

2010 Annual Meeting Abstracts

Industrial Oil Products

MONDAY

MORNING

IOP 1: Alternative Fuels

Chair(s): R.O. Dunn, USDA, ARS, NCAUR, USA; and B.R. Moser, USDA, ARS, NCAUR, USA

Biodiesel from Alternative Oilseed Feedstocks: Production and Properties. B.R. Moser, G. Knothe, S.F. Vaughn, USDA, ARS, NCAUR, Peoria, IL, USA

Fatty acid methyl esters were prepared and evaluated as potential biodiesel fuels from several alternative oilseed feedstocks, which included camelina (*Camelina sativa* L.), coriander (*Coriandrum sativum* L.), field mustard (*Brassica juncea* L.), field pennycress (*Thlaspi arvense* L.), and meadowfoam (*Limnanthes alba* L.) oils. Coriander and meadowfoam oil methyl esters were enriched in the unusual fatty esters methyl petroselinate (6Z-octadecenoate) and methyl 5Z-eicosenoate, respectively, whereas field mustard and field pennycress primarily consisted of methyl erucate (13Z-docosenoate). Camelina was comprised primarily of methyl linolenate (9Z,12Z,15Z-octadecatrienoate) and methyl linoleate (9Z,12Z-octadecadienoate). Fuel properties measured using standard methods included oxidative stability, low temperature operability, kinematic viscosity, cetane number, sulfur and phosphorous contents, acid value, free and total glycerol content, iodine value, heat of combustion, lubricity, and Gardner color. Coriander and especially meadowfoam oil methyl esters exhibited excellent oxidative stability, as indicated by induction periods (EN 14112, 110 °C) of 14.6 and 41.5 h, respectively. Lastly, a comparison to biodiesel fuel standards such as ASTM D6751 and EN 14214 was also made.

Biodiesel Derived From a Source Enriched in Palmitoleic Acid, Macadamia Nut Oil. G. Knothe, USDA, ARS, NCAUR, USA

Biodiesel is an alternative diesel fuel commonly produced from commodity vegetable oils such as palm, rapeseed (canola) and soybean. These oils generally have fatty acid profiles that vary within the C₁₆ to C₁₈ range. Thus, biodiesel fuels derived from these oils possess the common problems of poor cold flow and oxidative stability with varying severity. An approach to improving these problems is to utilize feedstocks with inherently different fatty acid profiles. Decanoic acid and palmitoleic acid are candidate fatty acids for enrichment in fatty acid profiles to improve biodiesel fuel properties. In this work, a feedstock moderately enriched in palmitoleic acid, macadamia nut oil, was utilized. Two macadamia oils with slightly varying palmitoleic acid content (15-20%) were used and the properties of the resulting biodiesel fuels determined. Although some differences were observed for biodiesel from the two macadamia feedstocks, at the present levels of palmitoleic acid in macadamia nut oil, enhancement of biodiesel fuel properties compared to biodiesel from commodity oils did not occur, likely due to the slight content of saturated C₂₀ and C₂₂ fatty acids. This highlights the necessity of reducing long-chain fatty acids to small amounts and increasing amounts of desirable fatty acids in order to improve biodiesel fuel properties.

Triacylglyceride as a Feedstock for Jet Fuel Production. P.D. Pansegrau, T. Aulich, C. Wocken, M. Kurz, B. Oster, Energy & Environmental Research Center, Grand Forks, ND, USA

The Energy & Environmental Research Center has developed a catalytic process for the conversion of crop oils, animal fats, algal oils, and waste greases to specification compliant fuels. The conversion process will be discussed, as well as the future production of low cost feedstocks.

Isolation and characterization of Acylated Steryl Glucosides (ASG) in Oil Seed Crops of Pacific Northwest (PNW). K. Duff, J. Van Gerpen, B. He, University of Idaho Biological and Agriculture Engineering, Moscow, Idaho,

Acylated sterol glucosides (ASG), a form of phytosterols, have been identified in a variety of agricultural products, including the oilseeds of soybean and rapeseed. Currently, there are limited data available on the quality and quantity of phytosterols in oil seed crops. During biodiesel production the esterification of ASG in oil extracts forms sterol glucosides (SG). These sterol glucosides in low concentrations (less than 50ppm) have been implicated in agglomeration of contaminants leading to subsequent filter clogging in biodiesel applications. Limited methods exist for the direct isolation and characterization of ASG. Methods rely on multistep extraction, saponification, acidification and derivatization for evaluation with GC-MS. The objective of this study is to characterize the ASG in agronomically significant oil seed crops of the Pacific Northwest. In this study HPLC-ESI-MS and HPLC-APCI-MS techniques were evaluated as characterization tools. Oilseeds were solvent extracted; the glycolipid fraction was isolated using a preparatory chromatography, and characterized using the validated MS techniques. Characterization of these natural products is important to the industry for developing strategies to minimize agglomeration in biodiesel.

Detection and Characterization of Selected Contaminants in Biodiesel. Michael J. Haas¹, Stephen Kasprzyk², Robert A. Moreau¹, ¹USDA, ARS, Wyndmoor, PA, USA, ²BlackGold Biofuels, Philadelphia, PA, USA

The biodiesel industry is facing new challenges in regard to feedstock and fuel quality: (1) As this fuel has gone from a small-volume research material to a component of the national fuel system it has been subjected to new handling procedures, such as extended low temperature incubations, that have caused new performance problems associated with the presence of previously unappreciated contaminants. Chief among these are the sterol glucosides. (2) Concerns over feedstock cost have recently led to an increased use of less expensive lipid-rich materials as feedstocks. However, these are often contaminated by species chemical structures not found in the refined and high quality lipids traditionally used in biodiesel production. These materials can complicate biodiesel production and compromise the quality of the product. This presentation will describe our studies on the presence of sterol glucosides in biodiesel samples and associated precipitates that may cause fouling during biodiesel production, storage, and distribution. We will also describe our experiences with the variable composition of trap grease, an extremely low value new feedstock for biodiesel production.

Testing of Biodiesel in Engines with Modern Emission Control Equipment. A. Williams, J. Burton, R.L. McCormick, National Renewable Energy Laboratory, Golden, CO, USA

Tests were conducted to study the impacts of biodiesel on emissions and fuel consumption for a Cummins ISB and an International MaxxForce 10, both 2008 model year. They utilize exhaust gas recirculation (EGR) for NO_x emissions reduction and actively regenerated diesel particulate filter (DPF) to reduce PM emissions. The engines were tested over the heavy-duty transient (HDT) test cycle in accordance with the Federal Test Procedure (FTP) for emissions certification on an engine dynamometer. Testing was carried out with various fuels including 2007 certification ULSD as the baseline fuel, B20 biodiesel from four feedstocks, soy, yellow grease, beef tallow, and camelina. In addition, a high-aromatic diesel, a low-aromatic diesel and a winter diesel were tested. Results indicate the DPF and diesel oxidation catalyst eliminated any effect of the fuel on tailpipe out emissions of THC, CO, and PM from both engines. Biodiesel's effect on NO_x ranged from a 0 to 2% increase. The fuel economy penalty while operating with B20 blends was approximately 2% for both engines. When a DPF regeneration event occurred during the heavy-duty transient cycle, NO_x emissions increased approximately threefold, independent of fuel type. The fuel economy penalty for DPF regeneration was estimated at 3% to 4%.

The Effects of Illumination Intensity and Period on Growth Rates and Fatty Acid Composition of the Microalgae. Haiying Tang, M. E. Danton Garcia, Ansheng Li, Hongzhi Ma, Meng Chen, Nadia Abunasser, Steven Salley, Simon Ng, Wayne State University, Detroit, MI, USA

Alternative, non-food based biomass fuel feedstock development is vital for our national security, economy and the environment. Microalgae are among the most promising of these alternatives. Microalgal cell growth rates and fatty acid content are affected by a combination of environmental parameters. In this work, the influences of light source, light intensity, CO₂ concentration, and photoperiod on the growth of *Dunaliella tertiolecta* (*D. tertiolecta*) were

studied. Moreover, the fatty acid methyl ester (FAME) content and composition of *D. tertiolecta* biodiesel was investigated with environmental parameters. Red light-emitting diodes (LEDs), white LEDs, and fluorescent lights all were effective for algal growth. Increasing light intensity significantly resulted in more rapid algal growth, while increasing the period of light also significantly increased biomass productivity. Similar growth rates were observed for 2%, 4%, and 6% CO₂ concentrations. Moreover, the different light source and intensity had no significant effect of FAME composition of *D. tertiolecta* biodiesel. The higher light intensity produced the higher biodiesel yield. The methyl linolenate and methyl palmitate are the major components of *D. tertiolecta* biodiesel and makes *D. tertiolecta* biomass a suitable feedstock for biodiesel production, however, a high content of unsaturated chains (such as C18:3) was found in *Dunaliella tertiolecta* biodiesel.

Low Pressures Catalyst for Deoxygenation of Pyrolysis Oils. W. Holmes, M.G. White, Mississippi State University, Mississippi State, MS USA

A catalyst has been prepared and characterized which will partially remove the oxygen atoms from the liquid phase products of biomass pyrolysis. The results from a model compound study in a micro reactor show that the converted products are alkanes, alkenes, and aromatics. The catalyst from these studies shows a certain amount of coke on the catalyst after brief testing. When these tests were repeated using a real pyrolysis oil very little coking was observed even though the pyrolysis oil had not been filtered or treated in any way. It appeared that the phenolic derivatives in the pyrolysis oil had been converted to substituted benzenes and naphthalenes.

Solubility Limitations of Saturated Monoglycerides in Biodiesel During Cold Weather. R.W. Heiden, Ph.D., R.W. Heiden Associates, LLC, USA

The formation of precipitates that block fuel filters above the cloud point represents an important challenge to the cold weather operability of biodiesel fueled vehicles. Normally, cold weather limitations of biodiesel fuels are predicted by standard cloud point/pour point, and cold soak filtration (CSFT), but these tests fail to predict the impact of the temperature on the solubility of some important impurities. Saturated monoglycerides (SMG's) are identified in previously reported work (1) as the prime factors in incidents of fuel filter blockages that struck fleets of maintenance vehicles using B-20 in the eastern part of the U.S. in 2006. Our initial studies of the temperature dependence of the solubilities of monopalmitin and monostearin in B100 and various blends are reported there. Now, two years later SMG's on filters are an important concern to the biodiesel industry and the solubility of SMG's has come to the forefront. We present here data that defines the magnitude of the SMG challenge. We have systematically studied the effects of various conditions that determine the SMG solubility in B-100 and various blends. The results of these studies are discussed.1) R. W. Heiden, "Impurities In B20 That Cause Filter Plugging In Cold Weather", The International Congress On Biodiesel -The Science and Technology, Vienna, November 5-7, 2007.

Low Temperature Oxidation of Biodiesel Surrogates in a Motored Engine. Y. Zhang, A. Boehman, The EMS Energy Institute, The Pennsylvania State University, University Park, PA 16802, USA

Low temperature oxidation of biodiesel surrogates (i.e., C7, C8 and C10 esters) was studied in a motored CFR engine. Within the test range of this study, pronounced cool flame behavior was observed from the oxidation of saturated esters. The comparison on the ignition behavior between saturated and unsaturated methyl esters revealed that the presence of unsaturation in the aliphatic chain of fatty acid esters inhibits their low temperature reactivity. Furthermore, the inhibition effect becomes more pronounced as the double bond moves toward the center of the aliphatic chain. Qualitative and Quantitative analyses of the reaction intermediates from the low oxidation of saturated esters showed that the aliphatic chain of saturated fatty acid esters experiences paraffin-like low temperature oxidation steps. Moreover, it is observed that the abstraction of H-atoms on the α -carbon of the ester carbonyl group plays an important role in the oxidation of saturated fatty acid esters. In contrast, for unsaturated esters, the autoignition can undergo olefin ignition pathways.

Study of the Effects on Oxidative Stability Biodiesel Blends Using Synergistic Antioxidants in the Presence of Metallic Prooxidants. R.C. de Guzman, H. Tang, S.O. Salley, K.Y.S. Ng, Wayne State University, Detroit, MI, USA

Biodiesel produced from animal and plant lipids retains the fatty acid profile of the source lipid. As a result, this bio-based fuel also retains its susceptibility to oxygen degradation mediated by air, heat, light and metallic contaminants. Among these factors, metal contaminant catalysis of autoxidation has the potential to be detrimental even at very low levels. This study reports the catalytic activity of Al, Cu, Fe and Zn in their nitrate form in reducing the oxidative stability, as measured by the induction period (IP) of soybean oil (SBO) based biodiesel blends with and without the antioxidant (AOx) tert-Butylhydroquinone (TBHQ). Results indicate that the catalytic effect of the metals follow the hierarchy: Cu >> Fe > Al ≈ Zn. The IP drops resulted mostly from the metals degrading TBHQ followed by the direct attack on the lipid producing radicals and metal transition states that further speed up the chain reaction. In B20, ultra low sulfur diesel (ULSD) proved to be invaluable in maintaining the oxidative stability by minimizing the metal attack on both the SBO component and its AOx.

Degradation of Biodiesel Blends. J. Krahl^{1,2}, A. Munack², L. Schmidt², ¹Coburg University of Applied Sciences, Coburg, Germany, ²Federal Research Institute for Rural Areas, Forestry and Fishery, Braunschweig, Germany

The degradation of RME and its blends were analyzed. In detail, 250 mL of RME were artificially aged by an ambient air bubble stream (200 mL/min) for 40 h at 110 °C. This aging process was spectroscopically traced by UV-Vis and FTIR. Subsequently the oxidized RME was blended with different diesel fuel components in different concentrations to analyze the appearance and the weight of occurring deposits. UV-Vis and FTIR spectra showed a correlation between the degradation of antioxidants and the formation of oxidation products during the aging process. After 4 hours of aging the antioxidants are mostly degraded and the formation of oxidation products significantly begins in term of deposits. Furthermore deposits of oxidation products accumulate in blends with highly nonpolar diesel fuel components like GtL and HVO. A maximum of deposit mass was found between 5 and 15 volume percent of RME in the blends, depending on the diesel fuel component. The interpretation could be made as follows: The antioxidants in RME firstly avoid the formation of oxidation products until they are degraded. Beyond this point the use of oxidized RME in blends forms deposits with nonpolar blend components. This is due to the change of polarity of the blends and the solubility of the polar oxidation products. The reason for the different maxima in deposit formation by the use of different nonpolar mixing components is due to the different polarities of these components.

AFTERNOON

IOP 2: Bio-based Lubricants, Plasticizers, and Value-added Products

Chair(s): D. Kodali, Global Agritech Inc., USA; and Z. Guo, Aarhus University, Denmark

Sustainable Plasticizers. L. Wiebe, Danisco, Grindsted, Denmark

For the past many years phthalates have been used as plasticisers for PVC, but now recent research has revealed that some of the phthalates can be harmful to human beings. In this context Danisco has developed a plasticiser, which can replace phthalates in a wide range of applications, without possessing these harmful properties. The first generation of a sustainable plasticizer is based on Castor oil – a triglyceride containing ricinoleic oil. This ricinoleic oil is used for the synthesis of a fully acetylated monoglyceride of 12-hydroxystearic acid. The rawmaterial for this plasticiser is Castor oil, which can only be grown in certain geographical regions of the World. The supply is limited and will not allow for a full replacement of phthalates. To overcome this constraint a second generation of sustainable, renewable plasticiser will be developed. The rawmaterial for this will be vegetable oils high in oleic acid. The approach will also include a different, less energy consuming process. Also volatiles solvents will be replaced by ionic liquids.

Developing Heterogeneous Catalysts for the Production of Value-added Biobased Products from Fats and Oils.

H. Ngo, T. Foglia, M. Haas, USDA, ARS, ERRC, Wyndmoor, PA, USA

The development of economically viable technologies for producing lubricating fluids and biofuels from renewable materials is highly desirable from environmental points of view. Lubricating fluids derived from unsaturated fats can, for example, potentially replace non-renewable and poorly degradable petroleum-based products. We have developed new heterogeneous catalysts for the synthesis of a variety of biobased products such as branched-chain fatty acids and fatty acid methyl esters. In this talk, I will discuss our research efforts using microporous and mesoporous solid acid

catalysts to convert unsaturated fatty acids into value-added biobased products that can have potentially positive impacts on the US agriculture and industry.

Development of Biodegradable Lubricating Oil Formulations from Non Edible Vegetable Oils. Ponnekanti Nagendramma, Savita Kaul, R.P.S. Bisht, Mange Ram Tyagi, IIP, India

World over, the use of vegetable oils in lubricating oil formulations is increasing due to their origin being from renewable sources, biodegradability and favorable eco-toxic characteristics. In Indian context, the use of non-edible vegetable oils is considered as a potential source in lubricating oil formulations. The fatty acid contents and their chemical structures define the physico-chemical and lubricating characteristics of a vegetable oil. As such they have certain limitations for their use in lubricating oil formulations. Therefore, these oils have to be subjected to chemical transformation to obtain base fluids with satisfactory performance characteristics. Keeping this in view, studies were undertaken at the Indian Institute of Petroleum on this subject. Under these studies, the vegetable oil esters were synthesized using alcohols such as oleyl alcohol and fatty acids from Karanja and Mahua oils using an indigenous ion-exchange resin catalyst. The synthesized products were characterized for their physico-chemical properties and tribological performance. These were then compared with commercial mineral oil based cutting oil. In the present paper, the results of the above study are presented.

Low VOC Alkyd Paints and Coatings via Sucrose Polyesters. R. Berger¹, D. Back¹, R. Starghill¹, V. Arredondo¹, N. Rogers², D. Eslinger², D. Ryer², ¹The Procter & Gamble Company, Cincinnati, OH, 45069, USA, ²Cook Composites & Polymers, North Kansas City, MO, 64116, USA

P&G and CCP developed novel alkyd resin technology, Chempol MPS, that enables formulation of paints and coatings with less than half the amount of VOCs while delivering performance advantages as well, such as fast dry, high gloss, film toughness and increased Renewable Content (RC) in a formulated consumer product. Sucrose polyesters made possible the development of this new alkyd resin technology. Derived from sugar and vegetable oils, they are a green chemistry solution to problems associated with both conventional and high-solid alkyd resin systems. For perspective, alkyd resin paints and coatings use large amounts of solvents to solubilize organic components and attain appropriate viscosities. Millions of gallons of these paints/coatings are sold for multiple applications in the U.S. and globally. These solvents are volatile organic compounds (VOCs) that contribute to ground-level ozone formation, a known hazardous gas to humans even at relatively low levels. Several natural vegetable oils such as soybean, linseed, and tung, were used to derive a series of sucrose polyesters. The evaluation and performance of coatings formulations made with sucrose polyester-modified alkyd resins and the potential environmental benefits of this novel alkyd resin technology are discussed.

A Direct Synthesis Route to Soy-based Thiol Oligomers. Zhigang Chen¹, Jennifer F. Wu¹, Shashi Fernando¹, Bret J. Chisholm^{1,2}, Dean C. Webster^{1,2}, ¹Center for Nanoscale Science and Engineering, North Dakota State University, Fargo, ND, USA, ²Department of Coatings and Polymeric Materials, Fargo, ND, USA

Utilization of biorenewable chemicals such as seed oil derivatives in green coating technologies including UV curable coatings and high solid coatings is a green solution to future materials need and ever-stricter environmental regulations. Soybean oil based thiol oligomers find potential uses in thiol-ene UV curable coatings, high solid thiol-urethane coatings, and as biobased lubricants. In this work, a novel one-step synthesis route to produce soy-based thiols directly from soybean oil is described. The synthesis reaction conditions were systematically varied and the products characterized by FTIR, NMR, rapid-GPC and viscometry. The effect of reaction time, reactant ratio and functionality, reaction atmosphere, and catalyst amount on the reaction conversion, and the functionality, molecular weight, and viscosity of the synthesized oligomer is illustrated. The direct synthesis route provides a low-cost approach to produce high value-added oil seed derived biochemicals for industry products.

Development of Soybean Oil Derived Plasticizers for PVC. D.R. Kodali, L.J. Stolp, M. Bhattacharya, University of Minnesota, St. Paul, MN, USA

Plasticizers are non-volatile organic liquids that can reduce the glass transition temperature (T_g) of polymers and make

them more flexible. Polyvinyl chloride (PVC), due to its unique combination of price, performance and versatile use is the second largest globally produced plastic (36 MMT/year). Plasticizers are an \$11 billion/year industry and account for 54% of plastics additives, mostly in PVC. The majority of plasticizers are petroleum derived phthalates which are known to have adverse impact on human health and environment. This prompted the plastic industry to develop bioplasticizers from renewable materials. The required structural features of an effective plasticizer must allow it to fit snugly in long polymer chain matrices and reduce the glass transition (T_g). It should also have reduced tendency to migrate to the surface. The required functionality dictates modification of soybean oil properties like polarity, molecular size, shape and hydrophobicity. We synthesized estolides from soybean oil fatty acid alkyl esters and characterized their structure and functionality. These experimental plasticizers showed reduction of glass transition temperature of PVC and low vapor pressure. The synthesis and functional evaluation of the new plasticizers will be presented.

TUESDAY

AFTERNOON

IOP 3: New Glycerol Uses

Chair(s): J. Kenar, USDA, ARS, NCAUR, USA; and T. Benson, Lamar University, USA

Glycerine as a New Carbon Building Block. D.J. Brown, HBI USA, Portland, OR, USA

Glycerine has been an important ingredient in many products from food and pharmaceuticals to tobacco and industrial uses for many years. In the past it has traded as a normal chemical additive, but with the advent of biodiesel production in Europe, at first, and now the U.S., South America, and South East Asia, its responding by-product glycerine production it is now traded as a general commodity and fallen to the lowest prices in the history of glycerine production. The old school of thought in the oleochemical production of glycerine as a co-product of manufacturing of fatty acids, fatty alcohols, and soap have given way to glycerine as only a by-product with marginal value to the producer. The development of cheap, plentiful glycerine of varying degrees of purity has spawned a new market for glycerine as a raw material in the manufacturing of many carbon-based compounds that previously produced from cheaper carbon sources, including petroleum. This cheap carbon source occurring from low cost glycerine will undoubtedly continue if the extreme overproduction of glycerine as a by-product of biodiesel continues. We will look at this possibility and its ramifications for future, cheaper hydrocarbons from glycerine.

Hydrogen Production from Glycerol: An Update. Sushil Adhikari, Auburn University, Auburn, AL, USA

The production of alternative fuels such as biodiesel and ethanol has increased over the last few years. Such fuels are vital for the reduction of energy dependence on foreign countries and to protect the environmental damage associated with the use of fossil fuels. Due to the increased production of biodiesel, a glut of crude glycerol has resulted in the market and the price has plummeted over the past few years. Therefore, it is imperative to find alternative uses for glycerol. A variety of chemicals and fuels including hydrogen can be produced from glycerol. Hydrogen is being produced by using several processes such as steam reforming, autothermal reforming, aqueous-phase reforming and supercritical water reforming. This paper reviews different generation methods, catalysts and operating conditions used to produce hydrogen using glycerol as a substrate. Most of the studies were focused on hydrogen production via steam reforming process and still less work has been done on producing hydrogen from crude glycerol.

A Biodiesel Feedstock of Microbial Oils from Seafood Processing Waste and Glycerol. Guochang Zhang, Todd French, Rafael Hernandez, Darrell L. Sparks, William E. Holmes, Earl Alley, David C. Swalm School of Chemical Engineering, Mississippi State University, MS State, MS 39762, USA

Biodiesel is a displacement fuel for traditional petroleum-derived diesel. Unfortunately biodiesel is an expensive fuel due in large part to the high cost of feedstocks. Oils derived from byproducts with no value could potentially be a cheap source of biodiesel. Byproducts of glycerol from industrial biodiesel production could be converted into oils by oleaginous microorganism. The byproducts of shrimp processing waste are heads and shells that contain a wealth of

carbon (e.g. N-acetylglucosamine) that could be hydrolyzed into organic compounds and used by the oleaginous microorganism for oil production. The objective of this investigation is to determine the feasibility of using oleaginous microorganism to convert these byproducts to triglycerides as a feedstock for biodiesel production. Experiments were conducted using N-acetylglucosamine at a concentration of 50 g/L. *C. curvatus* mass increased continuously within 118.8 hours to 18.4 g/l while growing on the N-acetylglucosamine. During the growth phase of *C. curvatus*, the oil content in of the cells was low. Since *C. curvatus* did not accumulate oil in the growth phase, *C. curvatus* grown N-acetylglucosamine were tested for the production of oil from glycerol. In this investigation, *C. curvatus* was first grown with N-acetyl- glucosamine as sole carbon and energy source. Then, the cells of *C. curvatus* were harvested during the growth phase and transferred to a fresh nitrogen-free media with glycerol as sole carbon and energy source for the oil production. The concentration of glycerol, initial cell mass concentration and the temperature were evaluated for the optimization of the procedure for the oil production from glycerol. The oil content in the cells reached over 30% of the dry cell weight with a 21.8% yield of oils from per gram of glycerol.

Harnessing the Microbial Fermentation of Glycerol for the Production of Fuels and Chemicals. R. Gonzalez, Department of Chemical and Biomolecular Engineering, Rice University, Houston, TX, USA

Given its availability and low prices, glycerol has become an ideal feedstock for fuel and chemical production via microbial fermentation. We recently reported the pathways and mechanisms mediating the metabolism of glycerol in *Escherichia coli* under anaerobic and micro-aerobic conditions. Following these studies, we have engineered *E. coli* for the conversion of glycerol to fuels and chemicals. Several biocatalysts have been developed for the production of ethanol, hydrogen, formate, succinate, lactate, and 1,2-PDO from glycerol-rich streams generated during biofuels production (e.g. crude glycerol, thin stillage). This presentation will include the discussion of our latest work related to the harnessing of microbial glycerol fermentation for the production of fuels and chemicals.

Catalytic Conversion of Glycerine to Renewable Amino Alcohol. V. Arredondo, N. Fairweather, P. Corrigan, D. Back, A. Cearley, M. Gibson, D. Kreuzer, The Procter & Gamble Company, Cincinnati, OH, USA

P&G is the world's largest producer of USP grade glycerine, a material widely used in many market applications. As a key stakeholder, P&G has had for a number of years a very active R&D program in the development of value-added new uses/applications of glycerine. In this paper we report the two-step process for the catalytic transformation of glycerine to 2-amino-1-propanol (2AP), a renewable-based amino alcohol. We will discuss the evaluation of different catalysts, the impact of impurities in crude glycerine, and the effect of reaction conditions and parameters on conversions and selectivities. This process offers a route to an amino alcohol not readily available in the market place. Biodiesel has experienced an explosive growth in recent years. As a result, the increased supplies of crude glycerine co-product have caused its prices to decline, putting also downward pressure on refined glycerine pricing. The new chemistry/process provides a market opportunity to convert glycerine to a value-added product, 2AP, an amino alcohol with wide-range application potential. It offers a more attractive new outlet for glycerine in a world of supply/demand imbalance and depressed pricing vs. when it is used for animal feed, burn value and other disposal applications.

Microbial Production of Glyceric Acid from Raw Glycerol and Development of Novel Bio-based Polymers. T. Fukuoka, H. Habe, D. Kitamoto, K. Sakaki, National Institute of Advanced Industrial Science and Technology (AIST), Japan

This study deals with the microbial production of glyceric acid (GA) from raw glycerol and the development of GA-based polymers. First, we searched for GA-producing strains among acetic acid bacteria and investigated the productivity of GA by the selected strains. We found that some strains belonging to *Gluconobacter frateurii* efficiently converted glycerol to GA at a yield of about 137 g/L and *Acetobacter tropicalis* selectively produced D-GA from glycerol. In addition, we have synthesized branched-type poly(lactic acid)s by polycondensation of lactide in the presence of GA as an initiator. The resulting branched poly(lactic acid)s had lower crystallinity and glass transition temperatures than those of linear poly(lactic acid).

WEDNESDAY

MORNING

IOP 4: Oleochemicals and Polymers

Chair(s): D. Pioch, CIRAD, France; and J. Metzger, University of Oldenburg, Germany

Oleochemicals Products: Feedstocks and Building Blocks for Polymers. Z. Mouloungui, Université de Toulouse, UMR 1010 INRA/INP-ENSIACET, Toulouse, France

Today's oleochemicals are substances which are used because of their chemical reactivity by the presence of double-bond functionality, unique properties of long-chain chemicals, special functional groups as hydroxyl and epoxy. A great number of plant oils such as linseed, soybean, sunflower, tall oil fatty acids, dehydrated castor, tung have been used to prepare a variety of bio-based polymers as true drying-oil paint and coatings, resins, adhesives, inks. The production of polymer-grade brassylic acid from high erucic oils as crambe and industrial rapeseed illustrates the potential end products and intermediate products. Pyrolysis of castor oil yields methyl undecylenate which is converted to 11-aminoundecenoic acid and its polymerization gives polyamide 11 known commercially as Nylon 11 or Nylsan 11. Castor oil itself is used as a polyol for the production of polyurethane. But the application of natural oil polyols will always be a relatively minor one. Now, new focus is borne to produce the polyurethane-based glycerine without isocyanate and polycarbonate-based glycerine. So, many possibilities exist to move oleochemical products into a larger scale position as feedstocks and building blocks for polymers.

Branched Fatty Acid Esters through Addition of Alcohols Catalyzed by Zeolites. D. Pioch¹, A.T. Nguyen¹, A. Finiels², C. Moreau², ¹Process Engineering and Bio-products Development, UMR 016 GPEB, CIRAD, UM1, UM2, Montpellier, France, ²Institut Charles Gerhardt, UMR 5253 CNRS, UM2, ENSCM, UM1, équipe MACS, Ecole Nationale Supérieure de Chimie, Montpellier, France

Low thermal and oxidation stability limits the use of vegetable oils and derived esters because of the presence of C=C double bonds. The reactivity of this double bond has been investigated to perform the addition of alcohols, in the presence of H-form zeolites, thus leading to saturated oxygen-containing side chains. On the chemical side, our previous results relative to the model reaction -addition of methanol to methyl oleate- have shown the influence of key parameters acting on the yield of the target product, methyl methoxy stearate (temperature, methanol excess, Si/Al ratio). The present study deals with an even more complex system: in addition to C=C bond migration and to a thermodynamic limitation related to the reverse reaction (de-methoxylation), already noted, methyl oleate here also undergoes alcoholysis as a parallel reaction, thanks to the acidic properties of the solid catalyst. Selectivity and reaction rates are discussed according to steric and electronic effects, the alcohol being solvent but also reactant upon the case. The initial rate of the alcoholysis being 4 to 10 times faster than the addition to C=C, the reaction medium first contains the ester with the higher alcohol, which is then alkoxyated at almost constant initial rate whatever the chain length from methanol to n-butanol. On the applied side, this work opens the way to a range of oleochemicals under "green" conditions; the catalyst yields C=C free, alkoxyated long chain esters, including di-alkoxyated when starting from linoleate, with selectivity higher than 70 mole%. The adduct is similar to a branched chain wax when starting from a common unsaturated ester, or is a normal chain wax but bearing an oxygen bridge in place of one CH₂ when starting from undecylenic ester. All these "new" alkoxyated esters "not yet manufactured at industrial scale but accessible" should bring interesting properties, for example in lubricant and cosmetic formulations, or for upgrading BTL fractions.

Catalytic Mono-Functionalization of Triacylglycerols. M. Rüschen, Klaas, R. Wahlandt, T. Vari, Neubrandenburg University of Applied Sciences, Neubrandenburg, Germany

Selective introduction of one functional group in a triglycerol molecule is an important target for the utilization of plant oils for polymer applications, e.g. paints and varnishes. A reported two-step procedure for the introduction of acryl groups in triglycerols consists of the epoxidation of C=C-bonds and the subsequent ring-opening of the epoxide with acrylic acid. Thus, a mono-acrylated triglycerol can be obtained by mono-epoxidation in the first step. This was carried out by the classic Prileshajev-epoxidation with peracetic acid and by the more selective chemo-enzymatic epoxidation. A (statistically) mono-epoxidized oil can also be made by the catalytic randomization of a commercial fully-epoxidized soybean oil with an adequate amount of any other triglycerol. The interesterification is favorably

catalyzed by a lipase, because the epoxide-ring might react under standard conditions with a strong base as catalyst. An acryl group can be directly introduced in a triglycerol by lipase-catalyzed interesterification. For that purpose we used trimethylol propane (TMP) triacrylate. Both two-step and one-step reactions were carried out with various unsaturated plant oils like linseed oil, soybean oil and hemp oil. Selectivities and product characteristics will be shown; safety concerns and different problems in downstream-processing will be discussed.

Esters of Calendula Oil and Tung Oil as Reactive Diluents for Alkyd Resins. Ursula Biermann, Werner Butte, Jürgen O. Metzger, University of Oldenburg, Oldenburg, Germany

Presently our interest is focused to plant oils containing unsaturated fatty acids with a highly reactive hexatriene system such as calendula oil and tung oil. The latter is a drying oil and is used for a number of products including varnish, resins and coatings. Tung oil contains about 84% of α -eleostearic acid (9-cis-,11,13-trans-octadecatrienoic acid). Similar properties are expected from calendula oil consisting of octadec-8,10-trans-12-cis-trienoic acid (calendic acid) as main fatty acid (59-65%). A simple protocol for the transesterification of highly unsaturated vegetable oils such as calendula oil with alcohols catalyzed by sodium methoxide to give the respective esters is described.¹ The esters were tested as reactive diluents for alkyd resins in coating formulations. Especially ethyl and isopropyl calendula oil esters showed good properties including low viscosity and good drying performance. Furthermore a shortening of the drying time of about 35- 40% compared to conventionally prepared formulations was achieved. Analogously, the respective esters of tung oil were synthesized and used as reactive diluent.¹ U. Biermann, W. Butte, R. Holtgreffe, W. Feder, J. O. Metzger, Eur. J. Lipid Sci. Technol. 2010, in press.

Industrial Hydroxylated Fatty Acids—New Opportunities in Polymer and Functional Chemicals. F.H.M. Graichen, M. S. O'Shea, G. Peeters, S. Kyi, CSIRO, Molecular and Health Technologies, Clayton, Victoria, Australia

There is significant global momentum around the (re)emergence of bio-derived feedstock for the chemicals and polymer industries. However, current industrial fatty acid options are limited (in broad terms) to palm, soybean, canola and castor sources. While there are many niche oils (and their associated fatty acids) naturally produced, these are normally unsuitable due to reliability of supply, cost or both. CSIRO's research in the areas of industrial oils and complex monomers is aimed at the production, evaluation and modification of novel oil and fatty acids for a range of industrial applications including: chemical intermediates, oligomers, cross-linkable polymers, bioactive compounds, fuel additives and thermo/mechano-chromic devices. The currently available plant sourced hydroxyl functional oils and fatty acids, Castor oil and ricinoleic acid respectively have found uses in a wide range of areas. This paper will cover some synthesis methods for the saturated and unsaturated alpha hydroxy fatty acids as well as applications ranging from adhesives to monomers and modifiers for polyurethanes, polyesters and polyamides. CSIRO's hydroxylated fatty acids program offers a shift in novel oil and fatty acids for industry supply and opens access to new sustainable product platforms.

Hyperbranched Polyols from Hydroformylated Methyl Soyate. Z.S. Petrovic, I. Cvetkovic, D.-P. Hong, I. Javni, Pittsburg State University, Pittsburg, KS, USA

Hydroformylation of methyl soyate produces a mixture of fatty acid methyl esters with zero, one, two and three hydroxyl groups, the major component being with two hydroxyls (around 50%). Polymerization of methyl esters of hydroxy fatty acids gives a hyperbranched product with different content of hydroxyl groups depending on the degree of conversion. At complete conversion total mass becomes a single molecule with infinite molar mass and infinite functionality. In real systems molecular weights have finite values and can be controlled by controlling the degree of conversion but also using monofunctional components. Monte-Carlo simulation of the polymerization of hydroxylated methyl soyate at the highest conversion shows that the products are physical gels, due to very high molecular weights. The simulation results were compared with experimental measurements of molecular weights, OH numbers and acid values. Reducing molecular weight to the workable viscosity range a family of new polyols can be obtained. Analysis of functionality of the polyols was carried out by determining conversion at the gel point when cured with a diisocyanate.

UV-curable Nano-composite Coatings from Soybean Oil: Sustainable Platform for Advanced Materials. Vijay Mannari, Jigarkumar Patel, Eastern Michigan University, Ypsilanti, MI, USA

Over the past several decades, a number of coatings material technologies have evolved that effectively address environmental concerns associated with emission of volatile organic compounds (VOC). Among these, water-borne and radiation-cure technologies have rapidly advanced and commercialized due to a number of technical benefits. At present, however, these technologies heavily rely on petrochemical feedstock as primary source. Material scientists are faced with an important challenge of offering an alternate renewable material platform for sustainable development of these advanced materials. The present research focuses on development of value-added materials from soybean oil for advanced coatings. We report novel UV-curable organic-inorganic hybrid nano-composite coatings and aqueous polyurethane dispersions (PUD) from soy-based intermediates. These coatings, in addition to having low VOC emissions, have high bio-based content and show excellent performance properties for a myriad of potential commercial applications.

Autoxidative Drying Characteristics of Water Borne Coatings from Renewable Resources. Partha Sengupta, Xiao Pan, Thomas Nelson, Adlina Paramarta, Dean Webster, Department of Coatings and Polymeric Materials, North Dakota State University, Fargo, ND, USA.

The three unsaturated fatty acid esters of sucrose used in this research work are sucrose linseedate, sucrose safflowerate and sucrose soyate, with different degree of unsaturation. Water borne dispersions of sucrose esters were prepared using surfactants for dispersion stability and rheology modifier for viscosity modification. For autoxidative curing four drier packages involving cobalt complex and other compounds for partial and total replacement of cobalt were explored. The surface, bulk and depth profiling of the drying characteristics of coatings was done by Drying Recorder, Real time FTIR and Confocal Raman microscopy respectively. Sucrose linseedate shows high surface drying but reduced through drying while sucrose soyate shows the best overall drying process due to higher oxygen permeation. König hardness, impact resistance and MEK double rubs validates the drying characteristics of the three different sucrose esters. Among the four drier packages, cobalt shows poor through drying while tetrafunctional thiol shows better overall curing process. Water uptake of the coatings was determined by Electrochemical Impedance Spectroscopy (EIS) and hardness with depth of coatings on wood was measured by nanoindentation. The high surface drying of sucrose linseedate gave lower water diffusion and higher variation of hardness along the depth of the coating.

Thiol-Ene Reaction of Vegetable Oils with Butyl Thiol: Sulfide Derivatized Vegetable Oils. James A. Kenar¹, Grigor Bantchev², Girma Biresaw², ¹Functional Foods Research Unit, USDA, ARS, NCAUR, Peoria, IL, USA, ²Bio-oils Research Unit, USDA, ARS, NCAUR, Peoria, IL, USA

Vegetable oils and their FA, renewable raw materials, are firmly established components in many industrial products, and their use continues to be of interest to many researchers. The development of new approaches to functionalize vegetable oils to derive novel oleochemicals with unique chemical and physical properties is integral to extend the variety of compounds and uses obtainable from these oils. The carbon-carbon double bonds of vegetable oils were reacted with butyl thiol using a UV initiated thiol-ene reaction. The effects of temperature, reaction time, type of vegetable oil, thiol to vegetable oil ratio were investigated and it was found that both low temperature and high thiol to vegetable oil ratio increased the addition of thiol to the vegetable oil double bonds. Reaction products were analyzed by NMR, IR, and GC-MS methods. Optimized reaction conditions gave up to 90% conversion of soybean oil double bonds into sulfide linkages in isolated yields of 60%. This presentation will present aspects of this work.

Fatty Acid Modified Anhydrides of Hydroxy Carboxylic Acids ? Novel Oleochemicals for the Lipid Modification of Renewables. Hans-Josef Altenbach, Rachid Ihizane, Bernd Jakob, Karsten Lange, Sukhendu Nandi, Manfred P. Schneider, Bergische Universität Wuppertal, Germany

Nature, and in this context agriculture, provides a considerable reservoir of useful and low cost raw materials such as fats and oils, plant proteins and carbohydrates. By selective combination of their molecular constituents a wide variety of materials with interesting properties can be prepared, all of them - due to their molecular constitution - being potentially biodegradable. We recently discovered that hydroxy carboxylic acids such as citric, malic and tartaric acid can be converted in one step and quantitatively into the corresponding fatty acid modified, O-acylated anhydrides,

excellent electrophiles for ring opening reactions with the above nucleophiles from renewable resources. The title molecules have thus been successfully employed for the lipid modification of various alcohols, including diols, polyols such as glycerol and pentaerythritol, polyethylene glycol and sugar alcohols (e.g.mannitol) and also numerous amino acids. Various monosaccharides such as D-glucose, D-mannose, D-glucosamine, L-ascorbic acid and disaccharides such as α , α -trehalose have also been modified using the title compounds. Next to their surface-active properties (detergents and emulsifiers), many of the thus resulting molecules show additional benefits such as antimicrobial properties, being able to form organogels and films or are oil soluble antioxidants for the stabilization of native oils. They are thus potentially useful for a wide variety of applications such as in cosmetics and food technology. The lecture will describe the syntheses of the title compounds and their use for the preparation of various lipid modified renewables; selected properties of the resulting products will also be discussed.

AFTERNOON

IOP 5: General Industrial Oil Products

Chair(s): D. Sparks, Mississippi State University, USA; and R. Hernandez, Mississippi State University, USA

Integrated Biorefinery based on Soybeans. D. Graiver¹, R. Narayan^{1,2}, K. Farminer², ¹Michigan State University, East Lansing, MI., USA, ²BioPlastics Polymers and Composites, East Lansing, MI., USA

Value-added intermediates and products are prepared from the various parts of the soybean (oil, meal and hulls) by different chemical processes. We have used ozonation under catalytic conditions to oxidize the oil and produce primary polyols, thermally stable lubricants, and fuel additives. The meal was used as a source of amine functional groups to produce aliphatic isocyanates, which could further be polymerized to polyurethane and polyamides. Grafting of reactive silanes onto the unsaturation sites of the fatty acids in the triglycerides yields one-component coating that are vulcanized by atmospheric moisture. These crosslinked coatings have excellent adhesion to metals and can further be formulated as anti-corrosion coatings or as moisture barrier over wood. Allylation of the fatty acids produces monomers that can be polymerized by free radical initiation or sulfonate to yield bio-based detergents. The chemistry and processes of such chemical modifications that are all part of our biorefinery concept will be described.

Effect of Lignocellulosic Inhibitory Compounds on Growth and Lipid Accumulation of Municipal Sewage Activated Sludge Microflora. A. Mondala, R. Hernandez, T. French, L. McFarland, W. Holmes, Mississippi State University, Mississippi State, MS, USA

A biorefinery concept utilizing existing municipal wastewater treatment plant infrastructures, wastewater, and activated sludge will be presented. It was hypothesized that sugars derived from the hydrolysis of lignocellulose biomass can be utilized by activated sludge (AS) microflora as fermentation substrates for biosynthesis of lipids for biofuel applications. However, hydrolysis of lignocellulose yields by-products such as furans and organic acids that may inhibit microbial growth and metabolism. This study then investigated the effects of two representative lignocellulosic inhibitor compounds, furfural and acetic acid, on cell growth, lipid accumulation, and glucose utilization by AS microflora. Batch fermentation experiments were conducted using a 20 % (v/v) inoculum of waste AS in a synthetic wastewater medium. Glucose was supplied as the sole carbon source at an initial C:N ratio of 79. Furfural and acetic acid were tested individually and in binary mixtures to determine their individual and combined effects. Results obtained from these experiments were used to evaluate the inhibitor tolerance capacity of AS microflora and determine if detoxification of lignocellulose hydrolyzate is necessary prior to fermentation.

Sub-critical Water Assisted Biodiesel Production from Activated Sludge. Lien-Huong Huynh, Yi-Hsu Ju, National Taiwan University of Science and Technology, 43, Keelung Rd, Sec.4, Taipei 10607, Taiwan

Faced with environment problem and exhaustion of fossil fuel, the idea of utilizing activated sludge (AS) as a source of renewable energy has attracted many researchers. Methods on the use of AS as an energy source, such as fermentation, pyrolysis and thermal-gasification have been investigated. However, due to the complicate nature of sludge, it is difficult to apply those methods for fuel production. AS has the potential to be used as a raw material for producing biodiese-an environmental friendly and alternative fuel. Sub-critical water (SCW) treatment of sludge has

been known as a cheap and effective method for reducing its organic compounds, especially those carcinogenic aromatic PCBs or PAHs. In addition, extractable lipid amount in sludge also increases after SCW treatment. In this study, dry sludge was firstly subjected to SCW treatment. The supernatant after SCW treatment was collected and centrifuged for further analysis whereas the remaining solid sludge was freeze dried and subjected to solvent extraction. Sludge oil (SO) obtained was then dewaxed, degummed to remove wax and phospholipids. Titration and saponification were employed to separate saponifiables lipids from the unsaponifiables in the dewaxed/degummed SO. Composition of the neutral lipids as well as its fatty acid profile were determined and compared to those obtained without SCW treatment.

Solvent Characteristics of Biodiesel Esters and Their Co-Products. J.W. King, K. Srinivas, N.S. Bobbitt, J.D. Vincent, University of Arkansas, Department of Chemical Engineering, Fayetteville, AR 72701, USA

The production of biodiesel ester mixtures and associated co-products such as glycerol in large excess require additional utilization markets be developed, such as their use as solvent or reaction media. To provide an expanded physicochemical data base on their solvent thermodynamic properties, we have employed inverse gas chromatographic (IGC) measurements abetted by miscibility correlations utilizing the solubility parameter χ Hansen 3-dimensional sphere approach. IGC measurements of n-alcohol binaries with both soya-derived biodiesel esters and glycerol at near infinite dilution conditions of mole and weight fraction activity coefficients, partition or Henry's Law coefficients, as well as free energies, enthalpies, and entropies of solution. The mole fraction carbon number activity coefficient trends for methanol to n-butanol increase and decrease, respectively, for their binary solutions with biodiesel and glycerol, respectively χ reflective of the alcohol's cohesive energy densities relative to those for the two solvents. Total and three component solubility contributions derived for soy-biodiesel are very similar whether derived from IGC measurements or Hansen solubility spheres while values reported for glycerol and been found to range from 32 χ 40 MPa^{1/2}. The implications of the above data will be discussed in terms of the design of separation processes to separate methyl esters and glycerol as well as their use as solvent media.

Biodiesel Production via Transmethylation of Triglycerides Using Dimethylcarbonate: A Glycerol-free Biofuel. M.S. Miguez, T.J. Benson, Lamar University, Beaumont, TX, USA

Some biodiesel processing concerns, namely wastewater and byproduct, could have a negative impact on the economic viability of this biofuel. In an effort to alleviate these economic and environmental strains on the biodiesel industry, an alternate process is proposed that uses dimethyl carbonate in place of methanol as the transmethylation agent. The products formed from one triglyceride molecule are two fatty acid methyl ester molecules and a glycerol fatty acid methyl ester that is completely soluble in the FAME's mixture; thus, eliminating the byproduct glycerol and greatly reducing the amount of wash water. This alternate biodiesel, depending on the feedstock, also meets the ASTM D6751 biodiesel standard. Using model reactant compounds, a screening of acid and bases catalysts was performed, and kinetic studies were carried out on the top-performing catalysts. The selection of catalysts includes alkali base catalysts that are currently used in biodiesel production facilities, as well as, heterogeneous-type catalysts that would be easier and more economical to recover and recycle. The experimental results, along with process modeling using Aspen 7.1, will be presented.

Biodiesel and Biofuel Production from High Acidic Feedstock. R. Verhe¹, V. Van Hoed¹, C. Echim^{1,2}, J. Maes², N. Zayakina², W. De Greyt², ¹Ghent University, Ghent, Belgium, ²De Smet Ballestra, Zaventem, Belgium

The use of edible vegetable oils as feedstock for the production of biodiesel has led to an increased competition with food and oleochemicals. Alternative resources such as oils and fats with high FFA content and side streams of refining can substitute the refined feedstocks, but require alternative technologies and/or purification steps. Vegetable oils, animal fats and used frying oils with more than 5% FFA can be converted into biodiesel using a two step process involving an acid esterification and alkaline transesterification. If the FFA content is lower than 10% higher yields are obtained by first a transesterification followed by an esterification. Low quality feedstocks need a preliminary refining for the removal of P-compounds (degumming) and metals, ash and S by adsorption. Soap stocks (after acidification) and deodorizer distillates (DOD) are converted into biodiesel and biofuels (CHP) by either a combination of esterification and transesterification with methanol or by esterification with glycerol followed by transesterification. The

esterification of high acidic oils with glycerine can be performed either by acid esterification (p-toluene-sulfonic acid) or by heating at 200°C without catalyst. A combination of these various technologies provides excellent procedures for the production of biodiesel and biofuels from high acidic oils.

Using Synthetic Biology to Create Renewable Chemical Building Blocks. N Renninger, D McPhee, E Cratsenburg, Amyris Biotechnologies, Inc., Emeryville, CA, USA

In spite of increasing interest in and demand for sustainable materials, there are limited options available today for renewable raw materials or ingredients that simultaneously meet the requirements of scale, cost-competitiveness, and performance. Industrial biotechnology is poised to shift the paradigm from the traditional petroleum-derived source of carbon to a bio-based renewable source of carbon. Recent advances in synthetic biology now allow us to utilize engineered microbial systems to convert fermentable sugars to molecules previously not made through fermentation. Some of these molecules are interesting and effective chemical building blocks for a variety of novel materials and applications, including, among others, lubricants, cosmetics, polymers, and transportation fuels. Amyris, a renewable product company, will discuss how it is combining advances in synthetic biology with a capital-efficient manufacturing model to commercialize large-scale renewable products in 2011. Amyris will also discuss examples of its product portfolio to demonstrate that by combining the best of biology and chemistry, high-performing and cost-effective sustainable materials will be commercially available in the very near-term.

Fungal Fermentation for Bio-oil Production. D. Mitra, P. Chand, D. Grewell, V. Chintareddy, J. Verkade, J. (Hans) van Leeuwen, Iowa State University, Ames, IA 50011, USA

The biofuels industry is somewhat stagnant and needs to expand opportunities to add value to co-product streams. Expanding the co-product market is essential to offset processing costs. Thin stillage is a leftover stream from corn-to-ethanol plants, while soy whey is a by-product stream from soybean processing. The central hypothesis of this research is that these streams contain important nutrients to support microbial growth. This research paper highlights our success in growing an oil-rich fungus *Mucor circinelloides* in these substrates, without external nutrient addition or enzymatic modifications. Thin stillage samples from three different corn-ethanol plants: Iowa(LTS), Nebraska(NTS), Minnesota(MTS) were used to evaluate the fungal biomass and oil production. Soy whey was prepared in the lab from defatted soyflakes. Preliminary experiments show the fungal biomass yields were