清華大學

Non-food feedstock and the road map of China’s bioethanol industry

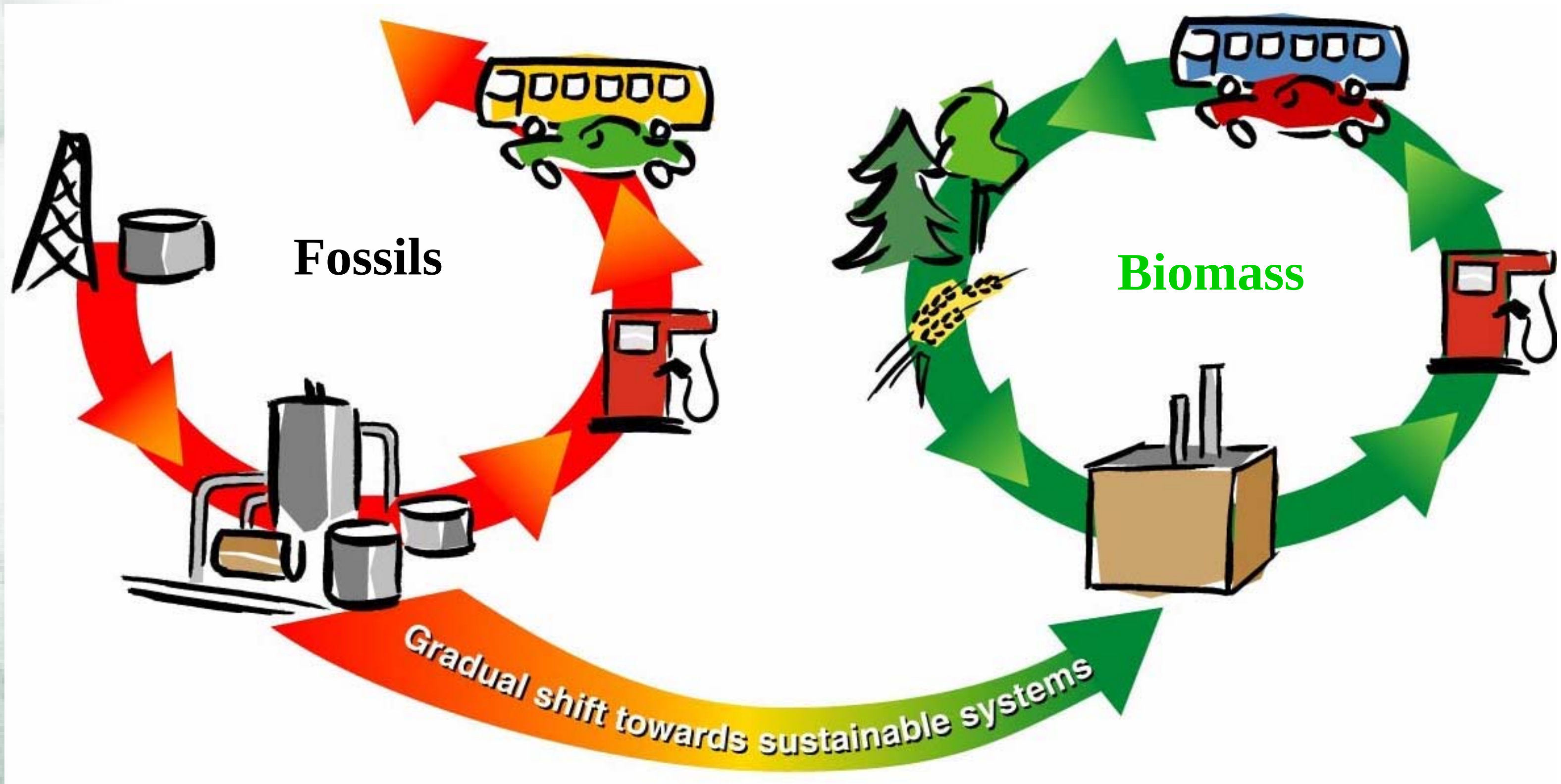
Shi-Zhong Li

Institute of New Energy Technology,
Tsinghua University
Beijing 100084, P.R. China
Tel: +86 10 62772123
Fax: +86 10 80194050
Email:szli@tsinghua.edu.cn

China is the world's second-largest oil consumer and CO_2 producer. China imported 99.95 million tons oil from January to June 2007.

清華大學

BROKEN CIRCLE | CLOSED CIRCLE



Ethanol is the largest volume biofuel and practicable to substitute oil and benefit environment and rural development.

1.32 million tons of fuel ethanol were produced from corn and wheat in 2006. E10 (10% ethanol +90% gasoline) is used in Helongjiang, Jilin, Liaoning, Henan, Anhui Provinces, and 9 cities in Hubei, 7 cities in Shandong, 6 cities in Hebei, 5 cities in Jiangsu.

Bioethanol in China, 2006

However, the volume potential of ethanol from food-crops is limited

- **About 140 million tons of corn were produced in 2006, more than 70% are used for cattle industry. Hence, it's impossible to use corn to produce ethanol like USA.**
- **Normally, China imports 0.8-1 million tons of sugar every year. Hence, it's impossible to use sugar cane to produce ethanol like Brazil**

For the concerns about food security and land requirements, non-food feedstock of bioethanol should be used to substitute food-crops

- Existing feedstock, cassava and other non-food starch such as sweet potato are preferable.
- Emerging feedstock, sweet sorghum should be appreciated.
- Future feedstock, Lignocellulose will be the main feedstock of bioethanol.

清華大學

1. Ethanol from tuber crops

- **Tuber crops have high biomass production yield (15-45 t/ha.) and starch content (20-33%)**
- **Cassava is suitable for growing in south China with special character such as easy to survive, less diseases and insects, resistance to drought etc.**
- **Sweet potato can also be planted in poor soil.**

Waste water treatment and production cost of ethanol are two longstanding challenges.

- The combination of DDG and anaerobic digestion improves the quality of emission waste water to meet the regulation.
- New methods have been developed to increase the final ethanol concentration in broth and upgrade the co-products of ethanol as valuable animal feed to reduce the ethanol production cost.

3 million tons of ethanol will be produced annually during 2007-2012, cassava and sweet potato are the main feedstocks.

2. Ethanol from Sweet sorghum

- Sweet sorghum is a energy crop with special characteristics such as drought resistance, tolerance to water logging, and saline-alkali resistance, etc.
- Sweet sorghum is suitably planted in north China and drainage areas nearby Yellow River, total 13 provinces, and 26 million hectares of barren and saline- alkali lands are available.

Xinjing autonomous region has the special advantages of producing fuel ethanol from sweet sorghum

Samples	Water content %	Reducing sugar %	Total sugar %
A	5.854	19.45	37.26
B	5.858	27.29	41.3

- USA and India started the research work to produce ethanol from sweet sorghum juice since 1960's.
- Currently, ethanol can't be produced from sweet sorghum juice cost-effectively, because of the seasonal feature of sweet sorghum, and the expensive juice concentration and storage processes.

清華大學

Hence, the solid state fermentation is preferred. However, the currently available classical fermentation and distillation techniques contribute to high ethanol (95%) production cost.

清華大學

A novel ethanol production technology has been derived from Tsinghua University can shorten solid state fermentation time from more than 72 hours to less than 44 hours. Ethanol yield is more than 94% of theoretical.

清華大學

A pilot plant with a 5m^3 rotary drum solid state fermentor is running well in Inner Mongolia.

清華大學

Executive summary

- **To shorten the fermentation time**, it takes only 44h to convert fermentable sugar in sorghum stalk to ethanol. While the time of corn ethanol is 48-60 hours (US ethanol handbook).
- **High ethanol yield**, more than 94% of theoretical. while the yield of corn to ethanol is only more than 91.5% in US.
- **Little wastewater** can be generated during solid state fermentation process, and the lees is the by-product as animal feed, can promote the cattle industry;
- **No cooking, saccharification processes** like using starch. The production cost of fuel ethanol can be reduced significantly, at least by 20% compared with ethanol from starch.
- **Less labour requirement**, and the whole production process can be autocontroled.

清華大學

- A demonstration plant with ten 265 m^3 rotary drum solid state fermentor , 5000 t/a fuel ethanol, will be built in this year.
- 0.5-1 million tons of ethanol will be produced from sweet sorghum annually during 2008-2010.
- Sweet sorghum is also a promising feedstock of cellulosic ethanol, since there is no collection problems for raw materials.

Sweet sorghum will be the main feedstock of fuel ethanol in the post 2010.

清華大學

3. Cellulosic ethanol co-produced with furfural and xylose

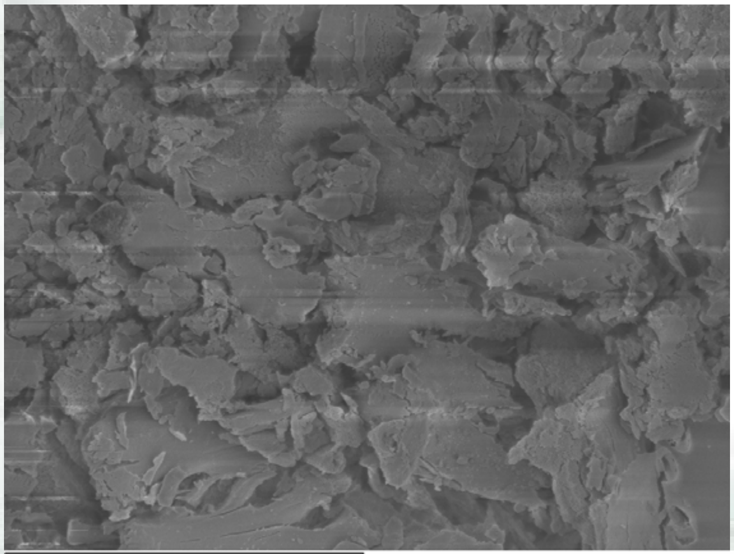
- Furfural and xylose are unique products from crop residues, mostly from corncobs, in China. And furfural can substitute C_4 fractions of petroleum to produce furan, THF and other derivatives.
- After the hydrolysis of hemicellulose to produce furfural and xylose, the dregs can be used to produce ethanol.
- A novel technology has been developed to produce furfural and xylose from corn stovers to reduce the production cost.

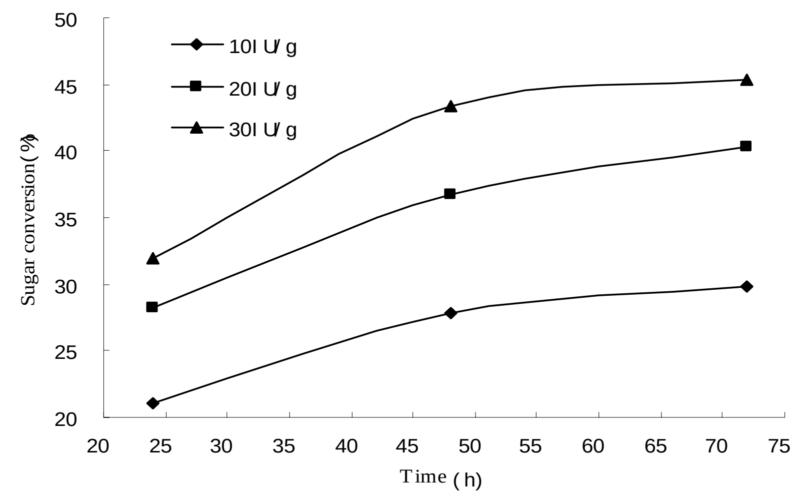
0.8 million tons of ethanol will be produced in the post 2010.

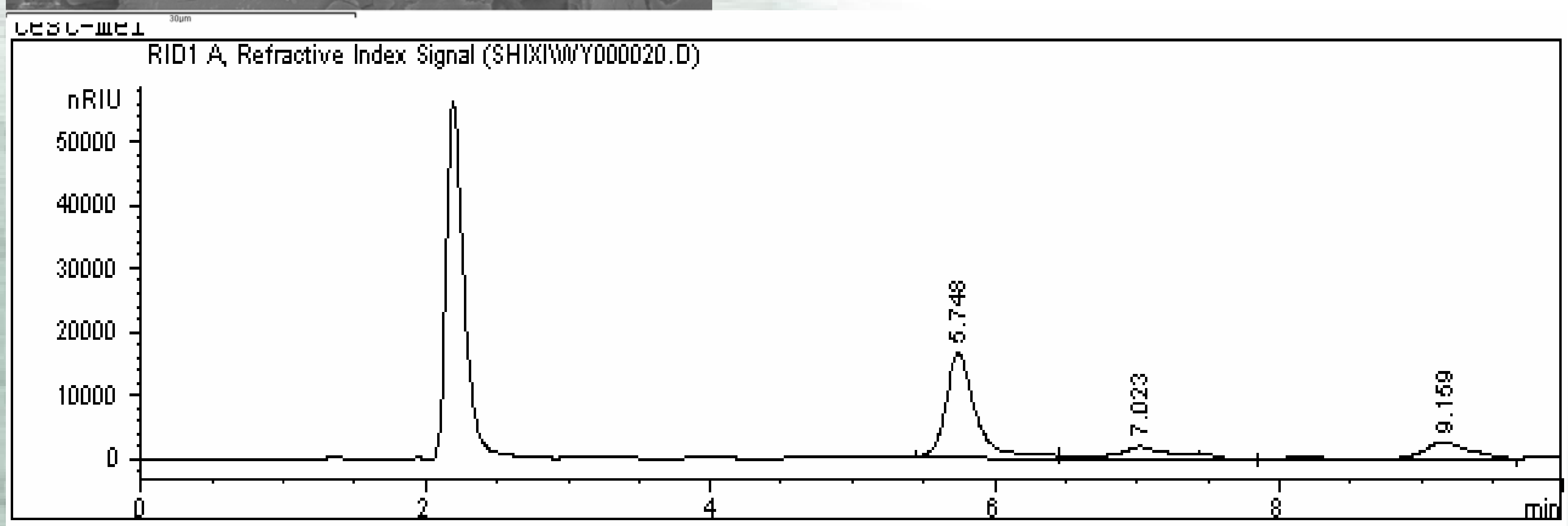
A pilot plant to produce furfural from corn- stover

清華大學

Hydrolysis of corncob dregs by cellulases







4. Cellulosic ethanol-the next generation of biofuel

Cellulosic ethanol from crop residues such as corn stover, wheat straw, rice straw and forestry residues represents a renewable and relatively low cost fuel option without concerns about food security and land requirements.

Cutting-edge methods of producing ethanol, not just from corn but from wood chips, stalks or switch grass. Our goal is to make this new kind of ethanol practical and competitive within six years.

George W. Bush

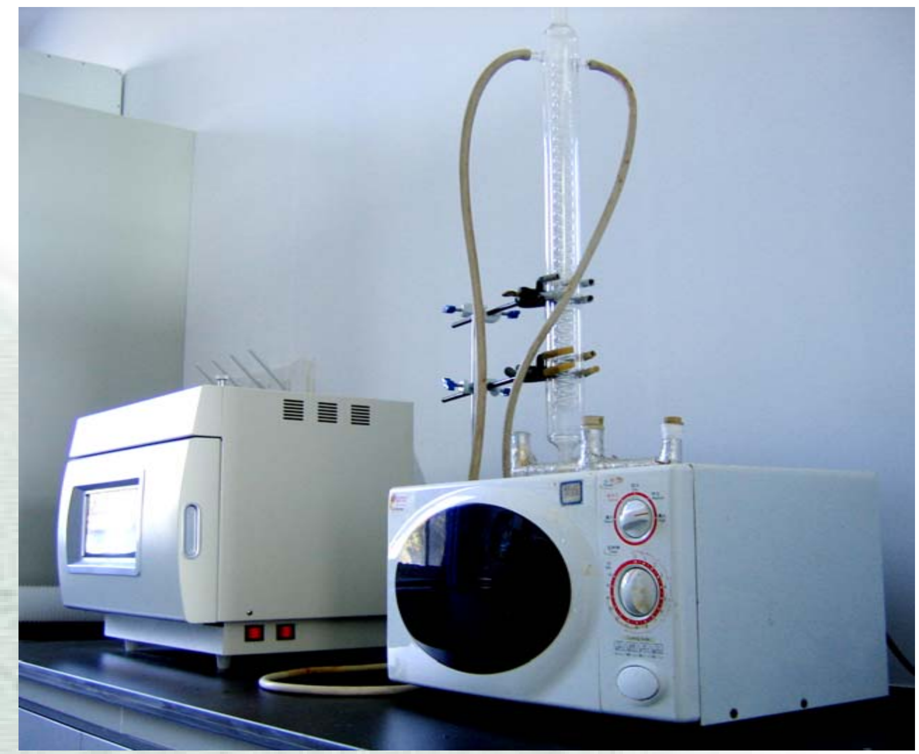
清華大學

Three technical hurdles should be overcome

- The efficient pretreatment of lignocellulose.
- How to hydrolyze cellulose is the central technical hurdle for cellulosic ethanol production.
- And an ideal microorganism should have broad substrate utilization.

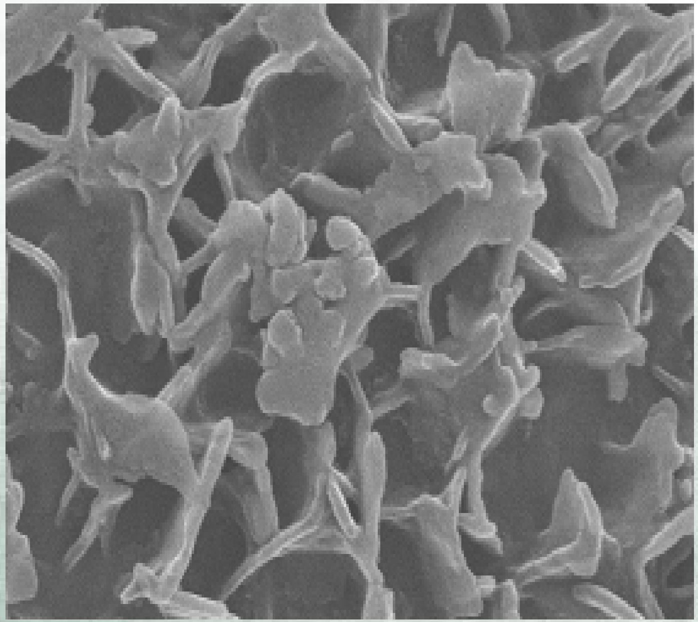
(1). Pretreatment of lignocellulose by the combination of chemical and biological methods

A new process named molecular vibration assisted diluted acid hydrolysis is being developed. After the hydrolysis of hemicellulose, a consortium of fungi, such as *Coridus versicolor,* are introduced to decompose lignin to expose more surface of cellulose.

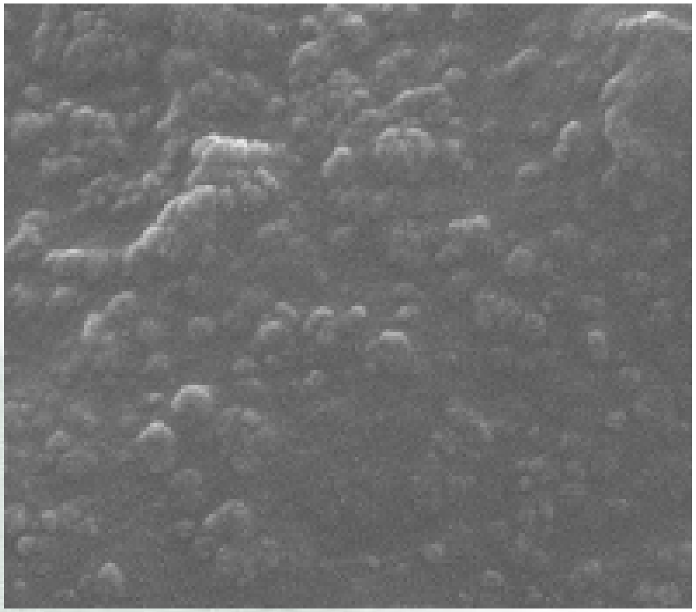


Hemicellulose hydrolysis time can be shorten 3 times.

The surface corn stover can be improved significantly by the partial decomposition of lignin, and let cellulose expose more surface to interact with cellulases.

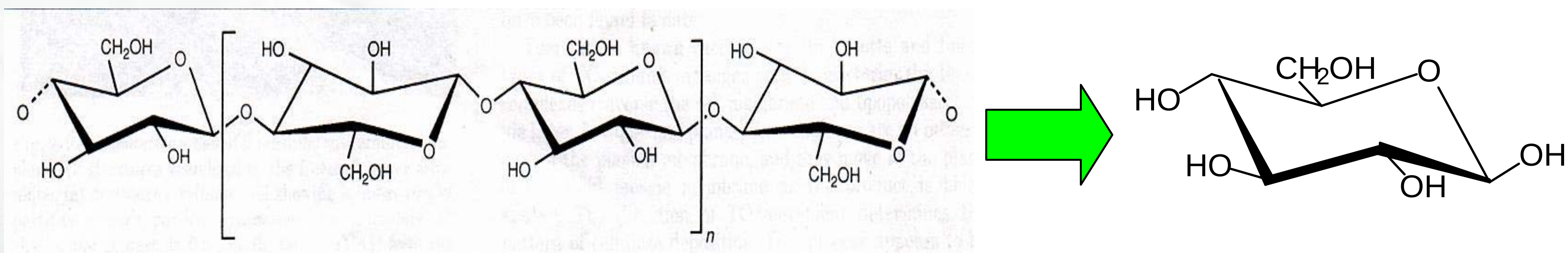


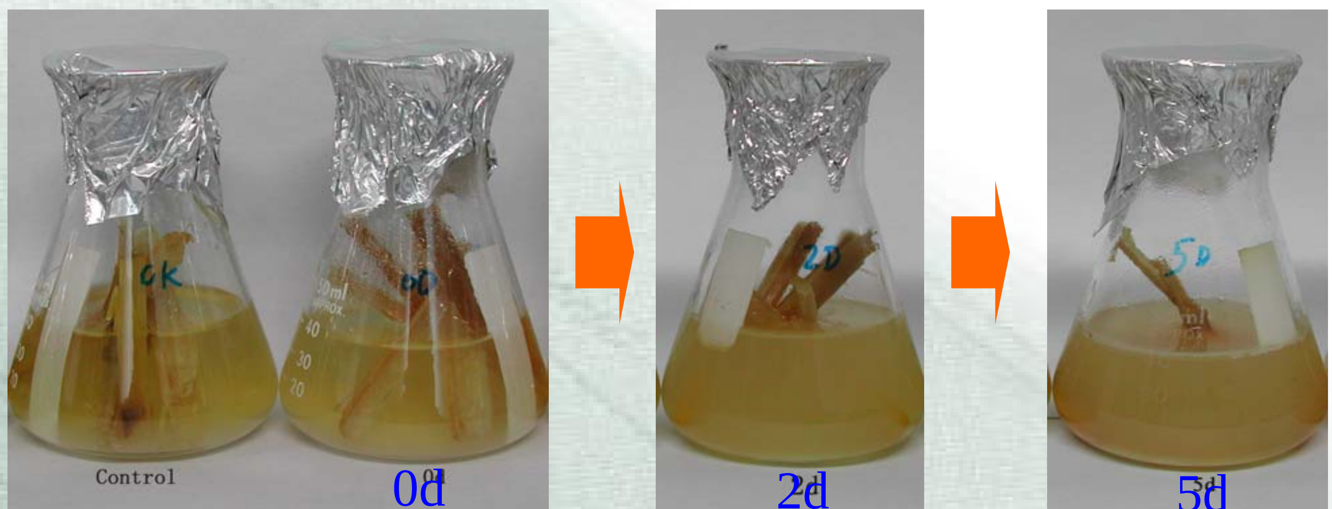
Particle size 400-500nm



Particle size 40-50nm

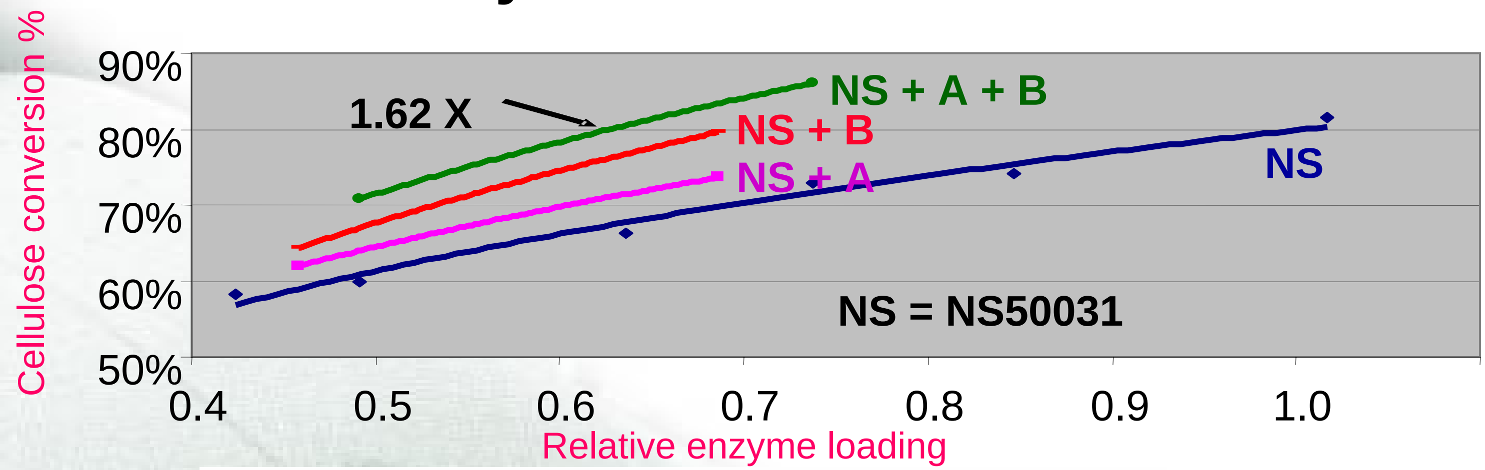
(2) The hydrolysis of cellulose by a consortium of microorganisms

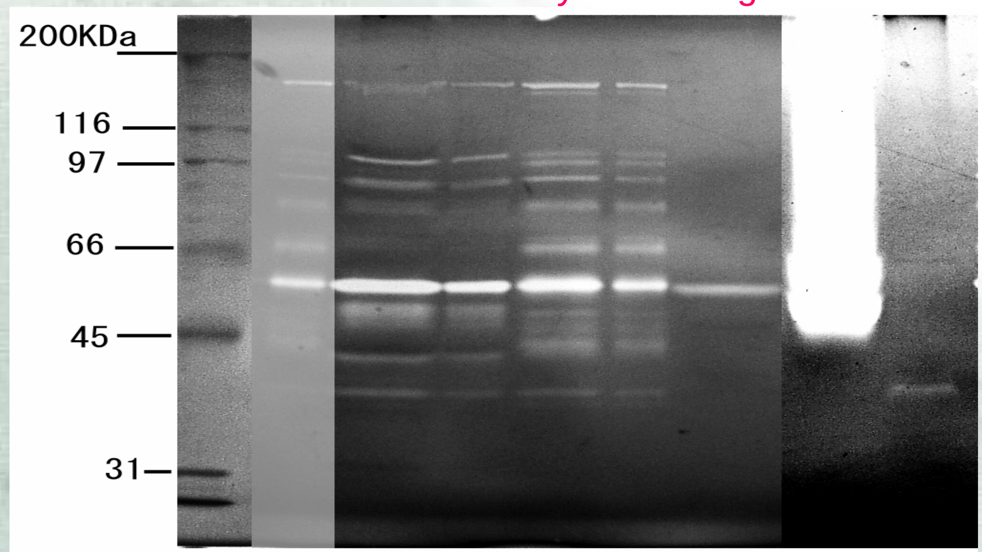




清華大學

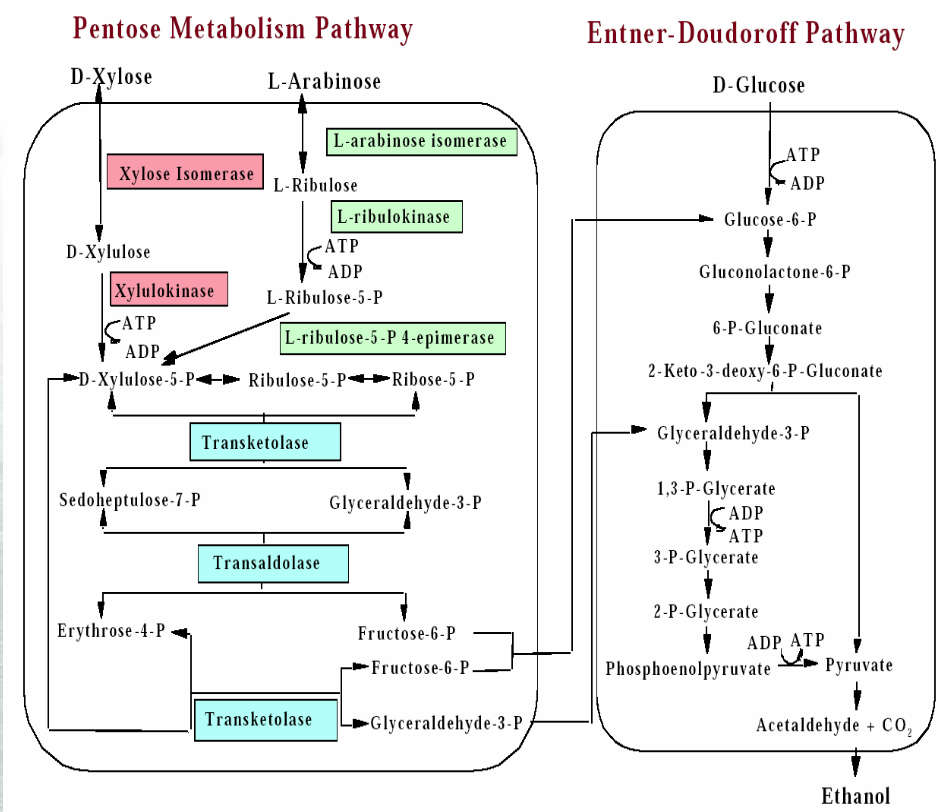
Our novel idea has been approved by the experimental results from Novozymes' lab





SDS page of Cellulases

(3) Engineered bacterium



Seven genes for pentose metabolism were integrated to the chromosome of *Zymomonas mobilis.* The new strain would not need any antibiotics to maintain and the foreign genes would not be lost during fermentation.

清華大學

Vision goals

Short-term (2007-2012)

3 million tons of bioethanol and derivatives /per year, mainly from non-food starch

Midterm-term (2008-2015)

8 million tons of bioethanol and derivatives /per year, mainly from sweet sorghum, other sugar canes, and bio industrial-waste.

Long-term (2015-2020)

9 million tons of bioethanol and derivatives /per year, mainly from lignocellulose.

20 million tons of bioethanol will be produced by 2020

清華大學

Thank You