INER-F0572 **INER-F0572**

出國報告（出國類別：其他）

參加 2012 年第二屆國際生物能源研討會

服務機關：核能研究所
姓名職稱：陳文華　副工程師
派赴國家：中國 大陸
出國期間：101 年 4 月 23 日~101 年 4 月 29 日
報告日期：101 年 5 月 24 日

摘　要

本次所參與『2012 年第二屆國際生物能源大會』之主題爲『開發可再生生物能源、促進可持續發展』。討論主題包括全球生物能源經濟與政策、技術開發、工業應用、生質酒精、生質柴油、藻類生物燃料、生物精煉和生物加工技術等生物能源相關議題。內容包括(1)生物能源領域的研究焦點及市場趨勢。(2)發表論文「不同規模與程序之生質物前處理系統，及其應用於稻稈原料之成效」之報告內容與會後討論(3)與諾維信公司人員就測試內容與未來可能合作方式進行討論。(4)參與「纖維素酒精商業化突破討論會」之內容過程。

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一、目　的

為因應核研所纖維酒精量化技術之開發及推廣，及瞭解生質能源相關領域之發展現況與方向，奉派前往中國大陸參加『2012 年第二屆國際生物能源大會』。此行之目的係(1)藉由此研討會發表及推廣核研所開發之不同規模與程序之生質物前處理系統與技術、共發菌及測試平台 (2)了解生物能源領域共同關注的研究焦點及市場趨勢，作為未來研發方向之參考。(3)與諾維信公司人員就現行平行測試結果及未來可能合作方式進行溝通與討論。(4)參與纖維素酒精商業化突破討論會，以瞭解現階段中國大陸於纖維素酒精工業商業化之現況及大規模商業化之瓶頸及預估時程。(5)與各國與會人員進行經驗交流，建立聯繫管道，以作為未來合作之基礎。

二、過　程

『2012 年第二屆國際生物能源大會』(The 2nd World Congress of Bioenergy; WCBE-2012) 於 2102 年 4 月 25-28 日在西安『中國西安曲江國際會議中心』舉行。會議時程表如下：

<table>
<tr><th>Date and Time</th><th>April 24, 2012 Tuesday</th><th>April 25, 2012 Wednesday</th><th colspan="2">April 26, 2012 Thursday</th><th colspan="2">April 27, 2012 Friday</th><th colspan="2">April 28, 2012 Saturday</th></tr>
<tr><td rowspan="7">8:00-12:00</td><td rowspan="16">Registration (Lobby, 3F)</td><td rowspan="7">Opening Ceremony & Nobel Lectures Forum (Part I) (Qujiang Auditorium, 3F)</td><td>Track 1</td><td>Session 100 (RN. 311A, 3F)</td><td rowspan="2">Track 1</td><td rowspan="2">Session 101 (RN. 311B, 3F)</td><td rowspan="3">Track 3</td><td rowspan="3">Session 302 (RN. 311A, 3F)</td></tr>
<tr><td colspan="2">Track 2 (RN. 311A, 3F)</td></tr>
<tr><td>Track 3</td><td>Session 300 (RN. 311B, 3F)</td><td>Track 3</td><td>Session 301 (RN. 312, 3F)</td></tr>
<tr><td>Track 4</td><td>Session 400 (RN. 312, 3F)</td><td>Track 8</td><td>Session 801 (RN. 311A, 3F)</td><td rowspan="2">Track 4</td><td rowspan="2">Session 402 (RN. 311B, 3F)</td></tr>
<tr><td colspan="2">Track 5 (RN. 312, 3F)</td><td colspan="2">Track 12 (RN. 311A, 3F)</td></tr>
<tr><td rowspan="2">Track 6</td><td>Session 600 (RN. 311A, 3F)</td><td colspan="2" rowspan="2">Track 13 (RN. 311B, 3F)</td><td rowspan="2">Track 9</td><td rowspan="2">Session 901 (RN. 311A, 3F)</td></tr>
<tr><td>Session 601 (RN. 311A, 3F)</td></tr>
<tr><td>12:00-13:00</td><td>Lunch</td><td colspan="2">Lunch</td><td colspan="2">Lunch</td><td colspan="2">Lunch</td></tr>
<tr><td rowspan="6">13:30-17:30</td><td rowspan="6">Keynote Forum (RN. 305, 3F)</td><td colspan="2">Track 7 (RN. 311A, 3F)</td><td rowspan="3">Track 4</td><td rowspan="3">Session 401 (RN. 311A, 3F)</td><td colspan="2" rowspan="6">NA</td></tr>
<tr><td>Track 8</td><td>Session 800 (RN. 311B, 3F)</td></tr>
<tr><td>Track 9</td><td>Session 900 (RN. 313B, 3F)</td></tr>
<tr><td colspan="2">Track 10 (RN. 313A, 3F)</td><td colspan="2" rowspan="3">Session for Young Scientist (RN. 311B, 3F)</td></tr>
<tr><td colspan="2">Track 11 (RN. 313A, 3F)</td></tr>
<tr><td colspan="2">Track 14 (RN. 312, 3F)</td></tr>
<tr><td>17:30-18:30</td><td>Free Social Hour</td><td colspan="2">Free Social Hour</td><td colspan="2">Free Social Hour</td><td colspan="2">Free Social Hour</td></tr>
<tr><td>18:30-20:00</td><td>Dinner</td><td>Welcome Banquet</td><td colspan="2">Dinner</td><td colspan="2">Dinner</td><td colspan="2">Dinner</td></tr>
<tr><td>Note</td><td></td><td colspan="7">RN=Room Number; 3F=3rd Floor
Track 1= Global Bioenergy Economy and Policy;
Track 2= Industrial Leadership Forums;
Track 3= Breaking Research and Enable Biofuel Technology;
Track 4= Biomass Feedstock I: Agricultural, Forestry Waste and Municipal Solid Waste;
Track 5= Biomass Feedstock II: Dedicated Energy Crops;
Track 6= Bioalcohols;
Track 7= Biodiesel;
Track 8= Algae to Biofuel;
Track 9= Biogases;
Track 10= Biofuel & Electricity Generation;
Track 11= Aviation Biofuels;
Track 12= Biorefinery/Bioprocess Tech;
Track 13= Biofuel Finance, Investment, Trade and Marketing;
Track 14= Cellulosic Ethanol Commercial Breakthrough;</td></tr>
</table>

行程詳述如下：

第一天:

4 月 23 日(星期一)：去程(台北-西安)。

第二天:

4 月 24 日(星期二)：報到註冊及準備資料。

第三天:

4 月 25 日(星期三)：參加開幕式及諾貝爾獎得主講座(Opening Ceremony &Nobel Laureates Forum)、主題論壇(Keynote Forum)與歡迎晚宴(Welcome Banquet)。

上午參加開幕式及諾貝爾獎得主講座。大會共邀請了 10 位諾貝爾獎得主參與開幕式，分別為 1988 年化學獎得主 Dr. Hartmut Michel 及 Dr. Johann Deisenhofer、1993 年生理醫學獎得主 Dr. Richard Roberts、2004 年物理學獎得主 Dr. David J. Gross 及化學獎得主 Dr. Aaron Ciechanover、2005 年生理醫學獎得主 Dr. J. Robin Warren、2006 年物理學獎得主 Dr. George Smoot III、2007 年生理醫學獎得主 Dr. Martin J. Evans、2009 年化學獎得主 Dr. Thomas Steitz 以及 2011 年化學獎得主 Dr. Daniel Shechtman。

接著分別由 2007 年生理醫學獎得主 Dr. Martin J. Evans、2009 年化學獎得主 Dr. Thomas Steitz、1993 年生理醫學獎得主 Dr. Richard Roberts、2005 年生理醫學獎得主 Dr. J. Robin Warren 及 1988 年化學獎得主 Dr. Hartmut Michel 演講。其講題如下：

Nobel Laureates Forum (Part I):

Time: 09:30-11:40, April 25, 2012 (Wednesday); Place: Qujiang Auditorium, 3rd Floor, QICC

Moderator *Dr. Richard Roberts*, Chief Scientific Officer, New England Biolabs, USA

Title: *Visions of Stem Cells*

Dr. Martin J. Evans, Director, Cardiff University, UK, Nobel Prize Laureate in Physiology/Medicine 2007

Title: ***Structural Insights into DNA Replication by the Replisome and Transcription by T7 RNA Polymerase***

Dr. Thomas Steitz, Professor, Yale University, USA, Nobel Prize Laureate in Chemistry 2009

Title: ***COMBREX- Genomes, Computers and Experimentation in Biology***

Dr. Richard Roberts, Chief Scientific Officer, New England Biolabs, USA, Nobel Prize Laureate in Physiology/Medicine 1993

Title: ***Discovering Helicobacter***

Dr. J. Robin Warren, Pathologist, Royal Perth Hospital, Australia, Nobel Prize Laureate in Physiology/Medicine 2005

Title: ***Membrane Proteins: Importance, Structures, Mechanisms***

Dr. Hartmut Michel, Professor, Max Planck Institute of Biophysics, Germany, Nobel Prize Laureate in Chemistry 1988

下午參加『2012 年第二屆國際生物能源大會』之主題論壇，演講者有 Mr. Floris Luger, Vice President, Business Development, Genencor, DuPont Industrial Biosciences, USA (美國杜邦公司工業生物科學事業部傑能科國際業務發展副總裁)、Dr. Xun Wang, Senior Vice President, Sapphire Energy Inc. CA, USA(美國 Sapphire 能源公司研發副總裁)、Dr. Rob Vierhout, Secretary General, the European Trade Association (ePURE), Belgium(歐盟生物酒精燃料協會 ePure 秘書長)、Dr. Xiucai Liu, Founder and Chief Executive Officer, Cathay Industrial Biotech Ltd., China(中國凱賽生物技術有限公司董事長兼執行長)以及 Dr. James Zhang, Vice President, Business Development, LanzaTech Inc., China (LanzaTech 公司中國區副總裁)。

其講題如下：

Keynote Forum:

Time: 13:30-16:10, April 25, 2012 (Wednesday); Place: Room 305, 3rd Floor, QICC

Moderator *Dr. James Zhang, Vice President, Business Development, LanzaTech Inc., China*

Title: ***DuPont Industrial Biosciences Strategies for Success: Building out the Bio-based***

Economy

Mr. Floris Luger, Vice President, Business Development, Genencor, DuPont Industrial Biosciences, USA

Title: ***Advancing the Algal Fuel Industry through Innovations***

Dr. Xun Wang, Vice President, Sapphire Energy Inc., USA

Title: ***Europe's View on Sustainable Liquid Biofuels***

Dr. Robert M. S. Vierhout, Secretary-General, ePURE, European Renewable Ethanol Association, Belgium

Title: ***Commercialization of Cellulosic Biofuel in China***

Dr. Xiucai Liu, Chairman and CEO, Cathay Industrial Biotech Ltd., China

Title: Waste Gases to Chemicals Platform

Dr. James Zhang, Vice President, Business Development, LanzaTech Inc., China

第四天:

4 月 26 日(星期四)：上午發表論文及聆聽演講、下午參加『纖維素酒精商業化突破討論會』。

論文發表安排於上午第一場第一位，中文題目爲『不同規模稀酸水解前處理系統開發及其應用於稻稈原料之效果』。報告及提問共 25 分鐘。接著即聆聽其他演講者之報告，其演講者與題目如下：

Track 6: Bioalcohols

Session 600: New Technology for Ethanol Production from Lignocellulosic Processes
Time: 08:30-10:30, April 26, 2012 (Thursday); Place: Room 313A, 3rd Floor, QICC

Chair: *Dr. Kasiviswanathan Muthukumarappan, Professor, South Dakota State University, USA*

Title: Different Scale Pretreatment System in Terms of Diluted-Acid Hydrolysis for Rice Straw

Dr. Wen-hua Chen, Associate Engineer, Institute of Nuclear Energy Research, Taiwan

Title: New Membrane Technologies for the Production and Utilization of Bioalcohols

Dr. Keiji Sakaki, Group Leader, National Institute of Advanced Industrial Science and

Technology (AIST), Japan

Title: Special Downstream Solutions – A Key Part in Making Second Generation Ethanol Commercial

Mr. Markus Lehr, Deputy Managing Director, VOGELBUSCH Biocommodities GmbH, Austria

Title: Development of Bio-based C4 Alcohols in GS Caltex

Dr. Doyoung Seung, Senior Vice President, GS Caltex Corporation R & D Center, South Korea

Title: Novel Characteristics of Pretreated and Densified Biomass

Dr. Kasiviswanathan Muthukumarappan, Professor, South Dakota State University, USA

Session 601: Highly Efficient Enzymes for Bioethanol Production

Time: 10:30-12:15, April 26, 2012 (Thursday); Place: Room 313A, 3rd Floor, QICC

Chair: *Ms. Deborah E. Dodge, Senior Manager, Product Marketing, Genencor, DuPont Industrial Biosciences, USA*

Title: Accellerase® TRIO: Advances in Cellulosic Enzymes for Biorefinery Development

Dr. Mian Li, Senior Applications Scientist, Genencor, DuPont Industrial Biosciences, USA

Title: How New Enzymes Change the Ways of Bioethanol Production

Dr. Gang Duan, Director, Application and Technical Services, Asia Pacific, Genencor (China) Bioproduct, Dupont Industrial Biosciences, China

Title: A Strategy How to Reduce the Enzyme Cost for Saccharification of Cellulosic Biomass

Dr. Masahiro Samejima, Professor, The University of Tokyo, Japan

Title: Commercialization of the Cellulosic Biofuels Industry: Advances in Biomass Enzyme Technology and Partnerships for Success

Ms. Deborah E. Dodge, Senior Manager, Product Marketing, Genencor, DuPont Industrial Biosciences,USA

下午參加由諾維信(Novozymes (China) Biotechnology Co., Ltd.)主辦之『纖維素酒精商業化突破討論會』，會中由諾維信介紹 2012 年 2 月上市之諾纖力賽

力三代(Cellic CTec3)之特與實際應用，並邀請中國大陸二代纖維素酒精行業重點企業，共同探討中國纖維素酒精大規模商業化的相關問題。

會議議程如下：

Track 14: Cellulosic Ethanol Commercial Breakthrough (Sponsored by Novozymes (China) Biotechnology Co., Ltd.)

Time: 13:30-17:10, April 26, 2012 (Thursday); Place: Room 312, 3rd Floor, QICC

致歡迎詞：諾維信全球應用研發副總裁–Erik Gormsen 先生

諾維信賽力三代性能介紹：諾維信生物能源業務拓展經理–*任海彧博士*

嘉賓討論：

主題：中國纖維素酒精大規模商業化的時間點還有多遠

嘉賓：中興能源有限公司–*曹珺先生*

康泰斯公司–*何翌先生*

中糧集團有限公司–*林海龍先生*

河南天冠企業集團有限公司–*王學平先生*

主持：諾維信政府事務和公共關係高級經理–*朱曉青先生*

第五天:

4 月 27 日(星期五)：聆聽演講及與諾維信公司人員進行合作討論。

聆聽演講的議程如下:

Track 12: Biorefinery/Bioprocess Tech

Time: 08:30-10:50, April 27, 2012 (Friday); Place: Room 311A, 3rd Floor, QICC

Chair: *Dr. Lew P. Christopher*, Director and Professor, Center for Bioprocessing Research & Development and Department of Chemical & Biological Engineering, South Dakota School of Mines and Technology, USA

Title: Metathesis: A Lipids to Chemicals Solution

Dr. Mel Luetkens, COO, Elevance Renewable Sciences, Inc., USA

Title: The Biolignin™ from the CIMV Process: A New Added Value Oligomer for the Chemical Industry

Dr. Michel Delmas, Professor, University of Toulouse; CIMV Inc., France

Title: Chemical Energy Carriers from Thermo-chemical Conversion of Biomass

Dr. Nicolaus Dahmen, Head of Division for Thermochemical Biomass Conversion, Karlsruhe Institute of Technology (KIT), Germany

Title: Efficient Conversion of Plant-biomass to BTX and Hydrocarbon Chemicals by Catalytic Pyrolysis

Dr. Wang Chang, Professor, Department of Environmental Science and Engineering, Tianjin University of Science &Technology, China

Title: Bioproducts from Hemicellulose in a Forest-based Biorefinery

Dr. Lew P. Christopher, Director and Professor, Center for Bioprocessing Research & Development and Department of Chemical & Biological Engineering, South Dakota School of Mines and Technology, USA

Session 101: Global Biofuel Programs/Biofuels in Developing and Developed Countries

Time: 10:30-12:15, April 27, 2012 (Friday); Place: Room 311B, 3rd Floor, QICC

Chair: *Dr. Jianzhong Sun,* Distinguished Professor & Director, Biofuels Institute of Jiangsu University, China

Title: The Economics of Enzyme Production for 2nd Generation Fuel Ethanol

Dr. Haiyu Ren, Business Development Manager, Novozymes A/S, Denmark

Session 401: Feedstock from Wood and Forestry and Conversion Technology

Time: 13:30-17:10, April 27, 2012 (Friday); Place: Room 311A, 3rd Floor, QICC

Chair: *Dr. Deborah S. Page-Dumroese,* Research Soil Scientist, USDA Forest Service, Rocky Mountain Research Station, USA

Co-Chair Dr. R. Kasten Dumroese, Research Plant Physiologist, US Department of Agriculture, Forest Service, Rocky Mountain Research Station, USA

Title: Torrefaction Processes for the Conversion of Agricultural and Food Residues in Biomass Derived Fuels to be Used in Coal Fired Power Plants

Dr. Giovanni Ciceri, Deputy Director, Environment and Sustainable Development Department, RSE Spa, Italy

Title: A Sustainable Process Development for Biomass Conversion into Charcoal for Metallurgical Processes

Dr. Ion Agirre Arisketa, Researcher, University of Leoben, Austria

Title: Bioenergy from Forests in Germany

Dr. Norbert Weber, Professor, Technische Universität Dresden, Germany

當天並與諾維信（Novozymes A/S）公司吳桂芳博士、李冬敏博士討論平行測試結果與未來合作方式。並與負責酒精及生物能源工業的工業銷售經理李明祺先生討論核研所前處理及共發酵技術在中國大陸推廣之方法與可行性。

第六天:

4 月 28 日(星期六)：聆聽演講。

聆聽『第三屆工業酵素與催化大會-The 3rd Symposium on Enzymes & Biocatalysis』之部份內容，其議程如下

SEB 501: Enzymes for Biofuel Production

Time: 08:30-10:50, April 28, 2012 (Saturday) ; Place: Meeting Room 313A, 3rd Floor, QICC

Chair: *Dr. Kasiviswanath Muthukumarappan*, Professor, South Dakota State University, USA

Co-Chair: *Dr. Zhen Yang*, Professor, Shenzhen University, China

Title: Diversity of Substrate Recognition by Microbial Endo-ß-1, 4-xylanases

Dr. Peter Biely, Research Professor, Institute of Chemistry, Slovak Academy of Sciences, Slovakia

Title: Extremophilic NiFe Hydrogenase Immobilization on Electrodes for H_2/O_2 Biofuel Cell Development

Dr. Elisabeth Lojou, Professor, CNRS – Bioénergétique et Ingénierie des Protéines, France

Title: Evaluation of Different Pretreated Biomass Materials by Cellic Ctec Product

Dr. Dongmin Li, Senior Research Scientist, Novozymes (China) Investment Co. Ltd., China

Title: Selection of Enzyme Combination, Dose and Temperature for Hydrolysis of Soybean White Flakes

Dr. Kasiviswanath Muthukumarappan, Professor, South Dakota State University, USA

Title: Enzymatic Production of Biodiesel in Ionic Liquids

Dr. Zhen Yang, Professor, Shenzhen University, China

Session 402: Biomass Feedstock: Agricultural and Food Residues, Industrial and Municipal Solid Waste

Time: 08:30-12:10, April 28, 2012 (Saturday); Place: Room 311B, 3rd Floor, QICC

Chair: *Dr. Chandrashekhar P. Joshi*, Professor, Center for Development of Science and Technology of Renewable Bioenergy, Chonnam National University, South Korea; School of Forest Resources and Environmental Science, Michigan Technological University, USA
Co-Chair: *Dr. Jens Bo Holm-Nielsen*, Head, Center for Bioenergy and Green Engineering, Department of Energy Technology, Aalborg University, Denmark

Title: Large Scale Utilization of New Feedstocks for Biofuels- Land Use Planning and Paradigm Shifts in Agricultural Growth System Approaches
Dr. Jens Bo Holm-Nielsen, Head, Center for Bioenergy and Green Engineering, Department of Energy Technology, Aalborg University, Denmark

Title: Greenhouse Gas Emission Reduction through Anaerobic Digestion of Pig Manure for Biogas Production
Dr. Xinmin Zhan, Lecturer, National University of Ireland, Ireland

Title: A Local Model for Bioenergy Generation Based on the Combined Use of Forage Crops in the Extreme South of Chile (Patagonia)
Dr. Christian Hepp, Director/Researcher, Tamel Aike Research Centre (Western Patagonia), Institute for Agricultural Research- INIA, Chile

Title: The Potential of Agricultural Residues and Wastes for Bioenergy Feedstrocks in China
Dr. Minpeng Chen, Associate Professor, Institute of Environment and Sustainable Development in Agriculture, Chinese Academy of Agricultural Sciences, China

Title: Co Firing of Biomass and Waste in Coal Power Plants
Mr. Thomas Koch, CEO; Mechanical Engineer, TK Energi AS, Demark

第七天:

4 月 29 日(星期日)：回程(西安-香港-台北)。

此行之目的除了發表論文，推廣核研所開發生質物前處理系統與技術、共發菌及測試平台外，主要希望能瞭解現階段中國大陸於纖維素酒精工業商業化之現況及大規模商業化之瓶頸及預估時程。並與各國與會人員進行經驗交流，

建立聯繫管道，以作爲未來合作之基礎。研討會中會見之主要人員及其單位如表一，所有參與人員名單請參閱附錄一，可依其研究相關領域進行聯繫與交流。

表一、研討會中會見之主要人員及其單位

	姓名	國家	公司/學校	職稱	領域
1	劉修才	中國	凱賽(Cathay)生物產業有限公司	董事長&總裁	工業生物
2	Paul Caswell	中國	凱賽(Cathay)生物產業有限公司	執行副總裁	工業生物
3	Tao Lin	中國	凱賽(Cathay)生物產業有限公司	生物部主任	工業生物
4	任海彧	中國/丹麥	諾維信(Novozymes)投資有限公司	業務發展經理	酵素生產
5	李云峰	中國	諾維信(Novozymes)投資有限公司	市場經理	酵素生產
6	吳桂芳	中國	諾維信(Novozymes)投資有限公司	高級經理	酵素生產
7	李冬敏	中國	諾維信(Novozymes)投資有限公司	高級研究員	酵素生產
8	劉萌萌	中國	諾維信(Novozymes)投資有限公司	研究助理	酵素生產
9	李明祺	中國	諾維信(Novozymes)投資有限公司	工業銷售經理	酵素生產
10	林海龍	中國	中糧集團有限公司 (國家能源生物液體燃料研發實驗中心)	高級科學家	生物液體燃料加工轉化
11	林增祥	中國	中國科學院上海高等研究院	博士後	生物煉制
12	Aaron Kelly	China	Genencor(China)Bio-Procusts Co. Ltd.	Regional Marketing Director	酵素生產
13	Mian Li	USA	Genencor/DuPont Industrial Biosciences	Senior Applications Scientist	酵素生產
14	Kasiviswanathan . Muthukumarappan	USA	Department of Agricultural and Biosystem Engineering, South Dakota State University	Professor	Food and Bioprocess Engineering
15	J. H. David Wu	USA	Department of Chenical Engineering, University of Rochester	Professor	Fermentation Biotechnology
16	蘇建中	中國	江蘇大學生物質能源研究所	特聘教授(所長)	昆蟲、生物能源
17	池俊利	台灣	遠東新世紀股份有限公司	研究員	生物技術
18	郭俊毅	台灣	遠東新世紀股份有限公司	研究員	生物技術
19	陳泰安	台灣	環球科技大學環境資源管理系	講師	環境工程
20	Shuguang Deng	USA	Department of Chemical Engineering, New Mexico State University	Professor	Advanced Materials
21	James J. Spivey	USA	Department of Chemical Engineering, Louisiana State University	Professor	Catalysis Biodiesel
22	Fabien L. Cabirol	Germany	Evonik Industries AG	Head of R&D Biotechnology	Biotechnology
23	Christopher Whiteley	Taiwan	Graduate Institute of Applied Science and Technology, NTUST	Expert Professor	Biomedical Chemistry; Enzymology;
24	Adriana Ferreira Maluf Braga	Brazil	University of São Paulo, Brazi	Environmental Engineer	Hydrogen production
25	Mélida del Pilar Anzola Rojas	Brazil	University of São Paulo, Brazil	Environmental Engineer	Hydrogen production
26	Rosa Ana Conte	Brazil	University of São Paulo, Brazil	Assistant Professor	Hydrogen production
27	Lucina Hernández	USA	Rice Creek Field Station, State University of New York Oswego	Director	Ecology and Conservation
28	Efstratios Kalogirou	USA/ Greece	Earth Engineering Center, Columbia Unversity/Global WTERT Council Greece	Vice President	Waste Management
29	Aaron Philippsen	Canada	Institute for integrated Energy Systems, University of Victoria	Mechanical Engineer	Seaweed Ethanol
30	Dana Williams	USA	Park City Municipal Corporation	Mayor	Policy

三、心　得

面對化石能源的枯竭和環境的污染，生物能源的開發利用爲經濟的可持續發展帶來了曙光。生物能源作爲可再生、污染極小的能源，具有無可比擬的優越性，將爲 21 世紀的經濟發展和環境保護注入強大的推動力。

『2012 年第二屆國際生物能源大會』(The 2nd World Congress of Bioenergy; WCBE-2012) 是由中國國家外國專家局、西安市人民政府以及中國醫藥生物技術協會主辦，中國國家外國專家局國外人才資訊研究中心、中國國際貿易促進委員會西安市分會、西安市高新區管委會、西安市外僑辦、西安市科技局、西安市食品藥監局、西安市會展辦、西安市外專局及西安市日報社承辦，同時由百奧泰國際會議（大連）有限公司、國家外國專家局國外人才資源總庫-大連生物與醫藥人才分庫以及西安市國際經貿會展有限公司作爲支援單位的國際性會議。於 2102 年 4 月 25-27 日在西安『中國西安曲江國際會議中心』舉行。

本次會議除了第二屆國際生物能源大會外，另有五個研討會同時舉行，包含

(1) 2012 中國西安第三屆國際 DNA 和基因組活動周
-BIT'S 3rd World DNA and Genome Day

(2) 第三屆工業酵素與催化大會
-The 3rd Symposium on Enzymes & Biocatalysis

(3) 首屆生物多樣性及生態文明國際大會
-The 1st Annual World Congress of Biodiversity

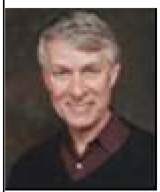
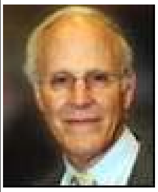
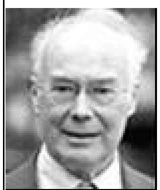
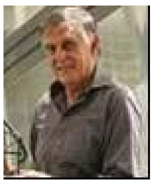
(4) 第五屆工業生物技術大會
-The 5th Annual World Congress of Industrial Biotechnology

(5) 第三屆石油微生物大會

-The 3rd Annual World Congress of Petro Microbiology。

共計六個與生物技術及生質能源相關之研討會一起舉辦，同時邀請 10 位諾貝爾獎得主參與及演講並聘爲顧問(表二)，估計至少上千人參與(圖一)。可見中國大陸對生物技術及生質能等相關研究與工業化之支持與重視。

表二、 大會邀請之 10 位諾貝爾獎得主

	**Hartmut Michel-**德國馬普生物物理研究所所長，1988 年諾貝爾化學獎得主。		**Johann Deisenhofer-**美國霍華休斯醫學院，1988 年諾貝爾化學獎得主。
	**Richard Roberts-**美國 NEB 公司首席科學家，1993 年諾貝爾生理醫學獎得主。		**David J. Gross-**美國加州聖塔芭芭拉 Kavli 理論物理研究所所長，2004 年諾貝爾物理學獎得主。
	**Aaron Ciechanover-**以色列技術研究所教授，2004 年諾貝爾化學獎得主		**J. Robin Warren-**2005 年諾貝爾生理醫學獎得主，發現幽門螺桿菌及作用。
	**George Smoot III-**美國加利福尼亞大學伯克萊分校教授，2006 年諾貝爾物理學獎得主。		**Sir Martin J. Evans-**英國卡迪夫大學生命科學學院主任，2007 年諾貝爾生理醫學獎得主。
	**Thomas Steitz-**美國耶魯大學教授，2009 年諾貝爾化學獎得主。		**Daniel Shechtman-**以色列理工學院教授，2011 年諾貝爾化學獎得主。

圖一、大會開幕與諾貝爾獎座論壇

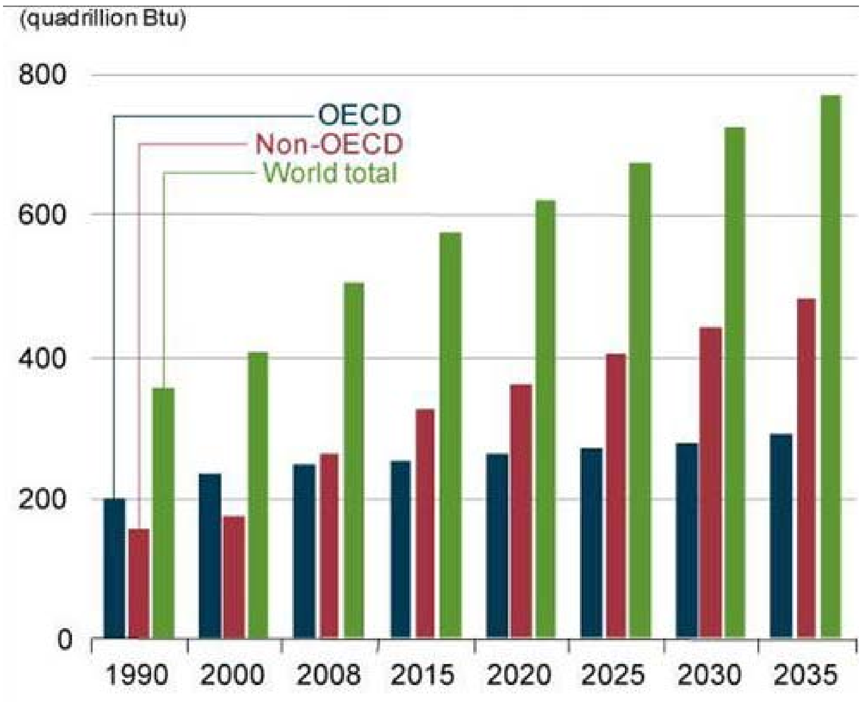
(一) 研討會演講摘要說明

國際生物能源大會主題爲『開發可再生生物能源、促進可持續發展』。除主題論壇外，另包含(1)全球生物能源經濟與政策—Global Bioenergy Economy and Policy) (2)工業領導者論壇—Industrial Leadership Forums (3) 生物燃料技術的最新研究進展—Breaking Research and Enable Biofuel Technology (4)生物質原料 I—Biomass Feedstock I: Agricultural, Forestry Waste and Municipal Solid Waste (5) 生物質原料 II—Biomass Feedstock II: Dedicated Energy Crops (6) 生質酒精—Bioalcohols (7)生物柴油—Biodiesel (8)藻類生物燃料—Algae Biofuel (9)生物沼氣—Biogases (10)生物燃料與發電—Biofuel & Electricity Generation (11)航空生物燃料—Aviation Biofuels (12) 生物精煉和生物加工技術—Biorefinery/Bioprocess Technology (13) 生物燃料金融、投資、貿易和市場—Biofuel Finance, Investment, Trade and Marketing (14) 纖維素酒精商業化突破討論會—Cellulosic Ethanol Commercial Breakthrough 等 14 個科技論壇和分會活動。

演講摘要說明如下

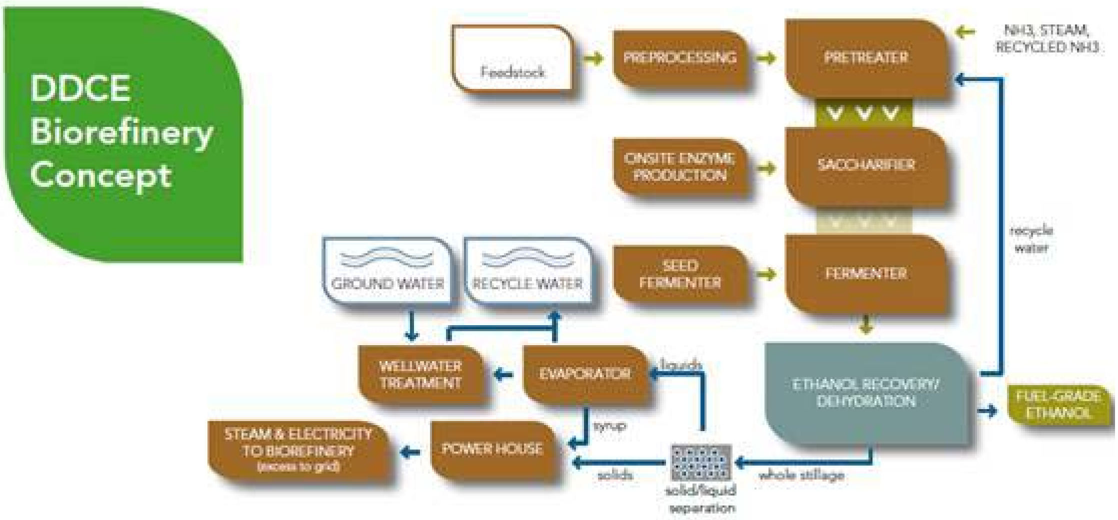
1. 杜邦公司(DuPont)-纖維素酒精開發

副總裁 Floris Luger 先生表示：IEA 報告預測由 2008 年至 2035 年，全球能源消耗量將增加至 53% (圖二)，尋求可持續替代能源是全球的當務之急。杜邦公司已著手投資第一代生質酒精和先進的生物燃料，包括第二代纖維素酒精及生物丁醇技術。在生物燃料領域，目前廣泛應用的是第一代生物燃料，這種技術因使用玉米、小麥等糧食作物作爲原料而廣受詬病；纖維素酒精屬於第二代生物燃料，該技術主要來非糧食作物，例如秸稈、枯草、工農業廢棄物等。

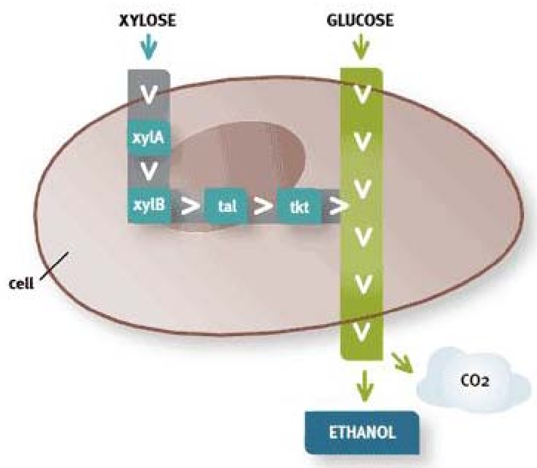


圖二、全球能源需求圖

杜邦公司之生產程序包含(1)研磨/預處理(milling/preprocessing)；(2)前處理(pretreatment)；(3)糖化和酵素水解(saccharification/enzyme hydrolysis)；(4) 發酵(fermentation)。其中，在前處理方面：以稀氨前處理程序(dilute ammonia process)爲主，氨是相對便宜且常見的工業化學品；易回收使用，也是一種發酵之營養物質，有助於降低成本。另外，因爲它易分散於生質物中，故可在低濃度、低溫低壓下反應。而在糖化和酵素水解程序中，其操作條件大於 25%固體濃度，主要使用該公司旗下杰能科(Genencor/DuPont)所開發之酵素(ACCELLERASER TRIO™ enzyme)可同時利用纖維素與半纖維素，生產程序如圖三所示。此外，該公司應用代謝工程改質發酵菌(Zymomonas mobilis) (圖四) 以提升半纖維素中五碳糖(木糖)使用率，提高酒精產率。



圖三、杜邦公司纖維素酒精之生產程序



圖四、Zymomonas mobilis 代謝工程

2008 年，杜邦公司與丹尼斯克公司成立了合資公司，一起推廣該公司所建立之纖維素酒精示範廠(Demonstration plant)，此示範廠約 74,000 平方英尺，位於田納西州(Tennessee)的 Vonore，主要原料爲當地的作物柳枝稷 (switchgrass)，於 2009 年 12 月開始生產酒精，預計在實現大規模生產後，年產量爲 25 萬加侖酒精，同時作爲優化技術的大規模生產測試。

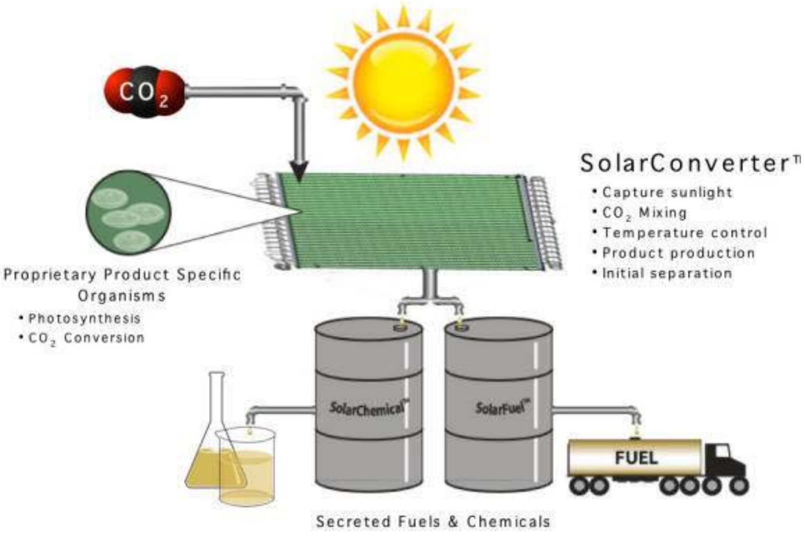
杜邦公司將於內華達州 (Nevada)、愛荷華州 (Iowa) 與 KBR 及 Fagen 公司合作建造玉米秸稈進料、年產量爲 28 百萬加侖酒精 (28MMgy) 之第一座商業的纖維素酒精工廠(commercial-scale cellulosic ethanol plant)，並與 Lincolnway Energy LLC 現有的玉米酒精廠相鄰，使兩廠在能源和物流管理等頁項目產生協同作用。該公司計畫以承包方式向設廠的大約 30 英里半徑範圍內的農民購買足量之玉米秸稈。預定於 2012 年開始由 KBR 進行前端的工程、採購和設施的詳細工程設計，接著由 Fagen 開始建造，同時，杜邦公司計畫與愛荷華州立大學合作開發玉米秸稈收集方式。

2. 美國 Sapphire 能源公司-藻類生物燃料開發

藻類在地球之生物固碳，氧的生成和氮循環乃在地球生態環境之演變扮演重要角色，藻類可利用光合作用把空氣中的二氧化碳固定，轉化生成油脂，可做為化學品和生質燃料(圖五)。且藻類可生長於半鹹水(brackish water) 或鹹水 (salt water) 的池塘中，故不與供應農田種植之淡水競爭。

研發副總裁 Xun Wang 博士表示：藻類的養殖和收穫成本昂貴，原本只用於化妝品和營養補充品等相對較高價的產品生產。該公司與農業生技 Monsanto 公司合作，進行培育可耐高 PH 值及高鹽度惡劣條件之藻類，並利用開放式養殖培育藻類以降低成本。在收穫方面， 生產 1 克的藻類需 1000 克水，分離和提煉油則需要大量的能量。因此該公司提出利用化學藥劑，使藻類糾纏在一起，以利收集。其所生產的藻油，稱之為綠色原油 (green crude)，是高支鏈、未修飾、類似輕原油，如傳統原油，可煉製為汽油、柴油和航空燃料。

該公司於新墨西哥州北部正建立一個 300 英畝藻類農場以作為藻類油生產的大型示範廠，日產 100 桶藻油。圖六為其水藻農場，現已經完成 100 英畝的農場段，預期至 2014 年，將有能力生產約 150 萬加侖的藻類原油，可以運到煉油廠，生產化學品、柴油和汽油等燃料。後續將針對泵效率、二氧化碳供應等改善系統性能及其藻類的基因工程進行研發。



圖五、藻類轉化成化學品和燃料示意圖

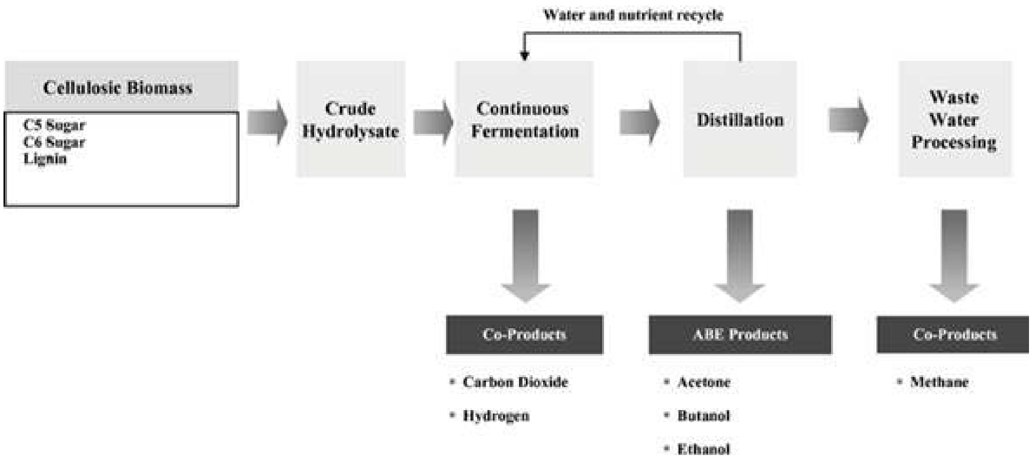
圖六、Sapphire 能源公司水藻農場

3. 中國凱賽(Cathay Industrial Biotech)公司-纖維素丁醇開發

中國凱賽公司董事長兼執行長劉修才(Xiucai Liu)博士表示：凱賽是一家工業生物科技產業公司，在中國擁有大規模綜合性生物產業平臺，目前該公司的主要產品爲二元酸(dicarboxylic acids)和生物丁醇(biobutanol)。其中，二元酸爲應用於合成反應之有機化合物，可廣泛用於多種工業化學品的生產，而生物丁醇則是一種應用廣泛的工業化學品，主要是用作工業溶劑。其他應用包括生產可塑劑、樹脂、油漆、塗料、除草劑與藥品的化學中間體，以及食品級提煉物，也可作爲汽油添加劑，即生物燃料。

該公司位於吉林省之生物丁醇生產廠係以玉米澱粉(corn starch)爲原料，利用多個連續發酵生物反應器生產，其生物丁醇年產量爲 2,100 萬加侖。在 2011 年底，開始進行以玉米芯和玉米秸稈等爲原料生產纖維素丁醇 (Cellulosic biobutanol)。係利用現有生質丁醇生產廠共構，以實現纖維素丁醇商業化的計畫。

其處理流程如圖七所示，前處理利用硫酸水解程序，主要取得五碳糖，隨後取得六碳糖，回收酸。此外，所分離木質素，則應用於鍋爐燃料以減少工廠公用系統成本。發酵菌則可利用五碳糖和六碳糖生產丁醇，劉博士認爲克服熱化學前處理及酵素水解程序之技術與降低投資成本以及有效地原料收集才能達到商業化之目標。

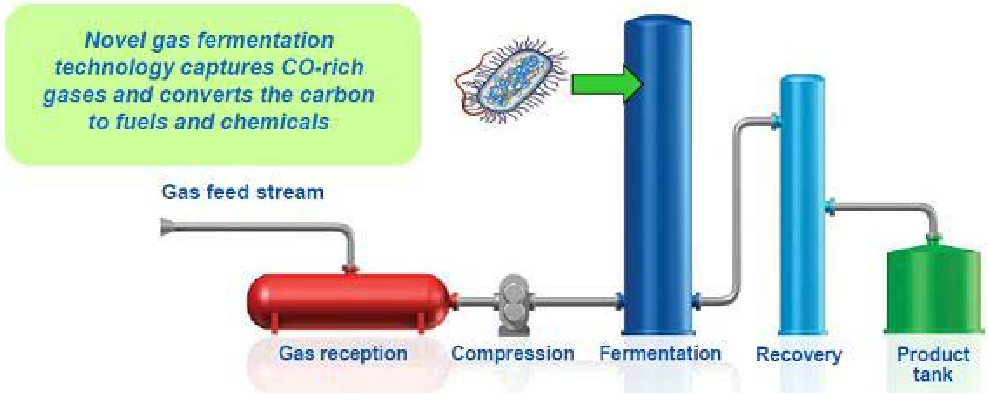


圖七、Cathay 公司纖維素計畫生產流程圖

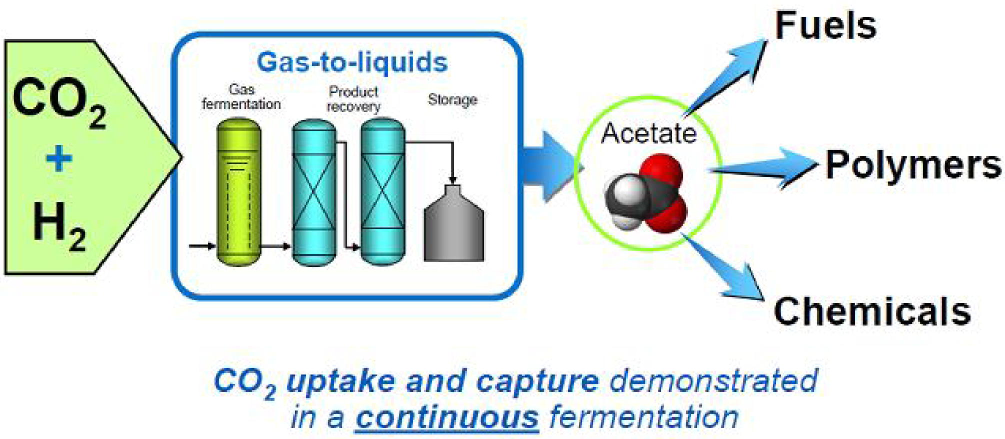
4. 紐西蘭 LanzaTech 公司-廢氣轉化液態燃料及化學品開發

紐西蘭 LanzaTech 公司中國區副總裁 Dr. James Zhang 介紹該公司之氣態發酵酵技術，由富含一氧化碳(CO)之廢氣轉化液態燃料和化學品。其程序如圖八所示。就 LanzaTech 技術應用於酒精生產潛力而言，由石油焦碳(petcoke; petroleum coke) 每年可生產 45 億加侖；由鋼鐵工業廢氣 (steel) 每年可生產 300 億加侖；若以美國之每年 13 億噸生質物 (biomass) 估算則可生產 1,900 億加侖酒精。該公司 2008 年測試廠酒精年產量爲 15,000 加侖；2011 年完成年產量爲 100,000 加侖之酒精示範廠；預期於 2013 年完成年產量爲 3,000 萬加侖之商轉廠。

此外，Dr. Zhang 表示該公司正開發以二氧化碳(CO_2)作爲碳源，經過連續發酵生成醋酸(Acetate)，再轉化爲燃料、高分子或化學品等產品，其示意圖如圖九所示。



圖八、LanzaTech 公司廢氣轉換成液態燃料及化學品程序流程圖



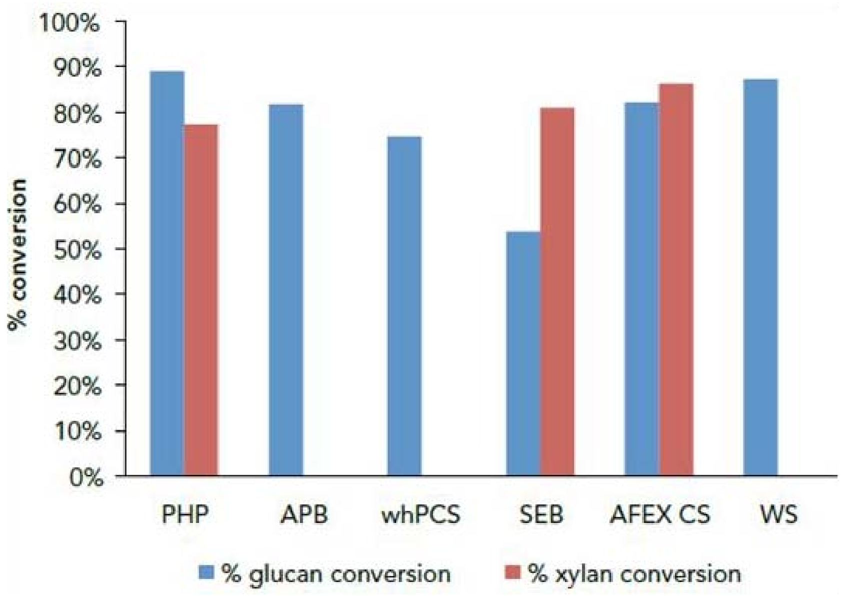
圖九、LanzaTech 公司醋酸生成程序示意圖

5. 杰能科(Genencor, DuPont Industrial Biosciences)公司-酵素開發

杰能科公司於研討會中 session 601 陸續介紹其酵素新產品(Accellerase

TRIO^{TM})，演講者包括資深應用科學家 Mian Li 博士、應用與技術服務部門主管 Gang Duan 博士以及資深經理 Deborah E. Dodge 經理。報告摘要如下：

選用菌株需考慮其合適之環境，如真菌(Fungi)之 pH 值約 3.3-4.5 左右、酵母菌(Yeast)則介於 4.0-6.0、細菌(Bacteria)則大於 7。杰能科公司新產品 Accellerase TRIO^{TM} 係以基因改質 Trichoderma reesei 所生產，利用雞尾酒(cocktail)調製方式，使其富含多種生物酵素，可同時轉化成可發酵的五碳糖和六碳糖，進而提高六碳糖的轉化率。在酵素水解程序中，於高固體含量下可有效地降低黏度，故可其劑量較原來酵素降低 2 倍。圖十為不同前處理原料酵素水解之測試結果，測試原料包含闊葉木漿 (PHP)、酸處理蔗渣 (APB)、酸處理玉米稈 (whPCS)、蒸汽處理蔗渣 (SEB)、氨水爆裂玉米稈 (AFEXCS) 及麥稈 (WS)。此酵素已應用於杜邦公司之纖維素酒精示範廠，該廠年產量為 25 萬加侖酒精，並計畫應用於杜邦位於美國愛荷華州所興建的纖維素酒精商轉廠。



圖十、Accellerase TRIO^{TM}於不同前處理原料之酵素水解測試

(二) 論文發表

論文發表係以口頭報告方式，推廣核研所開發生質物前處理系統與技術、共發菌及測試平台。安排於 4 月 26 日上午第一場第一位，題目爲『Different Scale Pretreatment System in Terms of Diluted-Acid Hydrolysis for Rice Straw-不同規模稀酸水解前處理系統開發及其應用於稻稈原料之成效』。

主要探討以稻稈爲原料，應用稀酸水解及蒸汽爆裂之前處理程序，由實驗室級至測試廠、由批次操作至連續操作之前處理設施開發及測試情形，本論文發表於研討會論文集第 121 頁。會後則有凱賽(Cathay)生物公司劉修才總裁、Paul Caswell 執行副總裁、Tao Lin 主任；中國科學院上海高等研究院林增祥博士；諾維信(Novozymes)公司李冬敏博士以及遠東新世紀公司池俊利博士接洽，就報告內容作進一步討論。

簡報請參閱附錄二，邀請函及論文摘要如下。

邀請函

BIT's 2nd Annual World

Congress of Bioenergy

Theme: Renewable Energy for Sustainability

Time: April 25-28, 2012 Place: Xi'an, China

Dear Dr. Wen-hua Chen,

With the impact of increased Bioenergy utilization factors, BIT Life Sciences and the organizing committee launched the 2nd **Annual World Congress of Bioenergy-2012 (WCBE-2012)**, with a theme of Renewable Energy for Sustainability will be held during April 25-28, 2012, Xi'an, China. On behalf of the organizing committee, it's my pleasure to ask if you would like to accept as well as your schedule allows you to attend this event as the **Speaker of Session 600: Lignocellulosic Biomass Pretreatment Approaches**. If the suggested thematic session is not your current focuse, you may look through the whole sessions and choose another one that fit your interest (more details about the program topics are at http://www.bitlifesciences.com/wcbe2012/fullprogram.asp).

WCBE-2012 is expected to bring together scientists, industrial leaders and decision makers from all over the world again in a great range of fields to celebrate the recent breaking researches through cluster conferences, expositions, excellent lectures, tech tours and training programs. WCBE-2012 will feature 1 plenary forum, 16 parallel tracks, 80 parallel scientific sessions.

The program of WCBE-2012 will highlight some recent breakthrough stories and successes in this particular field. We are especially interested in presentations in the following major aspects or sections: Breaking Research and Enable Biofuel Technology, Feedstocks and Biomass, Bioalcohols, Biodiesel, Biogases, Algae Biofuel, Productive Energy Crops, Biofuel & Electricity Generation, Biofuel Based Automotives, Aviation Biofuels, Biorefinery/Bioprocess Tech, Biofuel Standards, IP, Regulations.

As one of the Four Great Ancient Capitals of China, the conference place, Xi'an, with more than 3,100 years of history, the city was famous for Silk Road and Terracotta Army. In Xi'an, you will discover the unique and charming sightseeing during optional post-conference tour.

We look forward to seeing you in Xi'an in 2012 for this influential event.

Yours truly,

Organizing Committee of WCBE-2012

Bella Yu

East Wing, 11F, Dalian Ascendas IT Park
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Web: http://www.bitlifesciences.com/wcbe2012

BIT's Annual World Congress of Bioenergy
Organizing Committee
Since 2011

論文摘要

Title: Different Scale Pretreatment System in Terms of Diluted-Acid Hydrolysis for Rice Straw

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Associate Engineer
Institute of Nuclear Energy Research
Taiwan

Abstract

In concert with governmental policy for promoting the use of biofuels, the Institute of Nuclear Energy Research (INER) is dedicated to the research and development of technologies using local raw materials such as rice straw for cellulosic ethanol production. The pretreatment technology is a central part of the lignocelluloses-to-ethanol process. Thus, INER has developed lignocellulosic pretreatment technologies and completed different scales of pretreatment systems on the basis of dilute-acid hydrolysis and steam explosion, that have been applied on a lab-scale (400g/batch), a bench-scale (10kg/batch) and a pilot plant (1 ton/day) cellulosic ethanol testing platform at INER. In this article, the effect of solid loading, acid concentration, reaction temperature, residence time on the pretreatment efficiency with the rice straw as feedstock was studied for obtaining optimal operating conditions in the different scale pretreatment systems. These were evaluated by estimating the xylose yield after pretreatment and the glucose yield from the sequential enzymatic hydrolysis. For the continuous dilute-acid steam explosion process in the pilot-scale, the influences of rice straw size, presoaking screw speed and explosion pressure at 190 ^{o}C for 2 min with 0.5% H_2SO_4 were studied. Our results showed that small rice straw size, low screw speed and higher explosion pressure improved the enzymatic digestibility of cellulose. Moreover, the maximum total saccharification yield was obtained at a combined severity factor of 1.3-1.5 in the bench-scale and 0.4-0.7 in the pilot-scale pretreatment. This represents that the dilute-acid hydrolysis behavior of rice straw is different due to capacity and operational (batch or continuous) module.
Key Words: dilute-acid hydrolysis, rice straw, pretreatment, cellulosic ethanol, pilot-scale

Biography

Wen-hua Chen, female, received her doctoral degree in chemical engineering department from National Tsing Hua University in Taiwan in 1996. She had served a postdoctoral research fellow in the Institute of Atomic and Molecular Sciences, Academia Sinica, Taiwan from 1998 to 2006 and as an assistant professor at National University of Kaohsiung from 2003 to 2006. She has published 26 SCI papers and over 70 conference papers in the field of material synthesis, characterization and applications. Then, Dr. Chen joined Institute of Nuclear Energy Research as an associate engineer in 2006, where her research was focused on the biomass pretreatment technologies for cellulosic ethanol production. These researches also resulted in publication of 5 SCI papers and 3 patents in the bioethanol-related field.

(三) 與諾維信 (Novozymes)公司合作討論

2011 年核研所與知名酵素生產諾維信公司合作，以核研所測試廠前處理設施生產之酸催化蒸汽爆裂處理稻稈，以諾維信公司的酵素(Novozymes Cellic CTec 2)進行酵素水解平行測試。藉由本次研討會討論測試結果以及未來合作之可行性。會談人員與內容如下：

1. 酵素生產相關

生物能源業務拓展經理任海彧博士詢問核研所酵素生產之規劃及技轉是否包含酵素生產技術?若核研所推廣包含酵素生產技術，該公司在合作時之定位及合作可能性將會有所考量。現場回覆因核研所酵素生產係用於國內測試廠，暫不考慮推廣技轉，若諾維信公司能提供更便宜之酵素，核研所測試亦將選用該公司酵素。在技轉方面則以前處理與共發酵菌爲主。

2. 平行測試與未來合作方式

高級經理吳桂芳博士及高級研究員李冬敏博士爲與核研所合作之主要人員，首先釐清先前電話會議中之組成分析及酵素水解實驗方法疑點。後續討論合作方式，建議可由核研所提供平時運轉條件之前處理產物(未固液分離、固液分離和水解液)，分別以 Novozymes Cellic CTec 2 & CTec3 進行平行測試。

3. 技術推廣

與酒精及生物能源工業的工業銷售經理李明棋博士討論協助核研所前處理及共發酵技術在中國大陸推廣之方法與可行性。李博士詢問核研所希望之推廣方向與策略，如技轉或尋求其他公司合作推廣。現場回覆主要推廣技術爲前處理及共發酵菌，而推廣方向與策略則需確認，待確定核研所推廣策略後再行告知。

(四) 纖維素酒精商業化突破討論會

此會議由諾維信 (Novozymes (China) Biotechnology Co., Ltd.)主辦，先由諾維信生物能源業務拓展經理任海彧博士介紹 2012 年 2 月上市之諾纖力賽力三代(Cellic CTec3)之特性與實際應用，並邀請中國大陸二代纖維素酒精行業重點企業進行座談，探討中國纖維素酒精大規模商業化的相關問題。

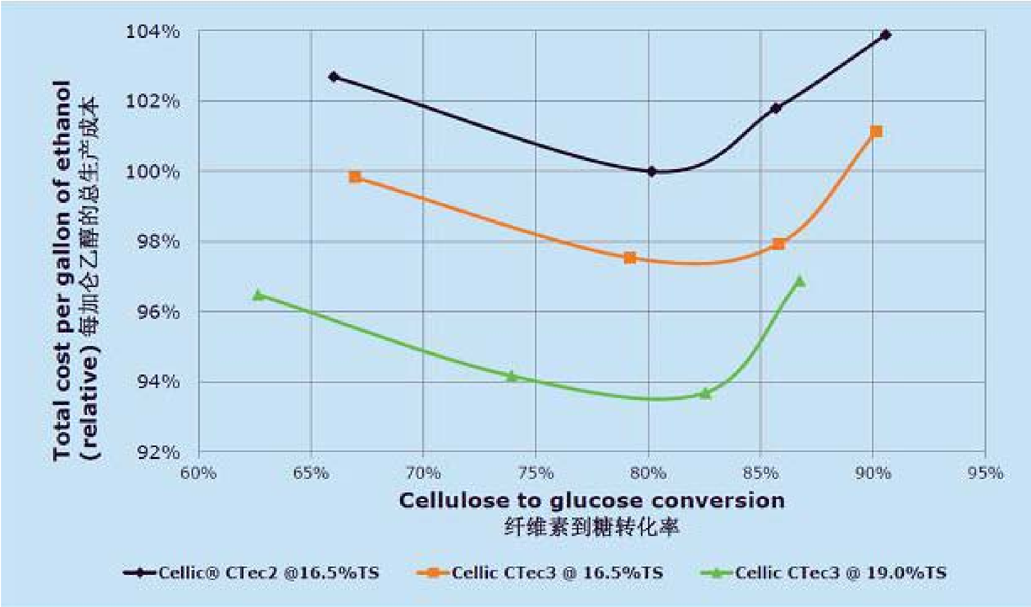
1. 諾維信(Novozymes)公司-酵素開發

諾維信公司生產多種酵素產品，包括技術級、食品級、飼料級酵素、洗滌劑工業用酵素和生物燃料酵素等。該公司新產品-諾纖力賽力三代(Cellic CTec3)，與二代產品(Cellic Ctec2) 比較，不但效率提升了 1.5 倍，且其總體生產成本為 2-3.5 USD/gal (Total cost of producing cellulosic Ethanol USD/gal) 亦降低了 5-10%。此外，與市場上其他酵素相比，生產等量的生物燃料，所需添加的諾纖力賽力三代的量是其他酵素劑量的 20%。採用這種新型酵製劑，可將纖維素 酒精的成本大大降低。圖十一為相同條件下諾纖力賽力二代與三代成本比較，以及三代對生產條件之影響。

就商業化而言，任海彧博士表示，並不一定需得到最高的轉化率，需結合纖維素酒精各生產程序之最佳生產條件及成本，得到最佳結合點 (sweet spot)，以達到足以商業化之低成本。

會中介紹該公司以賽力三代酵素與 M&G、Fiberight 及中糧、中石化合作成果。

(1) M&G/Chemtex 集團於義大利 Crescentino 之示範廠，以兩段式不加化學劑之熱水解 PROESA 程序，設計年產 1300 萬加侖，預定 2102 年開始運轉，該公司於 2009 年開始與諾維信公司合作，利用賽力三代酵素所得之生質物總糖轉化率 (Biomass to sugar conversion) 提升了 20%。

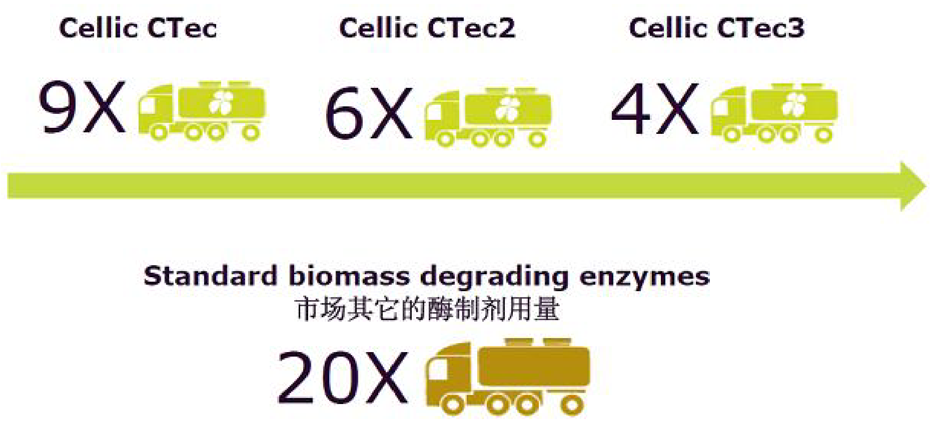


圖十一、諾纖力賽力二代與三代成本比較及三代對生產條件之影響

(2) 美國 Fiberight 公司成立於 2007 年，主要在於由城市固體廢棄物和其他有機原料回收轉化爲新一代生物可再生燃料。該公司於 2009 年 11 月購買位於愛荷華州 Blairstown 之第一代玉米酒精廠，改造爲將城市固體廢棄物轉化成纖維素酒精與沼氣之示範廠，隨後再改建爲年產量 600 萬加侖之商轉廠，預計於 2013 開始運轉。該公司於 2008 年開始與諾維信公司合作，以溫和之前處理條件，利用賽力三代酵素所得之生質物總糖轉化率提升了 50%。

(3) 中糧、中石化與諾維信公司合作開發纖維素酒精產業化技術，因賽力三代之引入使得生產成本降低了 40%。

最後，任海或博士表示，若以卡車運輸量爲例，年產量 3,500 萬加侖纖維素酒精廠，其每週所需酵素用量而言，諾纖力賽力一代 (Cellic Ctec1) 需 9 輛、二代 (Cellic Ctec2) 需 6 輛、三代 (Cellic Ctec2) 需 4 輛、而市場其他酵素需 20 輛，亦即諾纖力賽力三代 (Cellic CTec3) 的用量較市場其他酵素降低 5 倍。(圖十二)



圖十二、諾纖力賽力一、二及三代與市場其他酵素用量比較示意圖

2. 中國纖維素酒精發展現況-合作廠商座談

諾維信 (Novozymes) 公司所邀請合作廠商包括中興能源公司曹珺先生、中糧集團有限公司林海龍先生、河南天冠企業集團公司王學平先生以及康泰斯公司何翌先生。

中興能源以甜高粱之第一代生質酒精為基礎，2008 年開始規劃利用甜高粱莖稈生產纖維素酒精；中糧集團於 2006 年即著手玉米稈生產酒精研發，具有百噸規模技術裝置，現正進行設備優化，預期於 2-3 年內完成 3 萬噸廠，5 年蓋 10 座廠；河南天冠擁有 68 萬噸以小麥、玉米、木薯為原料第一代生質酒精廠及自去年開始運轉之 1 萬噸纖維素酒精廠，未來規劃建造 200 萬噸進料之纖維素酒精廠。康泰斯公司於義大利之 Crescentino 建造年產 4 萬噸纖維素酒精示範廠，以蘆竹、麥稈、木材餘料等為原料，進料尺寸為 5cm、10cm 及 15 cm，預定今年 (2012 年) 下半年開始運轉。

綜合而言，大陸開發纖維酒精工業皆以第一代生質酒精為基礎再擴展至第二代生質酒精，故一、二代共構應為可行之生產模式。現階段中國大陸於纖維素酒精工業大規模商業化之瓶頸包括原料收集、酵素成本、關鍵設備及系統設備技術 (如前處理、生物生產工廠工程化、控制及能源回收)。天冠集團認為若有政府政策的支持，預估可於 2-3 年商業化。

四、建 議 事 項

據估計，至 2020 年中國汽車量可能超過 2 億輛，對液體燃料的需求將大幅上升。爲此，中國已對生物液體燃料的發展進行了積極規劃。2007 年，中國國務院曾公佈《可再生能源發展規劃》，提出至 2020 年，中國的生物燃料酒精利用量將達 1,000 萬噸，加上生物柴油利用量 200 萬噸，總計替代約 1,000 萬噸之成品油。目前全球在纖維素酒精領域的潛在商機大概有 750 億美元，在中國，這種技術也正越來越受到重視。基於此，針對核研所纖維素酒精開發與推廣之相關建議如下：

(一) 酵素活性及生產成本爲商業化的重要因素，而在酵素生產方面，兩家公司(杰能科及諾維信)皆朝同時水解纖維素與半纖維素轉化爲可發酵五碳糖及六碳糖爲主要方向。酵素活性與劑量往往因前處理的方式而異，因此建議可嘗試未固液分離前處理產物進行 Accellerase TRIO™ 和 Cellic CTec3 酵素之測試，並依測試結果進行前處理條件與程序修改，以達最佳效率。

(二) 與諾維信公司合作方式，建議可由核研所提供平時運轉條件之前處理產物(未固液分離、固液分離和水解液)，分別以 Novozymes Cellic CTec 2 & CTec3 進行平行測試。

(三) 如會議中所提，現階段中國大陸於纖維素酒精工業大規模商業化之瓶頸包括原料收集、酵素成本、關鍵設備及系統設備技術 (如前處理、生物生產工廠工程化、控制及能源回收)，因此，中國大陸正積極尋求及克服量產的技術。在智財權有效保護及合於兩岸相關規定，並獲核准之條件下，後續可透過國際合作，例如與諾維信公司的產品或技術搭配，將核研所之纖維酒精量產研發技術應用於大陸纖維酒精工業。

(四) 在技術輸出之推廣方向與策略上應明確，以利核研所人員進行洽談，把握技術輸出的機會。

(五) 大陸近年來持續引進能源產業投資，大型國際性能源會議亦選擇於大陸召開，因此未來透過兩岸科技交流，分享生物能源開發技術與資訊，對我國拓展研發能量與產業應用推廣皆有正面助益。

五、附 錄

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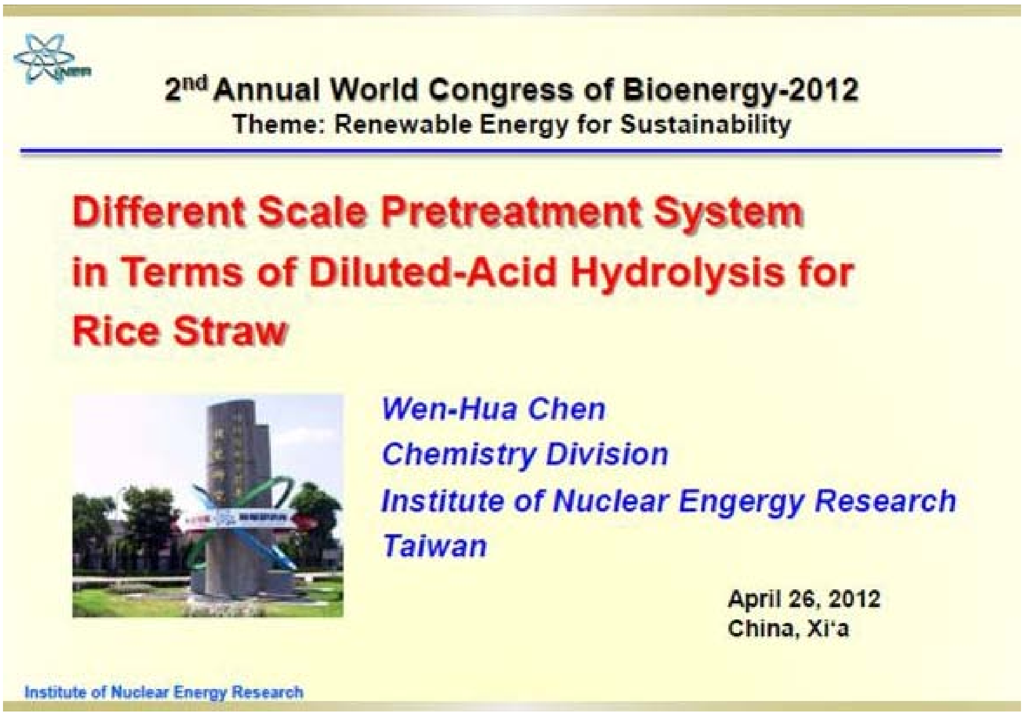
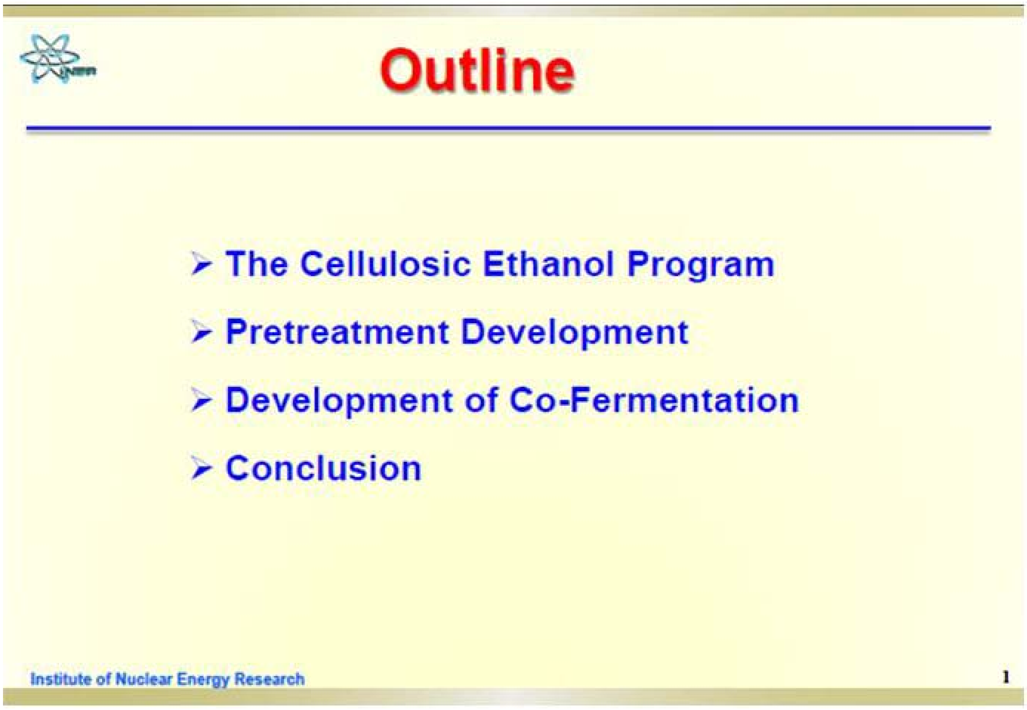
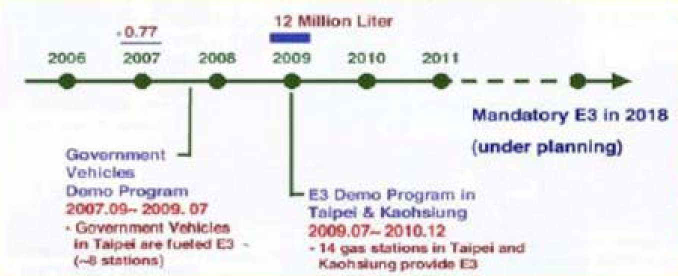
附錄二、論文發表口頭報告簡報內容





E3 Gasoline in Taiwan

- Government vehicles in Taipei started to fill E3 gasoline since 2007. Kaohsiung city joined the program in 2009 and currently there are 14 gas stations providing E3 gasoline. The subsidy provided to the E3 users was increased from NTD 1 per liter in 2007 to NTD 2 in 2009.
- Mandatory implementation of E3 gasoline



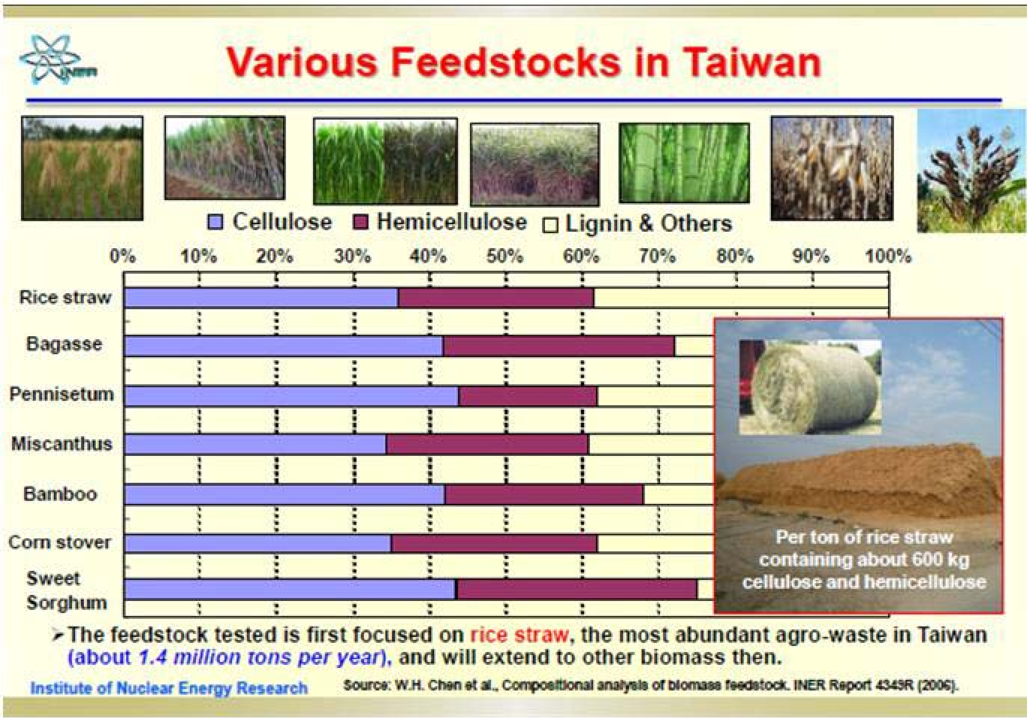
Timeline for E3 gasoline promotion in Taiwan (BOE)

Gas station

E3 Gasoline

The Cellulosic Ethanol Program

- In concert with government policy for promoting the ethanol blended gasoline, Institute of Nuclear Energy Research (INER) has devoted to the research and development of the technologies for cellulosic ethanol production.
- Establish comprehensive R&D capability based on biochemical process – from jar-test laboratory, unit process development facility to 1 TPD pilot plant. The pilot plant would be also served as a platform for validation of scalabilities of novel technologies developed for cellulosic ethanol and biorefinery.
- The feedstock tested is focused on local biomass in Taiwan.


Various Feedstocks in Taiwan
Cellulose
Hemicellulose
Lignin & Others
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Rice straw
Bagasse
Pennisetum
Miscanthus
Bamboo
Corn stover
Sweet Sorghum
Per ton of rice straw containing about 600 kg cellulose and hemicellulose
➢The feedstock tested is first focused on rice straw, the most abundant agro-waste in Taiwan (about 1.4 million tons per year), and will extend to other biomass then.
Institute of Nuclear Energy Research
Source: W.H. Chen et al., Compositional analysis of biomass feedstock. INER Report 4349R (2006).


The Cellulosic Ethanol Program
2005 -
Lab/Bench
2006-2007
Unit process development facility
2007-2009
Pilot plant
Institute of Nuclear Energy Research
5

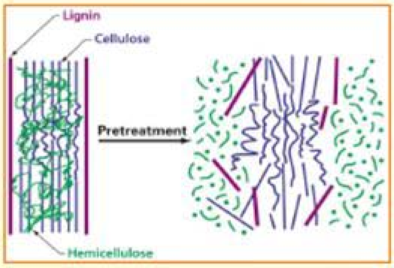
Pretreatment Development

-Dilute-Acid Hydrolysis & Steam Explosion-

Dilute-Acid Hydrolysis

- Advantage:
  - ✓Fast rate of reaction, which facilitates continuous processing
  - ✓Removal of hemicellulose
  - ✓Release of monosaccharides
  - ✓Reduce the need for enzymes
- Disadvantage:
  - ✓Degradation products (Inhibitors) formed
  - ✓Corrosion

Steam Explosion



Dilute-acid hydrolysis and the steam explosion technique are commonly used for scale-up

Acids can help water break up the long chains of hemicellulose/cellulose and turn it into the xylose/glucose.

Ref:

[1] Pedersen, M., Meyer. A.S. Lignocellulose pretreatment severity – relating pH to biomatrix opening, *New Biotechnology 2010*, 27(6):739-750.

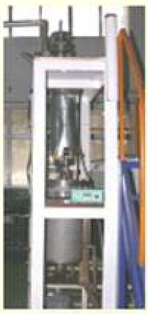
[2] N. Mosier et al., Features of promising technologies for pretreatment of lignocellulosic biomass, *Bioresource Technology* 2005, 96, 673-686

Pretreatment Development

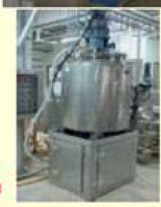
-Pretreatment System-

Lab Scale → Bench Scale → Pilot Scale

Batch → Continuous

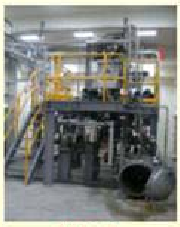


100g/batch
Steam Explosion



17-20kg/batch
Extruder/Extractor

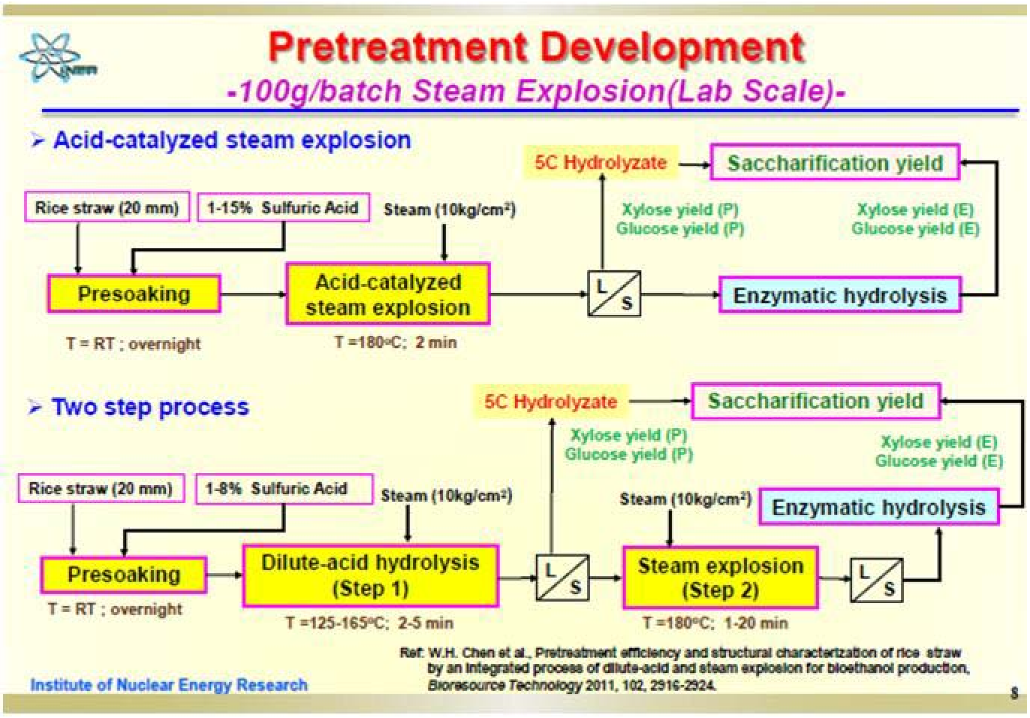
1kg/batch
Steam Explosion



10kg/h
Steam Explosion

100-200kg/h
Testing Plant System

- To increase xylose concentration with less inhibitors
- To reduce glucose conversion, but enhance enzymatic hydrolysis efficiency
- To lower energy consumption


Pretreatment Development
-100g/batch Steam Explosion(Lab Scale)-
Acid-catalyzed steam explosion
Rice straw (20 mm)
1-15% Sulfuric Acid
Steam (10kg/cm²)
Presoaking
T = RT ; overnight
Acid-catalyzed steam explosion
T =180°C; 2 min
5C Hydrolyzate
Saccharification yield
Xylose yield (P)
Glucose yield (P)
Xylose yield (E)
Glucose yield (E)
L S
Enzymatic hydrolysis
Two step process
Rice straw (20 mm)
1-8% Sulfuric Acid
Steam (10kg/cm²)
Presoaking
T = RT ; overnight
Dilute-acid hydrolysis (Step 1)
T =125-165°C; 2-5 min
5C Hydrolyzate
Saccharification yield
Xylose yield (P)
Glucose yield (P)
Xylose yield (E)
Glucose yield (E)
Steam (10kg/cm²)
Steam explosion (Step 2)
T =180°C; 1-20 min
Enzymatic hydrolysis
Ref: W.H. Chen et al., Pretreatment efficiency and structural characterization of rice straw by an integrated process of dilute-acid and steam explosion for bioethanol production, Bioresource Technology 2011, 102, 2916-2924.
Institute of Nuclear Energy Research
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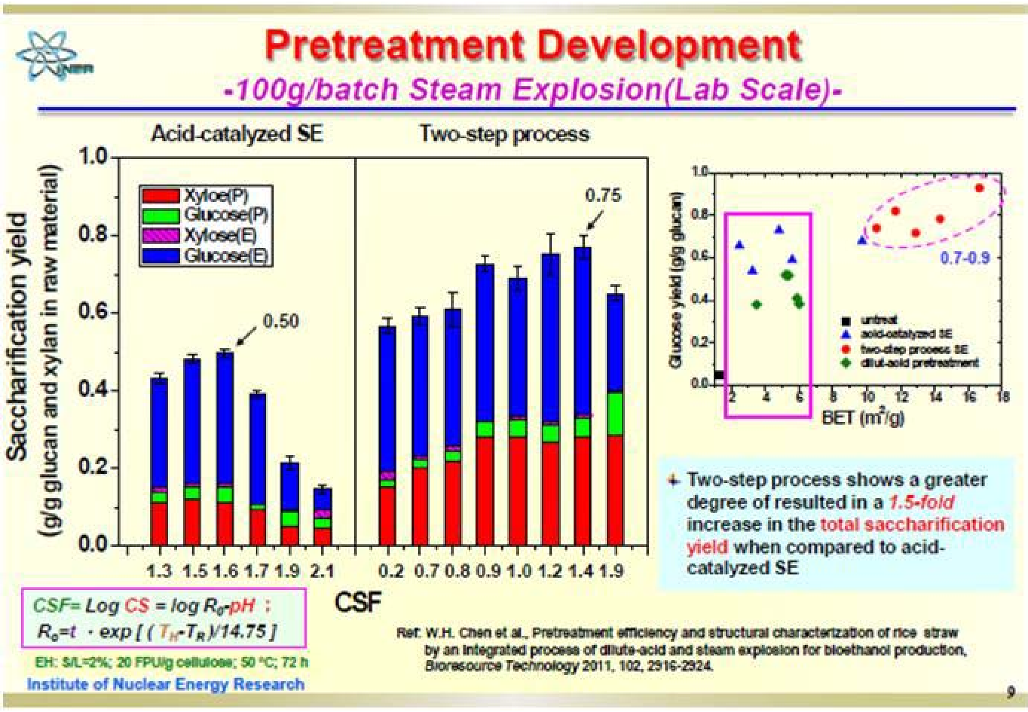
Pretreatment Development
-100g/batch Steam Explosion(Lab Scale)-
Acid-catalyzed SE
Two-step process
Saccharification yield
(g/g glucan and xylan in raw material)
Xyloe(P)
Glucose(P)
Xylose(E)
Glucose(E)
0.50
0.75
1.3 1.5 1.6 1.7 1.9 2.1
0.2 0.7 0.8 0.9 1.0 1.2 1.4 1.9
CSF
Glucose yield (g/g glucan)
untreat
acid-catalyzed SE
two-step process SE
dilut-acid pretreatment
0.7-0.9
BET (m²/g)
Two-step process shows a greater degree of resulted in a 1.5-fold increase in the total saccharification yield when compared to acid-catalyzed SE
CSF= Log CS = log R₀-pH ;
R₀=t · exp [(T_H-T_R)/14.75]
EH: S/L=2%; 20 FPU/g cellulose; 50 °C; 72 h
Ref: W.H. Chen et al., Pretreatment efficiency and structural characterization of rice straw by an integrated process of dilute-acid and steam explosion for bioethanol production, Bioresource Technology 2011, 102, 2916-2924.
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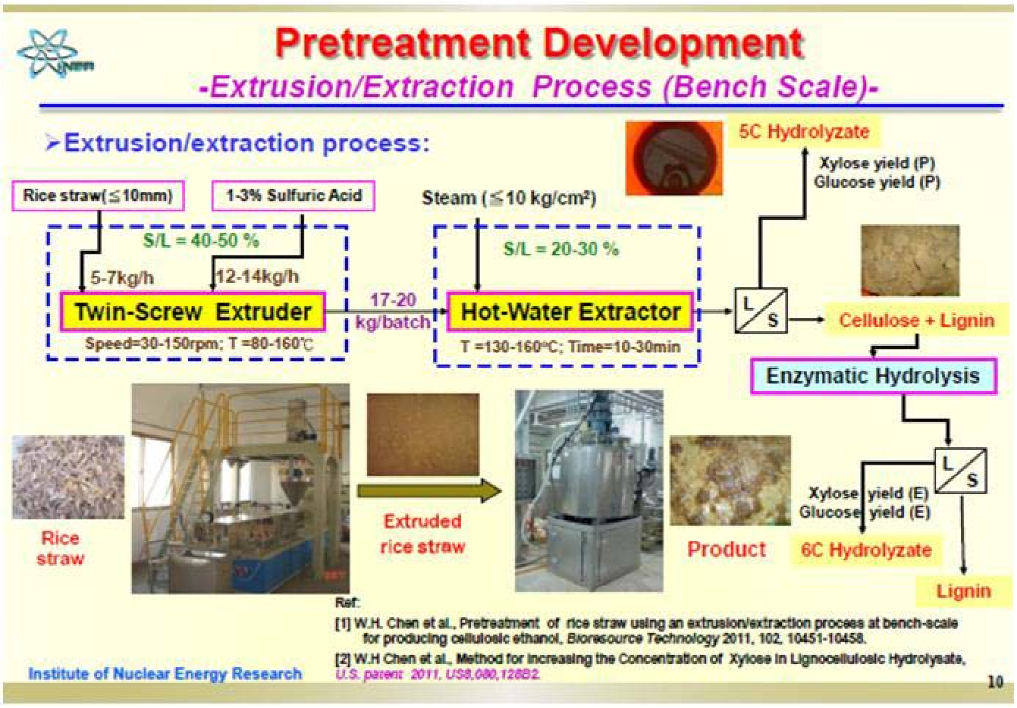
Pretreatment Development
-Extrusion/Extraction Process (Bench Scale)-
➢Extrusion/extraction process:
Rice straw(≦10mm)
1-3% Sulfuric Acid
S/L = 40-50 %
5-7kg/h
12-14kg/h
Twin-Screw Extruder
Speed=30-150rpm; T =80-160℃
17-20 kg/batch
Steam (≦10 kg/cm²)
S/L = 20-30 %
Hot-Water Extractor
T =130-160℃; Time=10-30min
5C Hydrolyzate
Xylose yield (P)
Glucose yield (P)
L S
Cellulose + Lignin
Enzymatic Hydrolysis
Xylose yield (E)
Glucose yield (E)
6C Hydrolyzate
Lignin
Rice straw
Extruded rice straw
Product
Ref:
[1] W.H. Chen et al., Pretreatment of rice straw using an extrusion/extraction process at bench-scale for producing cellulosic ethanol, Bioresource Technology 2011, 102, 10451-10458.
[2] W.H Chen et al., Method for increasing the Concentration of Xylose in Lignocellulosic Hydrolysate, U.S. patent 2011, US8,080,128B2.
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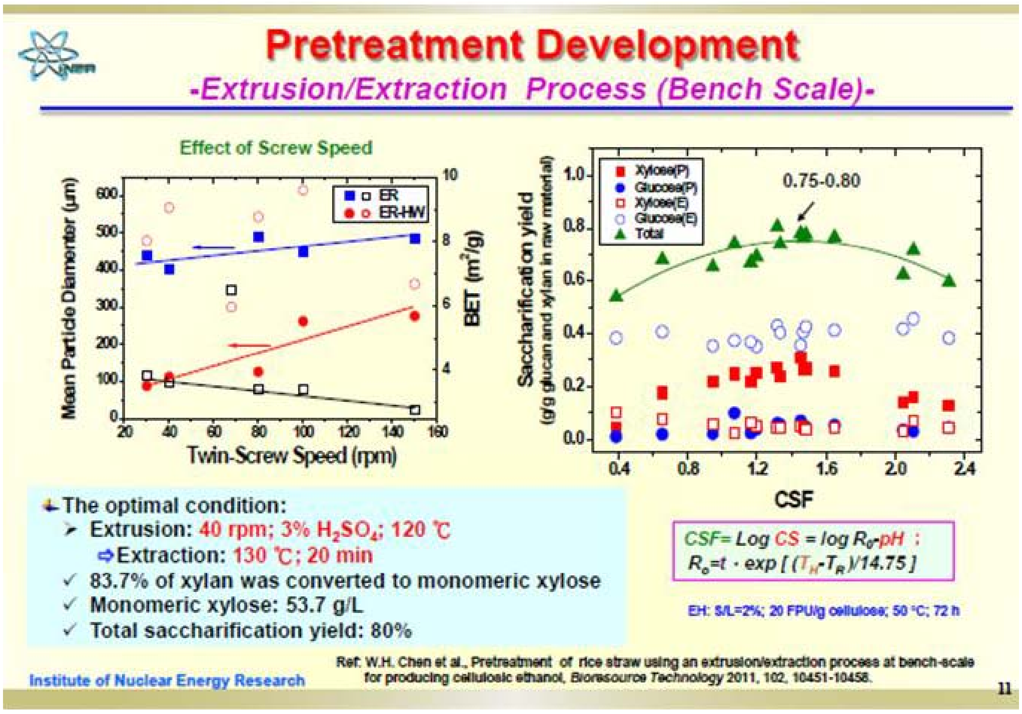
Pretreatment Development
-Extrusion/Extraction Process (Bench Scale)-
Effect of Screw Speed
ER
ER-HW
Mean Particle Diamenter (μm)
BET (m²/g)
Twin-Screw Speed (rpm)
Saccharification yield
(g/g glucan and xylan in raw material)
Xylose(P)
Glucose(P)
Xylose(E)
Glucose(E)
Total
0.75-0.80
CSF
The optimal condition:
➢ Extrusion: 40 rpm; 3% H₂SO₄; 120 ℃
⇨Extraction: 130 ℃; 20 min
✓ 83.7% of xylan was converted to monomeric xylose
✓ Monomeric xylose: 53.7 g/L
✓ Total saccharification yield: 80%
CSF= Log CS = log R₀-pH ;
R₀=t · exp [(T_H-T_R)/14.75]
EH: S/L=2%; 20 FPU/g cellulose; 50 °C; 72 h
Ref: W.H. Chen et al., Pretreatment of rice straw using an extrusion/extraction process at bench-scale for producing cellulosic ethanol, Bioresource Technology 2011, 102, 10451-10458.
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Pretreatment Development

-Dilute-Acid Hydrolysis & Steam Explosion -

100g/batch
Steam Explosion

Bench Scale
Batch

Max: 25 kg/cm²

Acid-catalyzed
steam explosion

1kg/batch
Steam Explosion

10kg/h
Steam Explosion

Batch **Lab Scale** Two step process **Bench Scale Continuous**

Max: 10 kg/cm² (step-1 dilute-acid; step-2 steam explosion)

Pretreatment Development

-1kg/batch Steam Explosion (Bench Scale)-

Goal

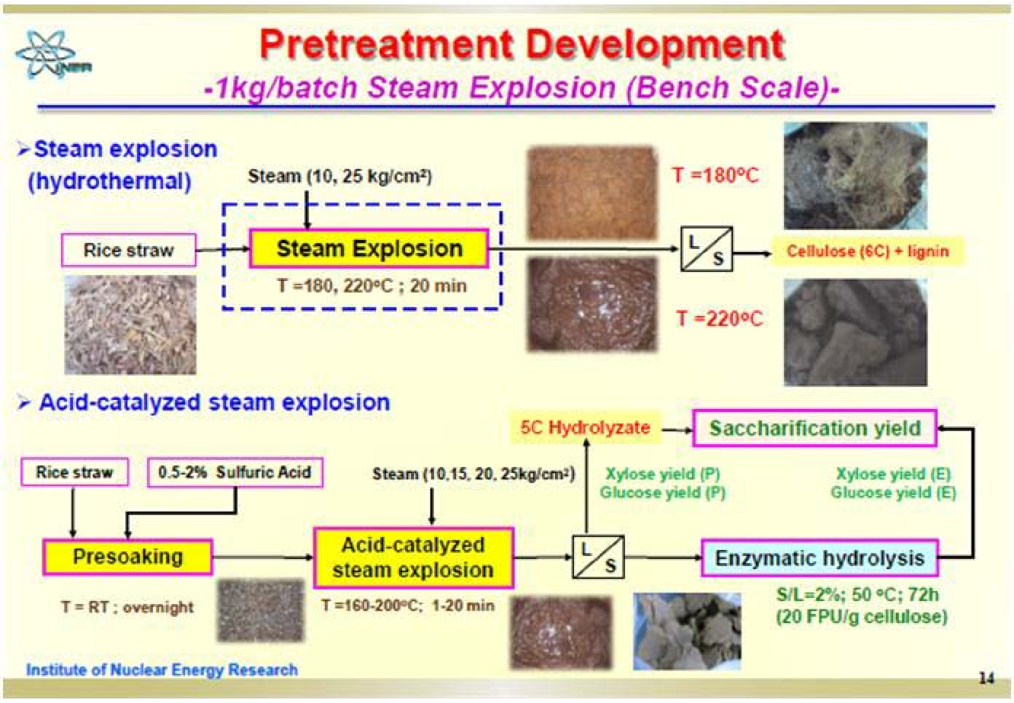
- ⇨ ***Scaling up*** **steam explosion reactor system** ***from 100 g/batch*** **to** ***1 kg/batch***
- ⇨ **Upgrading** ***manual*** **to** ***automatic control*** **during acid-catalyzed steam explosion process**
- ⇨ **Improve total saccharification yield of the acid-catalyzed steam explosion**

Focus of work

- ⇨ **Find suitable feedstock loading**
- ⇨ **Study the effect of the position of steam inlet on the pretreatment efficiency**
- ⇨ **Find the optimal parameters of** ***the acid-catalyzed steam explosion at a higher steam pressure (10, 15, 20, 25 kg/cm²)***
  - **Solid loading (20-30%); Acid concentration (0.5-2%); Temperature (160-200℃); Time (1-20min)**

Parameters

- ⇨ **Xylose conversion; Enzymatic hydrolysis efficiency; Total saccharification yield**


Pretreatment Development
-1kg/batch Steam Explosion (Bench Scale)-
Steam explosion (hydrothermal)
Steam (10, 25 kg/cm²)
Rice straw
Steam Explosion
T =180, 220°C ; 20 min
T =180°C
T =220°C
L/S
Cellulose (6C) + lignin
Acid-catalyzed steam explosion
5C Hydrolyzate
Saccharification yield
Rice straw
0.5-2% Sulfuric Acid
Steam (10,15, 20, 25kg/cm²)
Xylose yield (P)
Glucose yield (P)
Xylose yield (E)
Glucose yield (E)
Presoaking
T = RT ; overnight
Acid-catalyzed steam explosion
T =160-200°C; 1-20 min
Enzymatic hydrolysis
S/L=2%; 50 °C; 72h
(20 FPU/g cellulose)
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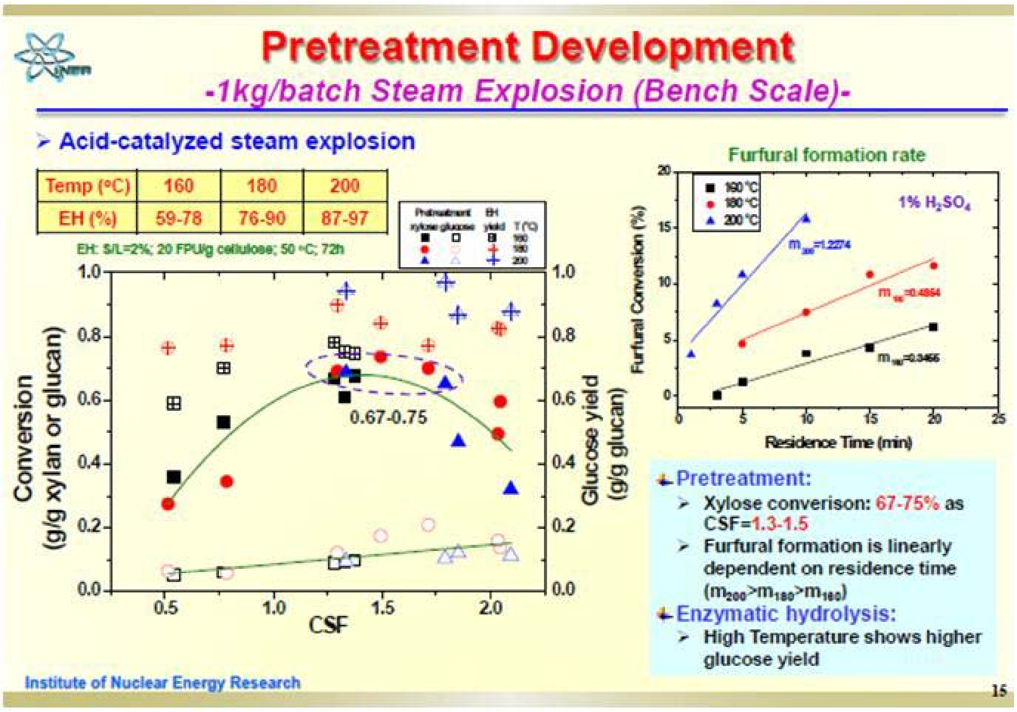
Pretreatment Development
-1kg/batch Steam Explosion (Bench Scale)-
Acid-catalyzed steam explosion
Temp (°C) 160 180 200
EH (%) 59-78 76-90 87-97
EH: S/L=2%; 20 FPU/g cellulose; 50 °C; 72h
Conversion (g/g xylan or glucan)
Glucose yield (g/g glucan)
CSF
0.67-0.75
Furfural formation rate
160 °C
180 °C
200 °C
1% H2SO4
Furfural Conversion (%)
Residence Time (min)
Pretreatment:
Xylose converison: 67-75% as CSF=1.3-1.5
Furfural formation is linearly dependent on residence time
Enzymatic hydrolysis:
High Temperature shows higher glucose yield
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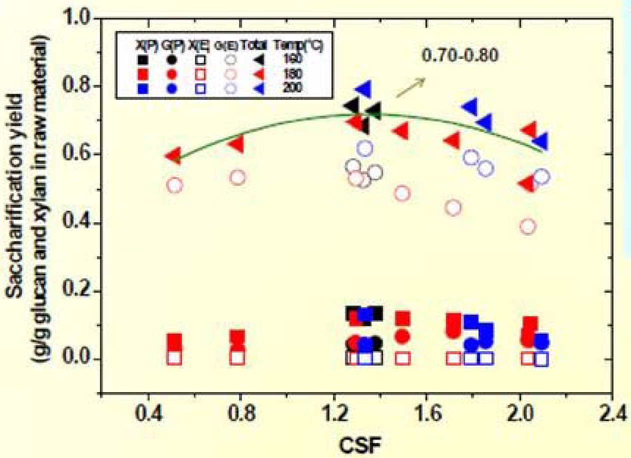
Pretreatment Development

-1kg/batch Steam Explosion (Bench Scale)-

➢ Acid-catalyzed steam explosion



- The optimal condition:
  - ➢ 1% H_2SO_4 ; 200 ℃; 1 min
  - ✓ Xylose conversion: 72%
  - ✓ Inhibitors concentration:
    - ⇨Furfural: 0.5 g/L
    - ⇨HMF: 0.2 g/L
  - ✓ Selectivity(X/G): 4.4
  - ✓ Enzymatic hydrolysis: 93%
  - ✓ Total saccharification yield: 82%

⇩

A higher total sugar yield can be obtained for *the acid-catalyzed steam explosion*

⇩

Pilot Scale

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Pretreatment Development

-Continuous Steam Explosion (Pilot Scale)-

Goal

⇨ *Scaling up* steam explosion reactor system

- ⇨ *From bench to pilot scale*
- ⇨ *From batch to continuous operation*

⇨ Upgrading *manual* to *automatic control* during all processes

Focus of work

⇨ Develop and complete *a pilot-scale continuous pretreatment system* on the basis of acid-catalyzed steam explosion

⇨ Apply on the pilot plant (1 ton/day) cellulosic ethanol testing platform.

⇨ Find the optimal parameters to enhance the pretreatment efficiency

⇨ Improve *the long-term operational stability and devices durability*

Parameters

⇨ Xylose conversion; Enzymatic hydrolysis efficiency; Total saccharification yield

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Pretreatment Development

-Continuous Steam Explosion (Pilot Scale)-

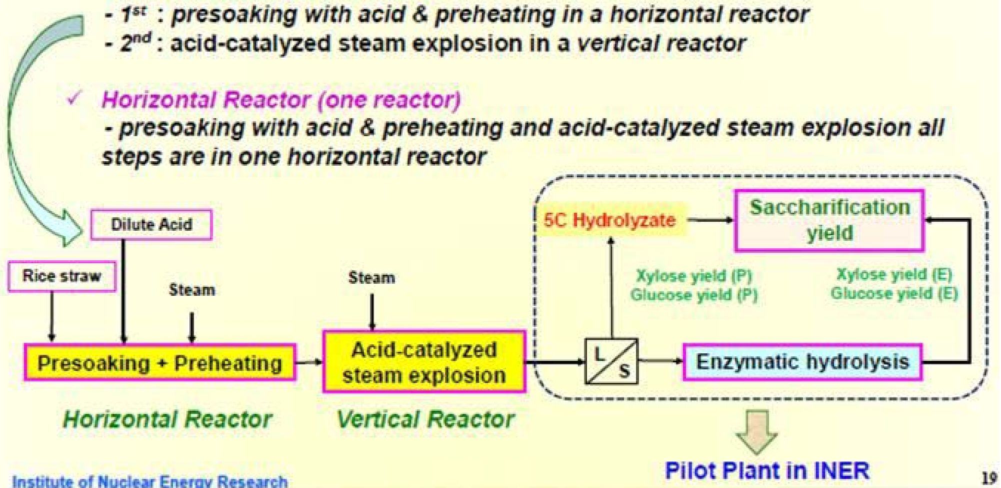
Testing Plant System

- Capacity: *100-200 kg/h*
- Piston pressure feeding device-continuous infeed of biomass to a pressurized system
- Mechanical design *-mixing and transfer*
- Modified outlet device for explosion- protect device from abrasion, cost reduction
- Pretreatment process*:*
  - ✓ *Vertical Reactor*
  - ✓ *Horizontal Reactor*

Pretreatment Development

-Continuous Steam Explosion (Pilot Scale)-

- Pretreatment process*:*
  - ✓ Vertical Reactor *(two reactors)*
    - *- 1st : presoaking with acid & preheating in a horizontal reactor*
    - - 2nd : acid-catalyzed steam explosion in a *vertical reactor*
  - ✓ *Horizontal Reactor (one reactor)*
    - *- presoaking with acid & preheating and acid-catalyzed steam explosion all steps are in one horizontal reactor*

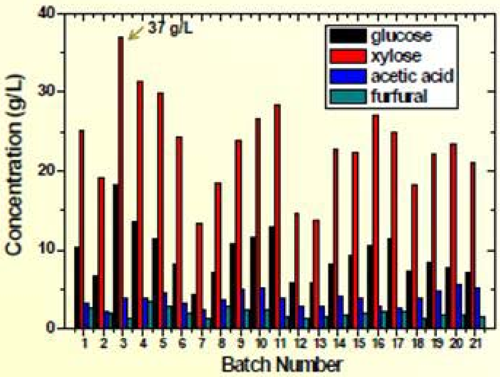


Pretreatment Development

-Continuous Steam Explosion (Pilot Scale)-

➢ **Pretreatment parameters:**

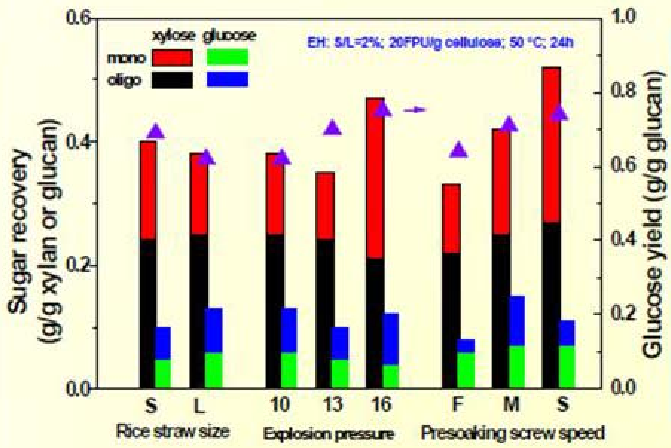
- **Feedstock: 100 kg/h rice straw**
  - ✓ Rice straw size
- **Parameters:**
  - ➢ *Horizontal Reactor*
    (Presoaking + Preheating)
    - ✓ Mixing time *(Screw Speed)*
    - ✓ Dilute acid:1.0-8.4% (w/w)
    - ✓ Preheating Temp.: 100-110℃
  - ➢ *Vertical Reactor*
    (Acid-catalyzed steam explosion)
    - ✓ Temperature: 160-190℃
    - ✓ Residence Time: 2-10 min
    - ✓ Explosion Pressure: 10, 13, 16 kg/cm^2



Pretreatment Development

-Continuous Steam Explosion (Pilot Scale)-

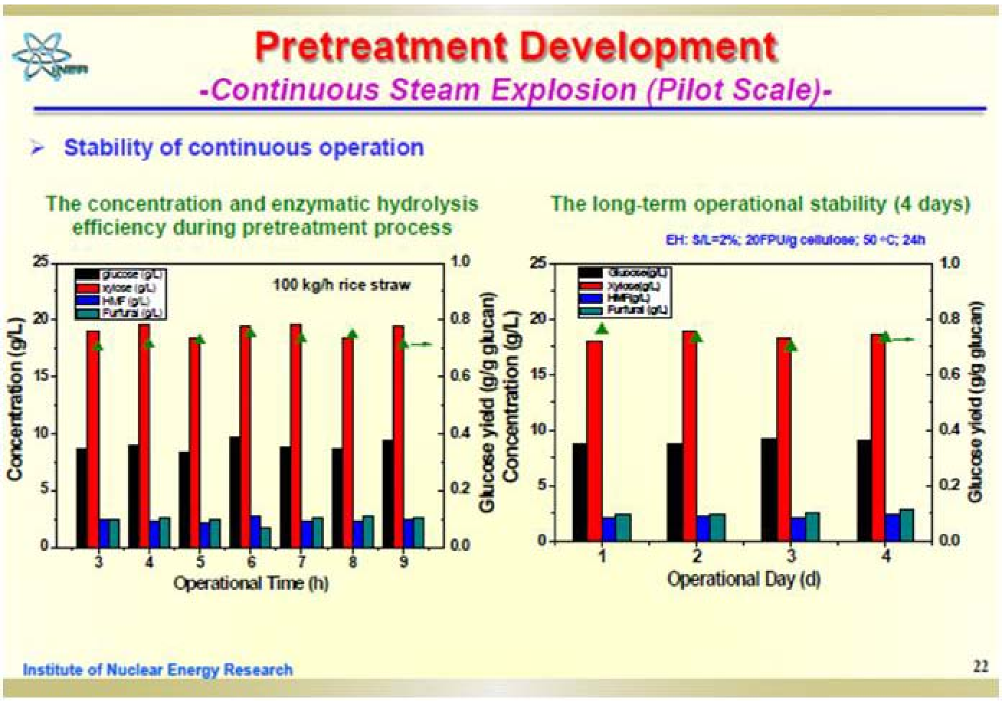
➢ **Operational parameters:**



- ✓ *Small* rice straw
- ✓ *High* explosion pressure
- ✓ *Slow* screw speed (longer mixing time)

⬇

- ➢ Enhancement of the enzymatic digestibility of cellulose
- ➢ High sugar recovery


Pretreatment Development
-Continuous Steam Explosion (Pilot Scale)-
Stability of continuous operation
The concentration and enzymatic hydrolysis efficiency during pretreatment process
The long-term operational stability (4 days)
EH: S/L=2%; 20FPU/g cellulose; 50 °C; 24h
100 kg/h rice straw
Concentration (g/L)
Glucose yield (g/g glucan)
Operational Time (h)
Operational Day (d)
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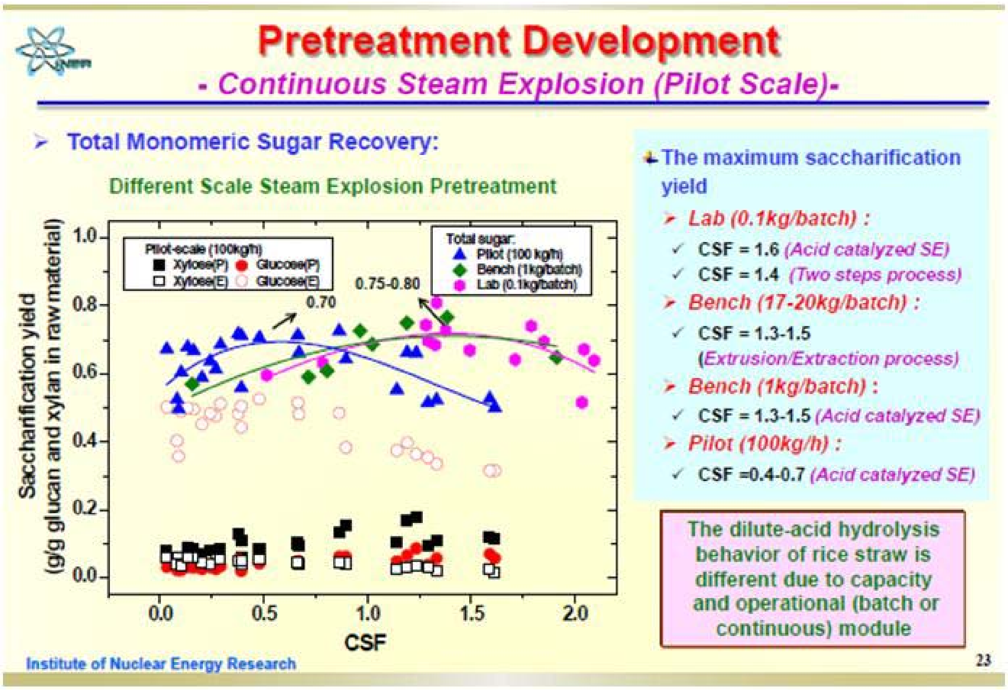
Pretreatment Development
- Continuous Steam Explosion (Pilot Scale)-
Total Monomeric Sugar Recovery:
Different Scale Steam Explosion Pretreatment
Pilot-scale (100kg/h)
Xylose(P)
Glucose(P)
Xylose(E)
Glucose(E)
Total sugar:
Pilot (100 kg/h)
Bench (1kg/batch)
Lab (0.1kg/batch)
0.70
0.75-0.80
Saccharification yield (g/g glucan and xylan in raw material)
CSF
The maximum saccharification yield
Lab (0.1kg/batch) :
CSF = 1.6 (Acid catalyzed SE)
CSF = 1.4 (Two steps process)
Bench (17-20kg/batch) :
CSF = 1.3-1.5
(Extrusion/Extraction process)
Bench (1kg/batch) :
CSF = 1.3-1.5 (Acid catalyzed SE)
Pilot (100kg/h) :
CSF =0.4-0.7 (Acid catalyzed SE)
The dilute-acid hydrolysis behavior of rice straw is different due to capacity and operational (batch or continuous) module
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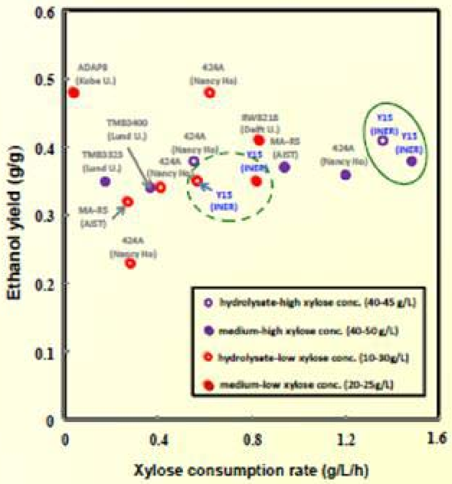
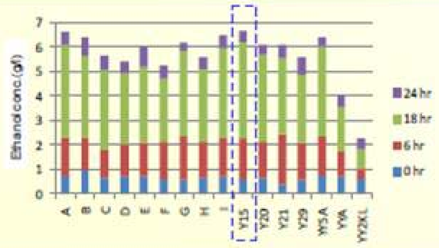
Development of Co-Fermentation





- A method for screening and isolating a xylose-utilizing strain of *saccharomyces cerevisiae* was successfully developed
- The xylose-rich hydrolysate fermentation for ethanol production by strain Y15 is under scale-up study in INER's pilot plant
- Technical authorization for co-fermentation yeast will begin in the near future.

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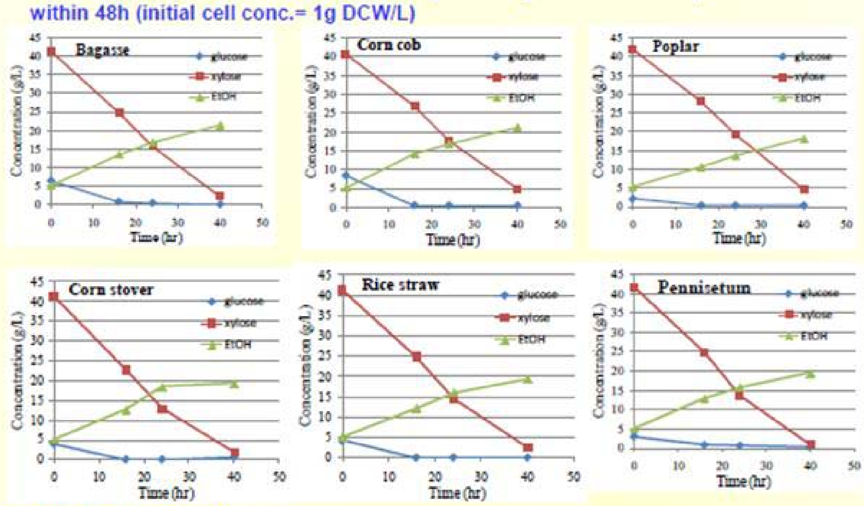
Development of Co-Fermentation

-C5 fermentation for lignocellulosic hydrolysate-

- Co-fermentation strain Y15 can completely utilize xylose for ethanol production within 48h (initial cell conc.= 1g DCW/L)



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Conclusion

- The dilute-acid hydrolysis behavior of rice straw is different due to capacity and operational (batch or continuous) module
- *A pilot-scale continuous pretreatment system* on the basis of acid-catalyzed steam explosion was successfully developed
  - ⇨ *Good operational stability and devices durability*
  - ⇨ Achieved maximum total sugar recovery of 70%
  - ⇨ Apply on the pilot plant (1 ton/day) cellulosic ethanol testing platform
  - ⇨ Feedstock diversity (Bagasse; Bamboo; Sorghum)
- A method for screening and isolating a *xylose-utilizing strain of saccharomyces cerevisiae* was successfully developed
  - ⇨ Co-fermentation strain Y15 can completely utilize xylose for ethanol production within 48h

Thank you for your attention