Advanced Biofuels Technology

Sponsored by DuPont

Monday, April 30th, 2012 - 8:30am to 10:00am

Biomass Saccharification Enzymes Reaching Cost Targets to Enable Commercial Biorefineries Build-up for Advanced Biofuels Production

Moderator: Valerie Sarisky-Reed, US Department of Energy

Manoj Kumar, DSM, NV

Sarah Teter, Novozymes, Inc

Brian Duff, US Department of Energy

Jim McMillan, National Renewable Energy Laboratory

<u>Abstract</u>

The U.S. Department of Energy (DOE), Office of Energy Efficiency and Renewable Energy (EERE) awadred financial assistance to four companies addressing research and development of enzyme systems to hydrolyze and saccharify pretreated lignocellulosic biomass, meeting the goal of producing ethanol from lignocellulosic biomass cost competitively by 2012. By 2007, a number of advances had been made to reduce the cost of these enzyme processes, but their use in process relevant conditions, at low cost remains to be achieved. In last four years, for the development of hydrolytic enzymes or enzyme system preparations that can effectively saccharify pretreated lignocellulosics to produce fermentable sugars under process relevant conditions has made large strides to reach economically viable cost contribution of cellulolytic enzymes. In this panel, we discuss first the vision and efforts of DoE Office of biomass program, specifically targeted toward enzymes cost reduction followed by three awardee companies on their accomplishments meeting the cost targets and goals set out four years back.

Monday, April 30th, 2012 - 10:30am to 12:00pm

Advanced Biofuels: Keys to Commercialization

Moderator: Amy Ehlers, Novozymes

Commercializing Advanced Biofuels: A First Hand View of the Key Success Factors
James Fawley, Coskata, Inc

Market Driven Approaches to Advanced Biofuel Commercialization
Bob Florence, Solazyme

The BioDME Project – Experience From the Demonstration of an Advanced Biofuel
Patrik Lownertz, Chemrec AB

Crucial Pathways to Advanced Alternative Fuels by 2020
Tim Zenk, Sapphire Energy

Abstracts

James Fawley

In the last few years, many advanced biofuel producers have shown the commercial viability of their technologies at demonstration scale. The crucial next step for these companies is building commercial production facilities. As one of the leading advanced biofuels producers commercializing its technology today, cellulosic ethanol producer Coskata Inc. can give a first-hand account of the challenges and opportunities that exist on the road to commercialization. Drawing from its own experience, Coskata can provide a “boots on the ground” summary of the milestones needed to break ground on commercial scale plants. What are the crucial concerns companies have to address make the leap, from demo to commercial scale? Coskata can provide details on the seven, specific elements involved in bringing advanced biofuel production to scale: 1- Technology: Is the initial concept really ready to scale? Has it been validated by a third party? 2- Feedstock Selection: Does the company have access to the most effective, ample raw materials at a target cost? 3- Site Selection: Does the site have all of the right attributes for a commercial scale project (including a local feedstock supply, available utilities, transportation infrastructure, and available permits)? 4- Product Placement: Is there a market for all of the fuels produced at the facility, at least through the payback period? 5- Engineering and Construction: Is the right EPC contractor and structure in place, along with an appropriate contract? 6- Financing: What is the plan to source and place debt & equity to finance the project? 7- Operations: Who is going to commission and operate the facility on a day-to-day basis? With this grounded overview of the basics for commercializing advanced biofuels, Coskata can explain the challenges and opportunities from the front lines of this young, breakthrough industry.

Bob Florence

By taking a customer-focused innovation approach, Solazyme is creating oil that goes beyond the volatile commodities market. Leveraging the tools of modern biotechnology and industrial fermentation, Solazyme is transforming low-cost plant sugars into high value tailored oils that cannot be achieved through blending of existing oils alone, and they are doing this in a scalable, reliable and cost-effective manner. Solazyme oils can be refined into clean, low carbon, renewable advanced biofuels that operate as 100 percent “drop-in” replacements with today’s existing production, refining, finishing, and distribution infrastructure, thus meeting the ever growing demand of advanced biofuel supply. Through partnership with the U.S. Navy, Chevron, and United Airlines, among others, the company has continued to drive down the cost of advanced biofuel production, producing over half a million liters of advanced biofuel to date that meets ASTM, EN, and U.S. military specifications; some of the most stringent in the world. Alone, these fuels have superior GHG performance, cold flow and stability properties, which make them ideal for refining and consumer partners. And as admixtures, these oils unable the upgrade of lower grade oils and expand market opportunities for natural oil producers, such as soy, allowing them to blend with Solazyme oil to operate in fuel markets previously inaccessible- i.e. European biodiesel market. This presentation will discuss how Solazyme has utilized the tools of modern biotechnology to create a platform capable of producing commercial levels of advanced biofuels and how they’ve leveraged a partnership approach to commercialization to continue to come down the production cost curve and enter the fuels market profitably.

Patrik Lownertz

The collaborative BioDME project includes partners Volvo Trucks (coordinator, heavy vehicles and diesel engine producer), Chemrec AB (gasification technology provider and plant operator) , Haldor Topsøe A/S (synthesis technology provider), Total (fuel and lubricants specifications), Preem (fuel distribution), Delphi (motor injection system provider) and ETC (process analysis). Within the project vehicles, fuel specifications, production process and distribution system for the advanced biofuel dithethyl ether (DME) has been developed, produced and demonstrated. The presentation will outline the properties of the fuel and the production path in terms of environmental, technical and economic performance, Further the project components, the implementation and the results from fuel production and use in heavy trucks in operation under commercial conditions will be described. Also the status of full-scale commercialization of the black liquor gasification process in combination with biofuel and biochemicals synthesis will be briefly described. For more background of the project, please refer to the BioDME project site, www.biodme.eu

Tim Zenk

One of the most pressing issues facing our world is how to meet growing demand of crude oil with a dwindling supply. By 2020, we will need 40% more energy than what we use today. Industry experts agree that technology readiness needs to be in place by 2020 to move the nation and world onto alternative crude oil sources or we will have real problems when it comes to oil shortages. It took us hundreds of years to move from wood to coal, and a hundred more to shift from whale oil to crude oil. We don't have another hundred years. It will take incentives and government resources to accelerate the transition. If algae received the same tax subsidies and incentives that other biofuels receive, as well as even a fraction of the $15-30 billion dollars in subsidies the oil and gas industries are given annually, algae could commercialize on a much quicker timeline. Public policy, technological advances, and the role of government support are essential to the growth of the algal fuels industry. Becoming more self-reliant through the domestic production of advanced biofuels can help America to regain a powerful leadership presence on the world stage in the green fuels and technology sphere. Domestic energy production has always driven our economic superiority and resulted in the capitol we need to be the most innovative nation in the world. Why would our nation want to slow the pace of progress and competitiveness by slowing the pace of a transition?

Monday, April 30, 2012 - 2:30pm to 4:00pm

The Future of Aviation Biofuels

Moderator: Don Schenk, ACA Associates

Steve Fabijanski, Agrisoma

Nancy Young, Airlines for America

Chris Tindal,U.S. Department of the Navy

Jim Rekoske, UOP, LLC

Abstract

A panel on the future of aviation bio-fuels should be able to link the components of the total chain (leading to the production of aviation bio-fuels). Ideally speakers could cover airline needs (driven off emission reduction and cost competitiveness) refiners needs, feedstock availability, the reality of where the industry is today and the needs of tomorrow.

Tuesday, May 1, 2012 - 8:30am to 10:00am

The Drive to Commercialization: Conversion Technology and Project Updates

Moderator: Jim Barber, Barber Advisors LLC

Dennis Leong, Chemtex Global

Mark Wong, Agrivida, Inc.

Jan Koninckx, DuPont

Doug Berven, POET

Abstract

The Renewable Fuels Standard (RFS) under the Energy Independence and Security Act of 2007 mandates the production of 36 billion gallons of biofuels in the U.S. by 2022, of which 21 billion gallons must come from advanced biofuels by 2022 and the remainder, 15 billion gallons, from corn-based ethanol. Assuming that advanced fuel biorefineries have an average annual capacity of 61 million gallons, approximately 345 new biorefineries must be built in the U.S. by 2022 to achieve the RFS mandate. Using a recent NREL report (citation available) for a mature biochemical conversion plant, total project capital investment of $6.72 per gallon of installed capacity, 21 billion gallons of biorefinery capacity will require a staggering $141 billion of capital investment over the next 10 years. While advanced biofuels have been under development for decades, the past 10 years have seen an explosion in formation of hundreds of new companies, technology platforms and billions of dollars in research and development and deployment funding. The funding included an important and often overlooked element of project commercialization: the development of integrated feedstock supply program for energy crops and crop residues. During this period, companies progressed from bench top designs to pilot plants and demonstration facilities on the path to integrated,commercialize-scale project designs. The technology developer's mantra: improve feedstock conversion yields for cellulose and hemicellulose feedstock fractions, reduce capital and operating costs and simplify process designs. The year 2012 likely will be viewed as an inflection point that launched a wave of commercial biofuels projects. POET, Abengoa, M&G and BP Biofuels, for example, are beginning construction of commercial biorefinery projects in 2012. Are we there yet?

Tuesday, May 1, 2012 – 2:30pm to 4:00pm

Getting Cellulosic Ethanol from Feedstock to Fuel Tanks

Moderator: Carrie Atiyeh, ZeaChem, Inc.

Reg Modlin, Chrysler Group LLC

Spencer Swayze, Ceres, Inc

Tim Eggeman, ZeaChem Inc.

Jason Blake, Novozymes

Abstract

This panel brings together leading companies in the advanced biofuels sector. The panel will outline innovations and advancements in biomass feedstock development; production of economical and sustainable cellulosic ethanol; regulatory need for and marketing of biofuels; and getting next-generation ethanol into the fuel tanks of conventional and flex-fuel vehicles (FFVs). Beginning with feedstock, a dedicated energy crop is a critical first step in the cellulosic biofuels value chain. The availability of sustainable, cost effective and plentiful raw materials is the cornerstone for an economically viable cellulosic biofuel facility. Ceres energy crops can provide more fuel or electricity, new opportunities for growers and a cleaner environment for us all. Ceres energy crops include sweet sorghum, high-biomass sorghum, switchgrass and miscanthus. ZeaChem's biorefining process is feedstock agnostic, highly efficient, and sustainable for the production of a wide range of economical advanced biofuels and bio-based chemicals. The company's 250,000 gallon per year integrated demonstration production facility in Boardman, Oregon will begin operations in late 2011 with cellulosic ethanol production beginning in 2012. The company's first commercial biorefinery of 25M or more gallons per year is currently under development. Valero Energy Corporation is the world's largest independent petroleum refiner and marketer, as well as a retail fuels distributor. Valero acquired 10 state-of-the-art ethanol plants, making it the first traditional refiner to enter the production of ethanol. Valero's efforts in alternative energy range from production of corn ethanol to wind energy to investments in emerging bio-fuels development, including cellulosic ethanol producers such as ZeaChem. Chrysler Group LLC, a leading global auto manufacturer, has long been committed to promoting the consumption of alternative fuels and to delivering flex-fuel vehicles (FFVs) to its customers.

Wednesday, May 2, 2012 - 10:30am to 12:00pm

Syngas-based Fuels and Chemicals Gain Industrial Relevance

Moderator: Manfred Kircher, CLIB2021

Syngas-based Fuels and Chemicals Gain Industrial Relevance
Eckhard Dinjus, Karlsruhe Institute of Technology

Marc Von Keitz, BioCee, Inc.

Mike Schultz, LanzaTech

Biofuels and the importance of "drop-in"
George Boyajian, Primus Green Energy

Abstract
More and more biomass-based production processes are under development. Many of them like e.g. enzymatic lignocellulose digestion are quite complex and end up in carbon sources of different value: C5- and C6-sugars as well as lignin. An alternative strategy is to break down the biomass to C1-bodies (syngas) by simple gasification and to use syngas-based fermentation to produce chemicals from that carbon source. Early developments target on ethanol but also more complex molecules are adressed.

The advantage of this technology is that it not only works with syngas from biomass but also with C1-bodies from industrial flue gases e.g. from a steel mill. Therefore syngas-based fermentation is on the way to a real platform technology. This panel will present the state of the art of syngas-based biotechnological production and discuss future applications.

Eckhard Dinjus

The bioliq project aims at the large scale production of synthetic biofuels from biomass (BTL, biomass to liquids). The bioliq process concept has been designed to overcome the problems met, when low grade, residual biomass should be used to a large extent as required in a BTL process. Biomass such as straw, hay, residual wood etc. usually exhibit low energetic densities, thus limiting collection area and transportation distances. On the other hand, the production of synthetic fuels requires large scale production facilities in accordance with economy of scale considerations. In the bioliq process, biomass is pre-treated in regionally distributed fast pyrolysis plants for energy densification. The products, pyrolysis char and liquid condensates, are mixed for form stable, transportable and pumpable slurries also referred as to biosyncrude. Thus biomass is energetically concentrated allowing for economic transport also over long distances. In industrial plants of reasonable size, the biosyncrude is gasified in an entrained flow gasifier at a pressure slightly above that of the following fuel synthesis. In the bioliq pilot plant synthetic fuels are produced via methanol as an intermediate. Thus, a gasification pressure of 80 bar is required. On site of KIT, a pilot plant has been constructed for process demonstration, to obtain reliable mass and energy balances, for gaining practical experience, and to allow for reasonable cost estimates. The construction, operation and further development is performed in cooperation with partners from chemical engineering and plant construction industries The fast pyrolysis plant, already in operation, has a biomass feed capacity of 500 kg/h (2 MW(th)). The high pressure entrained flow gasifier of 5 MW(th) thermal fuel capacity is an oxygen blown slagging reactor equipped with an internal cooling screen, particularly suited for the conversion of ash rich feeds and fast start up and shut down procedures. The raw synthesis gas is purified and conditioned by a high pressure hot gas cleaning system to remove particulates, sour gases and undesired trace compounds. Afterwards, CO_2 is separated. The purified synthesis gas is then converted to dimethylether in a one-step synthesis process, which in a subsequently following reaction is converted into gasoline. The process development is embedded into a coherent R&D framework, allowing operation and further development on a science based basis.

George Boyajian

Syngas-based fuels -- fuels produced from a syngas made from natural gas and/or biomass -- are highly promising because they offer the United States the opportunity to improve U.S. energy independence by reducing reliance on fossil fuels. The technologies in this industry with the greatest potential are liquid fuel synthesis technologies that create a renewable, drop-in gasoline that requires no new fuel distribution infrastructure, engine modifications or changes in consumer behavior.

Many companies are developing liquid fuel synthesis technologies that can produce diesel or jet fuel, and while these are two important fuel types, to truly bring syngas-based fuels into the mainstream, what is needed is more development of drop-in gasolines to fuel standard passenger vehicles. Drawing on Primus Green Energy's experience as the developer of a high-octane, drop-in gasoline, this presentation will discuss the importance of "drop-in" and how it will impact the syngas-based fuel industry moving forward.

Feedstock Crops and Algae Track

Sponsored by The Dow Chemical Company

Monday, April 30, 2012 – 8:30am to 10:00am

Toward Commercialization of Lignocellulosic Biofuels: Supply of Pretreated Biomass and Development of Co-products

Moderator: Bobby Bringi, MBI International

Supplying Pretreated Biomass – Both for Fuel and Feed Applications
Bobby Bringi, MBI International

Sustainable Cellulosic Ethanol as Biofuel and Green Chemical
Ulrich Kettling, Süd-Chemie AG

Maximizing Value from Lignocellulosic Sugar Streams – The Feed AND Fuel Biorefinery
Geoff Bell, Microbiogen

A New Approach in Lignocellulosic Biorefinery
Nhuan Nghiem, Eastern Regional Res. Ctr./ARS/USDA

Abstracts

Bobbi Bringi

The supply chain issues around biomass processing include transportation, storage and conversion. In addition, the demands of the food and animal feed markets will need to be achieved, while being able to meet the rising demand of the emerging industrial biotechnology segments. Recent work from Michigan State University and MBI will be presented that shows the new concept of Local Biomass Processing Centers (LBPC) will address all of these needs. The presentation will discuss the most advanced pretreatment system and the economics needed to meet the needs of smaller LBCP. It will show the advantages of having these centers near the farming communities and shipping high density pretreated material to central fuel and chemical fermentation facilities. In addition, new products will come out of these LBCP that can also be used for animal feeding thereby solving the "food versus fuel" controversy. The establishment of these LBCP will address supply chain issues and establish low cost sugar availability for fuel and chemical fermentation processes, while establishing a new low cost animal feed.

Ulrich Kettling

The last years have seen success in the development and deployment in the field of cellulosic ethanol production. The main challenge thereby remains to demonstrate that the technology is economically feasible for the up-scaling to industrial scale. Süd-Chemie AG, a Clariant Group Company, has developed the sunliquid® process, a proprietary cellulosic ethanol technology that reaches highest greenhouse gas (GHG) emission savings while cutting production costs to a minimum. In the presentation we will give an overview on the sunliquid® technology and its potential applications for the chemical and fuel industry.

The sunliquid® process (www.sunliquid.com) for cellulosic ethanol matches the ambitious targets for economically and ecologically sustainable production and greenhouse gas reduction. It was developed using an integrated design concept. Highly optimized, feedstock and process specific biocatalysts and microorganisms ensure a highly efficient process with improved yields and feedstock-driven production costs. Integrated, on-site enzyme production further reduces production costs substantially and assures independence from external suppliers. A proprietary and innovative ethanol separation method cuts energy demand by up to 50% compared to standard distillation. Thus, the energy derived from the byproducts like lignin and fermentation meet the entire electricity and heat demand of the production process, leading to close to 100% GHG reductions of the resulting ethanol. In July 2011 construction started on a demonstration plant with an annual ethanol output of 1,000 tons. The plant will start into operation early 2012. It will demonstrate the economic competitiveness to first generation processes and constitutes the last step from laboratory to commercial production.
Cellulosic ethanol has a huge potential to contribute to making transportation more sustainable. It is a new energy source derived from an existing renewable feedstock with high GHG savings, no food-vs.-fuel competition and no additional land use. But cellulosic ethanol itself is also a valuable platform compound for the chemical industry, e.g. for the production of green polyethylene. Furthermore sunliquid® opens up a route to a 2nd generation sugar platform that can result in products like organic acids (lactic acid, succinic acid…), green solvents, C4 alcohols, furfural or furfuryl alcohol and their derivates or other specialty and bulk chemicals which can be further converted into biobased plastics and polymers.

Süd-Chemie AG (www.sud-chemie.com). a Clariant Group Company, is a worldwide operating specialty chemicals company headquartered in Munich, Germany. With more than 150 years experience in life-sciences and industrial applications Süd-Chemie has sales of USD approx. 1.7 billion and more than 6,400 employees at its 80 sales and production sites worldwide. The generation of green chemicals such as bioethanol from lignocelluloses by new and innovative processes is a very attractive market for Süd-Chemie based on the company's technology platforms biotechnology, chemistry and adsorbers.

Geoff Bell

Microbiogen has developed non-recombinant strains of Saccharomyces cerevisiae that thrive in the inhibitory conditions found in lignocellulosic hydrolysates. When tested in real world hydrolysates our yeasts ferment cellulose-derived sugars into ethanol, more effectively than current commercially available yeast strains. These same strains also have the ability to aerobically convert xylose, ethanol, glycerol and acetate into yeast biomass. This yeast biomass itself has an inherent value as an animal feed due to its high phosphorous levels, favorable amino acid and protein levels which are more than comparable to soymeal. Such features along with its non-recombinant status make it a valuable co-product with global markets. Under the Microbiogen "feed AND fuel" biorefinery concept the same yeast thus performs two critical tasks instead of just one. It efficiently ferments the six-carbon sugars to ethanol and value-adds the remaining useable carbon sources into an aerobically produced yeast biomass, to be sold as a high value single cell protein. Having the capability to produce feed AND fuel from lignocellulosic sugars makes next generation ethanol a reality, and defuses the food vs fuel issue.

Nhuan Nghiem

Traditionally in a lignocellulosic ethanol process all available fermentable sugars are used for ethanol production. None of the organisms developed for conversion of both C5 and C6 sugars to ethanol is as efficient as the yeast Saccharomyces cerevisiae. In addition, having ethanol as the only main product may not be an economically attractive option considering the high capital costs of lignocellulosic processing plants. In our proposed new approach the pretreated biomass is first hydrolyzed by hemicellulase to produce a stream rich in C5 sugars, which is subsequently used for production of value-added co-products. The solid residue is hydrolyzed with cellulase to produce a glucose-rich stream, which is used for ethanol production with the yeast S. cerevisiae. We will present results obtained with biomass pretreated by either soaking in aqueous ammonia (SAA) or low moisture anhydrous ammonia (LMAA) process.

Monday, April 30, 2012 – 10:30am-12:00pm

Algal Biofuels: Advancements in Technology and Commercialization

Moderator: Martin Sabarsky, Cellana

Novel Microalgae Cultivation Technology for Higher Yield and Simplified Harvest
Joshua Yuan, Texas A&M University

Application of Computation Fluid Dynamics for Optimizing Inner Structure of a Draft-tube Airlift Bioreactor for Microalgae Cultivation
Chunzhao Liu, Institute of Process Engineering, CAS

Effects of Dissolved CO2 on Algal Growth Rates and Algal Cell Lysing with High Pressure Shear
Dean Tsoupeis, Culturing Solutions

Patrick Ahlm, Algenol

Abstracts

Joshua Yuan
One of the major technical barriers for algae biofuel is the harvest of SCO (Single Cell Oleaginous) microalgae from liquid medium. Harvesting and extraction could account for up to 50% of the total cost for algal biofuel production. Current harvesting strategies include centrifugation, flotation, microfiltration, flocculation,and others. Essentially all of these strategies have limitations when being scaled up for commercialization. A cost-effective harvesting strategy will provide essential enablement for algal biofuel development. Besides the harvesting, lipid and biomass yield also need to be further optimized to improve the sustainability and economic viability of algal biofuel. A novel technology has been developed both to reduce the harvesting cost and to increase the yield through pelletized cultivation of microalgae. Depending on the condition, the technology can reach complete or near-complete removal of microalgae from liquid medium. More importantly, the pelletized cultivation also leads to four time increases of biomass yield and nearly two times increase of lipid yield. We have demonstrated pelletized algae cultivation in both heterotrophic and complete autotrophic scenario. Pelletization can greatly promote the nutrient usage and enable the better biomass and lipid production. The technology has the potential to dramatically decrease the harvest and extraction cost for algal biofuel. Considering the dramatically improved cultivation performance, the technology can also reduce the production cost and improve the sustainability through better water recycling. The technology is being commercialized by Renewuel LLC, which provided several other complementary platforms to enable the combination of second and third generation biofuel as economically viable and sustainable option for the biofuel industry.

Chunzhao Liu

The key parameters of inner structure of a cylindrical airlift bioreactor, including ratio of cross-section area of the downcomer to cross-section area of the riser, clearance from the upper edge of the draft tube to the water level and clearance from the lower edge of the draft tube to the bottom of the reactor, significantly affected mass production of microalgae. In order to achieve high algal cultivation performance, the optimal structural parameters of the bioreactor was determined with the help of computational fluid dynamics (CFD) simulation. The simulative results were validated by the experimental data collected from microalgal cultivation in both 2-L and 40-L airlift bioreactors. The developed CFD model provides a powerful means for optimizing bioreactor design & scale-up without having to perform numerous time-consuming bioreactor experiments.

Dean Tsoupeis

This module is universal by its capacity to produce algae biomass from different strains accordingly to the customer's location and requirements for the final products. The Type II Hybrid consists of a combination of proprietary designed tubular photobioreactor, as an algae inoculator, and a closed looped covered pond as an algae production unit. Utilizing advantages of both solutions, this design will increase algae productivity by accelerating the growth rate after harvesting the portion of algae biomass used for oil extraction. The hybrid concept of the systems combined allows this module to be successful in various climate zones, including the northern regions. As an option, in the cases that modules are located in an area with substantial unused off-peak (night time) electric power, the artificial lighting by LED devices will be developed. Module will comprise a proprietary non-energy consuming anti-fouling system. Optimal parameters for growing microalgae in the module will be determined. Enhanced CO2 distribution with membrane technology will allow for the complete dilution of CO2 and other essential nutrients like Nitrogen and Sulfur. This membrane has been proven to increase growth rates up to 4x. A lipid extraction system as a final part of the module will use ultrasonic cavitation treatment and a non-energy consuming oil/biomass separation. The automatic computerized system for controlling algae growth and technological process parameters will also be implemented.

Proposed modules may be easily integrated into the complex processes of power generation, oil and gas, chemical, and other industries related to the emission of carbon dioxide. Enterprises will profit from carbon credits as a result of CO2 mitigation and conversion into biofuels and other valuable products. The universality of modules substantially expends the market for its commercialization by proposing the attractive business alternative, not only for the big business for mass production of biofuels and other valuable products, but also for the small business and farmers to establish a high profitable manufacturing of valuable products using 1-2 modules.

Culturing Solutions' commercial demonstration Facility is located in Port Richey Florida. Algae cultivation was enhanced threw the process of dissolving CO^2 from emissions into the growing media of algae in a Tubular Photobioreactor and a Type II Photobioreactor. Additionally the Nitrogen in the NOX emissions and the Sulfur in the SOX emissions were dissolved into the growing media. This was achieved by utilizing a membrane delivery and separation system. A 600-liter tubular photobioreactor was used as an inoculation platform for a 57,000-liter Type II Photobioreactor. The 600-liter tubular photobioreactor uses clear tubing through out the unit to increase photon absorption. The tube diameter is engineered for the most optimum path of a photon. The Type II Photobioreactor is a closed looped and hermetically sealed earthen tank that utilizes a proprietary pumping system that increases the concomitance of the algae to photons. The system also creates a current along the bottom, which provides for the circular flow.

Monday, April 30, 2012 – 2:30p – 4:00pm

Toward a Billion Tons: Biomass & Purpose Grown Energy Crops

Moderator: Michael Cunningham, ArborGen

Science Looks to Unlock Potential in the Undomesticated Tree through Precise Genetic Breeding
Michael Cunningham, ArborGen

Opportunity for Industrial Biotechnology Based on Feedstock in Russia and Neighboring Countries
Alex Ablaev, Russian Biofuels Association

Solving the Biomass Feedstock Supply Problem
Bob Randle, Genera

Economic Analysis of a Switchgrass Biomass Production and Supply System
David Bransby, Auburn University

<u>Michael Cunningham</u>
Scientific advances are unlocking ever more significant uses for the components of trees. In addition to the wood, pulp for paper and wood for fire, increasing demands are being made of trees for fine grade cellulosic sugars that can be converted to biofuels, polyethylene and other compounds for industrial use. Yet the tree itself remains an undomesticated plant. Far from its agricultural counterparts which have been bred for cold tolerance, drought resistance, improved yields and improved food quality, the tree has only been bred for a few generations and predominately to improve form for processing lumber.

ArborGen uses advance breeding techniques to shorten the time required to reach domesticated species for industrial purposes. Varietal propagation allows us to replicate one species to improve consistency. Mass Controlled Pollination allows us to improve a line by controlling one parent in a breeding pair. However, demands for wood cellulose are growing at a rate of acceleration that can never be matched at the conventional breeding level for a species that takes more than 20 years to mature. ArborGen scientists use precision breeding techniques to look at specific ways of improving and domesticating trees for industrial uses.

One excellent example is a lignin-modified *Eucalpytus* species that has proven to release more than twice the usual amount of sugar, making it a promising option as a biomass feedstock for liquid fuel. The tree is being studied by National Renewable Energy Lab (NREL). Using plant biotechnology the modifications were made at two points in the lignin biosynthetic pathway, with the largest increase in sugar release coming from cinnamate-4-hydroxylase (C4H) down-regulation. Although some "low recalcitrance" plant lines suffer from reduced growth, many of the C4H down-regulated lines from the *E. grandis x E. urophylla* cross grow well. C4H lines have an estimated biomass productivity of ten dry-tons per acre per year, with the potential to produce about 1,000 gallons of liquid biofuels per acre.

Scientists from NREL have characterized the C4H lines as containing half the lignin of the unmodified lines. Using a high throughput sugar release assay developed at NREL (Selig et al, 2011 *Biotech. Letters* 1-7), the modified lines were found to release up to 99 percent of their sugars, up from 40 percent in the non-modified plants. This result translates to an improvement of 150 percent, a dramatic demonstration of the impact of lowering recalcitrance.

Further work by NREL and ArborGen on these and similar lines will aim to understand exactly how the recalcitrance is lowered and how this knowledge can be used to develop healthy low recalcitrance lines in an array of species.

Alex Ablaev
Industrial biotechnology is passing the stage of lab scale & pilots plants and is entering the era of industrial scale biorefineries. The feedstock cost is the main factor, defining success or failure of the industrial biotechnology project. Russian and neighboring countries (Ukraine, Kazakhstan) is one of last places where arable land and water available to produce first & second generation of feedstock for industrial biotechnology. There are more than 10 wet-mills under construction in Russia now, which will produce cheap glucose, available for fermentation. Russia will inevitably participate in the market of fuels and chemicals from renewable feedstock, because Russia overproduces the grain and sugar beet due to the fact that agriculture is gradually began to introduce advanced technology in agriculture. For example, in 2008, with a harvest of 108 million tones, 70 million tones was domestic consumption, 20 million tons was exported, and 18 million tons left available for processing. Russia could be a place to have industrial biotechnology plants to produce bioplastics and biochemicals for the world market.

Bob Randle
"The chicken and the egg". "If you plant it they will come". "Till baby, till". "Ready in three to five years". These are all clichés that have been ascribed to the current state of the lignocellulosic conversion world.

For any biofuel, biochemical or biopower project to be feasible, it must consider the biomass feedstock supply problem. Project financiers will analyze the risk of the entire project before committing funds: Feedstock Supply—Conversion Technology—Offtake Markets. As the cellulosic industry has matured in the last couple years, an increasing emphasis has been placed on the availability, supply guarantee and economics of the biomass feedstock supply.

This presentation will focus on the development of productive, sustainable and economic biomass feedstock supply solutions using purpose-grown energy crops. We will focus on the lessons learned from the largest and longest running switchgrass production program in the country. This will include the agronomic practices, equipment requirements, production economics, logistics and management strategies for developing and implementing a commercial scale biorefinery project.

David Bransby
This study determined the delivered cost of switchgrass biomass to a processing plant as affected by selected variables within the production, harvesting and transport system. The analysis was conducted from commercial scale production, harvesting and delivery of switchgrass for co-firing with coal at a power plant at Gadsden, AL. It was assumed that switchgrass was mown, dried and chopped in the field, and transported to the plant in closed trucks. The base case model included the following values for input variables: yield, 7 tons/acre/year; plant size, 1,500 tons/day; proportion of land in switchgrass, 5%; labor rate, $16/hr; stand life, 20 yr; land rental rate, $50/acre/yr; diesel cost, $3.00/gal; truck capacity, 13 tons. These values resulted in a delivered cost of $65.67/ton. The analysis indicated that a 20% change in yield, truck capacity, diesel price and labor rate resulted in a change of $9.40/ton, $5.67/ton, $2.79/ton and $2.53/ton in delivered cost of switchgrass, respectively. Responses of the other variables evaluated in the analysis resulted in a change in delivered cost of less than $2.00/ton. Results suggest that improving switchgrass yield by genetic improvement probably offers the greatest opportunity to

reduce delivered cost. Although truck capacity had the next greatest impact on delivered cost of switchgrass, increasing truck capacity requires densification by means of costly processing into pellets or cubes. Therefore, this approach is unlikely to be effective in decreasing delivered cost.

Tuesday, May 1, 2012 – 8:30am – 10:00am

Fuels and Chemicals from Residues and MSW

Moderator: Gary Luce, Terrabon, Inc.

Glycerol Ethers from Biodiesel Waste Glycerine
Guerry Grune, Duke University

Making Biofuel from Municipal Solid Waste Using Biotechnology
Armindo Ribeiro Gaspar, Novozymes

Using a Hybrid Biological/Thermochemical System to Achieve Economic Feasibility of Biomass Conversion into Drop-in Biofuels
Cesar Granda, Terrabon, Inc.

Catalytic Conversion of Lignocellulosic Biomass to Conventional Liquid Fuels and Chemicals
Randy Cortright, Virent, Inc.

Abstracts

Guerry Grune
Development of a bio-based fuel additive, which can be blended with automotive fuels, including gasoline, diesel, biodiesel, and gasoline/ethanol as a renewable, innovative, clean fuel technology is beneficial to both the petroleum and biofuels industry. This product promotes conversion of biodiesel waste into a high value-add product that can increase the efficiency of biodiesel production, lower overall gasoline demand and consumption and also reduce greenhouse gas emissions. This product acts as an octane booster improving both engine performance and gas mileage. Removing and replacing MTBE (methyl tert-butyl ether), a fuel oxygenate that was required as an additive to gasoline to raise the oxygen content of gasoline and other fuels primarily in the United States, has become an urgent need. Development of processes and products for producing GTBE (glycerol tert-butyl ether), an environmentally friendly, non-toxic, fuel additive, has been developed in response to this need. Use of GTBE is a transparent “fix” and does not require any change in the current US fuel infrastructure or by the consumer. There are no other biofuel additives on the market and several other fuel issues which GTBE can help fix. Specifically, in addition to the fact that GTBE enhances fuel properties, is environmentally friendly and domestically producible, it is an ether that is similar in nature to MTBE (in that it has several oxygen groups and boosts octane). Thus, manufacture of GTBE provides an excellent fuel oxygenate in reducing green house emissions, and also an excellent octane booster, works well as an additive or replacement for AVGAS (aviation fuel) and improves engine performance and gas mileage. The additive is produced from a biomass (glycerol-based) source: glycerine. Glycerine is a waste by-product of biodiesel manufacturing. GTBE possesses none of the toxicity issues associated with petroleum based fuels with the exception of carbon dioxide emissions. With three -O-groups instead of one (as with MTBE), GTBE is a better fuel oxygenate, and because there are three ether linkages, it also particularly useful in reducing particulates and greenhouse gas emissions.

Armindo Ribeiro Gaspar

Municipal solids waste (MSW) – more commonly known as household trash – can be transformed into valuable biofuel. From 1960 to 2010, the total generation of municipal solid waste in the US has increased steadily from 88.1 to 249.9 million tons. As source separation and collecting of recyclable solid waste becomes a routine practice and also a vital facet in waste management strategy, a viable energy recovery scenario from MSW begins to make more sense as an alternative to reduce the landfill requirement and also decrease dependence on fossil fuels. The partnership between Fiberight, one of the first U.S. based companies to successfully produce biofuel from waste on an industrial scale, and Novozymes, the world leader on bio-solutions and bio-inovation, are using biotechnology to produce bioethanol from MSW as an economical viable reality. Fiberight with experience in the recycling and waste management business is uniquely positioned to benefit from emerging technologies creating a new and green business opportunity. Novozymes cannot only supply the proper enzymes but also help achieving the goals toward commercialization of MSW into biofuels, or a future cellulosic chemical platform.The first step on the road to making cellulosic ethanol out of MSW is to fractionate the waste stream. One of the materials is an organic biopulp. It is this biopulp fraction, making up about 45% of the MSW, which is used today to produce cellulosic ethanol. The core process really focuses on taking a nonhomogeneous feedstock and creating a washed and pretreated, homogeneous feedstock optimized for enzymatic hydrolysis. The optimized MSW biopulp is hydrolyzed into sugars before further fermentation into cellulosic ethanol. The use of Novozymes Cellic® products turned the hydrolysis of the lignocellulosic MSW biopulp feasible. Cellic products have shown their great robustness on a variety of feedstocks such as corn cobs, MSW, wheat straw, and sugarcane bagasse. As the technologies for cellulosic ethanol are commercialized, producers such as Fiberight will continue to rely on higher-performing enzymes.

Cesar Granda

The bioenergy field is swarming with many different technologies that promise to accomplish the same thing: The efficient conversion of biomass into liquid biofuels. These conversion technologies can be biochemical in nature, such as fermentations, or thermochemical conversions such as gasification and pyrolysis. Both fermentation and pyrolysis show great promise, however, they also have limitations. Fermentation often requires the pretreatment and hydrolysis of polymeric sugars prior to the conversion of the resulting free sugars into the desired product. Fermentations are also often performed using pure cultures that are prone to contamination and thus require aseptic conditions, many times difficult to attain. In addition, the pure cultures are commonly able to uptake only one type of substrate, such as sugars, which limits the types of feedstocks that can be converted. On the other hand, pyrolysis often does away with the need to priorly break down the feedstock into simpler molecules and is able to convert different types of substrates without the need for aseptic conditions. But, by the same token, the product generated by pyrolysis is much undefined and highly corrosive, as a result, it is very difficult to upgrade to an acceptable biofuel quality. In addition, high-moisture feedstocks cannot be efficiently processed through pyrolysis. In an effort to capture the best of both worlds without falling victim to their limitations, Terrabon, Inc. is commercializing a process that can convert any anaerobically biodegradable material into liquid drop-in biofuels by firstly fermenting the feedstock with natural mixed cultures of microorganisms, which are able to degrade many different types of substrates (e.g., proteins, cellulose, hemicellulose, fats, pectin, chitin, glycerol) with little differentiation and that, as a result, do not need aseptic conditions, making the fermentation very robust. The product from the fermentation, which is a mixture of carboxylate salts, is a much more defined feedstock for pyrolysis than raw biomass; therefore, the product from the pyrolysis of these salts is more defined, with its composition being mostly ketones such acetone. The ketones are very easy to upgrade and convert into liquid biofuels. The feedstock flexibility that this hybrid biochemical/thermochemical provides, has allowed Terrabon, Inc. to initially focus on converting the low-hanging fruit in biomass resources, municipal and agricultural solid wastes, into drop-in biofuels, such as bio-gasoline and bio-jet fuel. Terrabon has successfully demonstrated the science of this process and is making great strides towards its commercialization. Terrabon has extensive capabilities both in expertise as well as physical installations at the laboratory and pilot plant scale to fully develop this process. Its pilot or semi-works facility has the capacity to process the equivalent to 5 dry ton/day of biomass and is able to generate enough fermentation products to produce 300 gal/day of bio-gasoline. The semi-works plant monitors different parameters in the fermentation, such as conversion, selectivity towards acids and acid yield and biogas production. In the downstream chemical processing into hydrocarbons, many parameters are monitored, such as yields and selectivity, as well as the quality (e.g., octane number, IBP, FBP) of the final product. Results from these studies and their implications in the economics will be presented.

<u>Randy Corthright</u>

Virent Inc. is developing and commercializing innovative and novel catalytic methods that convert plant sugars into non-oxygenated hydrocarbon molecules that can be blended seamlessly to make conventional gasoline, diesel, and jet fuel. Additionally, Virent has developed technologies that converts biomass-derived oxygenates to chemical intermediates that are currently used to generate a broad range of commodity chemicals, fibers, and polymers. Virent's BioForming® technology is able to produce renewable “direct replacement” hydrocarbons that can be used as gasoline, diesel, jet fuel, and chemicals from a wide range of abundant biomass feedstocks, including non-food varieties. This patented platform technology utilizes catalysts and reactor systems similar to those found in standard petroleum oil refineries. . With this capability, the BioForming® process can also utilize the lowest cost biomass sources available in each location and supply more energy without reducing the available food supply.

Tuesday, May 1, 2012 – 2:30pm to 4:00pm

Cost Effective Sugars for Fuels and Chemicals Production
Moderator: Kef Kasdin, Proterro

Breaking the Sugar Cost Barrier
Kef Kasdin, Proterro

Cellulosic Sugars – roadmap to commercialization
Philippe Lavielle, Virdia

Craig Stuart-Paul, Fiberight

The Benefits of Distributed Production of Custom Cellulosic Sugars from Biomass
Karl Doenges, Sweetwater Energy

<u>Abstracts</u>

<u>Kef Kasdin</u>

The barrier to market adoption of industrial biobased fuels and chemicals is cost. Cultivation, harvest, transport and processing of agricultural feedstocks are together the largest contributors to the high cost of biofuels and biobased chemicals. Proterro is a venture-backed start-up developing, through a patent-pending process, a non-plant-based, noncellulosic fermentation-ready sugar feedstock that will enable the economical and scalable production of biofuels and biobased chemicals. Simply put, Proterro's sucrose is NOT derived from cellulosic biomass. Cellulosic sugars depend on an agricultural set of steps that Proterro avoids; they are made first in a constructive process that overshoots by building biomass that has a low-sugar content and, then, in a destructive process that removes toxins and isolates the desired sugars. These factors contribute to the high-capital and unit costs of cellulosic sugar. Proterro's sucrose, however, is solely made in a constructive manner. A sucrose molecule is built based on its elements, using a naturally occurring photosynthetic process. The company's patent-pending innovation combines an engineered photosynthetic microorganism with an advanced high-density, modular solid phase bioreactor to provide a low-cost, fermentation-ready sucrose. The photosynthetic organism Proterro utilizes naturally makes sucrose as an osmotic response. Proterro has successfully engineered the organism to trigger and control the sucrose production and to secrete the sucrose, enabling a continuous sucrose production system with high productivity. Cultivation of photosynthetic organisms is a challenging process that needs to simultaneously balance access to light, carbon dioxide, and water in an environment that supports growth. Most systems employ classical liquid phase bioreactors in a wide variety of designs to optimize the environment. Proterro has demonstrated and scaled an alternative approach, a solid phase photobioreactor that optimizes the organism's access to light and carbon dioxide, and uses significantly less water. The organisms grow on a composite fabric substrate, enclosed in a photobioreactor that surrounds them with their carbon-dioxide feedstock. Water and nutrients are trickled into the reactor. The modular nature of the bioreactor affords a robust, scalable and controlled cultivation environment for photosynthetic organisms. Proterro is already demonstrating sucrose productivity an order of magnitude greater than agricultural alternatives using this novel photobioreactor system. The company has developed a robust economic model that shows that Proterro sucrose costs well below the alternatives. Proterro's sucrose can be used to produce a variety of commercial-scale fuels and chemicals through standard industrial fermentation methods. Proterro's intended business model is to create joint ventures with biofuels or biobased chemicals partners.

Philippe Lavielle

Virdia is progressing on its path to commercialize industrial sugars made from cellulosic biomass. The presentation will give the latest update on the company plans to deploy its technology at a commercially relevant scale, and elaborate on the value proposition of cellulosic sugars vs. other sources of industrial carbohydrates.

Karl Doenges

The recent volatility of petroleum prices is stimulating the biorefining industry to diversify its raw material feedstock, using a broad-based sugar platform technology. Non -food agricultural residues, energy crops, and woody biomass are widely recognized as the promising high-volume, low-cost lignocellulosic feedstocks from which to derive C5- and C6-rich sugar streams that can be converted to biofuels and chemicals.

This presentation will review Sweetwater Energy's overall approach and concept of integrating a decentralize model, whereby a modular, feedstock-flexible commercial scale bioprocessing machine that has been optimized towards pretreating a variety of lignocellulosic biomass feedstocks on site, and generate custom designed quantities of C5 and C6 sugar-rich streams for biochemical and fuel processes. The cellulosic sugars are custom formulated, then transferred to a regional refining site as a bolt on or 'drop in' to the exiting site for the production of biofuels or chemicals. This talk will highlight: 1) the importance of innovative biomass harvesting, storage technologies and improved logistics from a distributed strategy to efficiently and economically process cellulosic feedstock, 2) characterization of the sugar stream to enable optimum bioconversion process, and 3) various process strategies for deriving custom designed streams rich in C6 and C5 sugars at a cost competitive price for a broader application.

Wedneday, May 2, 2012 – 10:30am to 12:00pm

Opportunities From Oilseed Crops

Jack Grushcow, Linnaeus Plant Sciences Inc

The Global Supply, Demand & Price Dynamics that Underpin Oilseed, Carbohydrate & Sugar Feedstocks - In Particular, Agricultural Price Linkages with Crude Oil
Sarah Hickingbottom, LMC International

Non-food Mono-unsaturated Oilseed Crops for Advanced Fuels and Lubricants
Jack Grushcow, Linnaeus Plant Sciences Inc.

Engineering Synthesis and Accumulation of Industrial Fatty Acids in Safflower Seed Oil
Allan Green, CSIRO

Abstracts

Sarah Hickingbottom

Since 2000 the agricultural industry has undergone a revolution with the advent of the biofuel sector as well as changes in population and increased meet demand. Global arable land area has expanded by a staggering 70 million hectares in direct response to these demand increases. However, since 2007, sugar, vegetable oils, animal fats and carbohydrate grains have all become priced based on novel linkages that have developed with petroleum via government energy policies. These complex and intertwined linkages have created extreme distortions in the sector and a full understanding of these is necessary for any company who intends to secure a plant-based feedstock supply chain. As the bio-based chemical sector moves increasingly towards large commercial scales, we will seek to explain how players will find themselves struggling to mitigate their exposure to volatility in crude oil prices. Moreover, we will offer forecast supply analysis designed to consider if the world can truly adapt to increased food, animal feed, energy, fuel *and* chemical demands.

LMC has a global reputation for delivering high quality, detailed analysis across all major agricultural & biomass commodities as well as the downstream biofuel, oleochemical and bio-based chemical sectors. We work with numerous industrial and government-based players and we speak at a large number of prestigious conferences around the globe. In particular LMC is focused on the economics that govern these markets, namely supply, demand and pricing as well as the determinants underpinning these numbers. Increasingly we have been unraveling exactly how crude oil influences the pricing of agricultural markets today.

Jack Grushcow

Sources of mono-unsaturated fatty acids, in particular Oleic Acid are prized for their functionality in the production of fuels lubricants and other valuable industrial chemicals. Current sources of oleic acid include High Oleic Canola and recently introduced High Oleic Soybean. Linnaeus Plant Sciences incollaboration with DuPont/Pioneer is producing the first non-food source of high oleic fatty acid that can be grown in a drought tolerant crop well-suited to production in marginal lands. This supply of High Oleic Acid will be game changing in terms of the ability to supply a non-food source of a highly functional fatty acid. This presentation will discuss the development of this mono-unsaturated fatty acid in camelina, summarize production capabilities and discuss end-user markets. The presenter will also be reviewing the production chain economics which will allow this product stream to be economically viable.

<ins>Allan Green</ins>
There is increasing interest to engineer production of unusual fatty acids in high productivity oil crops to provide renewable, productive and expandable supplies of important industrial chemicals currently obtained from petroleum or low potential crop plants. Safflower is a relatively minor food crop in Australia and has good potential for use as a broadacre crop platform for production of specialty industrial fatty acids. We have undertaken biochemical examinations of developing safflower embryo microsomes to define potential metabolic bottlenecks for the synthesis and accumulation of unusual fatty acids. For example, compared to the rapid accumulation of oleic acid into safflower oil, ricinoleic acid was poorly handled at most steps of the Kennedy pathway of triglyceride assembly. To alleviate these bottlenecks in safflower we are introducing genes encoding specialised triglyceride assembly enzymes obtained from organisms that accumulate very high levels of unusual fatty acids. Combinations of these genes are being expressed in yeast, benth leaf assays and Arabidopsis seeds in order to define a complete pathway for the synthesis and accumulation of unusual fatty acids. Results from these model systems and implications for the design of genetically modified safflower plants producing various industrial quality oils will be discussed.

Renewable Chemical Platforms and Biobased Material

Sponsored by Myriant

Monday, April 30, 2012 – 8:30am to 10:00am

The Succinic Acid Platform

Moderator: Sue Hager, Myriant

Myth vs. Reality: Overcoming Bio-Chemical Performance Misconceptions in the Marketplace
Alif Saleh, Myriant

Global Scale-up of Renewable Chemicals through Partnership
Babette Pettersen, BioAmber, Inc.

Commercializing Bio-Based Succinic Acid: The Benefits of a low pH Yeast Technology
Will van den Tweel, Reverdia

Global Scale-up of Renewable Chemicals through Partnership
Naoki Enatsu, Mitsui & Co., Ltd.

Abstracts

Alif Saleh
This panel will examine several green chemicals currently available on the market and present the case for making green chemicals the choice for industries looking for alternatives that:
•Meet or exceed the performance of conventional petroleum based chemicals;
•Are cost competitive with petroleum-based chemicals;
•Lessen environmental footprint of manufacturing by lowering greenhouse gas emissions and reducing product toxicity. Panelists will include:
• Representative from biobased chemical manufacturer, explaining the biochemical manufacturing process, and existing product availability [Producer, Myriant]
•Manufacturing representative describing process technology and how today's biochemicals can be utilized as a drop-in or chemical substitute for conventional petro-based chemicals ito produce a variety of products;
•Customer representative outlining direct and indirect cost savings.

Will van den Tweel
Multiple commercial scale plants for the production of bio-based succinic acid have been announced. They will all use bacteria based technology, except for one. Biosuccinium™ sustainable succinic acid is produced using proprietary low pH yeast technology. Reverdia™, powered by DSM and Roquette, has tapped into years of expertise in fermentation-, recovery- and plant scale-up expertise and has evaluated both bacteria as well as low pH yeast technology. Environmental, cost and quality benefits made it an easy choice. Examples of successfully commercialized bio-based acids are citric acid, itaconic acid, and lactic acid. All three are produced using low pH technologies. Biosuccinium™ today is successfully produced in a demonstration plant. The first commercial scale plant will start producing in the second half of 2012 and the site for the next larger scale plant is under discussion. Content of this presentation: - Overview of the unique benefits of low pH yeast technology to produce bio-based

succinic acid - Progress in market/application development - Update on Reverdia's manufacturing progress and plans Presenter: Will van den Tweel, General Manager Reverdia(TM) The JV Reverdia(TM), powered by DSM and Roquette, is subject to regulatory approval.

Babette Pettersen & Naoki Enatsu

The scale-up of renewable chemicals is just one of the challenges faced by companies in the field. Successful development of renewable chemicals is the first step; pilot scale manufacturing and investment to scale the technology follows, and once that has been achieved, large scale manufacturing infrastructure needs to be built to ensure that a robust supply chain is in place and security of supply is assured for customers globally, in order for the market to develop. This requires substantial investment at every stage of the process, and often involves multiple sources of funding, including private equity, government, and funding from large global commercial enterprises.

BioAmber has the only commercial scale biobased succinic plant in the world today, which was built in 2009, in partnership with ARD (Agro-Industrie Recherches et Développements) and integrated into an existing biorefinery located in Pomacle, France. The plant, which was financed by ARD at a cost of close to $30 Million, has been up and running since 2010, now at a capacity of 3000 Tons. ARD is the R&D centre of the French Champagne-Ardenne and Lorraine agro-businesses that grow cereals, sugar beets and alfalfa. ARD is focused on adding value to and finding new outlets for agricultural crops, and on developing innovative products that use the renewable carbon in plants after processing in a bio-refinery. BioAmber has selected Sarnia, Ontario as the location for its first North American biosuccinic acid plant. The Sarnia plant will have an initial capacity of 17,000 Tons, and will be commissioned in 2013. BioAmber will produce 35,000 Tons of biosuccinic acid and 23,000 Tons of biobased 1,4-Butanediol (BDO) at the Sarnia plant at its peak. Mitsui & Co, a leading global trading company , have partnered with BioAmber to build and operate the Sarnia plant. BioAmber and Mitsui will also partner to build and operate a second plant in Thailand, in partnership with PTTMCC Biochem.

Monday, April 30, 2012 – 10:30am to 12:00pm

Biobased Chemicals Coming of Age - Renewable Adipic Acid and an Emerging Portfolio Driven by Innovative Partnerships

Moderator: James Iademarco, DSM Biobased Products and Services

James Iademarco, DSM Biobased Products and Services

Lucio Siano, COIM USA Inc

Peter Nieuwenhuizen, Akzo Nobel

Catalyst and Process Development for the Production of Large Volume Chemicals from Renewable Feedstocks: Scale up of Bio-Based Adipic Acid
Gary Diamond, Rennovia, Inc.

Abstracts

James Iademarco

In the renewable chemicals and biobased materials space, open innovation and partnerships along a new value chain are no longer the exception but the rule. The industry is seeing both large and small chemical companies form joint developments with agricultural feedstock providers, emerging technology start-ups, as well as downstream converters and brand owners. Large multinationals like DSM, a global life sciences and material sciences company, started in this space some time ago, and continue to invest to develop a number of enabling technologies and introduce renewable biobased chemicals and materials through partnerships.

One of the latest announced developments are cutting edge new routes to a more sustainable production of adipic acid, a key raw material for polyamides, polyurethanes, plasticizers, and resins representing a global market over $5 billion. With benefits of renewability, lower carbon footprint, competitive economics, and potentially more stable long-term prices, the industry is taking notice. Such a breakthrough could have a favorable impact on several market sectors like automotive, textiles, and paints and coatings to name a few. Several companies have emerged with different approaches (biological and chemical) to make this a reality.

Leveraging several decades of experience in both biotechnology and chemistry, DSM has been building two businesses since 2005 under the umbrella of Biobased Products and Services. Enabling technology for Bioenergy (i.e. converting 2nd generation biomass to fuels) and enabling technology for Biobased Chemicals and Materials with the frontrunner being succinic acid. Also part of its emerging portfolio, DSM has explored multiple routes to renewable adipic acid and believes it will have a proprietary process expected to be commercial at large scale within the next 5 years. Clearly there are technical and business challenges ahead, but through the right combination of collaborations and open innovation, DSM expects success for themselves and their partners. Rennovia, a venture backed start-up whose mission is to bring renewable chemicals to the marketplace, is employing chemical catalysis to develop its first two targets, adipic acid and adiponitrile, both important for the Nylon 6,6, chain.

Two companies on this panel represent key players along the existing value chain for adipic acid and other large raw materials important to the chemical industry. COIM, a global polyurethane chemicals manufacturer with a long history founded in 1962, will discuss how they have invested in new technologies and share their view on the promise of "renewable materials" and it will impact their applications. Akzo Nobel, one of the largest companies in the coating industry will offer their perspective and strategy on the emergence of biobased chemicals and materials and how they plan to work with the emerging suppliers.

<u>Dr. Lucio Siano</u>

The production of chemicals through biotechnological processes is now becoming a reality as the processes are proving to be competitive with conventional ones and the products sustainable on long term basis.

COIM, a global polyurethane chemicals manufacturer founded in 1962, continues to invest in new technologies and innovative processes to develop new products, manufacture more efficiently and in a sustainable manner. One of the core competencies of COIM is the manufacture of aliphatic polyesters and its application in a variety of industries including automotive, coatings, adhesives, elastomers.
In the last few years, COIM has developed a number of aliphatic polyesters based on biobased chemicals like adipic acid, 1,3 propanediol, biosuccinic acid and 1,4 BDO which are comparable with conventionally

based aliphatic polyesters and are being qualified in several end uses through partnerships and co-operations with suppliers, customers and research partners.

An innovation can be successfully implemented only if there is a clear commitment of all the interested parties in the value chain.

Peter J. Nieuwenhuizen

As the largest coatings company, with leading chemical industry positions, AkzoNobel have a keen interest to work at the forefront of current developments in biobased and renewable chemicals. Recognized as a small but growing portion of raw materials, AkzoNobel aim to be in the forefront of biobased raw material developments, seeking to work with leading suppliers and developers of such chemicals and exploring opportunities to apply these in our key markets and products. In this brief presentation we will explain our strategy and how it was developed, and share some of the target molecules that we aim to source, including adipic acid.

Gary Diamond

The rapid increase in petroleum & petrochemical prices over the last decade has renewed interest in the production of today's petrochemicals from renewable feedstocks [1]. Rennovia is adapting chemical catalysis technology, already proven to be scalable and efficient in the refining & chemical industries, for the conversion of biorenewable feedstocks to today's major-market chemicals, while delivering fundamental cost advantage *vs.* incumbent petroleum-based processes [2]. Rennovia's first commercial target is adipic acid, which is produced today in a multi-step process from benzene. Adipic acid is widely used in the production of nylon resins and fibers, as well as polyurethanes and non-phthalate plasticizers, and has a global market of over 6 billion lbs/yr. Rennovia has employed its high-throughput catalyst synthesis and screening technology infrastructure to discover new heterogeneous catalysts for producing adipic acid in two steps from glucose: (i) a selective catalytic oxidation of glucose to glucaric acid, followed by (ii) a selective catalytic reduction of glucaric acid to adipic acid [3]. A fast-track scale-up program has moved the technology to 1 lb/hr continuous pilot units, to be followed by a commercial demonstration plant. A second driver towards bio-based chemicals is the potential for reduced environmental impact [4]. A detailed comparative Life Cycle Assessment was performed comparing Rennovia's process with the petro process [5]. The petrochemical process produces the powerful greenhouse gas N_2O as a by-product, contributing to a high "carbon footprint". Through a combination of renewable feedstock, lower energy usage, and avoidance of N_2O by-product, Rennovia's process greatly reduces the carbon footprint and other environmental impacts. This presentation will outline our general approach to the cost-advantaged production of renewable chemicals, and describe our scale-up of our renewable adipic acid process and how it offers significant commercial advantage over the current petrochemical process

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Monday, April 30, 2012 – 2:30pm to 4:00pm

Renewable Chemicals Development: Olefinics, Esters, Alcohols

Moderator: Damien Perriman, Genomatica

Isobutene, Butadiene, Propylene and Other Light Olefins from Renewable Resources
Marc Delcourt, Global Bioenergies S.A.

Greening Basic Chemicals: Perspectives on Butadiene
Damien Perriman, Genomatica

Transforming Petrochemicals to Bio-based Chemicals
Bob Walsh, ZeaChem Inc.

Transforming Petrochemicals to Bio-based Chemicals
Jerry Gargulak, Borregaard LignoTech

Abstracts

Marc Delcourt

As of today, bioproduction processes already industrialized or under development are based on enhancing metabolic pathways naturally existing in microorganisms. Light olefins (alkenes, such as ethylene, propylene, linear butylene, isobutylene, butadiene) are the core platform molecules of the petrochemical industry and represent altogether a market exceeding $300 billion. Because these molecules are not produced by microorganisms, and thus because nature offers no starting point, no DIRECT bioprocess to produce these molecules industrially from natural resources has been developed so far. Realizing the potential of this untapped enormous market, Global Bioenergies has been founded in 2008 to develop processes for the DIRECT biological production of light olefins from renewable resources. DIRECT refers to the fact that the product secreted by the micro-organism is the light olefin, and not an alcohol such as ethanol, isobutanol or butanediol which would then need to be dehydrated chemically and possibly undergo further chemical reaction steps (e.g. metathesis). The company's

processes are based on the implementation into microorganisms of an artificial pathway composed of mutated enzymes optimized to catalyze reactions non-observed in nature and of non-natural intermediates. At room temperature and hence in the production reactor, light olefins are gaseous and therefore spontaneously volatilize from the fermentation medium, entailing two major advantages compared to existing bio-production processes which usually lead to liquid end products: - The gas does not accumulate in the reaction chamber and thereby does not reach concentrations slowing down or inhibiting the microorganism's production. Ethanol for example becomes toxic for yeast at concentrations slightly over 10%. - The purification process is considerably easier and cheaper since no energy consuming methods such as distillation or phase separation are necessary to purify the end product. Proof of principle for this break-through innovation has been recently obtained in 2010 through the successful bacterial production of Isobutene. Isobutene is a key building block for tires, organic glass, plastics and various polymers. It can also be converted into Gasoline (IsoOctane), JetFuel and Diesel. In June 2011, the company has successfully carried out a 2,9 times oversubscribed IPO on Alternext to finance the industrialization of the isobutene process as well as to replicate its success to other light olefins such as Propylene and Butadiene.

Damien Perriman
Following industry progress in bio-based versions of BDO and succinic acid, basic chemicals like butadiene are emerging as the next frontier of sustainable chemicals. Used in tires, carpeting and latex products, butadiene has an expected 2011 demand of 20 billion pounds or $40 billion (Nexant), but faces supply challenges due to changes in the mix of traditional feedstocks used for its production. The panel discusses the role and status of bio-based butadiene in the U.S. and globally, as well as the value of on-purpose production approaches for butadiene.

Bob Walsh and Jerry Gargulak
This panel brings together leading companies in the renewable and traditional chemical industries. The panel will outline innovations and advancements in the production of bio-based chemicals including feedstock resources, products, markets, sustainability and economics. ZeaChem's biorefining process is feedstock agnostic, highly efficient, and sustainable for the production of a wide range of economical advanced biofuels and bio-based chemicals. The company's 250,000 gallon per year integrated demonstration production facility in Boardman, Oregon will begin operations in late 2011 with cellulosic ethanol production beginning in 2012. The company's first commercial biorefinery of 25M or more gallons per year is currently under development. By using natural, sustainable raw materials, Borregaard produces advanced and environmentally friendly biochemicals, biomaterials and bioethanol that can replace oil-based products. Borregaard is the world's leading producer of wood-based chemicals such as specialty cellulose, lignin, vanillin and bioethanol. Borregaard biochemical are used in the animal feed, agriculture, mining and construction industries, among others.

Tuesday, May 1, 2012 - 8:30am to 10:00am

Open Innovation and Partnerships for Speed to Commercialization of Biobased Chemicals
Moderator: Jean-Francois Huc, BioAmber, Inc

Shigeru Handa, Mitsubishi Chemical

Karsten Job, Lanxess AG

Marc Verbruggen, NatureWorks, LLC

Mike Salzburg, DuPont

Abstract

The race is on for the commercialization of biobased chemicals and derivatives, based on their potential to offer the market's desired level of performance, cost-effectively, via an environmentally responsible process. Success is, however, not predicated on technology alone; the use of open innovation and partnerships to accelerate the development and commercialization of a whole new chemistry set, based on renewable raw materials, has demonstrated success across a broad range of applications.

The panel:

BioAmber: 2011 EPA Green Chemistry Award Winner and first-to market with biobased succinic acid, Bioamber has demonstrated the use of open innovation and partnerships to accelerate the development and commercialization of a portfolio of renewable chemicals, starting with biobased succinic acid, and has a plant up and running in Europe - the only commercial scale biobased succinic plant in the world today - through leveraging the best technologies at every level of the value chain to accelerate speed to market and minimise cost of development and commercialisation. Open innovation has enabled BioAmber to leverage deep existing industry know-how and global infrastructure, reduce capital expenditure, accelerate programs, advance more rapidly and focus more externally. BioAmber's won a 2011 ICIS Innovation Award for Best Business Innovation.

Mitsubishi Chemical Corporation (MCC): Shigeru Handa; General Manager Sustainable Resources Business Development Dept. MCC is Japan's major chemical group and offers a wide variety of products and solutions in Performance Products, Health Care and Industrial Materials (Chemicals and Polymers). MCC believe that Sustainability, Health and Comfort are key words in 21st century society and they have developed a range of sustainable chemicals and polymers to meet the needs of the 21st century, including a polybutylene succinate biopolymer (PBS). MCC have partnered with BioAmber in the field of biobased sucinic acid, such that BioAmber is the exclusive supplier of biobased succinic acd to MCC. MCC has also partnered with PTT PLC to build a large scale PBS plant in Thailand, to come online in 2014, and PTTMCC Biochem have selected BioAmber as it's partner for this plant.

Lanxess: Jorge Nogueira, Senior Vice President Business Unit Functional Chemicals. Lanxess is a global leader in phthalate-free plasticizers. Lanxess has partnered with BioAmber to develop a new generation of bio succinic acid based plasticizers that are both renewable and phthalate-free. The portfolio of renewable succinate plasticizers will offer performance benefits over phthalates, at competitive prices, and the partnership will leverage both companies' strengths - Lanxess' global commercial network and manufacturing expertise and capacity in specialty, phthalate-free plasticizers and BioAmber's first-to-market advantage with biobased succinic acid.

NatureWorks PLC: Marc Verbruggen, CEO; NatureWorks LLC is an independent company invested in by Cargill and PTT Chemical who recently announced a $150 million investment in NatureWorks, the first company to offer a family of commercially available biopolymers derived from 100 percent annually renewable resources with cost and performance that compete with petroleum-based packaging materials and fibers. NatureWorks have applied their unique technology to the processing of natural plant sugars to create a proprietary polylactide polymer marketed under the Ingeo™ brand name.

Tuesday, May 1, 2012 – 2:30pm to 4:00pm

Building Blocks to Consumer Products

Moderator: Steve Tuttle, The Dow Chemical Company

Biobased Isobutanol for Chemical, Rubber and Plastic Applications
Bob Bernacki, Gevo

Mike Schultheis , Coca-Cola Company

New Bio-based Monomers and Polymers for Sustainable Chemistry
Ian McLennan, EcoSynthetix Inc.

A New Generation PXLK Bioplastic Based on C5 Carbohydrates.
Olga Selifonova, Reluceo, Inc

Abstracts

Bob Bernacki
Gevo—a leader in next generation renewables — has developed and patented a cost-effective process, GIFT®**.** (Gevo Integrated Fermentation Technology®), which converts fermentable sugars from sustainable feedstocks into isobutanol, a versatile platform chemical for the petrochemical and fuels markets that drops into existing value chains.

Because isobutanol isn't a new product, it fits into the existing infrastructure in the petrochemical products industry. Gevo has achieved a cost-breakthrough for the manufacture of biobased isobutanol using a low capital cost retrofit of existing ethanol plants. Because of this cost breakthrough, biobased isobutanol is being evaluated in many chemical applications as an alternative raw material whose price and availability are not linked to the supply or price of crude oil.
Gevo's renewable isobutanol can be used as-is to replace propylene based isobutanol or n-butanol produced via the oxo-process in solvents and chemical intermediates such as esters and acylates. It can also be dehydrated to isobutylene and mixed butenes which makes it a critical C4 building block for a variety of applications.

Isobutylene can be used as a feedstock in existing commercial petrochemical facilities to produce a variety of, monomers, rubbers, additives and plastics. It can be directly oxidized to form methyl methacrylate (MMA), or directly polymerized to form butyl rubber used in tire manufacturing. Isobutylene can also be converted to isooctene using commercial refining processes and then into renewable paraxylene, making possible the production of fully renewable polyethylene terephthalate, or PET. Gevo and Coca-Cola have announced a partnership to further develop and optimize the conversion of isobutanol to paraxylene for use in PET beverage bottles.

Ian McLennan
The EcoMer® technology platform is a family of derivatized sugar-based monomers that have been developed by EcoSynthetix. These are produced by the reaction of dextrose (D-glucose) with various alcohols, followed by maleation using maleic anhydride. The full range of EcoMer products includes bio-based specialty monomers suitable for copolymerization, either in bulk or via emulsion polymerization,

with conventional vinyl monomers. As glucose is a reducing sugar, it is neither chemically or thermally stable, nor is it co-soluble in vinyl monomers. The manufacturing process that has been developed at EcoSynthetix can chemically convert glucose to an alkylpolyglucoside (APG), wherein the alkyl group imparts solubility in the vinyl monomers, as well as improved chemical and thermal stability of the sugar. This development has resulted in a number of "saccharide-based building blocks" or "saccharide-based macromers". The use of sugar-based monomers as intermediates for other building blocks or monomers has not been exploited to a large degree. This paper will outline the capabilities of this technology to open up a new array of bio-based building blocks and biolatex® polymers that can be used in a variety of market applications such as paints and coatings, adhesives, and surfactants.

<u>Olga Selifonova</u>
XLTerra's technology provides a unique value proposition for making agriculture and forestry more efficient by enabling the use of C5 sugars, especially xylose ("wood sugar") derived from hemicelluloses for a high performance renewable engineering bioplastic PXLK. PXLK bioplastic has exceptional properties that are in line with the best fossil carbon based plastics and superior to all known major bioplastics (PLA, PHAs, cellulose acetate). XLTerra's bioplastic has a unique ring structure with properties that provide high heat deflection (Tg 115oC). PXLK is a transparent, colorless, ductile (not brittle) polymer displaying exceptional optical clarity, high impact resistance, thermostability and excellent tensile strength. XLTerra's feedstock integration approach is enabled by two industrially proven and a century long production practices of C5-derived xylitol and furfural from xylose and other pentoses.

Wednesday, May 2, 2012 – 10:30am to 12:00pm

Development of Sustainable Procurement Policies

Department of Defense Sustainable Procurement Policies and Supportive Initiatives
Moderator: George Handy, National Defense Center for Energy and Environment

Nancy Gillis, GSA

Dave Asiello, Office of Deputy Under Secretary of Defense I&E

Ron Buckhalt, USDA BioPreferred

Darden Hood, Beta Analytic

<u>Abstract</u>

<u>Dave Asiello</u>
This presentation will provide an overview of the Department of Defense (DoD) Strategic Sustainability Performance Plan (SSPP) and the Defense Logistics Agency (DLA) and National Defense Center for Energy and Environment (NDCEE) initiatives in evaluating and demonstrations sustainable / biobased products at DoD installations to stimulate awareness and increase implementation. The DoD's vision of sustainability is to adopt sustainable practices and incorporate sustainability into decision-making to better ensure our ability to operate into the future without decline – either in the mission or in the natural and manufactured systems that support it. DoD's commitment to sustainability will be discussed

as supported by policy directives and Federal Acquisition Regulations. The DoD SSPP is built on four key mission oriented themes which are comprised of: continued availability of resources; DoD readiness maintained in the face of climate change; performance ensured by minimizing waste and pollution; and decisions and practices built on sustainability and community. These regulatory drivers and DoD directives require all Federal agencies to increase the use of sustainable and biobased products. However, before these sustainable and biobased products are utilized by the DoD, their performance must be proven to meet government requirements. DLA Aviation and the NDCEE are evaluating and demonstrating green products as alternatives to existing petroleum based and non-green products. Defense Logistics Agency (DLA) Aviation formed the Hazardous Minimization and Green Products Branch based at Defense Supply Center Richmond (DSCR). The mission of the branch is to facilitate the increased availability and use of sustainable products by DLA Aviation customers. Branch initiatives include green products and services, hazardous minimization, and continual process improvement. As a critical component of the DoD's environmental quality investment strategy, the NDCEE investigat

Ron Buckhalt

There has been steady and increasing encouragement from Congress and the White House promoting the Bioeconomy and the development and marketing of biobased products. The USDA BioPreferred® Program uses two primary initiatives to achieve the mandate: a Federal procurement preference program and a voluntary labeling initiative. Mr. Buckhalt will discuss how the Federal Procurement Preference goals have been promoted through Senior Sustainability Plans, the Federal Acquisition Regulation, OMB scorecards, USDA reporting of results, and through other mechanisms. Mr. Buckhalt will also discuss how the USDA Certified Biobased label is helping the consumer to identify biobased products.

Darden Hood

The purpose of the USDA BioPreferred program is to promote the increased use and purchase of biobased products. A major initiative of the program is its voluntary labeling initiative. The USDA BioPreferred program launched the USDA Certified Biobased Product Label in early 2011. The label assures the consumer that a product or package contains a verified amount of renewable biological ingredients. All labeled products are tested by a third-party certifier to verify that the amount of biobased content meets the minimum standards for certification set by USDA. Since the launch, approximately 530 products have received the label (as of 11/29/2011). An increasing amount of companies from all over the world are recognizing how the label can assist in marketing and educating the general consumer on its biobased product. Several international companies have already applied and received certification. The USDA BioPreferred program proposes a panel discussion that explores the many benefits of labeling biobased products and applying international standards for label certification. The international audience and high-level executives, scientists and investors at The World Congress on Industrial Biotechnology and Bioprocessing would make this panel discussion a worthwhile panel to add to the program.

Specialty Chemicals, Pharmaceutical Intermediates, Food Ingredients

Sponsored by DSM

Monday, April 30, 2012 – 8:30am – 10:00am

Industrial Biotechnology in the Pharmaceutical Industry - Innovations and New Production Methods Towards Economic and Ecologic Efficiency and Sustainability

Moderator: Klaus-Peter Koller, Frankfurt Goethe University

Thomas Herget, Merck KGaA

Slonomics – Killing two birds with one stone
Heinz Schwer, MorphoSys AG

Biotechnological production of aroma molecules
Johannes Panten, Symrise AG

Abstract

Thomas Herget
Merck is a global pharmaceutical and chemical enterprise with around 40,000 employees in 67 countries. The Pharmaceuticals business sector comprises innovative prescription drugs as well as over-the-counter products.
It is the world's oldest pharmaceutical and chemical company. With the acquisition of Millipore in 2011, the product portfolio for bioprocessing has increased dramatically enabling innovative solutions for the Biotech industry. Prof. Herget will talk about Merck's ambitions to reduce manufacturing costs in drug production. 50-90% of these costs occur during downstream processing. A recent project (BioPur) is therefore aiming at cheaper chromatographic filtration techniques, which focus on the structural and functional properties of the targeted molecule and allow an efficient abscission of foreign proteins and other impurities. The identification of "switchable" ligands in cooperation with Technical University Darmstadt is founded by the German Federal Ministry of Education and Research (BMBF). The ligands can be used for affinity chromatography as well as for the monitoring analytics for selected chiral fine chemicals and pharma products, where not only the binding but also the exposition of the target molecule takes place in as physiological conditions as possible. First promising results in identifying these binding proteins and their production in yeast and bacteria are presented in Prof. Herget's talk.

Heinz Schwer
Slonomics is a proprietary genetic-engineering platform primarily developed as an enzyme engineering technology to bring down discovery time and expand project portfolios for industrial biotechnology companies. Following the acquisition of Sloning by MorphoSys in 2010, Slonomics has been converted into one of the most powerful tools to optimize therapeutic antibodies. First big pharma companies have non-exclusively licensed Slonomics and it lies at the heart of Ylanthia, MorphoSys next-generation antibody platform. With the recently announced licensing deal between MorphoSys and Novozymes, Slonomics is well on the track to become a key technology in both the pharma and the industrial biotechnology landscape.

Johannes Panten

Biotechnological production processes are used at Symrise AG for a long time. In the past the synthesis of flavors have been of major interest, but recently fragrance molecules get more and more in the focus of research efforts. Two examples that illustrate this development in more detail will be presented: a) the production of natural vanillin and b) the formation of aldehydes. Fatty aldehydes are an important class of fragrance and flavor materials. Their odor is described as fresh, citrus and waxy. Although they occur in many plants, its concentration in the corresponding oils are usually low. Here we will present a biotechnical synthesis from natural fatty acids using an α-dioxygenase.

Monday, April 30, 2012 – 10:30am to 12:00pm

Renewable Specialty Chemical Applications

Gwen Rosenberg, Senomyx, Inc.

Jeff Martin, Yulex

Beyond Acrylics: Alternative Diaper-Grade Superabsorbent Polymers.

Olga Selifonova, Reluceo, Inc

Biosynthesis of Conjugated Polyacetylenic Fatty Acids

Victoria Haritos, CSIRO

BioPlastics and Sustainability: How Viable Are Bioplastics and Biobased Materials in the New BioEconomy?

Amar Mohanty, University of Guelph

Abstracts

Olga Selifonova

Today the $40 BB+ industry of absorbent consumer products, including the proverbial mountain of infant diapers, is enabled and governed by the acrylic-based SAP (sodium polyacrylate). However, sodium polyacrylate is neither degradable nor renewable. As a result of its use, tens of millions of tons of untreated human waste swollen in spent diapers are deposited to permanent landfills every year. Reluceo SAP technology offers the path to solve the long-standing “end-of-life” problem of polyacrylic absorbent products. This presentation will highlight the development and commercialization of Reluceo’s new generation of degradable high performance non-acrylic superabsorbent polymers (SAP) with a clear path for its manufacturing from renewable resources.

Victoria Haritos

Polyacetylenics are an exciting class of chemical intermediates whose wider application has been limited by the difficulties and expense involved in chemical synthesis yet they occur widely in nature as anti-fungal and antimicrobial agents in plants, fungi, sponges and insects and these provide excellent sources for novel gene discovery. We have identified a three desaturase-gene pathway from insects which can be heterologously expressed in yeast or plant systems to convert a common fatty acid, oleic acid, into a conjugated polyacetylenic product. The genes were heterologously expressed as single genes, or in combination in the yeast, insect cells and Arabidopsis thaliana seeds. The acetylenic fatty acids produced included crepenynic acid (Z-9-octadecen-12-ynoic acid), dehydrocrepenynic acid (Z-9,14-octadecadien-12-ynoic acid), Z-9-octadecen-12,14-diynoic acid and Z-9,16-octadecadiene-12,14-diynoic acid. Seeds from A. thaliana expressing beetle desaturases and the ?12 acetylenase gene from Crepis alpina accumulated the highly unsaturated conjugated polyacetylenic product Z-9,16-octadecadiene-12,14-diynoic acid. There are no reported precedents for the bio-based production of conjugated polyacetylenic fatty acids and this opens exciting new routes to the biological manufacture of these valuable chemicals for use as high performance electro-optic switching elements, high quality coatings and pharmaceuticals.

Amar Mohanty
The sky rocketing price of petroleum along with its dwindling nature coupled with climate change concern and continued population growth have drawn the urgency for the plastic industries in adapting towards sustainability. The government's push for green products, consumers' desire and energy conservation are some of the key factors that drive research towards the development of renewable resource-based polymeric biomaterials. The use of bio- or renewable carbon unlike petro-carbon for manufacturing bioplastics and biobased materials is moving forward for a reduced carbon footprint. The goal is to use biobased materials containing the maximum possible amount of renewable biomass-based derivatives to have a sustainable future. Biobased or green economy is challenging to agriculture, forestry, academia, government and industry. The incorporation of bio-resources, e.g. crop-derived green plastics and plant derived natural fibres into composite materials are gaining prime importance in designing and engineering green composites. Biocomposites derived from natural fibers and traditional polymers like polypropylene, polyethylene, epoxy and polyesters have been developed for automotive parts and building structures. Renewable resource based bioplastics like polylactic acid (PLA), polyhydroxyalkanoates (PHAs), biobased polytrimethylene terephthalate (PTT), bio-polyolefin, bio-polyamide, cellulosic plastics, soy protein based bioplastics and vegetable oils derived bioresins need value-added and diverse applications to compete with the fossil fuel derived plastics. Through reactive blends, composites and nanocomposites new biobased materials are under constant development. Natural fibres are lighter, less expensive, have superior specific strength, require comparatively less energy to produce, are good for the environment, biodegradable and have superior sound abatement characteristics as compared to synthetic glass fibres. Hybrid and intelligently engineered green composi

Monday, April 30, 2012 – 2:30pm to 4:00pm

Commercialization of Transformative Technologies

Moderator: James Lee, Sustainable Chemistry Alliance

John van Leeuwen, EcoSynthetix

Keith Thomas, Vive Crop Protection

Mark Badger, Switchable Solutions

Revolutionizing the Bio-Based Economy with Next Generation Synthetic Biology
Grace Colon, Intrexon

Abstract

Transformative technologies are truly transformative when others can easily grasp its potential and envision different applications that adds new functionality, simplifies existing paths to value-creation or be completely disruptive – in the positive sense. Transformative technologies can also be a challenge to managing IP, creating new market acceptance and monetizing new know-how. The panel will speak about their technology and their road to commercialization. Switchable Solutions will discuss the application switchable solvent technology to recycle plastics, extract seed oil, clean up oily waste and reduce the environmental foot print in processing bitumen. Vive Crop Protect will speak about their encapsulation technology used to deliver more effective crop protection and extend the pipeline of new formulations. EcoSynthetix will discuss the multiple uses for their starch based alternatives to petroleum based products using renewable feedstocks. Intrexon will discuss the use of synthetic biology in redefining product development. As a panel discussion member FirstGreen Partners will provide an investors perspective on the commercialization of transformative technologies.

<u>Grace Colon</u>
Intrexon's technology redefines industrial product development cycles, reducing the time, cost, and technical risks inherent in engineering biological and cellular systems and increasing the likelihood of commercial viability. Our presentation will demonstrate how Intrexon's platform and workflow enable economic production of specialty chemicals from renewable substrates.

Intrexon utilizes the groundbreaking UltraVector® platform to produce thousands of novel, customized DNA vectors for a variety of host systems, using reusable parts and variants in a combinatorial fashion. A state of the art workflow including genome scale modeling, metabolic engineering, strain engineering, high throughput screening and systems biology leverages the UltraVector® platform to uniquely address the key challenges of bioindustrial processes. The workflow is further enhanced by a collection of innovative capabilities and components, including genome, cell, and protein engineering as well as transcription control chemistry and DNA and RNA modular component design.

The technology and workflow are host agnostic, and therefore the development process is not constrained by the characteristics of the relatively small set of industrial hosts currently in use. With enabled hosts spanning prokaryotes, fungi, yeast, algae, mushrooms, plants and mammalian cells, Intrexon can select the best one for each application and develop end to end integrated, economic industrial solutions for a broad array of applications including specialty ingredients, commodity chemicals and biofuels.

Tuesday, May 1, 2012 – 8:30am to 10:00am

Oil Palm Biomass: Integrated Sustainable Value Creation
Moderator: Patricia Osseweijer, Delft Univertsity of Technology

Malaysian National Biomass Strategy 2020
Bas Melsen, Inovasi Agensi Malaysia

Mohd Nazlee Kamal, BioTechCorp

Macro-economic and Ecological Impacts of Oil Palm Biomass Utilisation
L.A.M van der Wielen, BE-Basic-TUD

Scientific challenges in using Oil Palm Biomass for biorenewable chemical production
Ruud Reichert, PURAC

Abstract

Malaysia wishes to promote innovation in the Oil Palm Sector to become an economic and sustainability leader. Malaysia has a target of 40% reduction of greenhouse gas (GHG) emissions per 2020, relative to the year 2005 and the desire to achieve a developed nation status in the same year. To achieve these targets the development of a biobased economy is key. The transition to a biobased economy can only be successful when this undertaking is based on solid scientific date on best routes for innovation and value creation. Supported by a study on biomass mobilization and technology opportunities and a Macro-economic study by the Dutch LEI institute, the Malaysian Government has developed a sound National Biomass Strategy, which will be presented and discussed in this panel. Malaysia produces approximately 20 million tonnes of palm oil annually. But at least equally important is the coproduction of 80 million tonnes biomass. The biomass contains substantial amounts of valuable proteins, phytochemicals and nutrients (NPK) that originate from the fertilizer used in the plantations. Today the biomass is to a large extent not used and is left on the land. Changing this would offer both economical as well as sustainability and soil quality benefits: producing second generation biofuels, bioenergy and biochemicals as well as high quality fertilizer through biorefining and efficient conversion can make the economics of the utilization of biomass profitable and avoid unnecessary GHG emissions. Fully utilizing palm biomass can potentially contribute up to 3% of today's Malaysian GDP of RM 663 billion. In April 2011 The Malaysian Innovation Agency (AIM) started a technology roadmap study and macro-economic study. The latter was part of a cooperation agreement with BE-Basic with the aim to establish the Oil Palm Biomass Consortium (OPBC) in Malaysia, that will implement the results of the studies and focus on the use of palm waste as a raw material for the chemical industry. OPBC partners and BE-Basic partners aim to develop concepts of waste biomass utilization for biorenewable production, share knowledge on chain integration and socio-economic and sustainability issues and exchange students and researchers. The consortium will make use of the knowledge and experience that has been developed within the Dutch model of public-private partnerships, such as that reflected in the BE-Basic consortium.

Tuesday, May 2, 2012 – 2:30pm to 4:00pm

New Process Windows for Biocatalysis Enabling BioEconomy

Moderator: Andreas Liese, Biocatalysis2021: Hamburg University of Technology

Biocatalyst Improvement and Process Optimization for Challenging Reaction Conditions
Robert DiCosimo, DuPont

Efficient Low Cost CO_2 Capture Process Based on Immobilized Carbonic Anhydrase
Alex Zaks, Akermin, Inc.

Future Directions for Biocatalysis: Hydroxylations Catalyzed by P450 Enzymes
David Rozzell, Sustainable Chemistry Solutions

Opening New Process Windows by Combining Enzyme and Reaction Engineering

Andreas Liese, Biocatalysis2021: Hamburg University of Technology

Abstracts

To enable a highly efficient bioeconomy it is crucial to move to new operation windows for biotransformations. This demands biocatalysts that are highly stable at extreme pH levels, higher temperatures, higher pressures and in the presence of shear forces that exist in the harsh environments of industrial processes, specifically those that make use of renewable resources. However, to design processes in a bioeconomic way, molecular and micro biology need to be paired with reaction and process engineering. The successful analysis and assessment of the resulting economic conditions, as well as of the societal impact, lead to a biobased economy. Examples for innovative biocatalysts and processes operating under these new process windows will be given.The panel will discuss challenges and opportunities on the way to an efficient bioeconomy making use of Nature's own toolbox and beyond.

Robert DiCosimo

Examples of biocatalytic processes that utilize enzymes under conditions of high temperature or high shear will be presented, focusing on reduction of process costs through a combination of biocatalyst improvement and process optimization. Thermophilic perhydrolase variants based on a *Thermotoga maritima* wild-type CE-7 esterase have excellent stability at temperatures of up to 90 °C, making possible both a simple and economic isolation and purification process for enzyme production, and for use of the enzyme for perhydrolysis of acetyl esters over a broad temperature range. Spinach glycolate oxidase, useful for production of glyoxylic or pyruvic acid, is rapidly inactivated under high-shear conditions; immobilization of glycolate oxidase or expression of the enzyme in a microbial catalyst results in stabilization of the enzyme. The approaches employed in these two examples to resolve enzyme production and stability issues have broad applicability for development of new biocatalytic processes for challenging reaction conditions.

Alex Zaks

The paper presents the results of an enzyme-catalyzed approach to carbon capture in low enthalpy carbonate-based solvents. Potassium carbonate-based CO2 capture, despite being energetically and environmentally favorable, has not been considered practical for flue gas carbon capture due to the underlying kinetically limited rate of CO2 absorption. The use of a highly efficient ubiquitous enzyme, carbonic anhydrase, capable of hydrating ~10^6 molecules of CO_2 per second has a potential to improve the absorption rate significantly and convert the kinetically-controlled process into the mass transfer-controlled process. The use of carbonic anhydrases however is hampered by their relatively low stability in the harsh operational environment of a typical temperature swing absorbed/desorber unit (elevated temperature, presence of inhibitors, high shear force). The paper describes an approach to minimizing enzyme inactivation based on immobilization that demonstrates significant rate acceleration in the presence of the immobilized enzyme, enzyme tolerance to impurities in flue gas and the overall long-term system performance. In addition, the presentation will cover key results of Aspen simulation for enzyme-catalyzed potassium carbonate systems including sizing of the absorber column as a function of enzyme efficiency.

David Rozzell

Hydroxylations of aromatic and aliphatic compounds are difficult to control, particularly in the presence of other chemical functionality. Traditional chemical approaches are characterized by reagents that are difficult to handle and reactions that lack the desired selectivity and generate byproducts. In general, chemical hydroxylations lack sustainability and "greenness" and better alternative are being sought. Biocatalysis offers the opportunity to address the major problems in this important chemical reaction class. Biocatalyzed hydroxylations are typically regioselective and stereoselective, eliminating most unwanted byproducts, reducing waste, and improving the overall sustainability of the process. Before enzyme-based hydroxylations can fully realize their potential certain problems must be solved. We will discuss the future applications of biocatalysis in chemical hydroxylations, highlighting the key hurdles that must be addressed along if these enzymes are to become part of mainstream chemistry.

<u>Andreas Liese</u>

The Cluster BIOCATALYSIS2021 in Germany, supported by the Federal Ministry of Education and Research, coordinates the unique expert knowledge of 15 large companies, 19 small and medium-sized companies, as well as of 27 academic research groups and 7 agencies promoting innovations and economy. The primary goals of the Cluster are the use and application of new biocatalysts achieving novel synthetic effects by subjecting them to unconventional conditions. The enzyme systems are to be used both as final products and in subsequent processes for the production of fine chemicals and active agents. This is complemented by the development of an innovative process technology under unconventional conditions. This will be demonstrated on two selected examples ranging from mg to multi kg scale.

Wednesday, May 2, 2012, 10:20am to 12:00pm

Optimum Performance Properties of Enzymes

Moderator: Adam Kennedy, Metabolon, Inc.

Enzymes in Polymer Chemistry – What is Needed to Leverage
Andreas Buthe, c-LEcta GmbH

Enzymatic Technology for Low-Cost Carbon Dioxide Capture
Oscar Alvizo, Codexis

Liquebeet® - An Alternative Fermentation Substrate
Ulrich Kettling, Süd-Chemie AG

Enzyme Biocatalysts for Environmental Remediation of Pesticide Residues
Colin Scott, CSIRO

<u>Abstracts</u>

<u>Andreas Buthe</u>

As an alternative for fossil feedstock, much attention is currently being given to the use of polymers made of bio-based monomers and the composting of biodegradable polymers. However, the role of biotechnology in this realm is still far from being fully utilized since biocatalysts, namely enzymes have also proven efficient in polymerization and modification of polymers. Enzymes allow the polymerization under mild conditions without formation of side products, thus facilitating product purification as mandatory for e.g. medical polymers. Due to the catalytic selectivity of enzymes specifically structured polymers can be formed as well as functional additives can be incorporated deliberately into the polymer backbone. Thus industrially valuable features are conferred to the final polymer by the use of enzymes. However, this is currently hampered by insufficient economics and performance, why the screening for better enzymes as well as engineering thereof are considered as key enabling technologies. The talk will summarize the most recent achievements and trends. Moreover, application examples will be given to elucidate how underlying challenges can be addressed by enzyme engineering and how this might enable the full exploitation of the remarkable industrial and environmental potential in this emerging field.

Oscar Alvizo

Carbon Capture and Sequestration (CCS) is widely viewed as an essential tool for the large-scale reduction of carbon dioxide (CO2) emissions as part of overall global efforts for climate change mitigation. However, current CO2 capture approaches using solvents are largely uneconomic for wide-spread deployment . CO2 Solution of Québec City, Québec and Codexis of Redwood City, California are jointly developing a technology using the powerful enzyme catalyst carbonic anhydrase (CA). The technology allows the economical capture of CO2 with low-energy aqueous solvents that otherwise would not be viable due to their slow kinetics. Our current evolved CA enzymes are functional and stable in relatively inexpensive solvents for 24 hours at temperatures greater than 90°C. The technology has the strong potential to serve as a low-cost carbon capture approach which can be retrofitted into existing gas scrubbing technology. Codexis is an innovator in the directed evolution of enzymes for industrial processes and has twice received the U.S. Presidential Green Chemistry Challenge Award for its development of cleaner, greener pharmaceutical manufacturing processes using its optimized enzymes. In 2010, the Department of Energy awarded Codexis $4.7 M under its ARPA-E program to pursue the directed evolution of CA's capable of high activity and stability in carbon capture solvents. CO2 Solution has been an innovator in the use of CA with CO2 capture solvents for the past several years and holds several issued patents in this field. The presentation will discuss the basis of the technology, development results to date, and the opportunity to use CA to improve the economics of CO2 capture in coal-fired power generation and other large industrial applications.
Additional Authors: Jonathan Carley, Vice President, Business Development, CO2 Solutions

Ulrich Kettling

Sugar beet has been used as a source for fermentable sugars throughout Europe for years. To stay competitive, today low cost, easy to use fermentation substrates are needed. Süd-Chemie's Liquebeet® process significantly enhances the content of fermentable sugar by additional hydrolysis of insoluble parts. Through this gentle process the vitamins and minerals of the beet remain in the resulting solution, making Liquebeet® an all in one, ready-to-use and low cost fermentation substrate.
The production of bio-based fuels and chemicals requires renewable feedstocks at affordable costs. Sugar beet (*Beta vulgaris*) is among the agricultural crops with the highest sugar yields. Süd-Chemie, a Clariant group company, works on a proprietary and innovative process for the enzymatic liquefaction of the whole sugar beet without using diffusion method or adding any water to further increase the sugar content and make sugar beet an even more attractive feedstock. A key figure is Süd-Chemie's own optimized set of enzymes for the liquefaction of beets.

Due to the liquefaction process the content of fermentable sugar resulting from sugar beets will be significantly enhanced by additionally hydrolysing the cell-wall polysaccharides (cellulosic and hemicellulosic fraction of the sugar beet) and converting it into monomeric sugars. This makes Liquebeet® an low cost fermentation media usable for a variety of bioprocesses, such as production of ethanol, lactic acid or succinic acid and other bulk and fine chemicals. A main feature of this process is that no sugar beet pulp remains, which is dried for usage as animal feed in a very inefficient way needing a high energy input.

About Süd Cemie AG

Süd-Chemie AG (www.sud-chemie.com), a group company of Clariant AG, Muttenz, Switzerland, is specialty chemicals company operating on a worldwide scale. With sales of approx. €1.2 billion, Süd-Chemie AG is a world-wide leader in catalyst and adsorber technology and has an outstanding track-record in chemical and agro-chemical innovations for more than 154 years. With more than thirteen research centres and more than 6,400 employees world-wide, the company is one of the most distinguished companies for innovation in the chemical industry. Süd-Chemie AG actively develops sustainable solutions for the post-petroleum area. One of the solutions is the development of technologies for processing cellulosic biomass into fuels and chemicals.

Authors: Dr. Andre Koltermann, Dr. Ulrich Kettling, Corporate Research & Development, Süd-Chemie AG, Munich, Germany

Colin Scott
Pesticides and herbicides are integral components of most agricultural management, serving to increase yields by reducing losses due to pest and weed species. However, these anthropogenic pollutants are of major concern in both developing and developed nations because of their potential adverse effects on human health and the environment. Enzymes responsible for pesticide degradation have evolved rapidly in the environment. We have exploited such enzymes for the detoxification of insecticides, herbicides and fungicides, improving their performance using rational enzyme design and directed evolution were necessary. Our organophosphate-degrading enzyme has been developed into products for a number of static and moving water applications, including the use of immobilized and slow release formulations, and the development of products for other chemistries are well advanced.

Synthetic Biology and Metabolic Engineering

Sponsored by Codexis

Monday, April 30, 2012 - 8:30am to 10:00am

Microbial Synthesis to Renewable Chemicals

Moderator: Dave Anton, Codexis

Engineering Yeast for the Production of Adipic Acid
Thomas Beardslee, Verdezyne, Inc.

Systems Metabolic Engineering of Corynebacterium Glutamicum for Production of Bio-nylon from Renewable Resources
Nele Buschke, TU Braunschweig

Recent Advances in Polyhydroxyalkanoates Industrial Production and Applications
George Guo-Qiang Chen, Tsinghua University

The Cost Competitive Production of BioAcrylic Acid via the Platform Chemical Intermediate: 3-hydroxypropionic Acid
Michael Lynch, OPX Biotechnologies, Inc

Abstracts

Thomas Beardslee
Adipic acid is an important industrial chemical used to make nylon 6,6 and polyurethane resins for consumer products ranging from fibers for carpets and apparel, to footwear and engineering plastics. With an estimated global market of 5 billion pounds per year, it is currently produced from petrochemical sources by nitric acid catalyzed oxidation of cyclohexane. The production of adipic acid from renewable sources would allow the production of bio-based nylons and polyurethanes. Towards this goal, we have engineered the diploid yeast Candida tropicalis to produce adipic acid from renewable feedstocks. This yeast can normally utilize alkanes or fatty acids as the sole carbon source for growth by sequentially utilizing the omega-oxidation and beta-oxidation pathways. The omega-oxidation pathway oxidizes the terminal end of an alkane to a carboxylic acid resulting in a fatty acid, or in the case of a fatty acid the terminal carbon is oxidized to produce an alpha,omega-dicarboxylic acid. Both fatty acids and alpha,omega-dicarboxylic acids may enter cyclic degradation in the beta-oxidation pathway to provide energy and acetyl-CoA for cell growth. We have engineered the beta-oxidation pathway of C. tropicalis to halt cyclic degradation once the substrate reaches a length of six carbons thereby producing the six carbon dicarboxylic acid, adipic acid. The engineered beta-oxidation pathway successfully converts any chain-length substrate selectively to adipic acid enabling the use of mixed chain-length fatty acid feedstocks from virtually any plant-based oil product.

Nele Buschke
Nele Buschke[a], Stefanie Kind[a], Judith Becker[a], Hartwig Schröder[b], Christoph Wittmann[a]
[a]*Institute of Biochemical Engineering, Technische Universität Braunschweig, Germany*
[b]*BASF SE, Fine Chemicals and Biocatalysis Research, Ludwigshafen, Germany*

Bio-based polyamides are among the most promising products towards the new era of bio-economy [1]. They reveal excellent material properties and could replace conventional plastics which are still derived via petrochemical routes due to a superior eco-efficiency and sustainability concerning their production. Here, we report on systems metabolic engineering of *Corynebacterium glutamicum*, a traditional amino acid producer, towards bio-nylon, via fermentative production of 1,5-diaminopentane (cadaverine), a building block for these polymers. The design of the basic production strain comprised heterologous expression lysine decarboxylase from *Escherichia coli*. Subsequent rounds of strain optimization integrated systems-wide transcriptomics, metabolomics and fluxomics as well as in-silico pathway modeling towards a high performance producer with a molar yield up to 40 % on glucose. The modifications included global flux redirection in carbon core metabolism [2], discovery and elimination of undesired by-product formation [3] and engineering of cellular transport [4]. The strain engineering was complemented by extension of the substrate spectrum of the tailor-made producer to carbon five sugars [5]. This appears as a key to future production on non-food feedstocks, such as hemicellulose. For this purpose, the xylose pathway from *Escherichia coli* was implemented. Subsequently, a two-step process was established, coupling hydrolysis of hemicellulose in the first stage with bio-based

cadaverine production on the created sugars. This opens excellent possibilities towards novel bio-based polyamides.
Overall, the created process displays a valuable benchmark for the huge potential of *Corynebacterium glutamicum* bio-based production of chemicals, materials and fuels.

[1] Kind, S., Wittmann, C., *Appl Microbiol Biotechnol* (2011) 91:1287–1296
[2] Kind, S., Jeong, W. K., Schröder, H., Wittmann, C., *Metab Eng* (2010)12:341-351
[3] Kind, S., Jeong, W. K., Schröder, H., Zelder, O., Wittmann, C., *Appl Environ Microbiol*, (2010)76:5175-5180
[4] Kind, S., Kreye, S., Wittmann, C., *Metab Eng*, (2011)5:617-627
[5] Buschke, N., Schröder, H., Wittmann, C., *Biotechnol. J.* (2011) 6:306–317

Acknowledgements
We gratefully acknowledge financial support by the BMBF grant ‘‘Bio-based polyamides through fermentation’’
(No. 0315239A).

George Guo-Qiang Chen
Biopolyesters polyhydroxyalkanoates (PHA) produced by many bacteria have been investigated by microbiologists, molecular biologists, biochemists, chemical engineers, chemists, polymer experts and medical researchers. PHA applications as bioplastics, fine chemicals, implant biomaterials, medicines and biofuels have been developed. Companies have been established or involved in PHA related R&D as well as large scale production. Recently, bacterial PHA synthesis has been found to be useful for improving robustness of industrial microorganisms and regulating bacterial metabolism, leading to yield improvement on some fermentation products. In addition, amphiphilic proteins related to PHA synthesis including PhaP, PhaZ or PhaC have been found to be useful as a biosurfactant, and useful for achieving protein purification and even specific drug targeting. It has become clear that PHA and its related technologies are forming an industrial value chain ranging from fermentation, materials, energy to medical fields. Recent trends indicate that microbial polyhydroxyalkanoates (PHA) have become increasingly attractive as a source of polymers, chemicals, and biofuels. A Pseudomonas putida based platform for producing PHA homopolymers and block copolymers has opened a new area to diversify PHA monomers and structures. Further PHA development appears to be limited only by imagination.

Michael Lynch
As the demand for fuels and chemicals increases, their production from renewable feedstocks by fermentation becomes a more critical means of supplementing or even replacing traditionally petroleum-based products. Many commercial products may be derived from the core metabolic precursor, malonyl-CoA, including fatty acids (and hence long chain alkanes), polyketides including pharmaceuticals, and 3-hydroxypropionic acid (3-HP), a precursor of the industrial monomer acrylic acid. However, metabolic engineering is often required to construct microorganisms with the ability to produce compounds not normally the end-product of metabolism and to redirect metabolic flow towards the desired endpoint. We have engineered a microorganism for the production of 3-HP. A key focus of the strain development centered on increasing the cellular pools of malonyl-CoA, the first committed intermediate for the 3-HP production pathway. This engineered micro-organism associated bioprocess are currently undergoing scale up, and producing commercially relevant rates, titers, and yields of 3-HP/ These results enable the large scale production of biologically derived acrylic acid at production costs competitive with petroleum based sources.

Monday, April 20, 2012 – 10:30am to 12:00pm

Metabolic Engineering in Non- Traditional Microbial Chassis

Moderator: Jay Kouba, Glyce

Alexander Beliaev, Pacific Northwest National Laboratory

Biosynthetic Routes to Neutral Lipids and High-Value Products in Lipid Accumulating Bacteria
Brett Barney, University of Minnesota

Victoria Work, Colorado School of Mines

Adam Kennedy, Metabolon

Abstracts

Alexander Beliaev and Victoria Work

The major focus of this panel is to summarize the recent advancements in genomics-driven prokaryotic biology related to bioenergy research through the use of high-throughput approaches to obtain detailed information regarding intracellular gene expression, protein abundance, and metabolic flux. Ongoing efforts at Pacific Northwest National Laboratory are emphasizing system-level analysis of modules involved in photosynthetic energy conservation and reductant generation; CO2 accumulation, fixation, and reduction; biosynthesis of metabolic intermediates and monomers; and macromolecular synthesis. The gathered information is integrated into genome-scale metabolic reconstructions to understand metabolism qualitatively and quantitatively through a constraint-based flux analysis. When coupled with methods for the reconstruction of regulatory networks from transcriptomic data, this approach can provide experimentally testable predictions of: (i) fluxes to energy and reductant, (ii) reductant partitioning to carbon metabolism and other sinks, and (iii) analysis of anabolic and biosynthetic pathways that lead to macromolecular synthesis. Dr. Beliaev's presentation discusses approaches for designing of novel pathways and cellular functions through genetic and metabolic engineering and summarizes the current progress in developing alternative engineering platforms for high-density fuels production. Research at the Colorado School of Mines is providing a detailed understanding of the partitioning of photosynthetic reductant into the distinct metabolic pathways that facilitate bioenergy accumulation. The model cyanobacterium Synechocystis sp. PCC6803 has been successfully engineered to secrete fatty acids, synthesize the isoprenoid fuel additive ß-caryophyllene, and accumulate triacylglycerol. Several additional pathways and products are also under investigation, including alkanes, other isoprenoid derivatives, and precursor molecules relevant to other industries. The cyanobacterium Synechococcus sp. PCC7002 is emerging as a possible platform for high-level generation of these desired products. It is a close relative to 6803, and many of the same techniques and extensive knowledge of 6803 are also applicable to 7002. With a faster growth rate and viability in wider temperature and light ranges than 6803, the 7002 strain is a promising step toward scale-up. The research efforts at the University of Minnesota focus on enzymes that constitute the pathways for neutral lipid production in a small selection of bacteria. This pathway for carbon storage differs from the more common method utilized by bacteria to store reduced carbon as polyhydroyalkanoates, and generally results in the accumulation of either triacylglycerols or wax esters. As part of an ongoing project related to this topic, researchers in Dr. Barney's group cloned and purified a range of enzymes from several lipid accumulating bacteria that are involved in the pathways to produce wax esters, and also the enzymes that activate the fatty acid components and further reduce these to fatty alcohols, and are now in the process of characterizing the kinetic properties and post-translational regulatory elements of these enzymes. They are also probing the features of these enzymes that lead to the specificity (or lack thereof) that is found in the terminal enzyme in the pathway.

Brett Barney

Our laboratory is studying the enzymes that constitute the pathways for neutral lipid production in a small selection of bacteria. This pathway for carbon storage differs from the more common method utilized by bacteria to store reduced carbon as polyhydroyalkanoates (PHAs), and generally results in the accumulation of either triacylglycerols (TAGs) or wax esters (WEs). As part of an ongoing project related to this topic, we have cloned and purified a range of enzymes from several lipid accumulating bacteria that are involved in the pathways to produce wax esters, and also the enzymes that activate the fatty acid components and further reduce these to fatty alcohols, and are now in the process of characterizing the kinetic properties and post-translational regulatory elements of these enzymes. We are also probing the features of these enzymes that lead to the specificity (or lack thereof) that is found in the terminal enzyme in the pathway.

Adam Kennedy

Bioprocessing is a meticulous endeavor and efficient methods are necessary to minimize waste and take full advantage of capacity and resources. Maximizing the production of proteins, biomolecules and biofuels in cell culture and fermentation systems remains empirical and requires multiple rounds of systematic analysis to resolve issues pertaining to production and product quality. Metabolomic profiling provides a wealth of information regarding the biochemical characterization of a system and analysis of small molecules can provide early indication of the ensuing phenotypic changes, thereby guiding and improving strain design and selection, process development and scale up to improve overall productivity. Metabolon's global metabolomics platform is used to gain knowledge of biochemicals affecting cell metabolism at all stages of bioprocess development and production and in a large variety of expression systems including bacteria, yeast, algae and mammalian cells. Global profiling allows for the detection of the maximum number of metabolites in a system and tracking these changes over time can resolve potential interactions/cross-talk between pathways. For example, as systems become deprived of specific metabolites, others are catabolized to substitute for the depleted metabolites. Biochemical changes can also be correlated to performance data (e.g. production over time, cell viability, pH) to strengthen biomarker identification. Additionally, biochemical profiling of raw materials such as base and feed media components can identify differences which can be correlated to bioreactor performance. Changes in the biochemical profile can be utilized, leveraged and integrated in bioprocessing and fermentation systems to improve production and product quality.

Monday, April 30, 2012 – 2:30pm to 4:00pm

Bioprocess Production Improvements

Moderator: Lynn Bergeson, Bergeson & Campbell, P.C.

Advances in Recombinant Protein Production and Applications Development
Cameron Begley, CSIRO

Pilot Scale Production and Economics of Fermentable Sugars from Biomass
Ian O'Hara, Queensland University of Technology

Process Optimization for Lipase Production from Fusarium Solani (mbl 21) Through Solid State Fermentation Technique
Tehreema Iftikhar, GC University Faisalabad

Virus Contamination as a Major Threat for Productivity of Bioprocesses
Marcin Los, Phage Consultants

Abstracts

Cameron Begley
The pursuit of recombinant protein bio-polymers is entering a new phase of scale and production reliability. CSIRO and its partners have advanced their invertebrate silk platforms (from bee, ant and other species) developing a new level of production and structural control. Furthermore, these proteins are now being produced in industrial production systems that are delivering consistent protein quality for continuous wet spinning and transformation into a range of novel materials for applications including biomedical, technical textiles and defence applications. The key class of alpha-helical silks (patent WO 2007038837) which was introduced at WCIBB Chicago 2008 and advanced at WCIBB Washington 2010 has now moved into continuous fibre production and applications development in addition to ongoing characterization and discovery programs. This paper will update the progress being made on these novel silks.

Ian O'Hara
Sugarcane is one of the best biomass resources for the sustainable production of renewable fuels and chemicals. The co-production of biofuels, green chemicals and bio-products in integrated biorefineries offers opportunities for delivering real benefits in new regionally-based sustainable industries.

Queensland University of Technology (QUT) in Australia has established a $10 million pilot scale biorefinery for research, demonstration and small-scale production of biofuels and bio-products from lignocellulosic feedstocks such as sugarcane bagasse and corn stover. The pilot scale facility is located on the site of a major Australian sugarcane factory and has been operating for 18 months.
The pilot plant has a unique Andritz steam explosion pretreatment reactor capable of demonstrating various pretreatment processes including multi-stage chemical processes, integrated washing and steam explosion. Recent demonstrations of pretreatment processes including two-stage dilute acid, autohydrolysis and alkali-based processes are establishing benchmarks in the cost of fermentable sugar production from biomass. This paper will provide results from the pilot scale pretreatment trials and the impact of recent advances on the economics of fermentable sugars production from biomass for biofuels production.

The Mackay Renewable Biocommodities Pilot Plant is publicly accessible research and development infrastructure and is available for use by public and private sector research and commercial organisations. The facility has been funded by the Australian Government (NCRIS), Queensland Government and QUT with the support of Mackay Sugar Ltd.

Tehreema Iftikhar
The present piece of study has been designed to optimize the cultural conditions for the biosynthesis of extracellular lipases from Fusarium solani through solid state fermentation technique in order to exploit it for industrial usage. This work was done in Laboratory of Mycology and Biotechnology, Department of

Botany, GC University, Faisalabad. Different parameters i.e. incubation temperature, screening of substrates, incubation period, size of inoculum, volume of moistening agent, oils, carbon and nitrogen sources were applied to enhance the extracellular lipase activity. Various agricultural by products were screened to find the best suited substrate for maximum extracellular lipase biosynthesis. Due to presence of high starch contents wheat bran was found to be best for the growth of fungus and subsequently for lipase production. Different oils were used and maximum lipase activity was observed with brassica oil (3.78±0.04a U/mL). Effect of size of inoculum was also observed and maximum activity (4.32±0.05a U/mL) was noted at 2 mL of inoculum size. Maximum activity (5.36±0.10a U/mL) was obtained when fungus was incubated for 2 days (48h) and at 30mL of moistening agent (7.0 ± 0.03 a U/mL). Carbon and nitrogen sources were added in the medium as additional nutrient sources. Nitrogen sources like yeast extract, peptone, urea, NH_4Cl and $NaNO_3$ were applied, resultantly with $NaNO_3$ maximum lipase production (5.17 ± 0.07 a U/mL) was observed. Among carbon sources, $CaCO_3$ was proved to be best, showed lipase activity 7.66 ± 0.24 a U/mL. Incubation period and volume of moistening agent also played an important role to enhance the extracellular lipase activity.

<u>Marcin Los</u>

Contaminations are one of major threats in bioprocesses. If contamination occurs, it may result in complete paralysis of facility productivity. Although even the best protection do not guarantee that no contamination problems will occur, better prepared facility will recover faster, and the contamination will not turn into outbreak. During presentations main types of contaminations wold be presented and causes of contamination occurrence will be analyzed.

Tuesday, May 1, 2012 – 8:30am to 10:00am

Commercial Value Chain Integration

Moderator: Murray McLaughlin, Sustainable Chemistry Alliance

Doug Kemp-Welch, Solutions4CO2

Sandy Marshall, Lanxess Canada

Mike Hartmann, BioAmber

<u>Abstract</u>

Long-term success and viability of renewable and drop-in product businesses must have a solid business plan which includes the ability to manage economic down-turns as well as increased demand. Integration into the value chain with raw material supply, manufacturing clusters and customer sites provide a natural hedge against economic cycles. Integration also provides a significantly better sight and ability to plan and act on future changes and growth opportunities. This panel will speak to their technology and business plan. In doing so, they will also share insights on how they are integrated into their respective value chains. In this panel, Lanxess will share their global perspective and discuss value chain integration in a biohybrid chemistry cluster. Solutions4CO2 will discuss the business of sequestering CO_2 for conversion into higher valued nutra/chemical/fuel products and the integration with multiple technologies. BioAmber will discuss producing succinic acid in a manufacturing cluster with partners to move-up the biochemical building block into higher valued end-use products. Vertichem will discuss the conversion of forestry biomass into drop-in intermediates to supply growing renewables demand in the nutra, chemicals and energy markets.

Tuesday, may 1, 2012 – 2:30pm to 4:00pm

Biopolymers: Current Industrial Developments and Future Options

Moderator: Manfred Kircher, CLIB2021

Patrick Fuertes, Roquette Frères

Jo Kockelkoren, Reverdia

Harald Haeger, Evonik Industries AG

Enzyme Engineering – A Key Enabling Technology for the Sustainable Production of Chemical Products
Marc Struhalla, c-LEcta GmbH

<u>Abstracts</u>

Currently biopolymers represent only a niche in the total production volume of plastics. However, platform chemicals like succinic acid are on the way to bulk volumes and new high performance polymers capture additional market segments in sports, medicine and technical equipment. Another big market to be adressed in this field are plastics additives. All these developments are pushed (i) by the feedstock change which asks for the use of renewable feedstock instead of fossil carbon sources and (ii) the need to fill the product pipeline. This panel will present the current industrial development, it will give market insight and discuss future options in the field of biopolymers.

<u>Marc Struhalla</u>
The role of biotechnology for the production of chemicals products nowadays is becoming more and more important: From the synthesis of complex specialty chemicals by biocatalysis or biotransformation to the fermentative production of renewable chemicals. Applications range from food, feed and active pharmaceutical ingredients to bioplastics and biomaterials. Enzyme engineering is considered as a key enabling technology for the current and next generation of sustainable chemical products. Improving, adapting and changing enzymes by means of directed evolution is a technology segment which in the last decade has very rapidly and dynamically developed. Nowadays a powerful toolbox of methods is available which allows to rapidly and efficiently developing new proteins with desired catalytic properties in short timeframes. The talk gives an overview of recent technological developments and trends in the field of enzyme engineering. Different strategies and successful application examples will be introduced to demonstrate the power of this key enabling technology in the field of industrial biotechnology.

Wednesday, May 2, 2012 – 10:30am to 12:00pm

Alternative Feedstocks for Biorefineries

Moderator: Bill Baum, Genomatica

Investment Decision-Making for the Triticale Biorefinery: Productivity of Triticale Crop for Industrial Value Chaings
Francois Eudes, Agriculture and Agri-Food Canada

Carl Rush, Waste Management

Michele Rubino, Chemtex

Ajay Kshatriya, bio Architecture Lab, Inc.

Abstracts

Francois Eudes
Few crops have a competitive advantage as feedstock supply in the bioenergy-bioproducts economy, in northern latitudes having short growing seasons such as Canada. One crop having significant promise is a triticale, having a more vigorous and higher biomass yield than either of its progenitor species, and havinga n excellent outpout to input ratio. This second-generation lignocellulosic biomass is made of lignin (23%), cellulose (C6 glucose polymer, 40.6%) and hemicellulose (C6 and C5 polymers, 27%). Following deconstruction of these polymers, the chemistry of simple sugars leads to biochemicals and/or biopolmers, or can be fermented to biofuels. the amount of fermentable cellulose and hemicellulose per unit of land or input energy are critical for teh regional success of the triticale platform, on global competitive basis. Genetic engineering tools and classical breeding must be deployed to reduce lignin content, to enhance the overall biomass productivity, and accelerate the cycle of new variety development. The integration of biotechnologies, e.g. genomics information and genetic engineering, to this species can accelerate the yild gain and expend the genetic diversity of triticale for designing industrial triticale. This presentation provides an overview of the state-of-the-art in the genetic engineering of triticale.

Technical Presentations

Sponsored by Novasep

Monday, April 30, 2012 – 8:30am to 10:00am

Bioprocess Engineering and Scale – up

Advanced Purification Technologies For Your Bio-Based Chemicals
Thibault Lesaffre, Novasep

Davy Process Technology; Commercialising Process Technologies
Iain Gilmore, Davy Process Technology

Novel Green Materials from Lignin and Agro Based Resing Hybrid: Processing and Characterization
Manju Misra, University of Guelph

ß-poly (malic acid) production by fed-batch culture of Aureobasidium pullulans ipe-1
Yinhua Wan, Institute of Process Engineering, CAS

Abstracts

Thibault Lesaffre
Biomass is of extremely diverse nature. Transforming biomass through chemical or biochemical catalysts leads to mixtures of impure products: fermentation broths, biomass hydrolysates, and chemical reaction mixtures. On the other hand, bio-based chemicals must be very pure to enter the value chain and be transformed into end products!!
This is the challenge that every company developing a bio-based product is facing.

Novasep's advanced purification technologies can fill this gap!

Novasep is specialist in solving purification challenges, from process development to industrial installations, and from laboratory equipment to turnkey plants.

We provide process development and engineering services, equipment and contract manufacturing services, for the biopharma and industrial biotech industries.

Our unique know-how in separation and purification technologies includes membrane filtration, chromatography, ion exchange, adsorption, electrodialysis, evaporation and crystallisation. We use our proprietary computer modelling tools to speed up your process development and optimization.

Success stories that we may develop in the presentation:

- Organic acids purification by Continuous Ion Exchange: succinic acid, gluconic acid
- Polyols desalting and purification by industrial SSMB chromatography

- Cellulosic sugars separation and purification by industrial SSMB chromatography: C6 and C5 sugars, separation of xylose and arabinose
- Hydrolysis enzymes recovery by ceramic membrane filtration: highly preserved enzymatic activity recovered from cellulosic biomass hydrolysates
- Fermentation broth clarification with ceramic membrane filtration

These examples will show how Novasep integrates the purification operations with the upstream process, to maximize efficiency, minimize waste and improve the overall process economics.

<u>Iain Gilmore</u>
Davy Process Technology's (Davy) presentation will introduce Davy, its Technologies including and emphasising its Bio-Technologies. The presentation will describe Davy's business model and its strengths in research and development, process engineering, engineering and licensing of it technologies. The presentation will further describe how Davy develops its technologies from bench scale units through mini-plants to the design of the commercial unit and how Davy successfully transfers the information to enable a detailed engineering contractor to design and construct the plant.

<u>Manju Misra</u>
Authors: Manju Misra, Harekrishna Deka, Xiogang Luo and Amar K. Mohanty (Address: School of Engineering, Thornbrough Building, University of Guelph, Bioproducts Discovery & Development Centre, Dept. of Plant Agriculture, Crop Science Building, University of Guelph, 50 Stone Road E, Guelph, ON, N1G 2W1, Canada)

Lignin, the second most abundant natural biopolymer in the world, serves as a matrix component for cellulose and hemicelluloses in plant cell walls and provides mechanical strength to biofibres. Currently, about 70 million tons of lignin is generated annually as a co-product in the paper pulp industry . Furthermore, in order to fulfill the demand for lignoncellulosic bioethanol in the United States in the near future, about 225 million tons of lignin generation is expected from the cellulosic bioethanol industry. Only about 2% of the generated lignin is being used for value added applications while the rest is used as burning fuel in the same generating industry. Sustainability of these industries greatly depends upon the value added applications of this co-product. Lignin is an amorphous substance that has potential for material applications. It is a complex polyfunctional macromolecule which is composed of a large number of polar functional groups. Utilizing the functionality of lignin, a series of novel lignin based bioblends/biocomposites have been developed in our laboratory and show tremendous promise for applications in automotives and housing. In this work; three different lignin hybrids are developed from either poly(furfuryl alcohol) or -bio-based polyurethane (PUR) matrices, and various natural fibers and nano fibres as reinforcements are incorporated. All of the processed bioblends/bionanocomposites showed higher static and dynamic mechanical properties as compared to the neat matrix containing the same amount of bioresins. This presentation highlights innovative value added non-food industrial applications for underutilized vegetable/plant deri

<u>Yinhua Wan</u>
ß-Poly (malic acid) (PMLA) is a biopolyester which has attracted growing industrial interest for its potential applications in medicine and other industries. To enhance PMLA production, effects of temperature, exogenous addition of metabolic intermediates and inhibitors, sugar substrates and fermentation modes on PMLA production by A. pullulans ipe-1 were investigated. The results showed that 27.5 ? was concluded to be a temperature threshold for PMLA production. Exogenous addition of L-

malic acid, succinic acid, trifluoroacetic acid and avidin didn't significantly affect, while pyruvic acid and biotin inhibited PMLA production, indicating that PMLA biosynthesis was probably related to phosphoenolpyruvate (PEP) via oxaloacetate catalyzed by PEP carboxylase. Sucrose was most suitable for PMLA production, while fructose gave a higher yield of PMLA basing on the amount of PMLA produced per biomass. Compared to batch culture, fed-batch culture with fed-solution containing mixed glucose and sucrose led to 23.9% increase in PMLA concentration, reaching 63.2 g/L with a productivity of 0.88 g•h-1•L-1.

Monday, April 30, 2012 – 10:30am to 12:00pm

Commercial Scale Production of Renewable Chemicals

2012 – Commercial-scale Production of Sustainable Chemicals Is Here
Christophe Schilling, Genomatica

Biolatex® Binders: Next Generation Breakthrough Using Nano-starch Technology
Alexander Tseitlin, Ecosynthetix

Scaling a Catalytic Oxidation Platform for Novel & Drop-In Chemicals
Steve Donen, Rivertop Renewables

Driving innovation at Evonik and serving bioeconomy markets
Peter Nagler, Evonik Industries

Abstracts

Christophe Schilling
Plants expect to start making tens of thousands of metric tons per year of sustainable chemicals in 2012. Hear the details from four of the first plant operators and technology companies positioned to achieve that landmark.

Alexander Tseitlin
This paper describes a family of unique polymeric binders based on renewable natural raw materials that are re-engineered on a molecular level. Biolatex® binders provide a truly sustainable bio-based alternative to petroleum-based latex materials. Specially designed biolatex® binders can offer improved performance with simplified formulations, thereby enabling partial or full replacement of fossil fuel based binders in wide variety of industrial applications at lower cost. In addition, tailored biolatex® materials can be developed as a curable composition of multifunctional nano-particles that are easily dispersible in water to desired concentrations between 4 and 50 wt%. The biolatex® binders have broad utility in many industrial applications and can be used in paper coating, paper impregnation, building insulation, roofing fiberglass mat or a nonwoven filtration material as well as in customizable high-value specialty products. Options of fine molecular tailoring for specific applications will be discussed.

Steve Donen

Rivertop Renewables is scaling-up its proprietary catalytic oxidation process capable of producing a platform of novel sugar acids and drop-in organic acids. Rivertop's first application of the technology is to convert glucose to glucaric acid (A.K.A. saccharic acid).
The advantages of this re-invented technology include high product yields, feedstock flexibility, safety, efficiency and regeneration and recycling of the reagent. Utilizing off-the shelf equipment and adapting proven units of operation, Rivertop is scaling-up along parallel routes to commercialization: contract manufacturing will supply commercial volumes to early adopters starting in Q4 of 2012, and Rivertop will demonstrate an optimized process at the company's facilities in Montana prior to building a world-scale plant.
The feedstock flexibility of the technology enables Rivertop to produce a series of C-6 and C-5 chemicals and bio-based versions of commercial petrochemicals. Rivertop's oxidative environment is insulated from complications caused by carry-over products that may be produced when using less refined feedstocks.

<u>Peter Nagler</u>
Driving innovation at Evonik and serving bioeconomy marketsEvonik, the creative industrial group from Germany, is one of the world leaders in specialty chemicals. Its activities focus on the key megatrends health, nutrition, resource efficiency and globalization. In 2010 about 80 percent of the Group's chemicals sales came from activities where it ranks among the market leaders. Evonik benefits specifically from its innovative prowess and integrated technology platforms. Evonik is active in over 100 countries around the world. In fiscal 2010 more than 34,000 employees generated sales of around €13.3 billion and an operating profit (EBITDA) of about €2.4 billion.Evonik is active in bioeconomy. Evonik's portfolio comprises amino acids and derivatives, active pharmaceutical ingredients (APIs), (bio)catalysts/products for the production of biofuels and platform chemicals, biobased polyamides, biobased polyester polyols for coatings/adhesives, cosmetics actives, emollients, enzymatically produced chirale α- and β-amino acids/chirale alcohols/chirale amines, peptides and keto acids for pharma/food/cosmetics, pharmaceutical aids for peroral/parenteral controlled release drug delivery systems, and surfactants.We will illustrate how Evonik innovates and serves the bioeconomy markets. According to OECD bioeconomy comprises three segments - health, agriculture, and industry. To say it in short: Evonik is active in all three segments of bioeconomy. We will describe the products Biolys®, DYNOCOLL® Terra, RESOMER®, ThreAMINO®, TrypAMINO®, and VESTAMID® Terra. Evonik delivers high performance products to its customers. An important performance attribute is sustainability. We will illustrate life cycle assesement characteristics for Evonik's amino acids and biobased polyamides. Another important benefit to the customer is global supply security. We will describe Evonik's global amino acid supply network and long tradition in large-scale production of feed amino acids by industrial biotechnology. Finally, we will reflect on general commercializations trends in bioeconomy focussing on disruptive breakthroughs in industrial biotechnology and highlight the importance of open innovation clusters such as Cluster Industrielle Biotechnologie CLIB2021.

Monday, April 30, 2012 – 2:30pm – 4:00pm

Potential Feedstocks for Bioethanol

Pre-treatment Studies for the Bioprocessing of Sweet Sorghum Non-Grain Biomass
Praveen Vadlani, Kansas State University

Direvo BluCon-P: A Set of Extreme Thermophilics Converting Wood, Agricultural and Industrial Residues into Biofuels and Commodity Chemicals in a One-step Consolidated Bioprocess

Jorg Riesmeier, Direvo Industrial Biotechnology GmbH

Use of Hemicellulose and Cellulose for Ethanol Production : The Deinococci Platform
Michael Krel, Deinove

Abstracts

Praveen Vadlani
Bioprocessing of lignocellulosic biomass for the integrated production of fuel and other industrially important organic chemicals is critically important to abate the rising prices of fossil fuel, security issues regarding the oil supply, and environmental concerns such as global warming and air pollution. Significant efforts have been made in the production of ethanol fuel using fuel crops like corn and sugarcane. However, as production widens into commercial scale, food or fuel concern triggered the search for a more sustainable feedstocks for biofuel. Lignocellulosic biomass which include the residual non-food biomass from agricultural sector is a potential global alternative feedstock. However, the complex cross linking of the three basic chemical components: cellulose, hemicellulose, and lignin makes the biomass recalcitrant to hydrolysis for further biorefining. Hence, pre-treatment is essential as this converts lignocellulosic biomass from its native form. It basically removes and/or modify the surrounding matrix of lignin rendering the cellulose and hemicellulose more susceptible to enzymatic hydrolysis for further biorefining. In this study, combination of thermo-chemical and bio-chemical pretreatment were evaluated. The objective was to establish the most appropriate process for sweet sorghum bagasse, which will serve as basis for optimization for other agricultural residues. The thermo-chemical pretreatments were Soda, Kraft, and Organoslov with predetermined amounts of chemical catalysts: sodium hydroxide, combination of sodium hydroxide and sodium sulfite, and combination of ethanol and mild sulfuric acid, respectively. They were carried out at constant temperature (170oC), liquid to biomass ratio (10:1), residence time at treatment temperature (60 min), and cooling down (60mins). Hydrothermal process was performed using the same conditions without chemical catalyst and at higher treatment temperature of 200oC. Fiber yield (%) after pretreaBioprocessing of lignocellulosic biomass for the integrated production of fuel and other industrially important organic chemicals is critically important to abate the rising prices of fossil fuel, security issues regarding the oil supply, and environmental concerns such as global warming and air pollution. Significant efforts have been made in the production of ethanol fuel using fuel crops like corn and sugarcane. However, as production widens into commercial scale, food or fuel concern triggered the search for a more sustainable feedstocks for biofuel. Lignocellulosic biomass which include the residual non-food biomass from agricultural sector is a potential global alternative feedstock. However, the complex cross linking of the three basic chemical components: cellulose, hemicellulose, and lignin makes the biomass recalcitrant to hydrolysis for further biorefining. Hence, pre-treatment is essential as this converts lignocellulosic biomass from its native form. It basically removes and/or modify the surrounding matrix of lignin rendering the cellulose and hemicellulose more susceptible to enzymatic hydrolysis for further biorefining.

In this study, combination of thermo-chemical and bio-chemical pretreatment were evaluated. The objective was to establish the most appropriate process for sweet sorghum bagasse, which will serve as basis for optimization for other agricultural residues. The thermo-chemical pretreatments were Soda, Kraft, and Organoslov with predetermined amounts of chemical catalysts: sodium hydroxide, combination of sodium hydroxide and sodium sulfite, and combination of ethanol and mild sulfuric acid, respectively. They were carried out at constant temperature (170oC), liquid to biomass ratio (10:1), residence time at treatment temperature (60 min), and cooling down (60mins). Hydrothermal process was performed using the same conditions without chemical catalyst and at higher treatment temperature of 200oC.

Fiber yield (%) after pretreatment was in a decreasing order from Organoslov (58.75%)> Kraft (51.25)> Soda (38.28) >Water (25.63%). Sugar yields after acid hydrolysis of the pretreated biomass was found highest in Soda (30.22%) and Kraft (29.29%) processes, whereas Organoslov was at 15.37% and hydrothermal at 22.77%, respectively. The different pretreatment processes caused sugar degradation at different extents ranging from 8.29-53%. Also, delignification was effected by the pretreatment protocols and was best observed in Kraft process at 70.72%, Soda at 62.49%; Organoslov at 27%, and hydrothermal at 16.64%. Based on our studies, Soda and Kraft processes provided the most promising pretreatment for sweet sorghum biomass, however, the result using the hydrothermal process is very encouraging.

Jorg Riesmeier

Direvo´s new CBP-approach consolidates all relevant steps for production of 2nd generation biofuels and biocommodities from pretreated biomass into a single tank. Completely eliminating use of costly enzymes, oligo- and polymeric substrates are hydrolyzed generating a cheap sugar source for the subsequent conversion into ethanol, lactic acid and other chemical commodities. The high process temperature eliminates contamination risk and enables in-situ capture of volatile products.

With the necessity to exploit a multitude of lignocellulosic feedstock for production of biofuels and biochemicals being generally accepted, Direvo Industrial Biotechnology followed a carefully designed approach to identifying a set of ideal biocatalysts. Mustering biological samples from hundreds of individual microbial ecosystems, Direvo selected, isolated and identified a versatile set of extremely thermophilic microbes enabling the design of individual substrate- and product-tailored production processes. The BluCon-P microbes produce ethanol, lactic acid and a range of other commodity chemicals from the complete range of polysaccharides available from pretreated biomass. Cellulose and hemicelluloses are effectively broken down to fermentable sugars; C6- and C5-sugars as well as their respective polyols are converted with high substrate- and space-time-yield.

Already by the wild type strains, relevant product concentrations could be achieved. More than 20 different lignocellulosic feedstocks including different types of wood, various agricultural and industrial residues as well as a broad range of energy crops have successfully been tested and converted.

Consolidated bioprocessing (CBP) has the potential to significantly reduce lignocellulose conversion cost by reducing the number of unit operations while eliminating the use of costly enzymes. A high process temperature above 70 °C effectively protects the culture from contamination and allows for integrated recovery of volatile fermentation products like ethanol. Direvo has filed a broad IP portfolio describing the application of three different strain groups discriminated by their respective substrate and product spectra.
Dr. Riesmeier joined Direvo in 2010 from the venture capital firm LSP, Inc. (Boston), where he had been General Partner since 2006. He launched and directed the US office of this $1 billion global venture-capital firm, where he was responsible for developing and

managing a $100 million investment portfolio with a focus on clean technologies, agriculture, platform technologies, food and nutrition, and health. Prior to his position at LSP, Dr. Riesmeier was Head of Business Development at Burrill & Co. (San Francisco), where he held responsibility for both the AgBio and Nutraceutical funds, managing the Bayer account at Burrill and $100 million in venture capital. Previously, Dr. Riesmeier was President & CEO at PlantTec Biotechnologie in Potsdam, Germany (acquired by Bayer CropScience), an €8 million biotech startup that he created and supervised, maintaining leadership through acquisition by Bayer CropScience in 2000 and assuming strategic business development and R&D roles within Bayer. He received his PhD in biochemistry and molecular biology from the Free University of Berlin, Germany.

Michael Krel
For the past three years, Deinove has been developping a fermentation process in order to transform cellulosic and hemicellulosic biomass into ethanol, using the Deinococcus microorganism, one of the oldest living species. Deinove has already achieved the following milestones: creation of an ever-growing library of over 3000 strains with a wide variety of metabolic properties; selection of a unique collection of thermophilic deinococci capable of growing at over 45°C; the identification of many metabolic functions of interest; the implementation of metabolic, genetic and fermentation engineering tools with a view to optimizing the strains' industrial performance levels; broad, international patent applications for protecting these inventions. Hemicellulose in general and C5 sugars in particular represent between 20 and 30% of the total amount of sugar within the cellulosic material. Being able to transform these pentoses into a valuable compound such as ethanol through fermentation is key for a second generation process to become competitive. During this speech, Deinove will discuss why and how hemicellulose stream (on top of C6 streams) are converted into ethanol. Deinove will also present its last significative results toward a consolidated bioprocess using all C5 and C6 sugars to produce ethanol.

Tuesday, Mat 1, 2012 – 8:30am to 10:00am

Feedstock Processing

Integration of Bio-based Syngas, Hydrogen and Energy in Industrial Environments.
Markus Wolperdinger, Linde Engineering Dresden GmbH

Ralph Stöckel, TOTAL Deutschland GmbH

Rene Mank, Bilfinger Berger Industrial Services GmbH

An Efficient Harvesting Method for Microalgae by in Situ Magnetic Separation
Chen Guo, Institute of Process Engineering, CAS

Abstracts

The panel focuses on the scale-up and industrial implementation of a novel hybrid gasification process for the generation of syngas, hydrogen and energy from a wide range of renewable feedstock. The advantages of the process will be described and examples for applications of biogenic gases will be given. The concept of integrating biogenic syngas and hydrogen in industrial manufacturing environments, e.g., petrochemical refineries and chemical manufacturing, as environmentally friendly transportation fuel, or as energy source for the operation of large-scale infrastructures will be explained. In Talk 1, BIS will describe the gasification process and results achieved on the path to commercialization of this technolgy. Talk 2 by Linde focuses on aspects associate with the scale-up from pilot- to industrial scale and the integration of bio-based products in industrial environments. Talk 3 by Total will provide examples for the utilization of biogenic hydrogen in the petrochemical environment.

Chen Guo
A simple and rapid harvesting method by in situ magnetic separation with naked Fe_3O_4 nanoparticles has been developed for the microalgal recovery of Botryococcus braunii and Chlorella ellipsoidea. After adding the magnetic particles to the microalgal culture broth, the microalgal cells were adsorbed and then separated by an externally magnetic field. The maximal recovery efficiency reached more than 98% for both microalgae at a stirring speed of 120 r/min within one minute, and the maximal adsorption capacity of these Fe_3O_4 nanoparticles reached 55.9 mg-dry biomass/mg-particles for B. braunii and 5.83 mg-dry biomass/mg-particles for C. ellipsoidea. Appropriate pH value and high nanoparticle dose were favorable to the microalgae recovery, and the adsorption mechanism between the naked Fe_3O_4 nanoparticles and the microalgal cells was mainly due to the electrostatic attraction. The developed in situ magnetic separation technology provides a great potential for saving time and energy associated with improving microalgal harvesting.

Tuesday, May 1, 20120 – 2:30pm to 4:00pm

Global Innovative Clusters: Canada, India, China, Australia, United States

TRANSFORMING CANADA'S FORESTRY SECTOR – Bio-energy and Bio-products: Good for the Planet, Job Creation and Bottom Line
Jon Flemming, Forest Products Association of Canada

Global Innovative Clusters: India
Pramod Chaudhari, PRAJ

China's New Invention Landscape - An Analysis of the Chinese Patent Database to Identify Geographical Distribution, R&D Development, and Actors' Dynamics Within the Field of Biotechnology in China
Mats Lindgren, Kairos Future Group

Opportunities for Establishing Biorefineries in Australia
Cameron Begley, CSIRO

Phil Sheridan, Biofuels Center of North Carolina

Abstracts

Jon Flemming
The Forest Products Association of Canada recently released a breakthrough study showing how the Canadian forest sector can become a pivotal player in tomorrow's marketplace by thriving in the new

bio-age. The bio-economy is an exploding global market worth trillions of dollars that reflects a growing environmental sensibility and a paradigm shift towards products that come from natural renewable sources. The study, called The New Face of the Canadian Forest Industry: the Emerging Bio-Revolution, demonstrates how the forestry industry of Canada is uniquely positioned to take advantage of the new bio-economy and exploit a potential global market of around $200 billion for bio-energy, bio-chemicals and bio-materials that can be extracted from trees. These products include everything from renewable fuels to lightweight plastics, non-toxic chemicals and food additives. This study has extraordinary implications for Canada's future prosperity, producing a roadmap for a new business model that consolidates the economics of wood and pulp and paper production by extracting additional economic value from each tree harvested. This will have a huge economic, environmental and social impact. The report is the second phase of an exhaustive research study on how to best position the next generation forest products industry by extracting maximum value from every tree. Phase one broke new ground by showing the economic and job benefits of adding new high-value products into existing lumber and pulp and paper mills. These integrated operations could increase the job potential by up to five times that of stand-alone bioenergy plants. Phase two shows there are markets for these add-on products and documents the path forward. The presenter will review the opportunities available for the environment, forestry workers, communities and the economy at large, as well as discuss new opportunities for the forest sector and energy sector to collaborate to green the energy supply chain.

<u>Pramod Chaudhari</u>
The world is getting more and more connected. At a recent meeting of Global Growth Companies, it was rightly pointed out that growth will be a factor of how networked is the innovation engine to the global innovation system.

Each regional innovation cluster will have to be viewed in light of its global positioning, like the Indian Innovation Cluster. It is fast emerging as the center of innovation for Pharma Biotech and Chemicals and lately IT. Innovation Clusters did take some time to come to India, but it is now taking a focused direction. Innovation was more a purview of Government R & D Laboratories. Their perspective was guided substantially by Government funding and policies. Today, Innovation has become the watchword in the private sector with Government acting more as an enabler, providing infrastructure and policy directions.
The earliest form of cluster functioning was more focused upon indigenization which soon transformed into efficiency improvement and we now see the third phase which is focused upon basic innovation.

The Department of Science and Technology (DST), Ministry of Science & Technology plays an important role in promoting Innovative Clusters. They have initiated a Programme on "Promoting Innovative Clusters" (PIC) with a vision to promote collective research, development and commercialization among MSME clusters to promote production of high value goods and services using the innovation route. Investment in knowledge creation, acquisition, absorption and diffusion is critical for this purpose. This project aims to promote collective research and learning in clusters by facilitating linkages among enterprises and develop new and high value added products aimed at national and global markets.

Some of the leading innovative clusters include the pharmaceutical clusters of Ahmedabad-Vadodara (State of Gujarat), Hyderabad (State of Andhra Pradesh); Information and Communication Technology (ICT) cluster of Delhi-NCR and three foundry industry clusters of

Samalkha, Faridabad and Kaithal (all in State of Haryana).

India has undergone a major structural change with stronger IP protection laws, creation of infrastructure at par with global standards, providing fiscal incentives and creating a climate which would promote spillover from the benefit of such clusters. Being the largest market in the world makes it the most appropriate destination for such clusters to exist. Quality of manpower is yet another reason why such clusters have become more prevalent.
Global Innovative Clusters are also a good way to attract inward foreign investment and sustain it.

Mats Lindgren
Background:
Innovation is the very core of China's new development strategy, the next phase of the country's reform and opening up. But can it, as China's government hopes, bring about a "great renaissance of the Chinese nation" and turn it into a technology powerhouse by 2020? Lack of IP enforcement and an emphasis on rote learning in education, have long been causes for skepticism, but with a recent string of successful lawsuits over IP infringement, and a rising number of returnees from overseas, such concerns are voiced less frequently. The question is whether innovation in China will come from the top or the bottom, as well as within what fields and regions.
Method:

In the study underlying the presentation, we have used the complete database of Chinese invention patents, including its abstracts. We wanted to examine how the patent database is growing exponentially, diversifying geographically and technologically, and to what extent patenting is migrating away from state enterprises towards private entrepreneurs.

Key Results:

• What is the geographical distribution of patenting in China?

We have found, the center of gravity of innovation in China is shifting away from the three main poles of innovation - Beijing, Shanghai, and Shenzhen. Their share of domestic patents has declined from 40% in 2000 to 20% in 2010. 32 cities are represented on the top-50-list of clusters, many of them lower-tier cities in coastal provinces and larger cities in central and western China.

• What are the technology trends within invention patenting in China?

There are four main types of inventive clusters in Mainland China: (1) diversified clusters in tier 2 cities; (2) knowledge intensive ICT and electronics clusters; (3) inland innovation clusters in agricultural tech, biotech, foodstuff, and tobacco; and (4) manufacturing-based clusters in the Pearl and Yangtze River Deltas. Rising research and development trends include LED, solar and wind power, batteries, vehicle technology, and improved manufacturing systems and equipment.

• What does the innovation actors' landscape in China look like?

This part of the presentation looks at who drives innovation in China. We have compared the activities of universities, research institutes, companies, and other actors. The composition of China's innovation system is changing. Public research institutes contributed a third of domestic patents in 1985, but have experienced a relative decline since then. Universities increased their share of patenting between 1997 and 2005, after which it has remained steady at around 17%. Companies have changed from an obscure to a dominant force behind patenting in China, holding 56% of domestic patents in 2010. The annual number of patenting companies exceeded 35,000 in 2010, with an average growth rate of 32% since 2000. Since 2005, the share of domestic patents accounted for by the 10% largest corporate inventors has fallen from 72% to 53% in 2010 and 40% for the first half of 2011.

Conclusions:

With innovation hotspots springing up all over the country, this study makes the case it is justified to speak about a race, rather than a march, up the value-chain in China. Innovation is spreading geographically, exploring new fields of technology, and involving an increasing number of private patent holders. These are general developments, also affecting the biotechnology industry. The study enables us to examine biotechnology more specifically before the conference.

<u>Cameron Begley</u>
Australia is a large country with plentiful sunshine, substantial existing biomass and land for extension into future stocks. Recently the Government has committed to reducing greenhouse gas emissions through a carbon pricing mechanism commencing in July 2012. This mechanism, together with government funding for technology innovation, is likely to lead to significant investment in low carbon technologies.

Three of Australia's leading research and development institutions have come together to form the Australian Biorefineries Research Alliance (ABRA) to promote the establishment of biorefineries taking advantage of local resources and advanced infrastructure and skills platforms. The alliance consists of Monash University, Queensland University of Technology (QUT) and CSIRO, bringing a close connection to tropical and temperate biomass stocks and their cultivation, collection logistics and chemical and physical characteristics. The Alliance possesses detailed understanding of Australian biomass stocks, cost-curves and sustainable harvesting strategies and emphasis is placed on utilising intermediate platform chemicals enabling the biorefinery to operate efficiently year round, while accepting a wide range of biomass types.

ABRA key skills platforms include:

- Green Chemistry
- Industrial Biotechnology
- Carbohydrate Chemistry
- Genetic and Metabolic Engineering
- Heterogeneous Catalysis
- Pulp and Paper Processing
- Bio-Process engineering - modelling, integration and economics
- Advanced Materials
- Thermochemical processing
- Sustainability

Major Infrastructure includes:

- Renewable Biocommodities Pilot Plant

- Fermentation Pilot Plants
- Gasification pilot plants
- The Australian Synchrotron
- The Green Chemical Futures Building
- Extensive laboratory facilities and instrumentation

Major research centres:

- The Centre for Tropical Crops and Bio-commodities
- Institute for Sustainable Resources
- The Australasian Pulp and Paper Institute
- Green Chemistry Centre
- Monash Sustainability Institute

We have formulated an integrated biorefinery approach which includes fuels and chemical streams. The major strategic focus will be on chemicals production from biomass, particularly aromatics and olefins and products derived from them.

ABRA, working with industry partnerships, sees innovation in this sector as providing opportunities for the establishment of new biorefinery industries targeting the rapidly growing Asian and global markets.

Wednesday, May 2, 2012 – 10:30am to 12:00pm

Innovative Growth Strategies for Biopolymers and Biofuels

Biobased Chemicals: Assessing Capacity Growth
Ronald Cascone, Nexant

John Bissell, Micromidas Inc.

Abstracts

Ronald Cascone

There is a shift among bio-renewables developers and their partners from interest mostly on fuels to chemicals. Nexant has catalogued global announcements of new capacity for unique bio-based chemicals production through 2015. Nexant also assessed, based on a consistent set of judgment criteria, such as the nature of technology, number and types of developer partnerships, etc., the likelihood that individual announced projects will actually be accomplished and on schedule. Nexant will also present a panorama of many of the key developments in the sector and how they “flange up” or compete with the existing petrochemicals value chains.