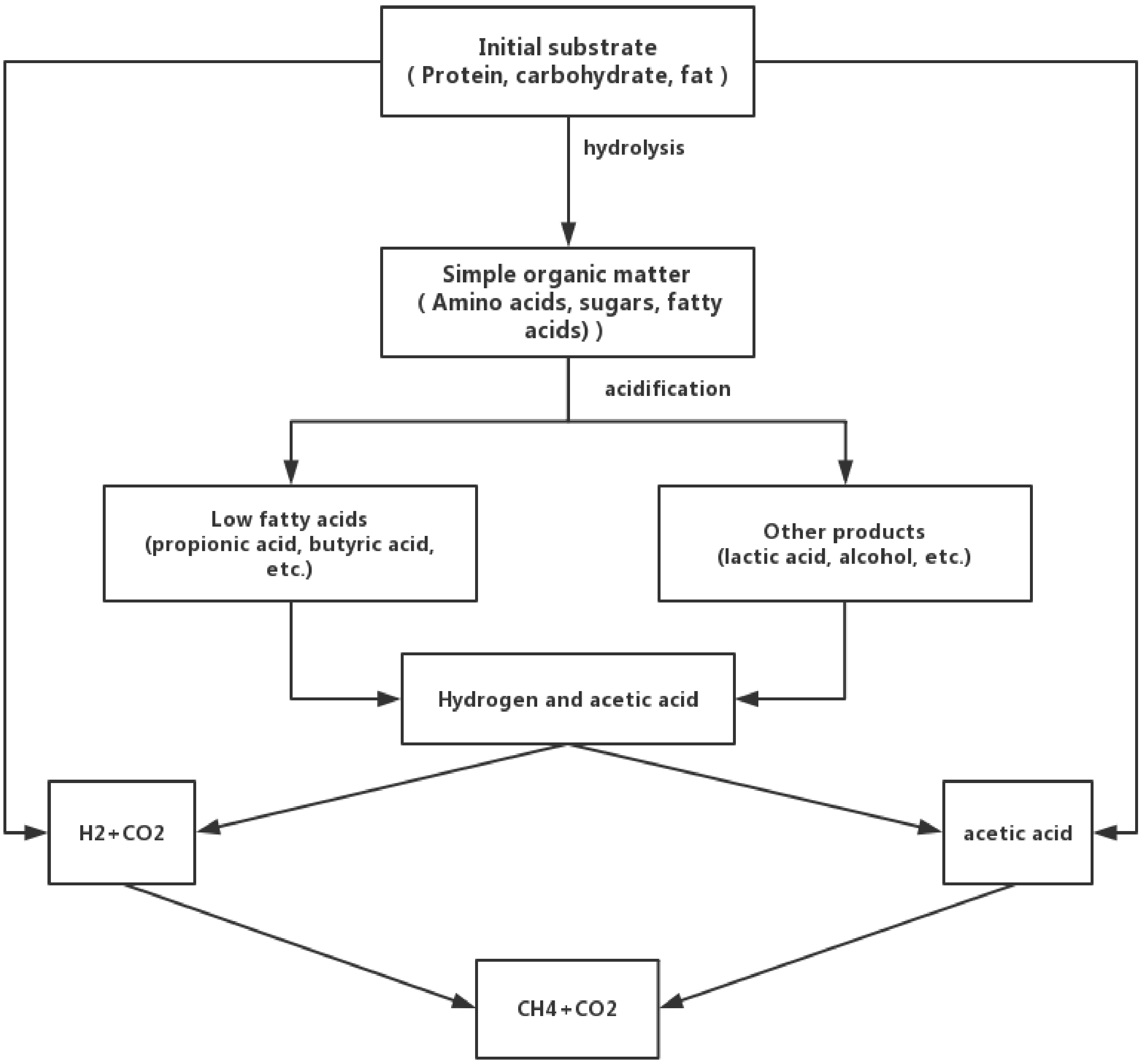
3.1.7 Anaerobic fermentation process

The first stage is the pretreatment of food waste. In the pretreatment part, the food waste is poured into the crusher, and the large food waste is crushed into small pieces and flows into the buffer tank together with the liquid. The broken food waste is transported to the heating tank for disinfection. Then it enters the three-phase separator to separate the food waste into solid phase, liquid phase and oil phase. The solid phase is used for composting, the oil phase is used for biodiesel production, and the liquid phase is transported to the fermentation tank for anaerobic fermentation. GRAPH 1 shows the pretreatment process.



GRAPH 1. The pretreatment process (adapted from Zhang 2017)

GRAPH 2 briefly describes the anaerobic fermentation process. First, food waste is used as the initial substrate, which contains protein, carbohydrate and fat. Food waste is hydrolyzed into simple organic units (amino acids, sugars, fatty acids). After acidification, it is decomposed into low-grade fatty acids and other products. These two products are used to produce acetic acid, H_2 and CO_2. Finally, CH_4 and CO_2 are generated. (Wang 2019)



GRAPH 2. Three-stage diagram of fermentation. (adapted from Wang 2019)

3.1.8 Advantage of biogas utilization

The main characteristic of biogas is renewable biomass energy. At present, fossil fuel is still the main fuel. but fossil fuels are non-renewable resources. The consumption of fossil fuels has had a great impact on the world's energy and economic aspects. The use of biogas can replace part of fossil fuel, which can effectively reduce fossil fuel consumption. (Zhou 2019, 2300-2303)

Biogas also has the characteristics of green and environmental protection, which can effectively reduce greenhouse gas emissions. Both the process of preparing biogas from organic waste and the replacement of traditional energy by biogas can directly or indirectly reduce CO_2 emissions. Biogas technology can also treat waste with high efficiency and environmental protection. From the perspective of global development, biogas always occupies a certain place and plays an important role in the progress of energy structure in developed countries such as Europe and the United States towards green and low-carbon development. (Zhou 2019, 2300-2303)

3.1.9 Application of biogas

The produced biogas can also be used after basic purification treatment or deep purification treatment and can be converted into bionatural gas or other chemical raw materials and chemical products after CO_2 removal or chemical transformation. The purification treatment or conversion contents of biogas implemented by different applications are different, the treatment cost is different, and the added value brought by the products is also different. Generally speaking, the utilization modes of biogas can be divided into three categories: direct utilization mode of biogas, pure utilization mode of biogas, utilization mode of biogas or chemical raw materials. (Yağlı, Koç, Koç, Görgülü & Tandiroğlu 2016, 923-932)

There are many applications of biogas. Biogas can be added to the combined heat and power (CHP) gas engine to generate electricity and heat, the exhaust heat in this engine can also have many applications such as heating, process heating. FIGURE 1 is a schematic diagram of the engine. The green biogas in the picture is mixed with air and then passed through the turbocharger. The mixture then passes through the heat exchanger and enters the biogas engine. Exhaust gas of 450 ℃ - 500 ℃ after passing through the engine. (Yağlı, et al. 2016, 923-932)

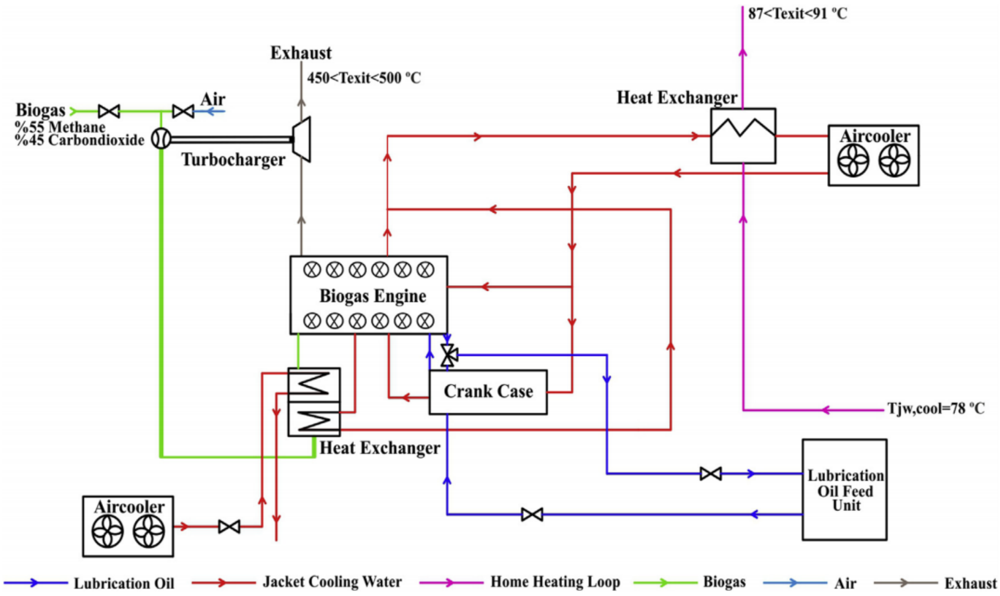


FIGURE 2. Engine schematic diagram. (adapted from Yağlı, et al. 2016, 923-932)

Biogas can also be used for vehicle transportation after treatment. The purified biogas can be used as vehicle fuel to provide power for vehicles such as biogas trains. The first biogas train in the world is in Sweden. FIGURE 2 shows the Swedish biogas train. The train has been in use since October 2005. (Laval 2006)

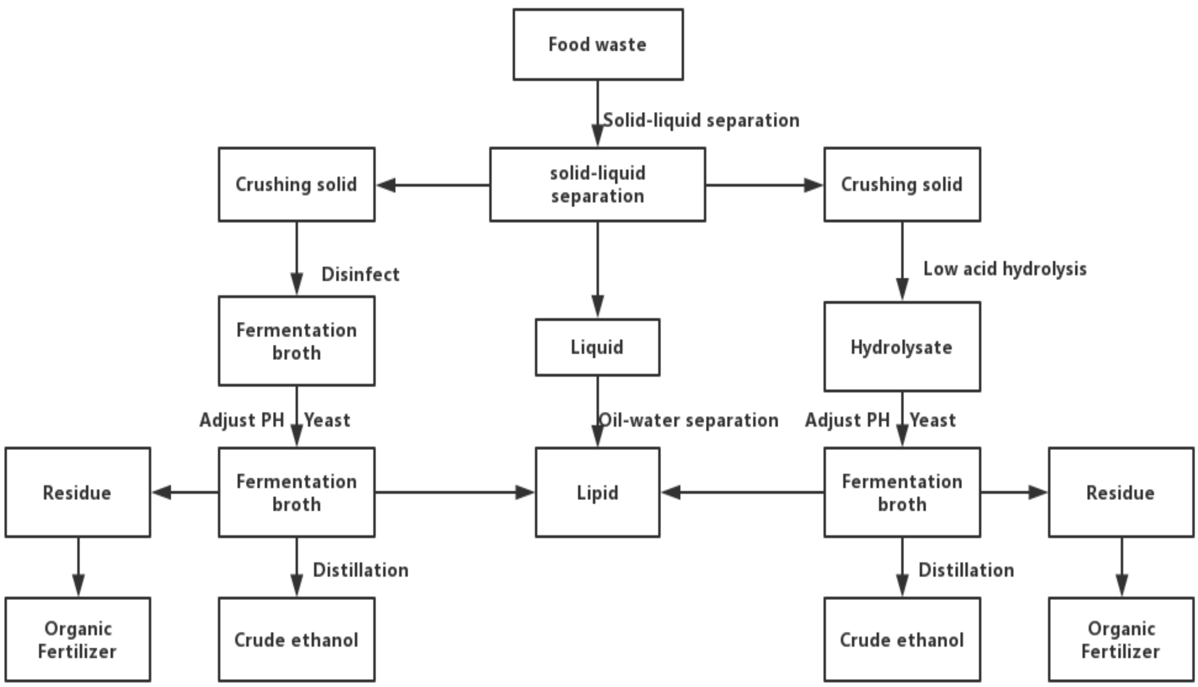
FIGURE 3. Swedish biogas train. (adapted from Barbarien 2006)

3.2 Bioethanol

Bioethanol is a widely used biofuel. Bioethanol belongs to biomass energy, which is bio liquid fuel produced by processing and transforming biomass raw materials. Bioethanol is sulfur-free and environmentally friendly. The carbon CO_2 emission of pure ethanol vehicles is much lower than that of similar gasoline vehicles (Mannberg, Jansson & Pettersson 2014, 286-299). At the same time, biofuel ethanol is also renewable energy. At present, the global fossil energy resources are increasingly scarce, the global carbon emission reduction pressure is increasing, and the oil security situation is becoming more severe. Bioethanol becomes the priority choice for countries to realize the transition from traditional fuel to clean and low-carbon. In the 21st century, global biofuel ethanol production has increased. At present, the countries and regions that promote the application of biofuel ethanol in the world mainly include the United States, Brazil, the European Union, China, Canada. Among them, the United States and Brazil are the countries with the largest biofuel ethanol industry. (Adewuyi 2020, 77-88)

3.2.1 Bioethanol production from food waste

Because food waste not only contains starch, but also contains protein. These substances are commonly used in the industrial production of bioethanol by yeast fermentation. Refined ethanol can be added to fuel oil as fuel ethanol, which is of great significance to alleviate the energy crisis. GRAPH 3 is the flow chart of ethanol production from food waste. (Wang 2015) First, the food waste is separated into solid and liquid. After that, the liquid is separated into lipid and wastewater. There are two ways to turn a solid component into ethanol after it is crushed. The first method is to hydrolyze the solid components in a low acid environment and adjust pH to about 5.5, then add yeast powder to ferment. The second method is to sterilize solids in a microwave reactor to regulate PH, then add yeast powder to ferment. After fermentation, the oil layer is recovered by liquid separation. The fermentation broth is distilled to obtain crude ethanol.



GRAPH 3. The process of preparation of ethanol from food waste. (adapted from Wang 2015)

The industrial synthesis of ethanol is mainly ethylene direct water method, which is divided into liquid-phase method and gas-phase method. At present, most of ethanol is produced by gas phase method. The principle is that ethylene gas reacts with water under the action of phosphoric acid and solid catalyst. The reaction equation is shown in the (1). (Guo 2015)

$$CH_2 = CH_2 + H_2O \rightarrow CH_3CH_2OH \quad \text{(Phosphoric acid)} \quad (1)$$

Biomass waste contains a complex mixture of carbohydrate polymers from cellulose, hemicellulose and lignin from plant cell walls. In order to produce sugar from biomass, the biomass is pretreated with acid or enzyme to reduce the size of raw material and decompose the raw material preliminarily. Part of cellulose and hemicellulose are decomposed or hydrolyzed to sucrose by enzyme or dilute acid, and then ethanol is produced by fermentation. The three main methods of extracting sugar from biomass are concentrated acid hydrolysis, dilute acid hydrolysis and enzymatic hydrolysis. (Chakraborty, Chatterjee, Mukhopadhyay & Barman 2016, 546-554)

The fermentation method is to use sugar as raw material and the anaerobic respiration of yeast to convert sugar into ethanol. This method is used to produce bioethanol from food waste. Food waste contains much sugar, starch and fiber. Food waste comes from a wide range of sources. First, the solid-liquid separation of food waste, hydrolysis or disinfection of the solid after fermentation. After that, starch and cellulose were hydrolyzed to glucose in acid condition or under the action of enzyme. After sterilization, bioethanol was further fermented to produce bioethanol. (Guo 2015)

3.2.2 Advantage of bioethanol utilization

Bioethanol has many advantages. Bioethanol has many advantages over conventional fuels. First of all, it is produced from renewable resources and absorbs CO_2 when crops grow, so there is almost no new CO_2 added to the atmosphere. Therefore, bioethanol is a new energy which is beneficial to the environment. A large part of the greenhouse gases in the atmosphere come from the automobile emissions during transportation. Now through the use of bioethanol, greenhouse gas emissions can be greatly reduced. And bioethanol is also biodegradable, less toxic than fossil fuels. Third, the use of bioethanol and gasoline blends can reduce oil consumption globally, thus ensuring higher fuel safety and avoiding dependence on fuel supplies between countries. Rural areas will also benefit from increased demand for essential crops for bioethanol production. (Małgorzata, Tomasz, Bartosz & Daria 2019)

Bioethanol also reduces carbon monoxide emissions from used car engines, improving air quality. Another major advantage of bioethanol is that it can be easily combined with the existing road transportation fuel system. The octane number of gasoline can be effectively increased by adding bioethanol to gasoline. Bioethanol can be easily mixed with conventional fuels without engine modification. (Smuga-Kogut, Piskier, Walendzik & Szymanowska-Powałowska 2019)

3.2.3 Application of bioethanol

Bioethanol can be used as a substitute for gasoline engine. It can mix with almost any percentage of gasoline. Most of the existing gasoline engines use a mixture of up to 15 % bioethanol and oil. Compared with the gasoline without ethanol, bioethanol has higher octane number, which can improve the compression ratio of engine and improve the thermal efficiency. It is also used to provide fuel for bioethanol fireplaces. It is smoke-free and does not require a chimney, so it is very suitable for residential use. Other major applications of bioethanol include thermal combustion power generation fuel, fuel in cogeneration system, chemical industry raw material and fuel for cell through thermochemical reaction. (Shi, S., Gao, M., Wang, Q., Zheng, J., Sonomoto, K. & Tashiro, Y. 2017, 118-121)

3.3 Biodiesel

Since the beginning of the 21st century, energy crisis and environmental pollution have become major problems facing all mankind. The contradiction between oil supply and demand is becoming increasingly serious. It has become the most important task to study new alternative energy. With the rapid development of economy, the demand for oil is increasing rapidly, and the supply gap is growing. Environmental pollution caused by the extensive use of fossil fuels has become a major challenge facing the world. In this context, the world is speeding up the development of alternative energy sources for petrochemical fuels, among which biodiesel has attracted the attention of all countries for its superior environmental performance. Biodiesel is a kind of liquid fuel which is produced by esterification or transesterification of renewable oil resources (such as animal and vegetable oil, microbial oil and waste cooking oil). (Guo & Ning 2019)

3.3.1 Biodiesel production from food waste

All sources of fatty acids, such as animal fats or vegetable fats, can be used as raw materials for biodiesel. Therefore, the raw materials of biodiesel are very extensive. TABLE 1 shows some raw materials for biodiesel production.

TABLE 1. Raw materials of biodiesel. (from Sun, Guo & Ning 2019)

Traditional raw materials		**Nontraditional raw materials**
Palm tree	Pumpkin	Fish oil
Birds	Corn	Microorganism
Tobacco seed	Waste cooking oil	Seaweed
Rape	Flax mustard oil	Fungus
Rice bran	Flaxseed	Microalgae
Desiccated coconut	Peanut	Latex
Sesame	Mustard	Philodendron
Sunflower	Olive	Jatropha
Barley	Lard	Cerbera
Cottonseed oil	Butter	Okra
Coconut	Jojoba oil	

But many of these resources are very important food resources. If food is used to produce biodiesel, there will be a food crisis. So now the main goal is to find a cheap and widely available nonedible oil. Biodiesel was prepared from a variety of cheap nonedible oil or waste cooking oil, nonedible oil, refining residue of oil processing and other new generation raw materials. (Sun, Guo & Ning 2019)

Edible oil refers to the animal or vegetable oil used in the process of food production. Edible oils are generally liquid at room temperature. Oil is an indispensable nutrient for human beings. Its energy density is high and its consumption is large. There are two kinds of edible oil: animal fat and vegetable oil. Because of their source, processing technology and quality, their properties, stability and nutritional value are different. Using human nutrition resources to produce biofuels will lead to food crisis. It can only be used in countries and regions with a large surplus of edible oil. Therefore, our main goal is to use nonedible oil or waste cooking oil as raw materials to produce biodiesel. (Stamenković, Banković-Ilić & Veljković 2012, 3621-3647)

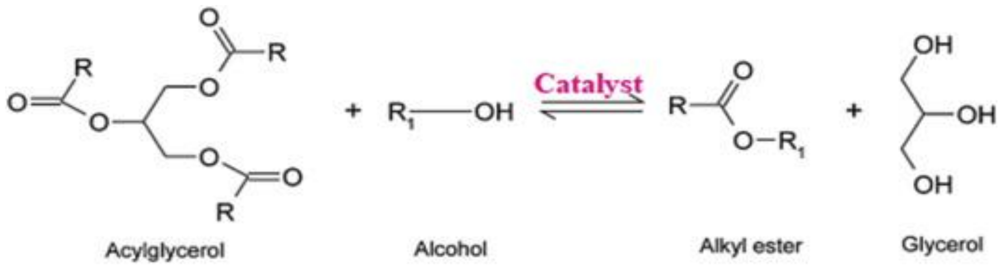
Nonedible oil refers to the oil that cannot be added to food production. The economic value of non-edible oil is low. It can significantly reduce the cost of biodiesel and has a wide range of sources. The source and production cost of raw materials are the important factors that affect the wide application of biodiesel, and the source and price of raw materials are the key factors that restrict the wide application of biodiesel. Using nonedible oil as raw material can reduce the production cost by more than 60 %. However, this kind of raw material is complex in composition and contains more free fatty acids and other impurities. Currently, the process of producing biodiesel with animal and vegetable fats as raw materials cannot effectively deal with these waste oil with complex components. (Stamenković, Banković-Ilić & Veljković 2012, 3621-3647)

People use animal and vegetable oils in their daily life. After that, waste grease will be produced. Although these waste oils can be treated innocuously by natural degradation, it is a waste of energy. The composition of waste oil and refined oil is similar and the price is cheaper. After treatment, waste oil can be turned into biodiesel. However, the source of waste oil is very complex, and the content of water, free fatty acid and unsaponifiable matter is high, so the preparation of biodiesel with waste oil as raw material needs to go through a complex pretreatment process to remove impurities and water. Due to the high acid value, it is often necessary to go through acid reducing treatment before transesterification, so it is still difficult to prepare biodiesel with waste oil as raw material. (Guo & Ning 2019)

According to the main physical change or chemical reaction in the preparation process, the preparation methods of biodiesel can be divided into physical method and chemical method. But chemical methods are still used to make high-quality biodiesel. (Ishola, Adelekan, Mamudu, Abodunrin, Aworinde, Olatunji & Akinlabi 2020)

The first method is physical method. The physical method is to change the physical properties of the oil, such as the freezing point and viscosity, by means of emulsification and dilution, so that it can meet the basic requirements of fuel oil. The phase formation and calorific value of vegetable oil and diesel oil are similar, but the high viscosity of vegetable oil results in nozzle blockage during the use. In order to reduce viscosity, mixed dilution and microemulsion were used. These methods can reduce the viscosity of oil products, but the carbon deposition of engine is serious and the nozzle is easy to be blocked. So physical method cannot produce high quality biodiesel. (Ishola, Adelekan, Mamudu, Abodunrin, Aworinde, Olatunji & Akinlabi 2020)

The second method is chemical method. In the presence of catalyst, transesterification is a process in which glycerides react with small alcohols to form new esters and alcohols. In the preparation process of biodiesel, the main components of oil are triglyceride and short chain alcohol, which form biodiesel and glycerin under the action of catalyst. At present, the best way to produce biodiesel from animal and vegetable oil is transesterification because of its fast reaction rate, mild reaction conditions, high conversion rate and good economy. Nowadays, transesterification is widely used in biodiesel industry. The reaction rate and the output of biodiesel can be increased by using catalyst. GRAPH 4 is a typical transesterification reaction. (Ishola, et al. 2020)



GRAPH 4. Transesterification reaction. (adapted from Ishola, et al. 2020)

Another method is hydrodeoxygenation cracking. The method is to convert animal and vegetable fats into liquid fuels with carbon chain length of 15 to 18 under the action of catalyst. The hydrodeoxygenation process can make the glycerides produce hydrocarbons with better low temperature performance under high temperature and pressure. But the reaction conditions are harsh, the energy consumption is high and the economy is poor. (Ishola, et al. 2020)

3.3.2 Advantage of biodiesel utilization

As a renewable fuel, biodiesel has many similar properties with diesel. However, compared with diesel, biodiesel has many advantages: Biodiesel has excellent environmental protection advantage. Compared with petrochemical diesel, biodiesel contains almost no sulfur, the sulfur emission of diesel engine is very low when it is used. The content of particles in tail gas is about 20 % of diesel, and the CO emission is about 10 % of petrochemical diesel, so the emission index can meet the emission standard. Biodiesel has good lubricity. The viscosity of biodiesel is higher than that of petrochemical diesel, which can reduce the wear rate of fuel injection pump, engine block and connecting rod, and prolong its service life. Biodiesel has good versatility. The use of biodiesel does not need to change the diesel engine, can be directly added to use. Biodiesel has strong climate adaptability. The ignition performance of biodiesel is better than that of ordinary diesel. Cetane number is a quality index to evaluate the fuel performance in compression ignition engine. Biodiesel has high oxygen content, high cetane number and better combustion performance than petrochemical diesel. Biodiesel has wide applicability. In addition to alternative fuels for buses, engineering trucks and other diesel engines, biodiesel can also be used as alternative fuels for other transportation fields. For example, as fuel for ships. Biodiesel has good safety performance. The flash point of biodiesel is much higher than that of diesel, so it is safe to store and transport. In addition, biodiesel will not pollute the environment and harm human health, because of its good biodegradability. (Ishola, Adelekan, Mamudu, Abodunrin, Aworinde, Olatunji & Akinlabi 2020)

3.3.3 Development status of biodiesel

The research of biodiesel began in the early 1960s. In the middle and late 1980s, Germany, the United States, Italy, France and other countries successively built special biodiesel research institutions, which invested Massive economic and human resources in the research of biodiesel. At the same time, the government encourages the research, production and application of biodiesel through various preferential policies, which makes biodiesel rapidly become the highlight of alternative fuels for petrochemical diesel. (Yang, Chen, Xu & Zhao 2019, 85-88)

Now, biodiesel will become an ideal alternative energy for fossil fuels because it is an environmentally friendly renewable fuel resource. At present, the key direction of biodiesel development is raw oil, reducing processing costs and developing environmentally friendly processing technology. The research of biodiesel plays an important role in solving the problems of environment, energy shortage and the shortage of oil raw materials. The preparation technology of new biodiesel will continue to develop, and gradually realize industrial production, so as to meet the growing demand for biodiesel. (Yang, et al. 2019)

3.4 Biobutanol

Under the influence of global energy shortage and various nonrenewable fuel combustion, the air pollution problems such as haze, acid rain are becoming serious, and people pay more attention to them. Biobutanol is one of the main chemical raw materials and clean fuels, which belongs to the second generation of biofuels. It will not form harmful gases during the actual combustion. Biobutanol is also a renewable fuel resource. Biobutanol is a kind of biofuel similar to bioethanol. Its raw materials and production process are similar to bioethanol, but its steam pressure is low, when it is mixed with gasoline, and high tolerance to impurity water, and it is corrosive. Compared with the existing biofuels, it can achieve a higher mixing ratio with gasoline, without the need for vehicle transformation. Therefore, it also makes the research and development of biological butanol is important. (Stoeberl, Werkmeister, Faulstich & Russ 2011, 1867-1874)

The reason why biobutanol is a new clean fuel is that it has strong advantages compared with other biofuels, and the advantages of biobutanol are as follows: Biobutanol is less corrosive and safer to transport. Biobutanol has a strong compatibility with gasoline, which does not need any adjustment of the engine. Biobutanol has a long carbon chain and strong similarity with gasoline, so its compatibility is high. Biobutanol has low volatility, high tolerance to water when mixed with gasoline, better adaptability to humidity and low water vapor pressure, and better storage. The energy content of biobutanol is high. The energy of combustion is relatively good, about 30 % of ethanol. The waste formed is similar to ethanol, and the combustion economy is relatively high. (Zhang 2018)

However, there are still some problems in the development of biobutanol. Butanol fermentation industry declined because of its high cost, which is the main reason to limit its large-scale development. The yield and yield of biobutanol are lower than that of bioethanol because butanol is toxic to bacteria. Another problem is the low concentration of solvents. If the traditional fermentation method is adopted, the consumption of equipment, power and energy will be increased. This problem is also the reason of high production cost of butanol. Traditional butanol fermentation uses corn and other food crops as raw materials. With the increase of food prices and the lack of food resources, the cost of butanol will be higher. However, food waste contains ingredients that can be used to ferment to produce biobutanol. This technology can effectively increase the production of biobutanol. (Zhang 2018)

3.4.1 Biobutanol production from food waste

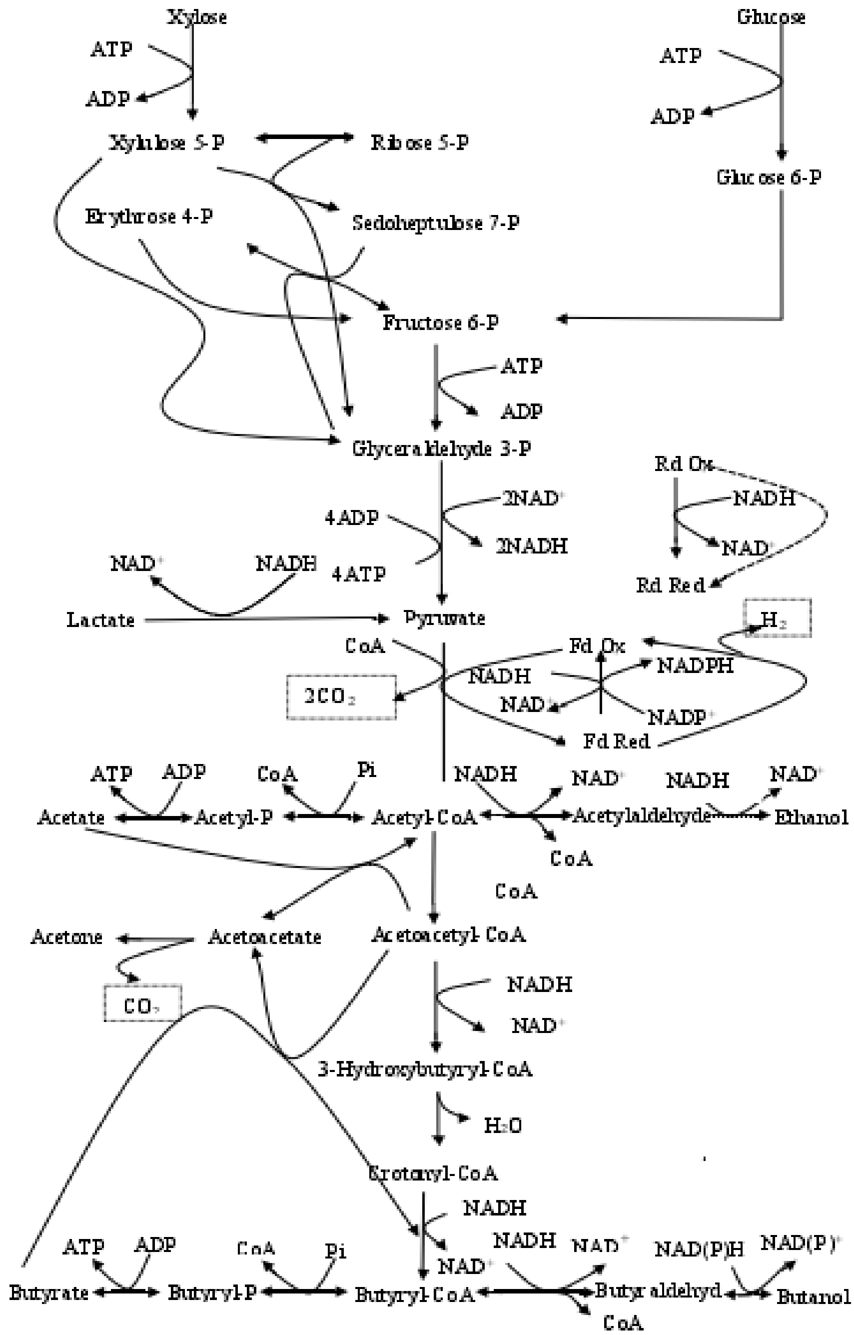
In this chapter, the preparation method of butanol will be introduced. Butanol can be produced by a fermentation process similar to that of ethanol. However, compared with ethanol, the cost of butanol production is much higher, that is to say, the production of butanol requires large evaporation, heating, cooling and other facilities, and the investment cost is higher. Therefore, the key to commercialization of biobutanol is to improve the conversion rate of raw materials into butanol and speed up the conversion process. It depends on the development of high efficiency biocatalyst and the optimization of production process design. (Shi, et al. 2017, 118-121)

At present, most of the raw materials used in butanol fermentation are molasses, starch, corn and other sugars, and the cost of raw materials accounts for a high proportion of the total cost. This is a serious problem for the industrial development of biobutanol. Therefore, the selection of non-grain and low-cost biomass raw materials is the key to realize the sustainable large-scale production of biobutanol. People are looking for cheap raw materials for butanol production, such as plant straw, agricultural waste and protein waste with high cell content.as plant straw with high cellulose content, agricultural waste and protein waste. However, the yield of butanol is different with different raw materials because of the different composition and content of substrate. The use of different strains also has a great impact on butanol production. (Shi, et al. 2017, 118-121)

There are four kinds of clostridium acetobutanol which can produce butanol in industry: clostridium acetobutyli cum, clostridium beijerincki, clostridium saccharobu tylicum, and clostridium saccharoper-butacetonicum. Among them, clostridium acetobutyricum is mainly composed of corn, cereal and other starch materials, which is called clostridium starch decomposing. The other three species are mainly fermented with molasses, cellulose hydrolysate and other sugar materials, which are called saccharified clostridium. (Wang, Gao, Bodjui, Wang & Wang 2019, 138-141)

3.4.2 Fermentation principle of clostridium acetobutyricum

Butanol degradation and metabolism can be divided into two parts: acid production stage and solvent production stage. The acid production stage occurs in the early stage of fermentation, when the bacteria rapidly propagate and grow, the substrate is decomposed to produce acetic acid, butyric acid, and release H_2 and CO_2 at the same time. Due to the accumulation of organic acids, the pH value drops sharply, which leads to the limitation of microbial reproduction and the slowing down of cell growth. The second stage is the solvent production stage: acetic acid and butyric acid are reduced to the target products ethanol and butanol, so the pH of the fermentation liquid rises gradually, which is the transition from the acid production stage to the solvent production stage. GRAPH 5 shows the fermentation process. (Shi 2016)



GRAPH 5. Principle of biolysis of butanol production. (adapted from Wang 2018)

3.4.3 Butanol fermentation process

The fermentation process of acetone butanol mainly includes three ways: batch fermentation, fed batch fermentation and continuous fermentation. Batch fermentation is widely used in acetone butanol fermentation plants in the last century. However, this method has the disadvantages of high labor intensity, low equipment utilization and low product concentration. Researchers continue to develop new fermentation technology to improve the economic competitiveness of acetone butanol fermentation. Fed batch fermentation has the advantages of alleviating the inhibition of substrate on bacteria and high cell concentration. Therefore, this technology is more suitable for acetone butanol fermentation. However, there is no extraction of fermentation liquid in the process of fed batch fermentation, only relying on the dilution of fresh culture medium to alleviate the inhibition of the product, so this process cannot solve the toxicity of butanol to the bacteria. (Wang 2018)

Continuous fermentation is to add fresh medium to the fermentation tank at a constant rate, while the mature fermentation liquid flows out of the fermentation tank at the same rate. In this way, the product concentration in the fermentation tank can be kept below its toxic value. Therefore, it can not only alleviate the inhibition of substrate, but also reduce the toxic effect of butanol on bacteria, thus improving butanol productivity. (Wang 2018)

3.4.4 Problems in butanol fermentation

As a new generation of bioenergy, the production of butanol by biological fermentation has a bright future. However, at present, ABE fermentation products are in a disadvantageous position in economy, and the main disadvantage of butanol fermentation lacking economic competitiveness is the high production cost, which is caused by the following reasons (Zhou, Li, Zhang, Liu, Li & Li 2019, 3461-3468): Population growth causes food crisis, and the production of acetone butanol by fermentation often uses corn, sweet potato and other food crops as substrates, which increases the production cost. Butanol is toxic to strains and increases recovery costs. The toxicity of butanol inhibited the low cell density of the strain, resulting in a low final butanol production rate and increased investment and operation costs. The heteromorphic fermentation of alcohol results in low yield of butanol and increases the cost of raw materials. In the process of butanol production by clostridium acetobutanol fermentation, a large amount of wastewater will be produced at the end of fermentation and the later purification process, and the treatment cost is relatively high.

4 CONCLUSION

The energy and environmental problems are increasingly tense at present. The resource utilization of food waste not only solve the problem of food waste polluting the environment, but also produce biofuels. From the comprehensive study of the utilization of food waste, burning, burying and mechanical grinding are the most direct treatment methods, but there are many disadvantages. Using this method will waste resources to a certain extent and do harm to the environment.

The anaerobic fermentation technology and aerobic biological treatment technology of food waste have high economic benefits and considerable development potential. However, in terms of process technology, it is also necessary to study the process system, improve the treatment technology and promote large-scale application according to the advantages of food waste. Using food waste to make biodiesel, ethanol and butanol is a perfect way to dispose of food waste while fully utilizing it. In this way, more resources can be obtained by using food waste, which has more environmental benefits. With the continuous progress of technology and processing technology, these technical bottlenecks can be optimized in the future. Significant benefits can be achieved by reducing processing costs and shortening processing processes.

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