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An overview on fuel ethanol product from lignocellulose as a feedstock

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ABSTRACT

The main properties of lignocellulose have been introduced. Different pretreatment methods for lignocellulose such as the physical method, the physical-chemical method, the chemical method and the biological method have been discussed.

KEYWORDS

Overview;
Lignocellulose;
Physical method;
Physical-chemical;
Chemical method;
Biological method.

INTRODUCTION

With the decrease of available mineral oil resources, the importance of traditional energy resources, such as coal and natural gas and lignocellulose, increases and converting lignocellulose to higher value products (fuel ethanol) becomes more and more important. This latter is expected to result in economic and social benefits[1].

Chinese economic and social development has been limited due to the shortage of natural resources. The output of Chinese crude oil production has been varied between 1.8 x 10^8 tons and 2.5 x 10^8 tons per year. Since the Chinese crude oil reservation is about 32.7 x 10^8 tons, the known crude oil resources are expected to cover the Chinese demands only for 16 years[2]. Since 52 % of the processed crude oil comes from overseas, the Chinese government introduced various policies to increase the energy production efficiencies and to decrease taxes for those companies which turn efforts to use renewable energy resources such as lignocellulose, wind and water, etc.

Nowadays the efficiency lignocellulose of utilization is very low in China, because most of these resources are fired and discharged into the environment. This latter has a serious negative effect on our health and living, strongly degrades the environment, and causes serious pollution; therefore researchers and engineers turn a lot of effort in the development of this area, focusing on increasing the efficiency of lignocellulose utilization with maximal economic benefits.

In the present paper, the main properties of lignocellulose have been introduced. Different pretreatment methods for lignocellulose such as the physical method, the physical - chemical method, the chemical method and the biological method have been discussed.

RESULTS AND DISCUSSION

The properties of propylene carbonate

Lignocellulose consists of cellulose (35 % ~ 50 %), hemicellulose (20 % ~ 35 %) and lignin (10 % ~

25%)[3]. Lignocellulose must be pre-treated due to its stable and complicated structure, so its operation fees will be increasing. The purpose of the pre-treatment is to break the chains of cellulose, hemicellulose and lignin. Ethanol generated from lignocellulose is not widely used in industries. Figure 1 shows structure diagram of lignocellulose. Cellulose is one type of 1000 ~ 10000 glucose monomers who is a linear polysaccharide connected with glucosidic bonds. Furthermore, its composites are cellobiose. Hemicellulose is one type of heteropolysaccharides, such as hexose (D - galactose and L - galactose), pentose (D - xylose and L - arabinose) and uronic acid. Lignins are not carbohydrates, but they are polymeric procyanidins of phenyl propane units, so they can prevent cellulose hydrolyzing[4]. TABLE 1 presents different cellulose, hemicellulose and

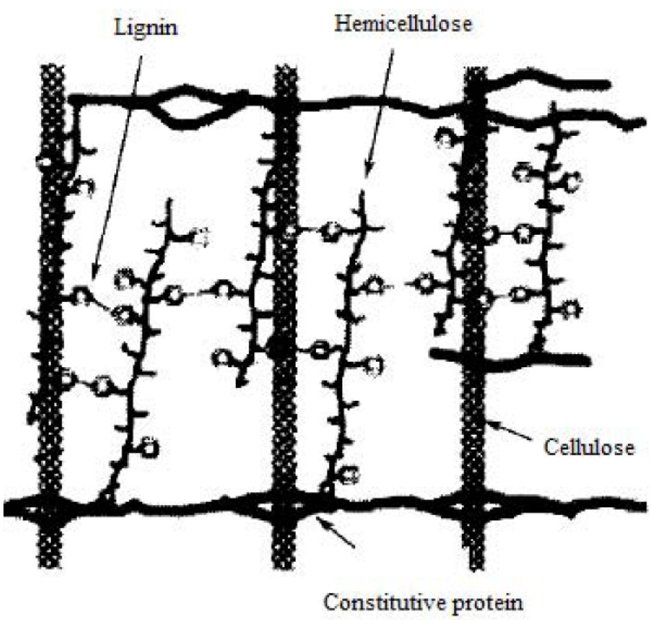

Figure 1 : The structure diagram of lignocellulose

lignin contents of crops and waste. Different crops or wastes have different contents of cellulose, hemicellulose and lignin[5].

PRE-TREATMENT METHODS

Pretreatment of biomass mainly includes crushing, dissolving, hydrolysis and separation of cellulose, hemicelluloses and lignin[6]. The main objective of the pretreatment is to reduce the molecular mass of cellulose, to open its dense crystalline structure in order to reach further decomposition and transformation[4].

Different pretreatment methods have been taken

TABLE 1 : Different cellulose, hemicellulose and lignin contents of crops and wastes

Crops or wastes	Cellulose, %	Hemicellulose,%	Lignin, %
Drying hardwoods	40 ~ 50	24 ~ 40	18 ~ 25
Drying softwoods	45 ~ 50	25 ~ 35	25 ~35
Net shell	25 ~ 30	25 ~ 30	30 ~ 40
Corncob	45	35	15
Pasture	25 ~ 40	35 ~ 50	10 ~ 30
Wheat straw	33 ~ 40	20 ~ 25	15 ~ 20
Straw	40	18	5.5
Leaves	15 ~ 20	80 ~ 85	0
Classified garbage	60	20	20
Cottonseed hair	80 ~ 90	5 ~ 20	0
Coastal Bermuda grass	25	35.7	6.4
Switchgrass	30 ~ 50	10 ~ 40	5 ~ 20
Solid cow dung	1.6 ~ 4.7	1.4 ~ 3.3	2.7 ~ 5.7
Pig wastes	6.0	28	-
Initial total suspended solids	8 ~ 15	NA	24 ~ 29
Paper	85 ~ 99	0	0 ~ 15
Newspaper	40 ~ 55	25 ~ 40	18 ~ 30
Chemical pulp of waste paper	60 ~ 70	10 ~ 20	5 ~ 10

based on different material properties, such as the physical method, the physical-chemical method, the chemical method and the biological method. The physical methods include mechanical grinding and thermal decomposition. Steam blasting, CO_2 blasting method, and ammonia fiber explosion belong to the physical-chemistry methods. The chemical methods are composed of decomposition of ozone, acid or alkaline hydrolysis, oxidative delignification, and organic solvents. The biological methods are mainly used brown, white or soft rot fungi to degrade hemicelluloses and lignin among the fertilizer[7]. TABLE 2 presents the comparison of different pretreatment methods.

Pretreatment methods are mainly to reduce the loss of materials. And it can improve the yield of sugar in the subsequent hydrolysis process. Generally, the pretreatment process costs more in the process of cellulosic ethanol fermentation. Therefore, it brings more concerns

TABLE 2 : Comparison of different pre-treatment methods

Methods	Material	Condition	Effects	Reference
Steam explosion	Wheat straw	0.9% H_2SO_4 pre-infusion, 180 ~ C, 10 min	300g sugar / kg wheat straw	[8]
	Aspen (hardwood)	21.7 MPa, 112 ~ 165 °C, 10 ~ 60 min	(14.5 ± 2.3)% theoretical value	
Supercritical	Aspen (hardwood)	21.7MPa, 165 °C, 3O min	(84.7 ± 2.6)% theoretical value	[9]
carbon dioxide	Southern Pine (softwood)	28.3 MPa, 112 ~ 165 °C, 10 ~ 60 min	(12.8 ± 2.7)% theoretical value	
	Southern Pine (softwood)	21.7M Pa, 165 °C, 30min	(27.3 ± 3.8)% theoretical value	
AFEX	Coastal Bermuda grass	100 °C, 3O min	94.8% theoretical value	[10]
Wet oxidation	Husk	185 °C, 0.5MPa, 15min	67% cellulose recovery, 89% lignin removal	
			and 70% dissolved hemicellulose	[11]
Alkaline (NaCO3) wet oxidation	Tobacco stalks and peel waste	195 °C, 1.2MPa, 15min	About 90% cellulose recovery	[12]
Ozone France	wheat straw<1mm	2.7% ozone, air / ozone flow rate 60L / h	88.6% hydrolysis yield	[13]
	Rye straw<3 ~ 5mm	3% ozone, air / ozone flow rate 90L / h,	57% hydrolysis yield	
		20% of NaOH wetting		
Dilute France	Spruce (softwood) <0.42mm	180 °C, 30min, l% H_2SO_4	56.7% total sugar recovery	[14]
	Spruce (softwood) <0.42 mm	180 °C, 30 min, l% H_2SO_4	87.9% total sugar recovery	
		and 18 g / L Na_2SO_3		
Organic solvent	CA pine	Acetone water (volume ratio 1:1),	99.5% theoretical value	[15]
		195°C, 5 min, pH 2.0		
Alkaline hydrogen	Barley straw (100g / L)	2.5% H202, pH 11.5, 35 ?C, 24h	94% theoretical value, 6O4mg / g	[16]
peroxide	Bamboo	1% H_2O_2 and 1% NaOH, 90°C, 60 min	Six-carbon sugar and total sugar production was	[17]
	(5 ~ 8cm long, 3 ~ 5 cm wide)		399 and 568mg / g dry bamboo separately	
Hydrothermal	Wheat straw <5 mm	188 °C, 40min	43.6% sugars rate of hemicellulose hydrolysis, and	
			79.8% theoretical value of enzymatic hydrolysis	
		184 °C, 24 min	71.2% hemicellulose sugar recovery	[18]
		214 °C, 2.7 min	90.6% % theoretical value of enzymatic hydrolysis rate	
Biological pretreatment	corn fiber	Brown rot fungus (Gloeophyllum trabeum)	34% corn fiber biodegradable	[19]
		2 weeks suspension culture,		
		Brown rot fungus solid fermentation experiments, buffer anaerobic culture, mixed with yeast	11% corn fiber into a reducing sugar, and final ethanol production 4 0g/100g corn fiber	
		Brown rot fungus solid fermentation experiments,	11% of the corn fiber into a reducing sugar, and	

Methods	Material	Condition	Effects	Reference
Alkaline hydrolysis	switchgrass (<2mm)	buffer anaerobic culture, no yeast 50°C, 24h, 0.10 g Ca $(OH)_{2/}$ g raw materials, rinse concentration 100mL water/g raw materials	final ethanol production 3.3g/100g corn fiber Glucose, xylose, total reducing sugar production was 239.6 , 127.2, 433.4 mg / g raw materials	[20]

in the current research and production applications.

CONCLUSION

The lignocellulose sources can be used to produce high value chemicals in China. These lignocellulose sources based methods protect the environment and increase the income of a petrochemical plant. The main benefits are as follows: using crops or wastes and protecting the local environment, decreasing fossil fuel consumption, and avoiding greenhouse gas emissions, such as SO2, NOx, and CO2, and total suspended particles. Economic developments are initiated and improved using the reviewed new developments.

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