Utilization of Biomass Waste Empty Fruit Bunch Fiber of Palm Oil for Bioethanol Production
(*works in progress*)

LIPI

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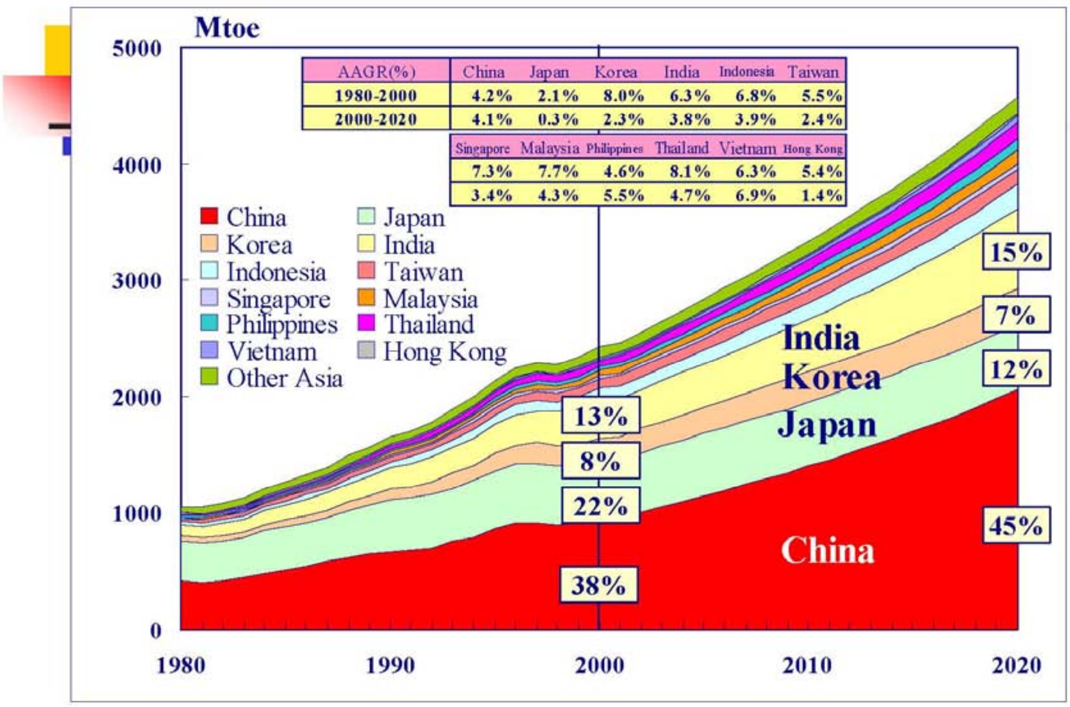
Primary Energy Demand by Region in Asia



2000
2,423Mtoe
⇩
2020
4,570Mtoe

A 1.9-fold increase

Mtoe: Million tons of oil equivalent

http://eneken.ieej.or.jp/en/data/pdf/329.pdf#search='koyama energy demand asia'

Source: IEEJ "Asia/World Energy Outlook", March 2004

CO_2 EMISSION per GDP (MtC ／BUSD) in 2004

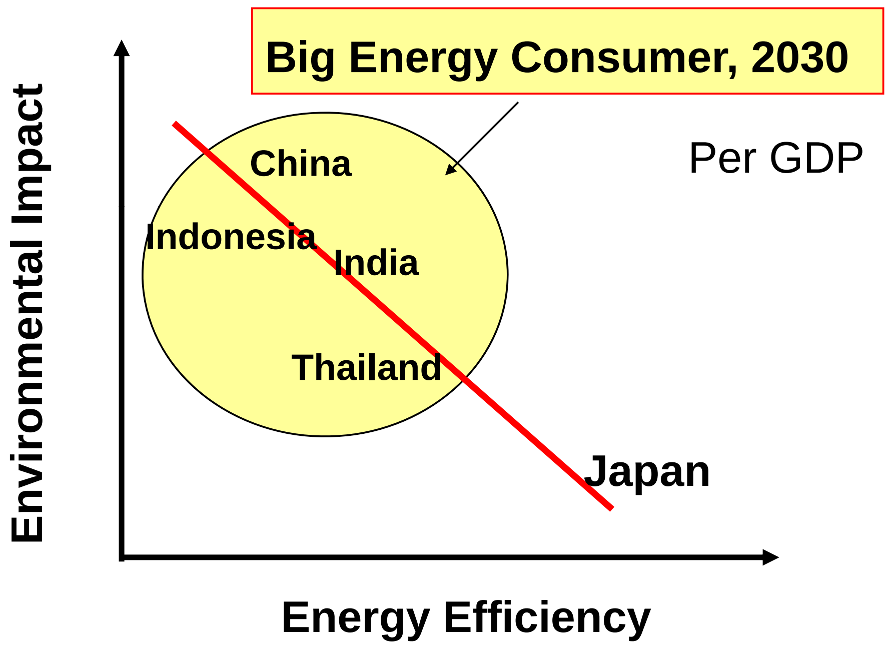
• JAPAN	0.069	SINGAPORE	0.151
• KOREA	0.212	PHILIPPINES	0.227
• THAILAND	0.408	MALAYSIA	0.410
• VIETNAM	0.433	INDIA	0.539
• INDONESIA	0.539	CHINA	0.820

Ref: Y. Nishikawa: Sustainable Energy and Environment 2006

Larger value number high **Environmental Impact**

- The growing energy demand and CO_2 emission, this data clearly shows that we are now facing critical environmental and energy crisis.
- we need to develop renewable energy and suppress energy use by technological development and renovation of life style, and international cooperation.

Two sides of the same coin: Energy and Environment



Role of Bio-energy for Community

Our Community

New Energy

Demand

Less Environmental Impact

Energy Diversification

Require !!

Utilize

Bio-energy
Solar energy
Wind energy
Nuclear, **Etc**

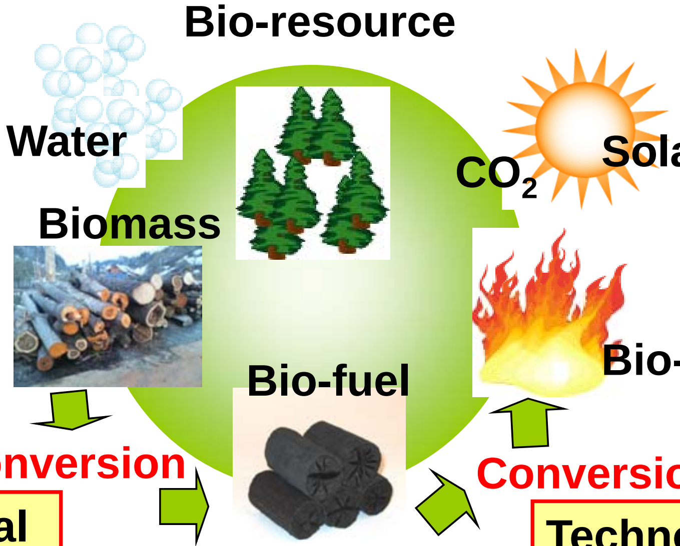
Global Warming
Energy Security

Technological Innovation for Bio-energy: How it can be used as much as sustainable

Bio-energy

- Carbon neutral
- Renewable

Bio-resource



Technological Innovation

Technological Innovation

BACKGROUND

- Indonesian people are very wasteful in using oil, especially in transportation sector. The excessive use of this natural resource increase greenhouse gas emission that contributes to the global warming.
- Indonesia's fuel reserves may deplete within 15-20 years if:
- Dependency on fossil fuel continue where fuel consumption higher than domestic production
- Indonesia does not diversify energy resources

OIL :

- Growth rate of oil production decreased, while its consumption increase.
- Since 2003 Indonesia has become a net importer of oil, with the increasing rate in coming years.
- Oil consumption/year: 60 million kL (50% for transportation)

NEED POLICY TO DIVERSIFY ENERGY SOURCES

World fuel ethanol production, 2006

Country or region	Production (million litters)	Share of total (%)
United states	18,300	47.9
Brazil	15,700	41.1
European Union	1550	4.1
China	1300	3.4
Canada	550	1.4
Colombia	250	0.7
India	200	0.5
Indonesia	170	0.4
Thailand	150	0.4
Australia	100	0.3
Central America	100	0.3
World Total	38,200	100.0

Source: Biofuels for transport, Earthscan, 2007, Modified

Bioethanol production in Indonesia (2002~2007)

Company name and investor	Location (city and province)	Raw material	Annual production (million liters)	Investment (million US$)
Indo Acidatama (b)	Central Java	Molases	46.2	
Indolampung Distillery (b)	Lampung	Molases	39.6	
PT. Molindo Raya Industrial (a) (b)	Malang, East Java	Molases	39.6	
Aneka Kimia Nusantara (b)	Mojokerto, East Java	Molases	14.9	
PT. PG. Rajawali II (b)	Cirebon, West Java	Molases	15.0	
PT. Perkebunan Nusantara XI (b)	East Java	Molases	7.2	
BPPT (Pilot plant) (a)	Bandar jaya, Lampung	Cassava	2.4	
Under conctruction				
PT. Medco Ethanol Lampung (a) (b)	Kotabumi, Lampung	Cassava, Molases	60.0	34.3
PT. Sampoerna Bioethanol (a)	Pacitan, East Java	Cassava	60.0	80.0
PT. Alco Yosa Sejahtera (a)	Probolinggo, East Java	Cassava	12.0	6.0
PT. Molindo Raya Industrial (a)	Lampung	Cassava	50.0	25.0
PT. Mitra Sae International (a) *(LBL Network Ltd., South Korea)*	Sumedang, West Java	Cassava	200.0	100.0

Source: Antara news (Dec, 2006); Bisnis Indonesia (Dec- Nov, 2006); BKPM/IICB (2006); Kompas (Feb, 2005); The Jakarta Post (July, 2005); Tempo (Dec, 2006); Warta Ekonomi (July, 2006) – Purpose of ethanol production for (a) fuel and (b) chemical industry

INDONESIAN PALM OIL

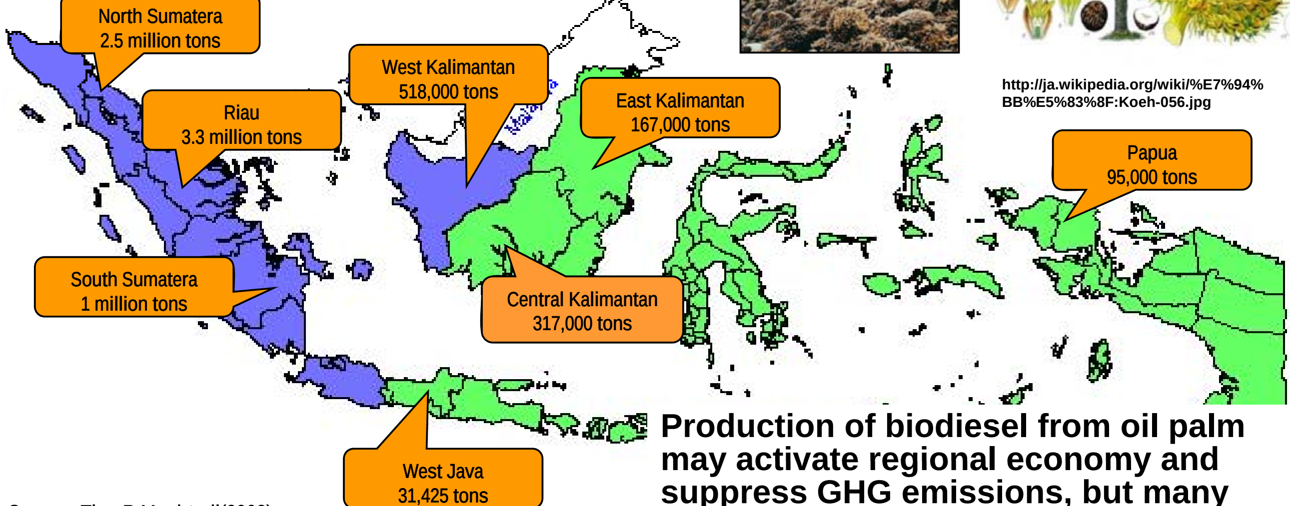
Biomass: A new international market resource for industries

- Palm oil plantation and CPO* production in 2008

-Plantation area ± 6.78 million Ha

-CPO production 17.37 million tons

http://ja.wikipedia.org/wiki/%E7%94%BB%E5%83%8F:Koeh-056.jpg



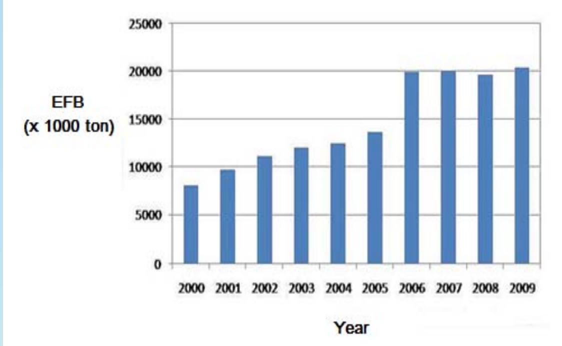
Source: Tien R,Muchtadi(2008)

Production of biodiesel from oil palm may activate regional economy and suppress GHG emissions, but many important factors associated must be taken into account.

Potency of EFB in Indonesia

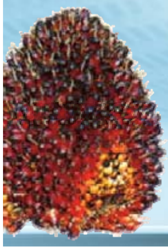
In 2008, Indonesia produce approximately 17.37 million ton of CPO resulted large amount of biomass waste such as empty fruit bunches fiber (EFB) and fruit shell.

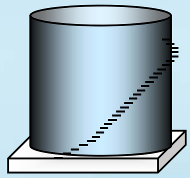
Every ton of CPO produced 1.1 ton of EFBs . Increase in CPO production will increase EFBs and will become serious problem for the environment. Therefore, there is considerable scope for producing useful and marketable products from EFBs.



Prediction of EFB's Potency in Indonesia based on CPO Production Data

(Dirjen Perkebunan, Ministry of Agriculture)





Bioethanol

Lignocellulose of EFB

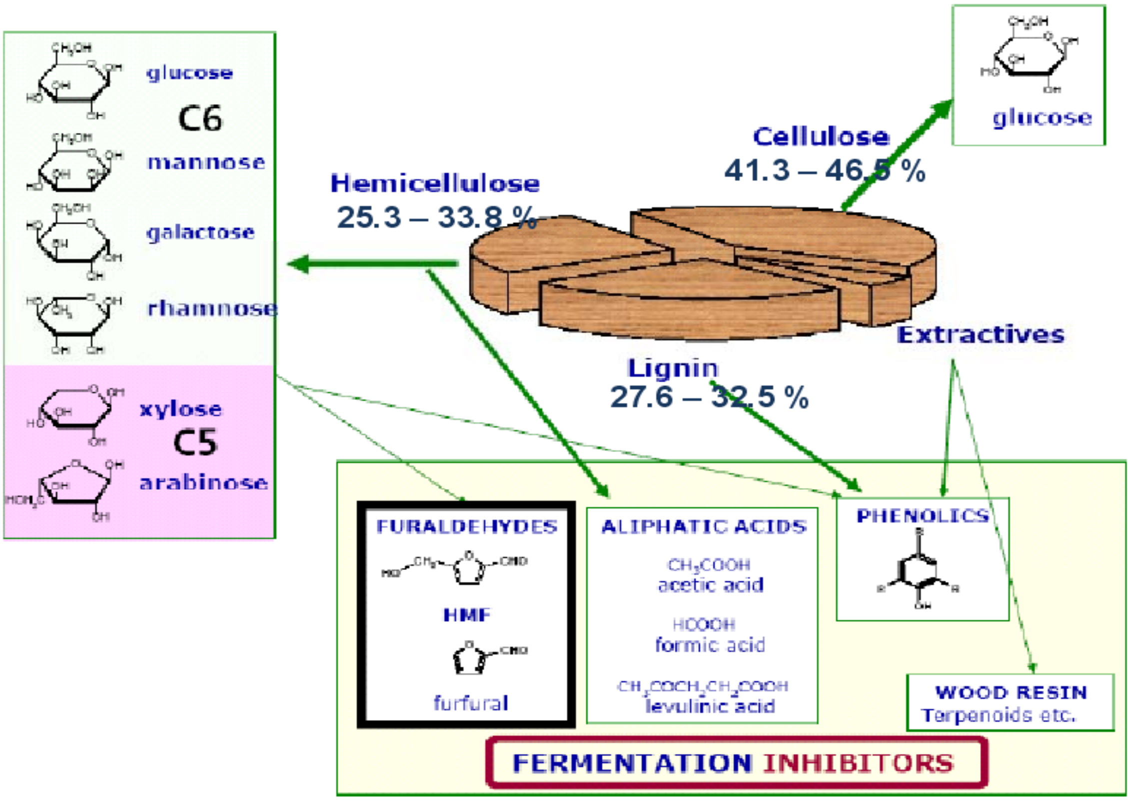
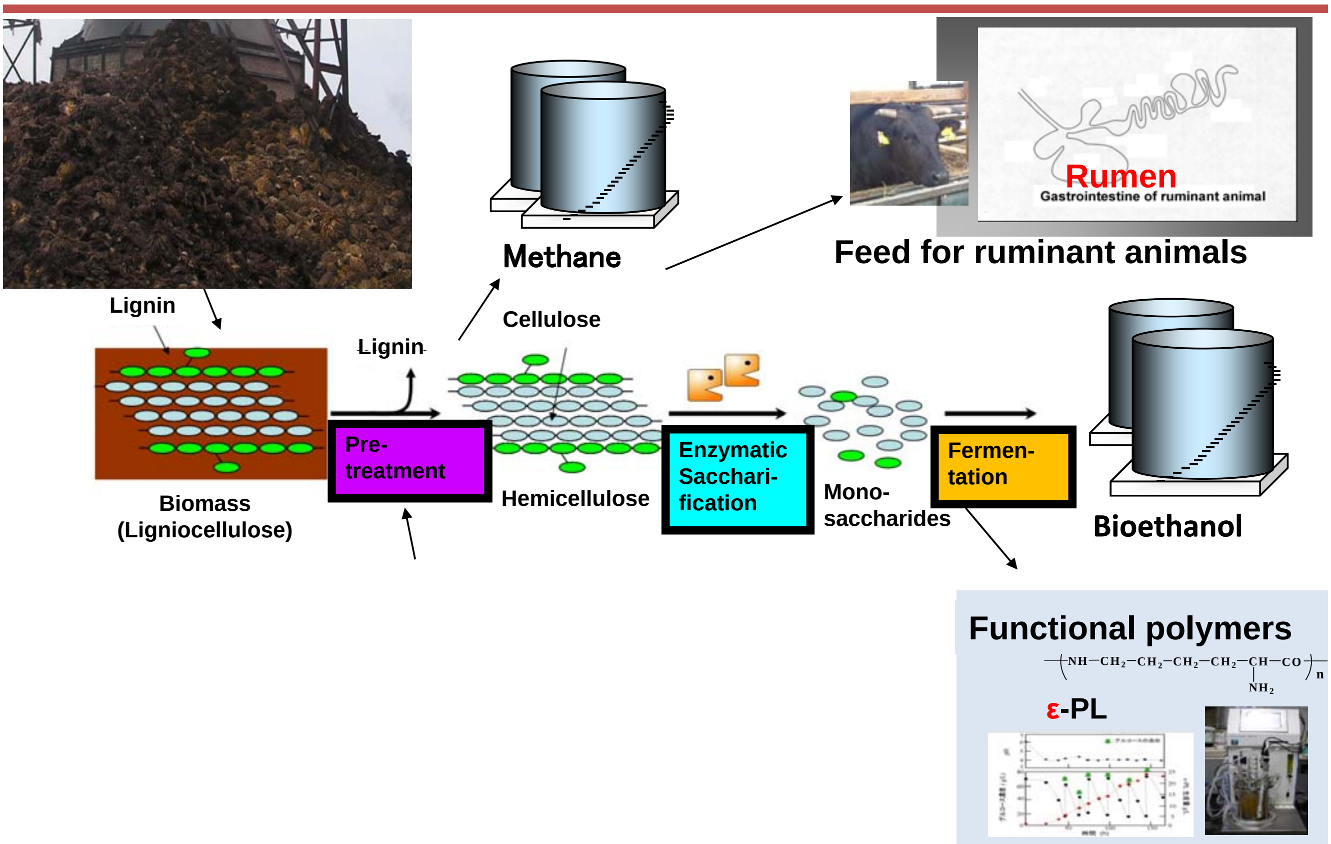


Table 1. Assumed Ethanol yield from glucose

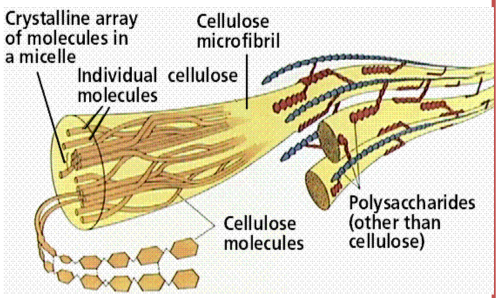
EFBs	1 tonne (1000 kg)
Cellulose content	× 0.45
Cellulose conversion and recovery efficiency	× 0.76
Ethanol stoichiometric yield	× 0.51
Glucose fermentation efficiency	× 0.75
Yield from glucose	131 kg ethanol = 151 L (40 gallons)

Conversion of EFB biomass



There are two major technological problems for the efficient ethanol production from lignocellulosic materials:

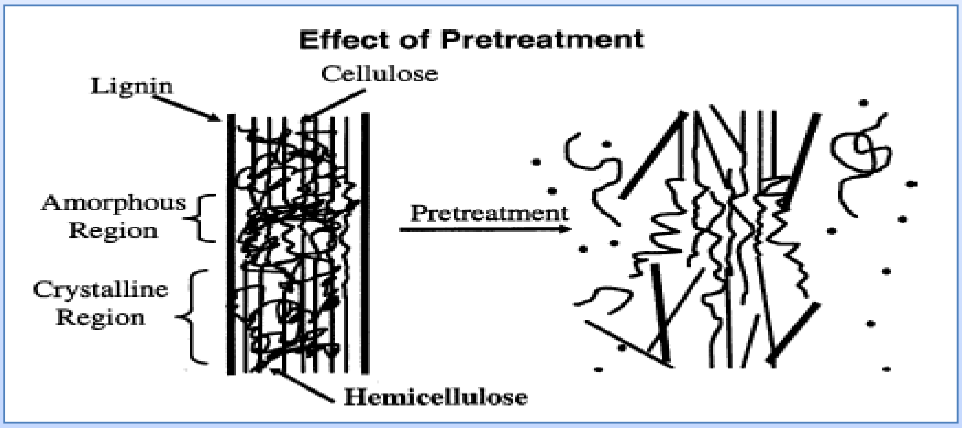
(1) cellulose, the major component of lignocellulose is crystalline and difficult to hydrolyze;



(2) pentose sugars, such as xylose and arabinose, exist in hemicelulose.

To overcome those problems,pretreatment should be done before the enzymatic hydrolysis.

Pretreatment

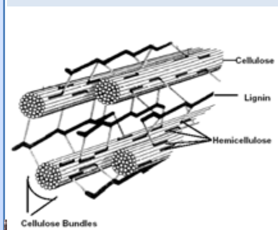


Mosier *et al*., *Bioresource Technology*, **96**: 673–686 (2005)

The purpose of the pretreatment is to break the crystalline structure of the lignocellulose and remove the lignin to expose the cellulose and hemicellulose molecules

The goal is to break the lignin seal and to make cellulose more accessible to the enzymes that convert carbohydrate polymers into fermentable sugars, and to increase the porosity of the materials

Physical, chemical and thermal pretreatments

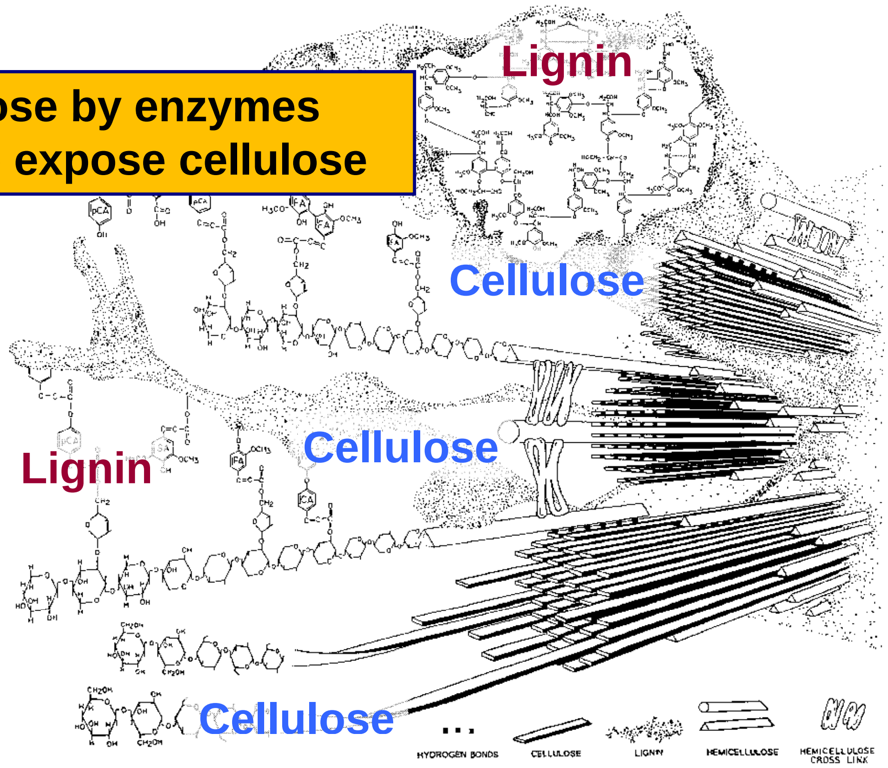


Plant cell walls

Hydrolysis of cellulose by enzymes
→ Pretreatments to expose cellulose

Hemicellulose

Hemicellulose



Physical, chemical and thermal pretreatments

J. Bidlack, M. Malone, and R.Benson, Proc. Okla. Acad. Sci. 72:51-56 (1992)

Objective

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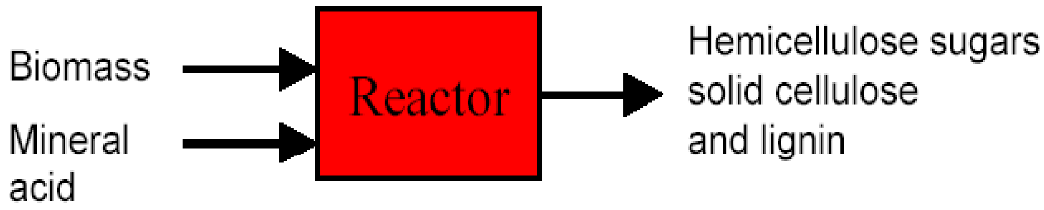
- To develop methods for efficient pretreatment, saccharification of EFB and fermentation of hydrolyzate to ethanol.
- To utilize EFBs for producing useful and marketable products such as ethanol

Expected Output

- Ethanol production based on lignocellulose waste with appropiate to be utilized as biofuel.

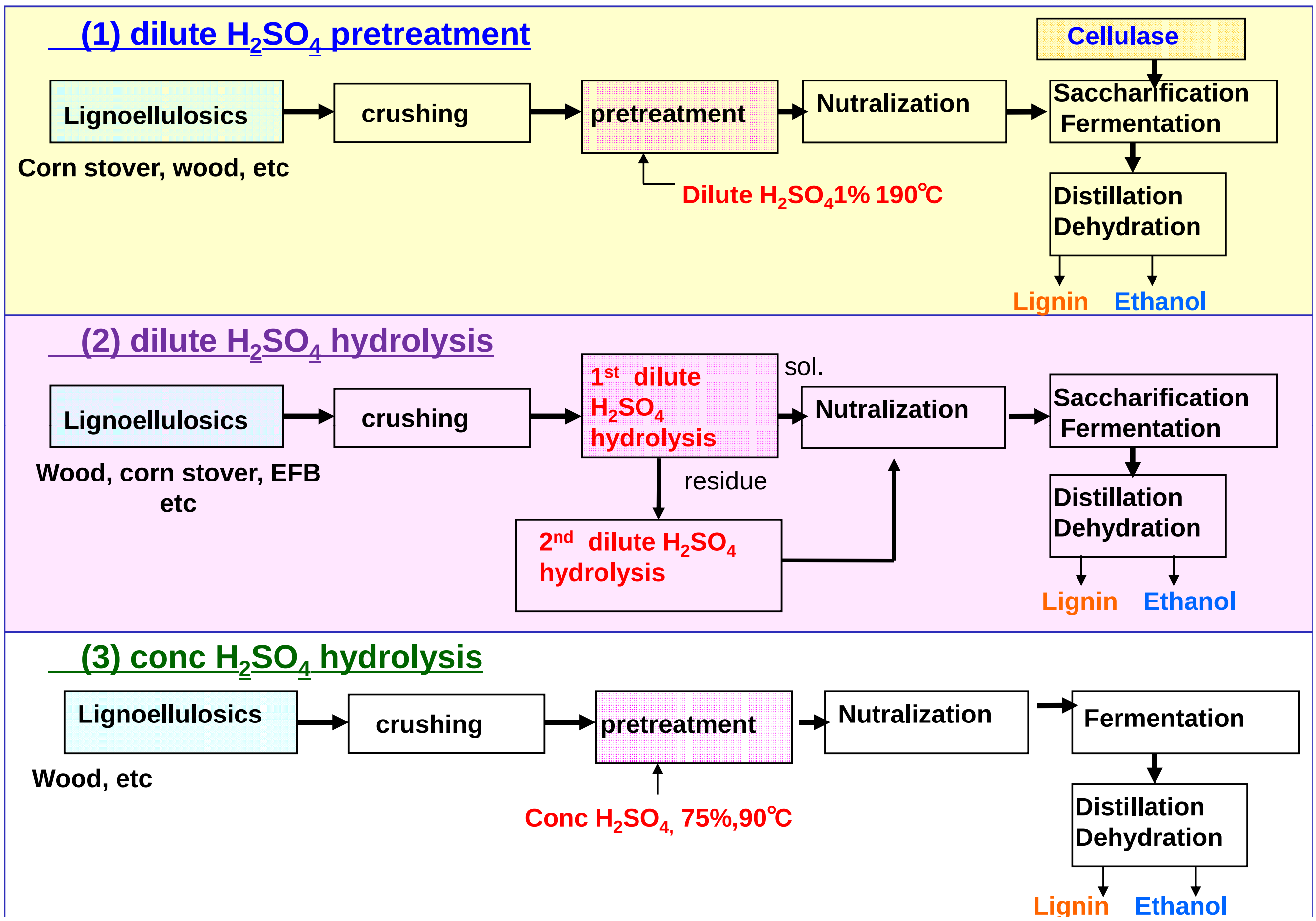
Increase experience and skill of research staff after research program and further collaboration work with others Institute.

Dilute Acid Pretreatment



- Mineral acid gives good hemicellulose sugar yields and high cellulose digestability
- Sulfuric acid usual choice because of low cost
- Requires downstream neutralization and conditioning
- Typical conditions: 100-200°C, 50 to 85% moisture, 0-1% H_2SO_4
- Some degradation of liberated hemicellulose sugars

Fuel ethanol production process using H_2SO_4



Results

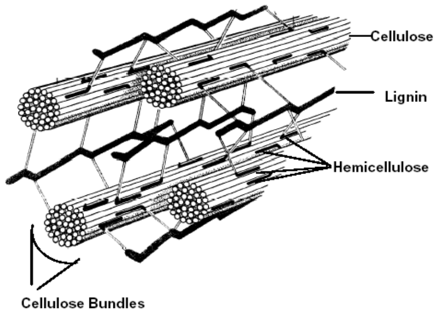
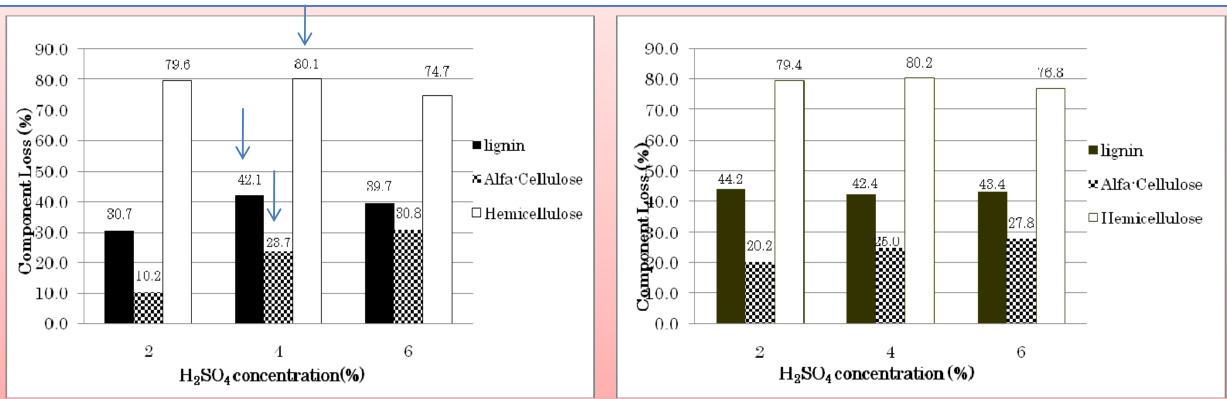


Table 1. Physical Pretreatment
The major component of EFBs

	Percentage (%)[a]
Water content	8.56
Oil content	0.98
Main components:	
Lignin	25.83
Holocellulosa:	56.49
• Alfa-cellulosa	33.25
• Hemicellulosa	23.24
Extractive, others component	4.19

[a]Composition percentages are on a dry-weight basis

Fig. 1. Loss of lignin, cellulose and hemicelluloses during acid pretreatment of EFB



pretreatment of EFB with H_2SO_4 at 121^0 C in 60 minutes

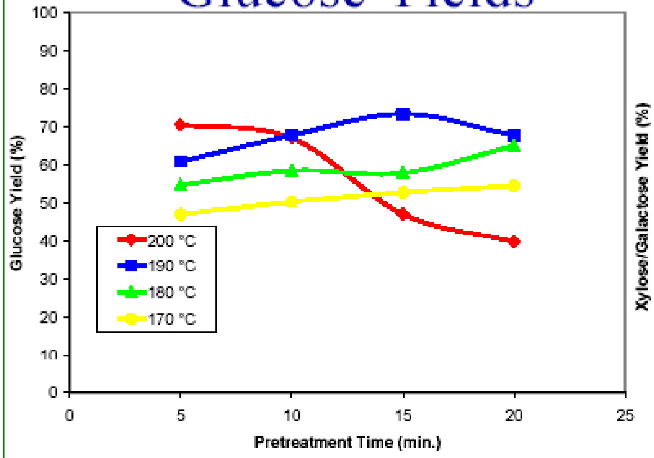
pretreatment of EFB with H_2SO_4 at 121^0 C in 90 minutes

Loss of lignin, cellulose and hemicellulose optimum was obtained on samples pretreated with 4% H_2SO_4 and heated at 121°C for 60 minutes.

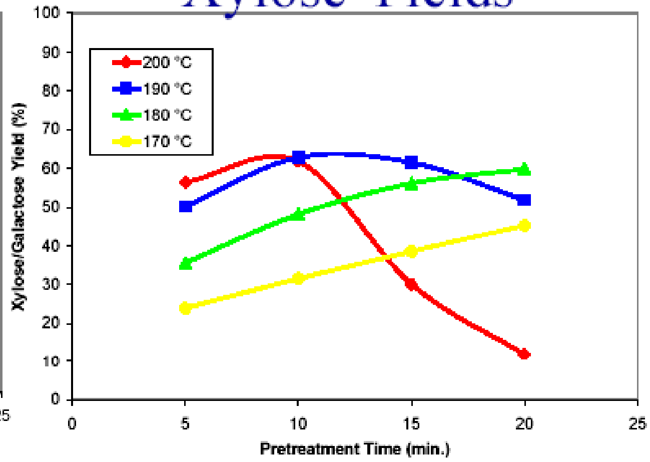
The loss of lignin in the pretreatment is one of the most important indicators of pretreatment effectiveness because the presence of lignin impedes enzymatic hydrolysis of the carbohydrates by blocking access of cellulases to cellulose and by irreversibly binding hydrolytic enzymes

Cellulose Digestibility vs Hemicellulose Solubilization

Glucose Yields



Xylose Yields



Controlled pH Hot Water Pretreatment (non flow-through) improves digestibility primarily by removal of hemicellulose without degrading the monosaccharides → improved porosity / enzyme accessibility

Table 2. Effect of Enzyme Concentration

Pretreatment Condition	Enzyme Loading (FPU)	Yield of Saccharification[c]		
		Glucose[a]	Xylose[a]	% Saccharification[b]
	2 0	9.81	12.41	-
	4 0	2.99	4.01	10.62
H_2SO_4 2%, pH 4.5	6 0	6.89	8.83	24.47
	20	5.17	6.69	18.34
H_2SO_4 2%, pH 5.0	4 0	8.63	10.96	30.61
	6 0	9.21	11.68	32.67
	2 0	13.63	17.45	49.21
H_2SO_4 4%, pH 4.5	4 0	19.45	24.62	70.22
	6 0	15.13	19.29	54.61
	2 0	9.51	12.36	34.34
H_2SO_4 4%, pH 5.0	4 0	16.62	21.13	60.01
	6 0	16.92	21.508	61.09

[a]mg/mL; [b]after 48 hours saccharification

The highest yield of monomeric sugar (70% of total carbohydrate content) was found in EFB (12.5%, w/v) pretreated by 4% dilute sulfuric acid and saccharified for 48 hours

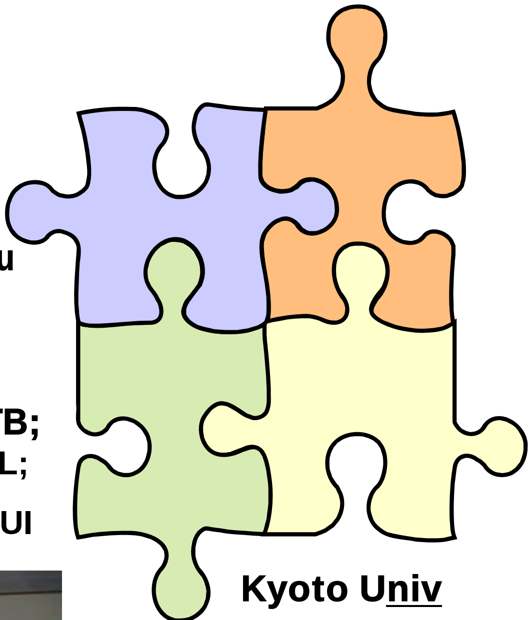
Pretreatment with sulfuric acid result in high saccharification yield of EFBs associated with the reduction in lignin and hemicelluloses content and the increase in cellulose content.

Further research will be conducted to ferment sugar into ethanol using SSF (simultaneous saccharification and fermentation) method.

Networking:

PTP VIII Kertajaya

Suply Bahan Baku



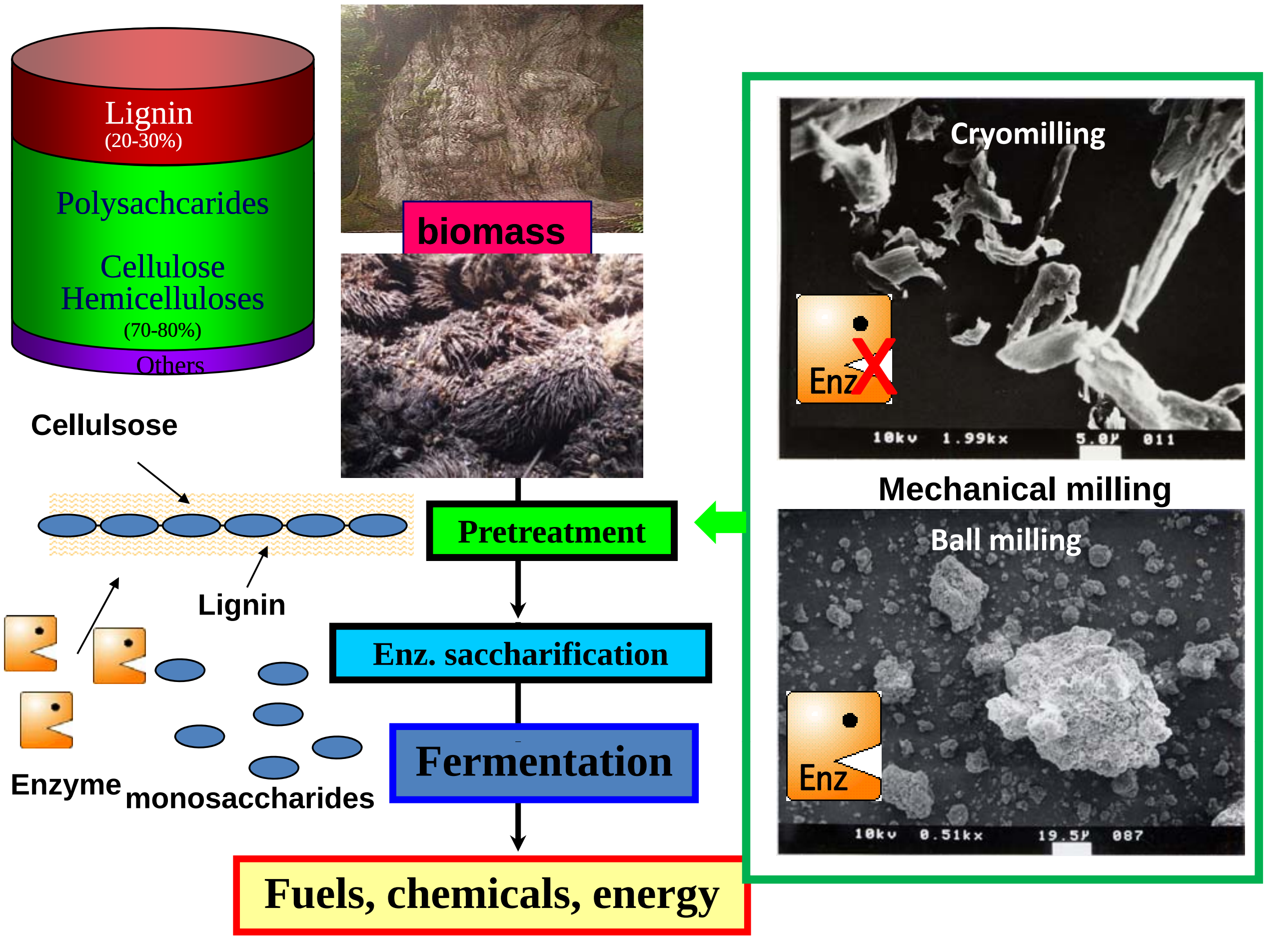
TK-ITB;
UNMUL;
Kimia-UI

Kyoto Univ

Thank you for your kind attention!

Technology Comparisons for Pretreatment Processes

No	Technology	Positives	Negatives
1	Alkali	Delignification	Acid alkali usage
2	Concentration Acid	Complete hydrolysis	Impurities
3	Steam explosion	Removal of HC possible	High temperature and pressure
4	1st stage dilute acid	-	Degradation products
5	2nd stage dilute acid	Furfural possible	-
6	AFEX	Fast 95% yield	Ammonia handing
7	Enzymatic hydrolysis	Best, clean, maybe cheaper	None


Lignin
(20-30%)
Polysachcarides
Cellulose
Hemicelluloses
(70-80%)
Others
biomass
Cellulsose
Lignin
Enzyme
monosaccharides
Pretreatment
Enz. saccharification
Fermentation
Fuels, chemicals, energy
Cryomilling
Enz
Mechanical milling
Ball milling
Enz