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**PREPARATION OF FUEL ETHANOL FROM LIGNOCELLULOSE
AND DESIGN OF FERMENTATION TANK**

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Name of thesis PREPARATION OF FUEL ETHANOL FROM LIGNOCELLULOSE AND DESIGN OF FERMENTATION TANK		
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<p>With the development of economy and the depletion of fossil fuel, it is urgent to seek sustainable development of green and clean energy.</p> <p>The development of fuel ethanol plays an important role in the development plans of various countries. At present, the global biofuel ethanol industry is in a period of transformation from the main form of grain and non-grain fuel ethanol to the second generation of cellulose fuel ethanol.</p> <p>This thesis mainly introduces the basic situation of fuel ethanol production from lignocellulose based on China's national conditions, including the development and preparation methods, and the design of fermentation tank using the related chemical principles and knowledge.</p>		

Key words Biomass, lignocellulose, fuel ethanol, fermentation tank
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CONCEPT DEFINITIONS

IEA	International Energy Agency
LCB	Lignocellulosic biomass
SHF	Separate enzymatic hydrolysis and fermentation
SSF	Simultaneous saccharification and fermentation
SSCF	Simultaneous saccharification and Co-fermentation
CBP	Consolidated bioprocessing
CD	Catalytic domain
CBMS	Carbohydrate-binding modules
IRENA	Renewable Energy Agency

ABSTRACT

CONCEPT DEFINITIONS

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1 INTRODUCTION

As is known to all, with the continuous development of economy, the demand of people for fossil energy is also increasing gradually. The development of modernization is inseparable from the use of energy. However, excessive development and dependence on fossil energy, such as oil, will not only cause serious harm to the environment, such as water pollution, air pollution, soil pollution. It will also cause serious harm to national security. Excessive dependence on the import of oil resources will affect national security.

The development of new energy and industrial production are imminent, such as fuel ethanol. Although the preparation technology of fuel ethanol in the countries where fuel ethanol is used has been very mature and has reached industrial production, it is mainly grain. The current research focus is the preparation of fuel ethanol from non-grain biomass. The optimization of the preparation process of lignocellulosic fuel ethanol is still a research focus at home and abroad. The use of this clean energy can not only reduce environmental pollution, but also bringing considerable economic benefits, and making non-oil producing countries reduce their dependence on oil imports, to ensuring national security.

The research process is mainly based on literature review and device design. In the part of literature review, it mainly introduces the current energy utilization in the world, the utilization of lignocellulose in China, the development prospect of biomass and the process of preparing fuel ethanol from lignocellulose. In the design part of the device, the structure of the main medium fermentation tank and the design principle are used to design the corresponding scale fermentation tank.

2 RESEARCH BACKGROUND

China is a energy demand country. With the continuous development of economy and technology, the demand for automobiles is increasing. At the same time, the contradiction between energy supply and demand is increasingly prominent. As far as the world energy reserves are concerned, the exhaustible fossil fuel accounts for about 80% of the total world energy supply. Assuming that under the condition of fixed production and consumption, the known oil reserves can only hold at present in the next 41 years or so, the natural gas reserves can last for 64 years, and the coal reserves can last for 155 years.

(Goldemberg 2007) But in fact, the annual production and consumption show an increase phenomenon, which means that the energy consumption is faster than expected. In addition to supply and demand, the exploitation and use of fossil energy also bring serious pollution problems, such as soil pollution, ecological environment damage, global warming caused by greenhouse effect. In addition, due to the political instability of oil supply areas, people are increasingly concerned about the security of oil supply. In the long term, it is necessary to find new energy sources that can replace traditional fossil fuels. Nowadays, the development and use of sustainable energy have become an important energy strategy for many countries to ensure sustainable economic development. China is the largest developing country with the largest carbon emission. (Huang 2019) In order to change this situation, China has been actively exploring new environmental protection energy and increasing investment in renewable energy. According to the “Renewables in Cities 2019 Global Status Report” published by REN21, China has become the largest investor in renewable energy in the world for the seventh consecutive year. In 2018, China's investment in renewable energy accounted for almost one-third of the world's total, reaching 9.12×10^{10} , compared with 4.85×10^{10} in the US and 6.12×10^{10} in the EU. (REN21 2019)

In the research of renewable energy, fuel ethanol has attracted much attention because it can replace ordinary fuels, effectively solve the agricultural issues and conform to the national security strategy (Na 2019) According to incomplete statistics, at present, more than 40 countries and regions in the world have promoted and developed bioethanol and vehicle ethanol gasoline. The annual consumption of ethanol gasoline is about 6×10^8 t, accounting for about 60% of the world's total consumption of gasoline. Compared with the United States, Brazil and European Union countries, China's promotion of biofuel ethanol and vehicle ethanol gasoline is relatively slow, although China and the large fuel ethanol production country like Brazil and the United States also started to develop ethanol fuel at the end of the

20th century. In addition to the development of the project of using raw materials as fuel ethanol, the project of non-grain fuel ethanol has also been carried out. For example, in 2007, China launched the world's first commercial project of using cassava as raw materials for fuel ethanol and implemented it in Guangxi. The annual design capacity of the project is 200000 tons (Fei 2017.). However, due to the limitation of many factors such as raw material price, resource quantity and environmental protection requirements, the development of non-grain fuel ethanol project in China has been stagnant. By 2019, China's annual production of fuel ethanol is still far behind that of large ethanol producers, as shown in the TABLE 1. But it also means that China has a large space for the development of fuel ethanol in the future. Looking for a more efficient fuel ethanol production process and its industrial scale production should be the key points of development.

TABLE 1. Comparison of fuel ethanol production between major countries and China in 2019 (unit: million gallons) (Source: RFA analysis of public and private data sources)

Re- gion	2014	2015	2016	2017	2008	2019	% of world pro- duc- tion
USA	14, 313	14, 807	15, 413	15, 936	16, 061	15, 800	54%
Brazil	6, 760	7, 200	6, 760	6, 860	7, 920	8, 620	30%
Euro- pean Union	1, 445	1, 387	1, 377	1, 400	1, 430	1, 440	5%
China	635	813	845	860	1, 050	900	3%

3 LIGNOCELLULOSE ETHANOL

In this section, a detailed review of the relevant literature on lignocellulose ethanol, such as the relevant definitions and the preparation process of lignocellulose ethanol, the preparation method and its advantages and disadvantages.

3.1 Fuel ethanol

In this section, fuel ethanol will be introduced, including its definition, classification and environmental impact.

3. 1. 1 Definition of fuel ethanol

Fuel ethanol is currently the world's largest bio-energy production. Fuel ethanol refers to the absolute ethanol with a volume concentration of more than 99. 5% which can be used as an alternative vehicle fuel. (Chen 2007) Ethanol contains 35% oxygen, which can be used as a good oxygenator and blending agent for gasoline. After being mixed with gasoline in a certain proportion, it can make the gasoline burn more fully, thus reducing the emissions of hydrocarbons, carbon monoxide, nitrogen oxides and other pollutants. Its octane number is as high as 115, which can replace the lead additive to improve the explosion-proof performance of gasoline. In addition, it is also widely concerned because of its renewable, biodegradable, non-toxic, can reduce the emission of greenhouse gases and reduce the air pollution caused by solid particles and other toxic gases. (Balat & Balat 2009) The development and utilization of fuel ethanol can not only alleviate the global energy crisis, but also improve the environment and resource utilization. In addition, with the depletion of fossil energy sources such as petroleum and the environmental problems that it has brought about, accelerating the development and use of this new clean and renewable resource has become an international hot spot.

3. 1. 2 Classification of fuel ethanol

The current classification of fuel ethanol is generally based on different raw materials. The first-generation fuel ethanol is mainly produced using grains, sugar crops and oilseeds (corn, sorghum) and other food crops. The generation 1.5 fuel ethanol is mainly produced using sugarcane, cassava and other non-grain economic crops. (Dong 2016) The second-generation fuel ethanol mainly uses lignocellulosic crops and their by-products (sugar cane and bagasse, grains and straw, forest residues), organic parts of municipal waste (domestic kitchen waste) and special raw materials (target-grown plant grass, short-rotation forests and other Energy crops)(Ralph et al. 2009). The third-generation fuel ethanol uses algae (microalgae, cyanobacteria) as raw materials.

The production process of the first-generation fuel ethanol has matured and has achieved commercial scale, but it has been controversial because of the problem of wasting food and land. In addition, because China is a country with a dense population, this brings more pressure on the environment and the economy. The 1.5th and 2nd generation fuel ethanol are in the stage of rapid development due to its advantages of extensive sources and environmental protection. However, because of the complicated processing process and high cost, it has not yet reached commercial production. (Pengxiang et al. 2019)

At present, the third generation of algal ethanol is in the preliminary development stage. Because the algal raw material has the advantages of higher sugar content and no lignin, which makes the algal easier to transform into monosaccharide in the degradation process than the second generation. However, at present, more attention is paid to the manufacture of algal diesel oil, algal ethanol is still in the exploration stage. (Cao et al. 2019.). The classification and development process of fuel ethanol are shown in TABLE 2. It is generally believed that the second generation of fuel ethanol is more sustainable than the first generation. After establishing a mature development mechanism, in addition to saving food, it can greatly improve the efficiency of land use. (Sims, Mabee, Saddler & Taylor 2010.).

TABLE 2. Different raw material sources of fuel ethanol and the current development process

Fuel ethanol type	Raw material	Development process
1 st generation fuel ethanol	Cereals, sugar crops and oilseeds	The process is very mature, achieving the industrialization of mature production
1. 5 th generation fuel ethanol	Non-grain economic sugar crops	Pilot scale development
2 nd generation fuel ethanol	Lignocellulosic crops and their by-products, organic parts of municipal waste, special raw materials	In the stage of research and development, pilot scale development
3 rd generation fuel ethanol	Algae	Initial stage of development

3.2 Lignocellulosic biomass

Lignocellulose is insoluble in water, weak acid and alkaline solution; the neutral pH value can improve the corrosion resistance of the system. Lignocellulose has a small specific gravity and a large specific surface area. It has excellent thermal insulation, heat insulation, sound insulation, insulation and breathability. It has uniform thermal expansion and does not crack, higher wet film strength and coverage. Lignocellulose has excellent flexibility and dispersibility. After mixing, it forms a three-dimensional network structure, which enhances the support and durability of the system, and can improve the stability, strength, compactness and uniformity of the system. But to use the cellulose in it, this strong three-dimensional network structure should be destroyed. In this section, Biomass and lignocellulosic biomass are mainly introduced, including their stock, structure, and current situation in China. (Chen 2014)

3.2.1 Biomass

According to the definition of International Energy Agency (IEA), biomass refers to all kinds of organisms produced by plants through photosynthesis, including all plants, microorganisms, animals fed on

them and waste produced by them. (Dong 2016) The main sources of biomass are shown in FIGURE 1. It can be seen from the FIGURE 1 that biomass sources are very extensive. At this stage, scientists focus on the research of biomass in agroforestry and industry. Because the biomass in city is difficult to collect and separate, it is relatively expensive to process. Biomass has two significant characteristics. First, it is rich in reserves. The total biomass energy generated by plant photosynthesis on the Earth is about 2.2×10^{11} tons per year. (Guo 2011) According to this conversion, the annual production capacity is about 10 times the current world consumption level. Second, it is renewable. In the presence of solar radiation, plant photosynthesis will not stop, and production capacity will not stop. From the point of view of the law of conservation of energy, biomass energy can be viewed as a permanent and clean energy source. (Guo 2011)

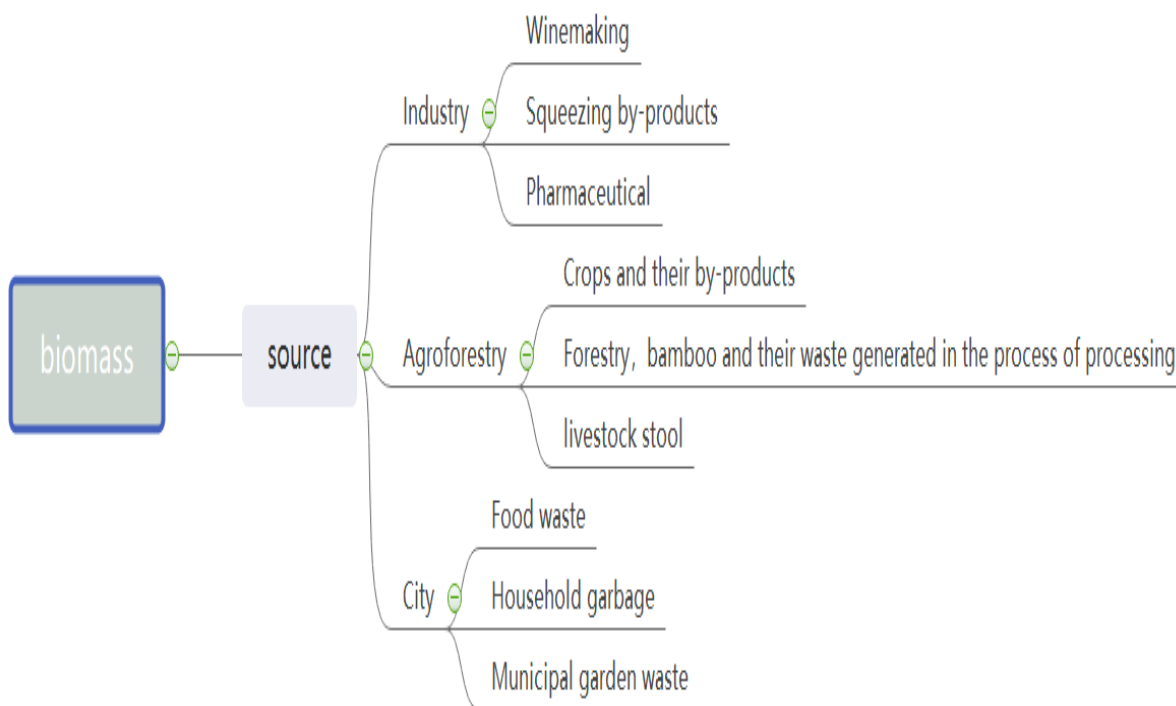


FIGURE 1. The main source of biomass (Adpated from Dong 2016)

Biomass can produce various types of energy substances such as fuel and gas through a certain conversion technology, which can effectively solve the problem of shortage of fossil fuels. (L. long 2002) Nowadays, in order to promote the development of renewable biomass energy, all countries have put forward clear development goals and formulated several development plans and regulations in light of

their own national conditions. Biomass Energy Program in the United States and the National Fuel Alcohol Program in Brazil, the New Sunshine Project in Japan, the National Fuel Alcohol Program in India, and in October 2008, the British Carbon Fund Corporation launched the world's largest algae biofuel project at the time, investing 26 million pounds in the development of related technologies and infrastructure. The project is expected to be commercialized by 2020. Finland, Sweden and other countries plan to completely replace petroleum-based vehicle fuel with biofuel by 2040. (Berndes, Hoogwijk & van den Broek 2003)

According to the International Renewable Energy Agency (IRENA), by 2050, the demand for renewable energy in industry will more than quadruple, and biomass will play an important role, accounting for about one third of renewable energy consumption. It can be seen from FIGURE 2 that, in the development period of 2015-2050, industrial energy utilization will undergo structural change, renewable resources will replace non-renewable resources as the main energy, and biomass energy utilization will from 7% in 2015 to 19% in 2050, about 30% of the total renewable energy utilization. (IRENA 2019)

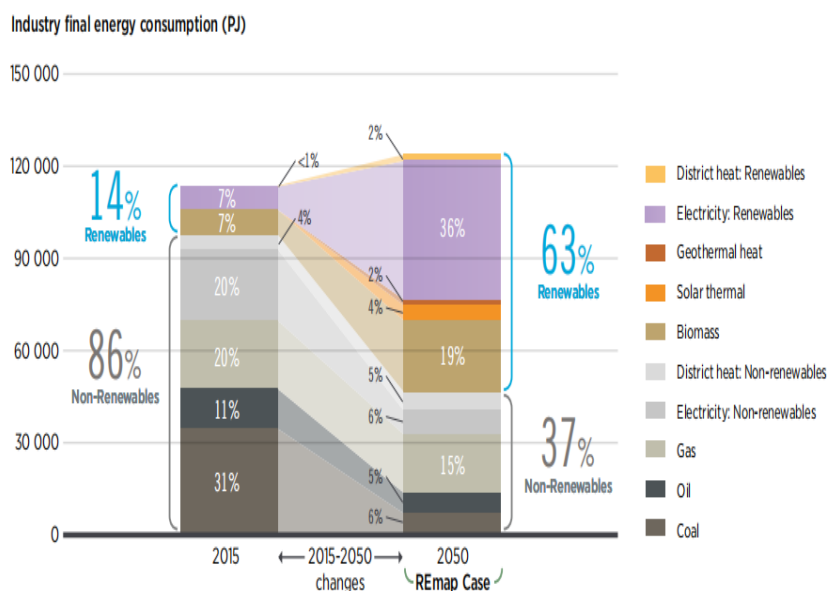


FIGURE 2. World industrial energy development trend forecast map (Adapted from IRENA 2019)

However, it is worth mentioning that despite the progress made in the efficiency and utilization of biomass and the attention of all countries, the whole is not on the track to achieve the Paris Agreement or

Sustainable Development Goal 7 (SDG7). In 2018, due to increased consumption of fossil fuels, global energy-related carbon dioxide emissions are expected to increase by 1.7%. (Global New Energy Report 2019) This shows that in general, countries rely heavily on fossil raw materials, and the research and development and utilization of biomass energy lags fossil raw materials. The world still needs to strengthen the awareness of environmental protection and accelerate the process of biomass energy research. (Global New Energy Report 2019)

3.2.2 Structure of the LCB

In the field of bioethanol, lignocellulosic biomass (LCB) as a widely used and highly efficient raw material for the 2nd generation fuel ethanol has become a category of concern. LCB consists of three parts: cellulose, hemicellulose and lignin. Among them, cellulose accounts for 40% to 50%, hemicellulose accounts for 25% to 35%, and lignin accounts for 15% to 20%. Natural cellulose has complex properties, is highly crystalline, difficult to dissolve, and is tightly surrounded by lignin and hemicellulose, making it difficult to be directly biodegraded. (Zhiguo D. 2016)

Cellulose fibers interact through hydrogen bonding and can form crystalline regions and amorphous regions; hemicellulose is a heteropoly polysaccharide composed of different types of monosaccharides (including pentose and hexose), the proportion of xylan produced by hydrolysis is about 60%, the fermentation speed of alcohol production is slow, and the cycle is long. Lignin is an amorphous, aromatic polymer with a molecular structure rich in oxyphenylpropanol structure or its derived structural units, which is difficult to use. (Congbo Xin 2013) The internal structure of the LCB is shown in FIGURE 3. Lignin is dispersed between cellulose fibers, but the two are usually not directly chemically connected. Lignin mainly plays a compressive role; hemicellulose penetrates between lignin and cellulose fibers. Between them, it plays the role of connecting the two, and then forms a very strong cellulose-hemicellulose-lignin network structure. If people want to use the cellulose inside, must have to destroy the solid network structure through pretreatment. (Energy Research Institute of Xiamen University 2018)

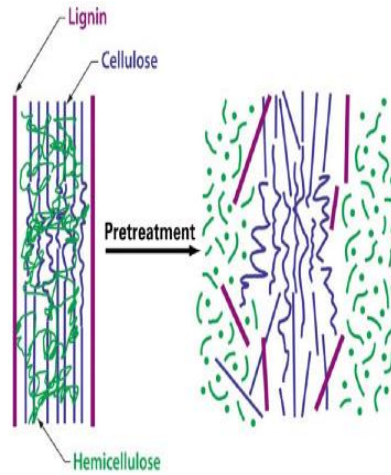


FIGURE 3. The internal structure of the LCB and pretreatment (Adapted from Mosier et al. 2005)

3.2.3 Current situation of LCB in China

LCB generally includes agricultural and forest residues, energy crops and cellulose waste. Agro-industry lignocellulose includes both food and non-food crops. Globally, wheat, corn, rice and sugar cane are the main cultivated crops, and its waste can be used as a wide range of raw materials for the production of fuel ethanol. According to statistics, the annual output of dry biomass in the world exceeds 5.3×10^9 tons, of which more than half is hemicellulose and cellulose. (Rezania, Oryani, Cho, Mohammadi 2020) China is a country rich in plant resources and a large agricultural country. The crop straw output alone is as high as 7×10^8 tons. (Including straw 2.3×10^8 tons, corn straw 2.2×10^8 tons, wheat straw 1.2×10^8 tons, cotton, beans, peanuts and other straw 2×10^8 tons) (Wang et al. 2019). The proportion can be seen from FIGURE 4, in addition, straw is the most extensive source of straw-like LCB in China.

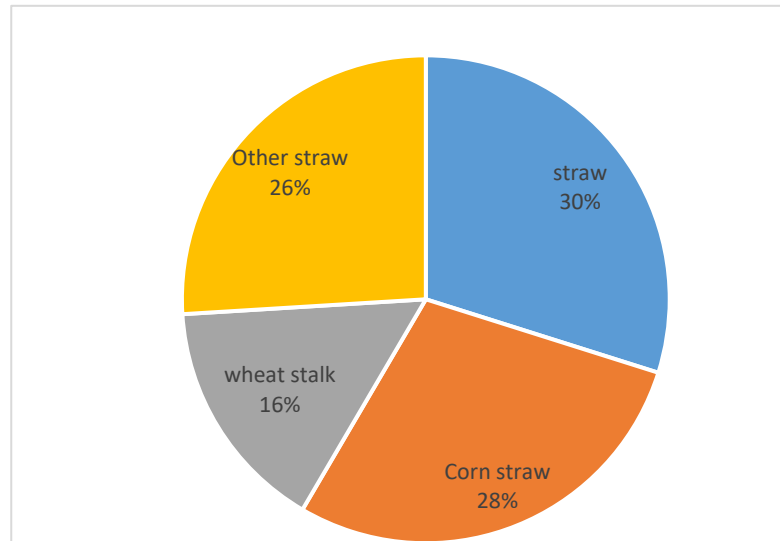


FIGURE 4. The main source and proportion of straw-like LCB (Adapted from Zhang. 2007)

In addition, there are also millions of tons of LCB waste produced by forest harvesting every year. However, due to the imperfect garbage mechanism in China, most of the above LCBs have not been fully utilized for a long time, the burning of crop straw has caused serious environmental pollution, increased the amount of PM 2.5 and other particles in the air, and also produced a large number of harmful gases such as carbon monoxide, carbon dioxide, nitrogen oxides, which have an impact on the environment and human health. It is estimated that as long as 1 / 2 of straw is fully utilized to produce ethanol every year, the ethanol production can meet the ethanol consumption in China. (Man 2018)

4 PREPARATION OF LIGNOCELLULOSE FUEL ETHNANOL

The lignocellulosic raw materials should be pretreated to remove some or all of the lignin in the raw materials to break the solid structure. The treated raw material is hydrolyzed by cellulase to prepare the enzymatic hydrolysate containing glucose, and then the glucose is metabolized and fermented by yeast to obtain ethanol mature mash. The mature mash is dehydrated by distillation and molecular sieve to obtain fuel ethanol products. The flow chart is shown in FIGURE 5. (Feng et al. 2019) With the development of C5-C6 sugar co-metabolism strains, xylose produced by hemicellulose hydrolysis can also be used to ferment ethanol. At present, although the production route of cellulose ethanol has been broken, many technical bottlenecks still exist in the process of biotransformation.

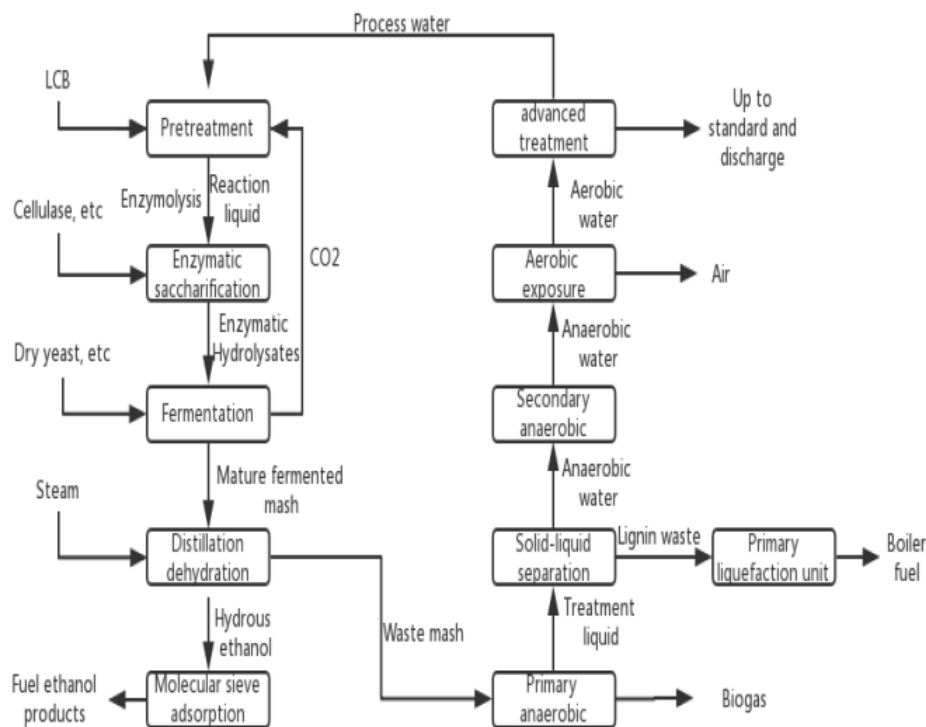


FIGURE 5. Roadmap for the production of fuel ethanol from LCB (Adapted from Feng et al. 2019)

4.1 Pretreatment of lignocellulose

As can be seen from the previous introduction, lignocellulosic raw materials have complex structural characteristics, which makes them naturally resistant to microbial degradation processes. Therefore, pretreatment of raw materials is required before enzymatic hydrolysis to break this structure. (Cao et al. 2020) The pretreatment process is a key technical step in the bioconversion of lignocellulose into biofuel. Its main purpose is to promote the effective contact between enzyme and substrate by destroying the structure of cellulose polymerization, reducing its crystallinity, increasing the porosity a specific surface area of cellulose, so as to improve the yield of fermentable sugar. (Li et al. 2019) Common pretreatment methods include physical method, chemical method, biological method. TABLE 3 lists the common pretreatment methods and their advantages and disadvantages. (Soltanian et al. 2020)

The physical method mainly achieves the purposes of reducing fineness, increasing specific surface area, changing cellulose structure, and being easily catalyzed by cellulase through physical mechanical behavior. The physical method is generally not used alone, but as the first step of lignocellulose pretreatment, combined with other pretreatment methods to achieve the purpose of reducing the crystallinity of cellulose and improving the enzymatic performance of cellulose. Chemical pretreatment is a method that uses various chemical reagents (including water) to pretreat lignocellulose to improve the efficiency of cellulase hydrolysis. At present, the chemical method is still the main method in the cellulose pretreatment process. Physicochemical method is one of the most promising pretreatment methods that people think of in terms of industrialization. It is a method that combines chemistry, physics, and machinery. However, it also has the disadvantages of high equipment requirements and incomplete lignin separation. Biological pretreatment is a pretreatment method that uses microorganisms or enzymes produced by microorganisms to degrade lignin and hemicellulose, thereby improving cellulose accessibility. The microorganisms commonly used in the pretreatment of lignocellulose are mainly microorganisms capable of degrading lignin in nature, mainly using fungi, which can effectively degrade lignin and promote subsequent enzymatic hydrolysis reactions. The biggest advantage of biological method pretreatment is low energy consumption, no pollution, and mild processing conditions, but it also has certain disadvantages, such as slow process and long cycle, so it is difficult to industrialize biological method. (Chen 2014)

TABLE 3. Common pretreatment methods and the merits and drawbacks

	Pretreatment Method	Main merits	Main drawbacks
Physical methods	Milling	*Reduce the polymerization degree of lignin and hemicellulose *No inhibitor produced	*High cost and energy consumption
	Microwave	*Shortens the reaction time *Enzyme requirements reduced	*High cost *Inhibitor production *Difficult to large-scale industrial application
	Acid	*Reduce the average degree of polymerization of cellulose *Mild pretreatment conditions	*Easy to corrode equipment *Inhibitor production *high cost in reactor
Chemical methods	Alkaline	*Reaction at room temperature *Increase enzyme activity	*High production of inhibitor *Difficult in neutralization, reagent recovery
	Ironic Liquid	*Without explosive and toxic gases release *Low production of inhibitors	*High temperature of pretreatment *Long pretreatment period
	bacterial	*Low production of inhibitors *Relatively fast growth	*Long pretreatment period
Biological methods	Enzymatic	*Low production of inhibitors *No need to recycle and dispose of chemicals	*Loss of carbohydrates *High cost of enzyme production and purification
	Microbial consortium	*Increased productivity *Both hemicellulose and cellulose can be degraded	*Sensitive to environmental fluctuations
	Hydrothermal method	*Increase the contact area between cellulose and enzyme *No need of chemical reagent, high efficiency of enzymolysis	*The hydrolysate is complex and the yield of reducing sugar is low *Large feed liquid-solid ratio
Physical & chemical methods	Ammonia explosion	*The accessibility of cellulase hydrolysis was improved	*High energy consumption and cost of ammonia recovery
	Steam blasting	*Short pretreatment period *Low energy consumption, no pollution *High enzymolysis efficiency,	*Low yield of polysaccharide *Hemicellulose is not completely degraded

In addition to the above conventional pretreatment methods, there are currently many new methods such as chemical /physical-biological combined pretreatment methods, electrochemical pretreatment. However, most of the new technologies are still immature and are in the laboratory stage, large-scale production has not yet been achieved. (Soltanian et al. 2020)

4.2 Enzymatic saccharification of LCB

The common hydrolysis of lignocellulose includes enzymolysis and acidolysis. Acidolysis includes concentrated acidolysis and dilute acidolysis. TABLE 4 is a comparison of three hydrolysis methods. (Jiang 2016) Compared with acid hydrolysis, enzymatic hydrolysis is better, mild reaction conditions and high yield of glucose, but it takes longer time. In addition, enzymatic hydrolysis has the advantages of high sugar yield, less by-products, no environmental pollution, so it has attracted wide attention from all over the world. (Liu 2015)

TABLE 4. Comparison of three hydrolysis processes (Adapted from Jiang 2016)

Technology	Catalyst type	Time	Temperature	Glucose yield
Concentrated acid hydrolysis	30% -70% sulfuric acid	2-6h	50-100°C	90%
Dilute acidolysis	1% sulfuric acid	3min	160-240°C	50-70%
Enzymatic hydrolysis	Cellulase	1. 5d	40-60°C	75-95%

4.2.1 Cellulase of enzymatic hydrolysis

Enzymatic hydrolysis is a key step in the hydrolysis and saccharification of LCB, cellulase is usually completed by cellulase. It is a complex enzyme that can degrade the cellulose in LCB into glucose monomer. The cellulose complex enzyme system mainly contains endoglucanase, exoglucanase and β -glucosidase. Cellulase mainly consists of the catalytic domain (CD) with catalytic action and the carbohydrate-binding modules (CBMs) with substrate binding ability. However, not all cellulases have CBMs. The presence of CBMs does not affect the catalytic function of cellulase, However, CBMs can not only recognize and adsorb cellulose chain, but also specifically adsorb lignin. The adsorption of lignin and CBMs is very strong, but cellulase cannot degrade lignin. Therefore, how to reduce the non-characteristic adsorption of cellulase and lignin is of great significance to improve the degradation activity of cellulase and reduce the production cost of fuel ethanol. (Lynd Weimer van Zyl & Pretorius 2002)

4.2.2 Influencing factors of cellulase

At present, there are two main methods to improve the enzymatic activity of cellulase: one is to increase the binding capacity of cellulase to cellulose, and the other is to reduce the non-specific adsorption of lignin to cellulase. The mechanism of cellulase hydrolysis is not clear, but it must rely on the synergy of various enzymes in the complex enzyme to degrade LCB into glucose monomers. (Jiang 2016) There are many factors that affect the efficiency of enzymatic saccharification. In addition to cellulase and reaction conditions that affect enzyme activity such as temperature and pH, there are also properties of LCB itself, such as pore size and lignin content. The larger the pore size, the easier the cellulase enters, and the higher the enzymatic hydrolysis efficiency; the more lignin content, the more non-specific adsorption occurs, and the lower the enzymatic hydrolysis efficiency. To improve the enzymatic hydrolysis efficiency, improving the accessibility of cellulose is quite necessary. (Zhang 2010)

4.3 Fermentation process

In the saccharification step, the glycan is hydrolyzed to monosaccharide, which is fermented to ethanol under the action of microorganism. The fermentation of fuel ethanol belongs to the industrial concept of fermentation, which is a very complex biochemical reaction process. In addition to the production of ethanol, it also includes the continuous process of enzymatic hydrolysis and saccharification, the decomposition of protein and the production of CO₂ and other by-products. In the production process of fuel ethanol, the fermentation intensity is an important index to evaluate the fermentation industry. High alcohol concentration, high osmolality, high yeast number and other characteristics of high mash fermentation. High gravity fermentation technology has the advantages of increasing the content of ethanol products, reducing energy consumption, saving water, effectively reducing costs, realizing cleaner production, so it has a wide range of application value. (Miao 2020) At present, there are four main fermentation processes for cellulose ethanol after enzymatic saccharification, separate enzymatic hydrolysis and fermentation (SHF), simultaneous saccharification and fermentation (SSF), Simultaneous saccharification and Co-fermentation (SSCF) and Consolidated bioprocessing (CBP). (Miao 2020)

4.3.1 SHF

SHF is the first fermentation mode of cellulosic ethanol. Because the process is simple and the operation is convenient, the commercialization is earlier. The saccharification and hydrolysis of cellulase to monosaccharide and the fermentation of sugar liquor to ethanol are carried out in two steps. Because the optimal conditions of cellulase and yeast are different, the advantage of SHF is to ensure that both of them are carried out under the optimal conditions, but there is a disadvantage that the inhibition of cellulase activity leads to negative feedback inhibition with the increase of saccharification products. (Liu 2013)

4.3.2 SSF

In order to reduce the negative feedback effect of the SHF process, Gauss and other researchers proposed SSF in 1976 (Guass 1976), that is, the cellulase enzymatic saccharification process and the fermentation of sugar liquid into ethanol are performed simultaneously in the same container. The advantage of this method is that it can make the saccharification products obtained by enzymatic hydrolysis are immediately converted into ethanol by microorganisms, which effectively reduces the inhibitory effect of saccharification products on cellulase during the enzymatic hydrolysis process, shortens the reaction cycle and reduces the amount of cellulase. The concentration of saccharification products in the reaction system is maintained at a relatively low level. The low level and the presence of ethanol leave the fermentation process in an anaerobic environment, so the probability of infection is greatly reduced, and the yield of ethanol will also increase. However, the disadvantage is that the optimal reaction temperature of cellulase and yeast is different, respectively 50 °C and 35 °C, both of them need to be considered in the reaction process, which may lead to the situation that LCB hydrolysis is not complete and the concentration of fuel ethanol product is low, which makes it difficult to recover ethanol and increase the cost. In addition, it is also difficult to recover microorganism. At present, it can be improved by developing high temperature resistant strains through genetic engineering. (Guo 2020)

4.3.3 SSCF

After pretreatment, C5 and C6 sugars from cellulose and hemicellulose were fermented to produce ethanol. The same as SSF, it can be enzymolysis and fermentation in the same reactor, but SSCF not only reduces the product inhibition of the enzyme process, but also reduces the time of five carbon sugar fermentation alone. The advantage of SSCF is to improve the substrate utilization rate and ethanol yield, but it has high requirements for the fermentation flora, so it is necessary to find a compound strain or a strain with the fermentation capacity of C5 and C6 sugars . (Wang 2013)

4.3.4 CBP

CBP refers to the biological processing process that integrates the production of cellulase and hemicellulase, cellulase saccharification, C5 and C6 sugars fermentation processes into a single system under the effect of a single or combined microbial community. It is currently the most advanced fuel ethanol preparation process. It is convenient and efficient to convert the substrate into ethanol in one step under the high-efficiency metabolism of microbial populations. Under the same conditions, comparing the CBP and SSF processes, the results show that the ethanol conversion rate of the CBP process is higher. (Xu, Singh & Himmel 2009)

CBP is actually a hydrolysis process of microbial action, specifically including four biological conversion processes: saccharification enzyme production, carbohydrate production, C5 and C6 sugars fermentation. Lynd Provided two suggestions on the cultivation of microorganisms after the experiment. (Lynd et al. 2002) One is to use the existing microbial flora mainly based on fungi. The microorganisms currently studied are mainly *C. thermocellum*, which can grow in an environment where the ethanol concentration is above 60g / L. Second method is the use of genetically engineered microorganisms. Through genetic modification to cultivate microorganisms with higher ethanol fermentation capacity and tolerance, the current research work is mainly concentrated on fungi and yeasts. (*E. coli* & *S. cerevisiae*) (Lynd et al. 2002)

The key to the CBP process is to reduce the formation of organic acids, salts and other by-products in the process, while improving the ability of microorganisms to withstand ethanol. However, the current process is not mature, the main reason is that no microbial flora can be found that can secrete the enzyme required for hydrolyzing raw materials and has high yield and is resistant to ethanol. With the development of modern technology, the future development of LCB fuel ethanol will be closely related to genetic engineering. The conversion of sugar to ethanol and its productivity can be improved through genetic engineering of microbial species. It is important to focus on improving the production and capacity of cellulose hydrolases because these enzymes account for more than 50% of the cost of producing sugar

from biomass. In addition, genetic engineering can also be used to increase the yield of crop production and change its internal structure to make it easier to separate cellulose. (Karimi & Chisti 2015)

4.4 Distillation and dehydration

The fermented mature mash obtained by fermentation is mainly composed of volatile impurities and non-volatile impurities. Volatile impurities are containing methanol, acetaldehyde, fusel oil. Non-volatile impurities are containing lactic acid, glycerin, inorganic salt fatty acids, succinic acid, lactic acid, Yeast and non-fermentable sugar. The distillation of ethanol is to separate the ethanol and volatile impurities in the fermented mature mash. The common azeotropic distillation process and common distillation process are rarely used for the industrial development of fuel ethanol due to factors such as high energy consumption and high cost. The following focuses on the introduction of salt extraction rectification process and ionic liquid extraction rectification process. (Lei et al. 2005)

4.4.1 Salt extraction rectification process

When soluble salts are added to the ethanol-water system, the resulting "salt effect" can significantly increase the relative volatility of fuel ethanol in the mixed solution. The most used soluble salts are calcium chloride, sodium acetate and potassium acetate. Cook and Furter used potassium acetate to perform extractive distillation in a pilot-scale bubble column and found that the relatively small amount of salt can make ethanol-water azeotropes disappear. (Cook RA & Furter 1968) Barbara comparing the extractive distillation with azeotropic distillation, extractive distillation with organic extractant, solvent extraction and membrane pervaporation, found that the energy consumption of extractive distillation with CaCl_2 as extractant is similar to that of membrane pervaporation, and the two methods are more advantageous. (Barba. et al. 1985)

In the process of extractive distillation with salt addition, two or more soluble salts can be added at the same time, and the efficiency of rectification can be improved easily by different ratios of salts. In addition, the process can extract absolute ethanol from the fermentation broth with only one tower and has the advantages of minimum energy consumption and non-toxicity. It is a fuel ethanol rectification process with broad development prospects. (Cook RA & Furter 1968)

4.4.2 Ionic liquid extraction rectification

Ionic solution is usually a mixture of organic cation and inorganic anion. Because of its low viscosity, thermal stability, good solubility and lower corrosiveness than high solubility salt, it is a promising extractant in ethanol-water extractive distillation. (Lei. et al. 2005) The process has the following advantages: high separation capacity, easy operation, no solvent entrainment problem of the tower top products. It is like soluble salt, but less corrosive. Ionic liquid as extractant can greatly improve the relative volatility of fuel ethanol in water. (Lei. et al. 2005)

5 DESIGN OF FERMENTATION TANK

In this section, the fermentation tank used in the preparation of fuel ethanol fermentation is analyzed, including the structure and characteristics. Take actual production as an example, the fermentation tank of corresponding scale is designed by using the relevant knowledge of chemical engineering.

5.1 Structure and characteristics of fermentation tank

Fermenter is a vessel that provides a stable environment for a specific biochemical reaction process. The tank body is welded by cylinder and elliptical or dished head. The thickness of steel plate varies according to the volume of fermentation tank. It is made of 4-8 mm thick stainless steel or composite stainless steel. The ratio of tank height to diameter is 1.7 - 4. Generally, the number of snake tubes is not less than 0.25 m² cooling area per cubic meter of fermented mash. The snake tube can be installed in two groups and fixed. It is also equipped with a drenching pipe or a drenching enclosure on the top of the tank. (Liu 2003) The plate makes the water flow down the tank wall to achieve the purpose of cooling the fermented mash. The fermentation temperature control is achieved by adjusting the cooling flow of the cooling system. At home and abroad, the jacket of the outer wall of the tank is used to pass into the low-temperature alcohol water to cool the fermentation liquid in the tank. The disadvantage is that it requires an intermediate heat exchange cycle of alcoholic water. For larger fermenters, these two cooling methods can be used simultaneously. The top of the tank is provided with a CO₂ discharge pipe, a heating steam pipe, and a mash input pipe. However, the pipeline setting should be simplified as much as possible, so that one tube can be used for multiple purposes, which has an important role in reducing the dead angle of the pipeline and preventing the contamination of miscellaneous bacteria. The top and sides of the large fermentation tank should also be provided with manholes for easy cleaning. Its structure is shown in FIGURE 6. (Liu 2003)

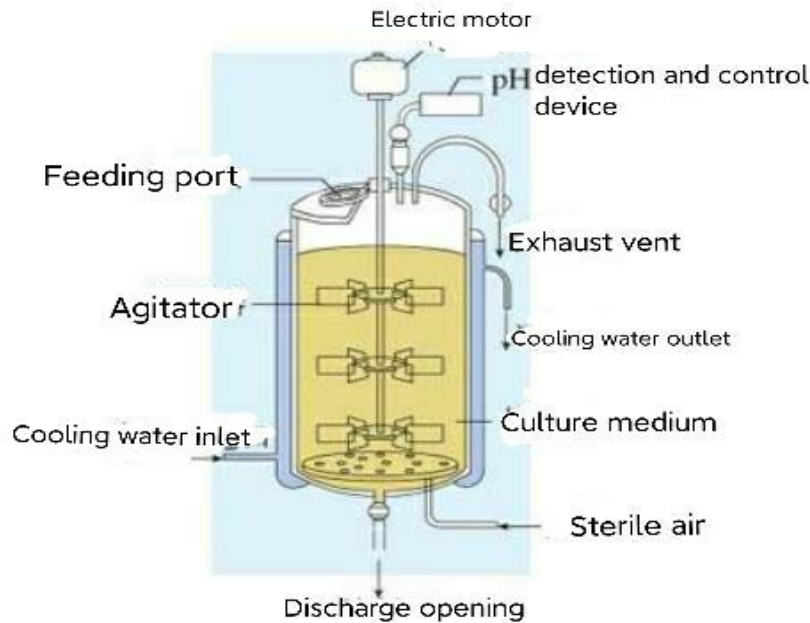


FIGURE 6. Structure and characteristics of fermentation tank (Adapted from Liu 2003)

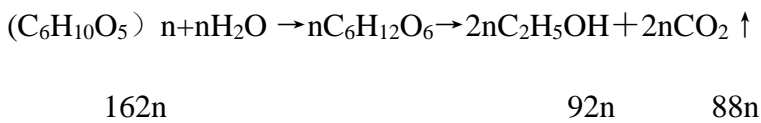
Fuel ethanol fermentation is a process that consumes a lot of energy and consumes a lot of cooling water and electricity. The rational design of alcohol fermentation tanks is crucial. A good fermentation tank device and composition should have the three main characteristics, tight structure, good heat and mass transfer rate, and have reliable supporting monitoring devices and control instruments. A good fermentation tank can play a role in saving production costs and improving fuel ethanol production efficiency.

5.2 Calculation of fermentation tank

In this case, a plant with an annual output of 150,000 tons of fuel ethanol is used. The plant's annual start-up time is 300 days. The case uses SHF technology combined with relevant knowledge of chemical engineering to design a fermenter.

5.2.1 Calculation of raw material consumption (based on 1 ton of fuel ethanol)

The total chemical reaction formula for producing ethanol from corn stalk raw material is shown.



Theoretical cellulose consumption for producing 1 ton of fuel alcohol (ethanol content in fuel ethanol is above 99.5% (V), equivalent to 99.18% (m)):

$$1000 \times 162 \div 92 \times 99.18\% = 1746.5 \text{ kg}$$

Actual cellulose consumption for producing 1 ton of fuel ethanol, the distillation rate is 98% and the fermentation rate is 95%):

$$1746.5 \div 98\% \div 95\% = 1875.9 \text{ kg}$$

Production of 1000 kg fuel alcohol corn stalk raw material consumption (corn stalk raw material contains 37.4% cellulose, pretreatment consumption 3%, cellulose hydrolysis rate 95%, fermentation mash accounts for 90% of the hydrolysate)

$$1875.9 \div 37.4\% \div 95\% \div (1-3\%) \div 90\% = 5443.1 \text{ kg}$$

5.2.2 Calculation of fermented mash

For the convenience of calculation, if the raw material slurry entering the hydrolysis process contains only cellulose, (the dry matter content of the raw material slurry is 7%), the quality of the raw material slurry is

$$5443.1 \times 37.4\% \times 97\% \div 7\% = 28209.25 \text{ kg}$$

This design the single concentration alcohol continuous fermentation process, after evaporation through a four-effect downstream evaporator, the sugar content is 8% concentrated to 20% (Shubiao J. 2004) Then the amount of fermented mash is

$$28209.25 \times 8\% \div 20\% = 11283.70 \text{ kg}$$

The factory starts 300 days a year, Nissan product alcohol content:

$$150,000 / 300 = 500 \text{ tons}$$

Alcohol per hour:

$$500 \div 24 = 20.83 \text{ (t)} = 20833 \text{ kg}$$

The amount of main raw straw:

Daily consumption:

$$500 \times 5443.1 \div 1000 = 2721.55 \text{ tons}$$

Annual consumption:

$$2721.55 \times 300 = 816,465 \text{ tons}$$

The total material balance is shown in TABLE 5

TABLE 5. The total material balances

Material balance	Production of 1000kg 99.5% fuel ethanol material	Per hour (tons)	Per day (tons)	Per year (tons)
Fuel alcohol	1000	20.83	500	150,000
Corn stalk raw material	5443.1	113.38	2721.55	816,465
fermented mash	11,283.70	235.039	5641.75	1,692,525

5.2.3 Volume of fermentation tank

According to the existing equipment of the fermentation tank, the volume of medium and large fermentation tanks is generally 100 m³ to 500 m³. According to the existing productivity of the factory, 500 m³ can be used, the upper part of the fermentation tank is a standard elliptical head, and the lower part is a conical head. For simplicity of calculation, assuming that the upper and lower heads are approximately the same

$$H = 2D \quad (1)$$

$$h_1 = h_2 = 0.1D. \quad (2)$$

$$V = \frac{\pi}{4} D^2 H + 2 \times \frac{\pi}{4} D^2 \left(h_1 + \frac{1}{6} D \right) = 500 \text{ (m}^3\text{)} \quad (3)$$

D: inner diameter of fermentation tank (m)

H: the height of the fermentation tank (m);

h_1, h_2 : respectively the height of the bottom head of the fermentation tank and the height of the top head (m).

Result: $D = 6.31$ m, rounding is $D' = 6.4$ m, $H = 12.8$ m, $h_1 = h_2 = 0.64$ m

The surface area of the fermentation tank is the sum of the area of the cylindrical part and the area of the head part. Since there is no precise formula for the surface area of the elliptical head, it can be approximated to the surface area of the conical head.

$$F_1 = \pi D H \quad (4)$$

$$F_2 = F_3 = \frac{\pi}{2} D \sqrt{h_2^2 + \left(\frac{D}{2}\right)^2} \quad (5)$$

$$F = F_1 + F_2 + F_3 \quad (6)$$

F_1 : area of circular part

$F_2 = F_3$: surface area of elliptical head

F : surface area of fermentation tank

Result: $F_1 = 257.23$ (m²), $F_2 = F_3 = 32.79$ (m²), $F = 322.81$ (m²)

5.2.4 Number of fermentation tanks

$$V_e = \frac{WT}{N} \quad (7)$$

$$V_t \times \Psi = V_e \quad (8)$$

$$\frac{Q}{\rho} = W \quad (9)$$

$$500 \times 80\% = 191.12 \times \frac{48 - 12}{N} \quad (10)$$

V_e : effective volume, m^3

W : feed per hour, m^3/h

T : fermentation time, h

N : number of fermentation tanks

V_t : total volume

Ψ : filling coefficient of fermentation tank, generally 80%

Q : Volume flow of fermented mash 235, 039 kg/h (From TABLE5)

ρ : density of fermented mash, 1230 kg/m^3 (Shuyi Q. 2009)

Result: $N = 12.422 \approx 13$

5.2.5 Design of cooling device for fermentation tank

Total fermentation heat:

$$Q = Q_1 - (Q_2 + Q_3) \quad (11)$$

$$Q_1 = GSq \quad (12)$$

$$Q_3 = F\alpha (t_w - t_B) \quad (13)$$

$$\begin{aligned} \alpha &= \alpha_c + \alpha_r \\ &= 1.7 \times \sqrt[4]{t_w - t_B} + \frac{C \left[\left(\frac{T_w}{100} \right)^4 - \left(\frac{T_B}{100} \right)^4 \right]}{t_w - t_B} \end{aligned} \quad (14)$$

$$Q_t = Q \times N \quad (15)$$

G: Mash of fermented mash per tank, kg

S: the percentage of sugar reduction, using 1%

q: per kg of sugar fermentation exotherm, found 418.6 kJ

Q₁: The amount of heat released by reducing the sugar content by 1 degree per hour during the main fermentation period, kJ / h

Q₂: the heat of evaporation carried away by metabolic gas, generally between 5% and 6% Q₁, using 5%, kJ / h

Q₃: Regardless of whether the fermentor is indoors or outdoors, it must radiate heat to the surrounding space Q₃, kJ / h

Q: the cooling heat load of a single fermentation tank

F: surface area of fermentation tank

α: radiation convection combined heat supply coefficient

α_c: convection heat supply coefficient

α_r: Radiation heating coefficient

t_w(T_w): the wall temperature of the tank, in this case is 38 °C(K=273+t_w)

t_B(T_B): the average temperature in the area where the factory is located, in this case is 25 °C(K=273+t_B)

Result: Q_t=1.08×10⁷ (kJ/h)

Calculation of cooling water consumption:

$$W_c = \frac{Q_t}{C_p(t_2 - t_1)} \quad (16)$$

W_c : cooling water flow, kg/h

C_p : specific heat capacity of water at constant pressure, 4.18kJ/ (kg×K)

t_2, t_1 : inlet and outlet temperature of cooling water, in that case t_1 is 20°C, t_2 is 27°C

Result : $W_c=3.69 \times 10^5$ (kg/h)

Calculation of cooling area:

The snake pipe is selected as the water gas transportation steel pipe, its specification is $\Phi 114 \times 4$, two rows of snake pipes are concentrically installed in the tank and enter the cooling water at the same time. The radius of the coil is $R = 3.3$ m, and $A = 6.45$ from the water temperature difference.

$$F = \frac{Q}{K \cdot \Delta t_m} \quad (17)$$

$$K = 1 / (1/\alpha_n + 1/\alpha_w + \Sigma R) \quad (18)$$

$$\alpha_n = \alpha_1 + \alpha_2 \quad (19)$$

$$\alpha_2 = 4.186 \times A \frac{(\rho \omega)^{0.8}}{d^{0.2}} \times \left(1 + 1.77 \times \frac{d}{R} \right) \quad (20)$$

$$\omega = \frac{W_c}{t \times S1 \times 2 \times 1000} \quad (21)$$

$$\Delta t_m = \frac{(t_F - t_1) - (t_F - t_2)}{2.3 \log \frac{t_F - t_1}{t_F - t_2}} \quad (22)$$

$$\Sigma R = \Sigma \delta / \lambda \quad (23)$$

F : cooling area, m²

K : total heat transfer coefficient, kJ/ (m²·h·°C)

Δt_m : logarithmic average temperature difference, °C

α_1 : cooling water flow rate in the pipe, kJ/(m²·h·°C)

α_w : reciprocal of the thermal resistance of the water dirt layer on the pipe wall, kJ/(m²·h·°C)

ω : cooling water flow rate in the pipe, m³/s

T_F : fermentation temperature in that case is 30°C

$\Sigma \delta$: tube wall thickness , m

λ : thermal conductivity of the tube, kJ/(m²·h·°C)

Result: F=864. 6 m²

5.2.6 Other sizes of fermentation tanks

Wall thickness of fermentation tank

$$S = \frac{PD}{2[\delta]\phi - P} + C \quad (24)$$

$$C = C_1 + C_2 + C_3 \quad (25)$$

S: wall thickness of fermentation tank, m

P: design pressure, 1.05 times the maximum working pressure, now 0.5 MPa

D : inner diameter of fermentation tank, m

$[\delta]$: Allowable stress of A3 steel, $[\delta]=127$ MPa

Φ : weld coefficient, its range is between 0.15 ~ 1, take 0.7

C: additional wall thickness, cm

C1: negative deviation of steel plate, depending on the thickness of the steel plate, the range is 0.13 ~ 1.3, C1 = 0.8 mm

C2: corrosion margin, 1mm corrosion on one side, 2 mm corrosion on both sides, C2 = 2 mm

C3: Processing thinning amount, for cold working C3 = 0, hot working head C3 = S0 × 10%, take C3 = 0.

Result: S=2.06 mm

According to the result, Wall of fermenter are made of 30 mm thick A3 steel plate (Sifang W. 2006)

Inlet diameter of dilute sugar solution:

$$F = \frac{\pi}{4} d^2 \quad (26)$$

$$F = \frac{V}{u} \quad (27)$$

$$V = \frac{W_{in}}{\rho_{in}} \quad (28)$$

F: feed tube cross-sectional area, m^2

V: volume flow into the mash tower, m^3/h

W_{in} : The flow into the mash tower, kg

ρ_{in} : the density of the mash, kg / m^3

d: Inlet diameter, m

Result: $d=0.597\text{ m}=578\text{ mm}$

The seamless steel pipe $\Phi 580 \times 10$, spacing $> 578\text{ mm}$.

Outlet of dilute sugar solution:

Since the amount of exported materials is greater than the amount of imported materials, the diameter of the outlet pipe is larger than the diameter of the inlet pipe of dilute sugar liquid, which can meet the requirements of $\Phi 600 \times 10$ seamless steel pipe. (Sifang W. 2006)

5.2.7 Others tank equipment

The other equipment of the fermentation tanks includes manholes, safety valves, pressure gauges, thermometers, and supports. The selection of each part should conform to the design principles mentioned above and meet the actual production conditions.

Manhole refers to the opening structure used for personnel to access equipment for installation, maintenance and safety inspection. It is mainly composed of short barrel (or short pipe), flange and manhole cover with handle. In consideration of safety inspection, the number of manholes required to be opened for pressure vessels and their minimum size shall refer to their inspection holes. Manhole materials are

carbon steel and stainless steel, generally made of 304, 316L stainless steel plate or carbon steel. According to the pressure condition, manholes are divided into normal pressure manholes and pressure manholes. According to the shape of manholes, manholes are divided into circular, elliptical and rectangular manholes, and rectangular manholes are only suitable for normal pressure equipment. According to the installation position, manholes are divided into horizontal and vertical manholes; the fixing method of manhole cover is complete rotating cover and hanging cover. After opening, the speed of manholes is common type and quick opening, and the structure and size of manholes are generally standardized, which can be referred to selection or design of relevant manuals. (Keqing C. 1995) In this case, the circular diameter of manhole is 500 mm, the cover plate is removable, and the flange is sealed, HGJ503-513-86. (Huang Y. 1987)

Safety valve is a special valve that the opening and closing parts are normally closed under the action of external force. When the medium pressure in the equipment or pipeline increases beyond the specified value, the medium pressure in the pipeline or equipment is prevented from exceeding the specified value by discharging the medium outside the system. Safety valve belongs to automatic valve category, which is mainly used in boiler, pressure vessel and pipeline. The control pressure does not exceed the specified value, which plays an important role in protecting personal safety and equipment operation. Note the safety valve can only be used after pressure test. Safety valves belong to the category of automatic valves, which are mainly used in boilers, pressure vessels and pipelines. The control pressure does not exceed the specified value, which plays an important role in protecting personal safety and equipment operation. In this case, the diameter of the safety valve is 25mm, use temperature <math><200\text{ }^\circ\text{C}</math>, use medium: water, steam, air tube. (Appendix I)

Select diaphragm type corrosion-resistant pressure gauge with accuracy class 2. 5. Adopt rod type fixed electric contact glass mercury thermometer Wxa-01F type, measuring range 0-100 °C. Because the fermenter is very large and the total weight is large, the skirt support is selected and made of reinforced concrete.

6 CONCLUSION

With the continuous development of the economy, human demand for fossil energy is also gradually increasing, but excessive development and dependence on primitive fossil energy such as petroleum will cause serious harm to the environment and national security. Such as soil pollution, destruction of the ecological environment, global warming caused by the greenhouse effect. In addition, the political instability of the oil supply area makes the country pay more attention to the development of new energy.

China is the largest developing country in the world and the largest carbon-emitting country. As a big country with a sense of responsibility, China is making every effort to increase the development and utilization of new energy. It has become the largest country for renewable energy for seven years, accounting for about one-third of the world's investment.

Biomass, as a renewable energy source with abundant reserves and a wide range of sources on Earth, can be regarded as a permanent clean energy source. Countries are also increasing their research and development expenditures. It is expected that by 2050, the total amount of biomass energy developed will account for 30% of total renewable energy utilization.

Fuel ethanol has a long history of development and has long been used in actual production, but research on fuel ethanol has continued. LCB is the most concerned raw material category in bioethanol. LCB has a wide range of sources, but it is difficult to use because of its complex cellulose-hemicellulose-lignin network structure.

The preparation of LCB fuel ethanol first needs to undergo pretreatment. Common pretreatment methods include physical method, chemical method, biological method. Different methods have different advantages and disadvantages. At present, there are many new pretreatment methods, but most of them are in the laboratory stage. After pretreatment, the LCB must be hydrolyzed and saccharified. The current commonly used hydrolysis method is enzymatic hydrolysis. Enzymatic hydrolysis has the advantages

of mild reaction conditions and high hydrolysis yield. At present, the main research is to improve the activity of cellulase. The current common fermentation technologies for LCB fuel ethanol are SHF, SSF, SSCF, and CBP. Among them, CBP has extensive development potential due to the combination of biotechnology engineering, but it is still in development. Fuel ethanol after hydrolysis and saccharification needs to be dehydrated by rectification, which is mainly used for the separation of ethanol and volatile impurities. The dehydration rectification technology is currently mature, and its research is mainly focused on reducing costs and energy consumption.

Fermentation tank is an important equipment for LCB fuel ethanol. Using relevant Chemical Engineering knowledge, the material balance of the fuel ethanol production plant with an annual output of 150,000 tons can be calculated, and the size design of the corresponding fermentation tank can be carried out. Due to time, CAD was not used for drawing design.

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APPENDIX 1

Product mode	Product code	Nominal Diameter (mm)	Nominal pressure (MPa)	Set pressure (MPa)	Sealing Pressure (MPa)	Weight(kg)
A21Y-250C/P	1K10	10	1.6	1.2	1.0	2.7
A21Y-250C/P	1K15	15	0.1	0.072	0.06	2.7
A21Y-250C/P	2K4	4	25	22	20	2.7
A21Y-250C/P	2K6	6	25	22	20	2.8
A21Y-250C/P	3K10	10	6	3.3	3.0	3.05
A21Y-250C/P	3K10M	10	6	4	3.6	3.05
A21Y-250C/P	3K10G	10	2.5	1.27	1.1	3.09
A21Y-250C/P	3K10H	10	4	3.15	2.8	3.03
A21Y-250C/P	3K10I	10	1.0	0.22	0.2	3.05
A21Y-250C/P	4K4	4	25	18	16	2.5
A21Y-250C/P	4K6	6	25	17.6	16	2.68
A21Y-250C/P	5K10	10	2.5	1.76	1.6	2.68
A21Y-250C/P	5K15	15	2.5	1.65	1.6	3.8
A21Y-250C/P	6K4	4	10	7.2	6.4	2.8
A21Y-250C/P	6K6	6	10	7.6	6.4	2.65
A21Y-250C/P	6K6G	6	10	9.2	8.4	2.73
A21Y-250C/P	6K15	15	1.0	0.72	0.6	2.93
A21Y-250C/P	8K4	4	10	8.8	8	0.6
A21Y-250C/P	8K10	10	6.0	4	3.6	3.05
A21Y-250C/P	101K10	10	0.6	0.31	0.28	1.72
A21Y-250C/P	152K10	10	1	0.9	0.8	2.97
A21Y-250C/P	252K10	10	4.0	2.55	2.3	2.88
A21Y-250C/P	002K15	15	1.6	0.27	0.24	3.1
A21Y-250C/P	101K15	15	1.6	0.245	0.22	2.83
A21Y-250C/P	1K20	20	0.1	0.07	0.06	3.4
A21Y-250C/P	8K25	25	6.0	4.4	4	1.8
A21Y-250C/P	001K25	25	1.0	0.125	0.11	6.29
A21Y-250C/P	002K25	25	1.0	0.3	0.27	4.97
A21Y-250C/P	302Ad-h15	15	1.6	0.3-0.8	0.27-0.72	4.6
A21Y-250C/P	302Ad-p32	32	1.6	0.065-0.8	0.035-0.72	5.7
A21Y-250C/P	505Aa10	10	4.0	3.2-4	2.88-3.6	3.2
A21Y-250C/P	915Ab4	4	25	19-22	17.1-19.8	3.1
A21Y-250C/P	915Aa-c6	6	25	16-22	14.4-19.8	2.8