BIOLOGY

Strain Discovery and Development - How to Get the Best Strains for Production of Fuels and Commodities

Monday, October 15 / 1:45 pm - 3:15 pm

Waterway 6, Level 2

Weissman, Joseph [1:45pm]

Exxonmobil Research & Engineering

High-Light Selection of Algae for Fast Specific Growth Rate

Joseph Weissman and Maria Likhogrud Corporate Strategic Research, ExxonMobil Research and Engineering, Annandale, NJ Wei Fang, Dylan Thomas, Devin Karns, and Matthew Posewitz Colorado School of Mines

In order to use microalgae for the production of a commodity, the algal cells must perform nearly flawlessly under mass culture conditions. The low production costs required demand the highest productivity and culture stability. The algae must photosynthesize at a very high rate and dissipate the fewest photons possible, under highly variable conditions where cells may be exposed to high light for prolonged periods of time, or low light for a long time, and may move from low light to high light, or the reverse very quickly. The cells must respond to these changes without lags, and without having their photosynthetic rate depressed by high irradiance. A very fast doubling time is essential in a batch process for establishing a productive level of biomass and, also, for recovering from upsets. High photosynthetic rate is also one factor that may help decrease the dissipation of photons due to light saturation, by increasing the ratio of light utilization to light capture. This again, increases productivity. For these reasons and others, we decided to enrich collections of natural waters for algal cells that reproduce the fastest under very high light in dilute culture, using a turbidostat, or other continuous-type culture. We selected for an organism of the genus Picochlorum, with a doubling time of less than 2.5 hours, which was also very stable when exposed to high light under various conditions. The selection protocol imposed also selected for a somewhat reduced antenna size and one that is very sensitive to irradiance, becoming very small at high light when the algae are growing the fastest. All of these attributes should lead to higher biomass productivity if they can both be maintained in dense culture through genetic manipulation. Future work will focus on understanding what allows this alga to grow so fast and stably in high light.

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Monday, October 15 / 1:45 pm - 3:15 pm

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Negi, Sangeeta [2:00pm]

New Mexico Consortium

Expression of Heterologous Sucrose Non-Fermenting Related Kinase (SnRK) Leads to Improved Growth in Chlorella sorokiniana.

Taylor Britton1, Raul Gonzalez2, Shawn Starkenburg2, Amanda Barry2, John Roesgen1, David Hanson1, Richard Sayre3, Sangeeta Negi1,3. 1. University of New Mexico, Biology Department, Albuquerque, NM 87131, USA 2. Los Alamos National Laboratory, Los Alamos, NM 87545, USA 3. New Mexico Consortium, Los Alamos, NM 87544, US

Photosynthetic organisms fundamentally depend on light- and sugar-driven metabolic and signaling networks, which integrate environmental cues to govern and sustain growth and survival. SnRKs (SNF1 related protein kinases) are well-studied regulators of energy and stress metabolism, and coordinate energy balance and nutrient metabolism in plants. Previously, we demonstrated that knocking out phototropin (PHOT, a blue light photoreceptor) leads to a two-fold increase in photosynthetic efficiency and biomass in Chlamydomonas reinhardtii. Concomitantly, a 10-fold increase in SnRK expression was observed in the same PHOT knock-out lines. These findings suggest an existence of coordinated interactions between light (PHOT) and sugar signaling (SnRK) in microalgae. We hypothesized that if we recapitulated SnRK overexpression in transgenic algae, we could increase carbon assimilation resulting in improved growth and productivity. To test this idea, we overexpressed a heterologous SnRK from the halotolerant microalgae Picochlorum soloecismus in the biomass production strain Chlorella sorokiniana. A vector containing the Chlorella psaD and actin promoter/terminator pairs driving the SnRK and Sh-ble (zeocin resistance) gene expression was transformed into the genome via electroporation. Putative transformants were identified by integration of the transgene by PCR. We further validated transgene expression by RT- and q- PCR. SnRK overexpression lines show an increase in biomass, starch accumulation, and photosynthetic rates. These properties define SnRK overexpression lines as prime biofuel crop candidates. (Supported by the DOE funded Producing Algae for Coproducts and Energy grant, the New Mexico Consortium, University of New Mexico, and New Mexico EPSCoR.)

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Knoshaug, Eric [2:15pm]

National Renewable Energy Laboratory

Manipulating Transitory Carbohydrate Synthesis and Degradation Rates in Desmodesmus armatus to Drive Biomass Productivity and Carbon Assimilation Potential

Knoshaug, E. P., Fedders, A., Sweeney, N., Douchi, D., Wang, B., Politis, A., Van Wychen, S. and Laurens, L. ML. National Renewable Energy Laboratory, Golden, CO 80401

In plants and algae, carbon is stored in the form of temporary carbohydrate polymers to sustain the energetic demands and growth of the cells, when photosynthesis is not possible (at night). Manipulating this carbon sink to either reduce the night-time degradation rate or increase the day-time synthesis rates has been shown to increase the overall, summative quantum yield efficiency of photosynthate over the course of plant growth or algae cultivation. In light of a continuous drive to increase algal biomass productivity improvement to reach techno-economical feasibility, we specifically targeted starch metabolism in a previously documented and commercially-relevant species, Desmodesmus armatus (SE00107). We have characterized the diel cycle of transitory biochemical composition over a 24 period at 4 different time points throughout a cultivation over the physiological transition from nutrient replete to nutrient deplete conditions under a strict mimicked outdoor cultivation condition representing Phoenix, AZ. We collected transcriptomics data to specifically study the underlying gene expression profiles that drive the regulation and control over this temporary carbon storage mechanisms. We have carried out targeted and untargeted genetic approaches to influence D. armatus carbohydrate metabolism and will present findings on the initial characterization of our top performing mutant strains in a controlled laboratory setting. This presentation aims to cover our most recent progress in both understanding storage carbohydrate regulation in a commercially-relevant green alga as well as controlling the impact of carbohydrate metabolism on cell biomass productivity in an outdoor-relevant setting.

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Waterway 6, Level 2

Uliczka-Opitz, Frank [2:30pm]

Algenol Biofuels Germany GmbH

Generation of Enhanced Cyanobacterial Strains for Production of Mycosporine-like Amino Acids for Use as UV Protection Agents

Frank Uliczka-Opitz, Marco Schottkowski, and Ulf Duehring Algenol Biofuels Germany GmbH*

Algenol Biotech is a leading edge biotechnology company that develops and produces products from multiple types of algae from laboratory to commercial scale. Algenol's R&D facility in Berlin, named Algenol Biofuels Germany GmbH, focuses on the development and application of state-of-the-art molecular biology and strain selection methodologies. The generation of production strains utilizes advanced technologies for selection, transformation, and metabolic engineering that enable us to use cyanobacteria as heterologous expression systems and to optimize metabolic flux into desired products. Algenol is exploiting synthetic biology and systems biology tools for advancing multiple new product opportunities, including food and feed ingredients, cosmetics, industrial enzymes, and other high value products using proprietary strains of cyanobacteria and other microalgae grown in Algenol's patented low-cost flexible film vertical bioreactors. Included in the new products recently developed at Algenol are mycosporine-like amino acids (MAAs), which represent the most common group of naturally occurring ultraviolet radiation absorbing secondary metabolites found in many cyanobacteria and algae. These molecules absorb light in the UV-A and UV-B range (maximum absorbance between 310 and 362 nm) and therefore are well suited to replace conventional synthetic UV-absorbing compounds in current sunscreens, many of which have been potentially implicated in various human health and environmental issues, including damage to coral reef communities. In addition to their main function as effective UV protectants, MAAs are also of interest as functional skin care ingredients due to reported anti-inflammatory, anti-oxidant, anti-cancer, and skin renewal benefits. In this presentation, we report on the creation and optimization of cyanobacteria that produce the MAAs mycosporine-glycine, mycosporine-2-glycine and shinorine. These strains produce MAAs at rates and levels (% of dry weight) that are several-fold higher than native and recombinant MAA-producing strains that have been reported in the literature to date. We are actively looking for partnerships to commercialize this technology.

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Strain Discovery and Development - How to Get the Best Strains for Production of Fuels and Commodities

Monday, October 15 / 1:45 pm - 3:15 pm

Waterway 6, Level 2

Davis, Aubrey [2:45pm]

MicroBio Engineering Inc.

Domestication of Microalgae: Selection of Strains for Cultivation

Aubrey Davis(1,2), Ruth Spierling(1,2), Claire Greco(2), Paul Camarena(1,2) Tryg Lundquist(1,2), John Benemann(1) Affiliations: (1) MicroBio Engineering Inc; (2) California Polytechnic State University*

The US DOE goal for microalgae production is to demonstrate by 2020 at the pre-pilot-scale a yield of 3,700 gallons or equivalent of biofuels intermediates per acre per year (US DOE BETO, Multiyear Program Plan, 2016). Reaching such yields will require "domestication", that is the genetic improvement, of algal strains for increased productivity of algal oils, carbohydrates and/or other biofuel feedstocks, and additional attributes required for their cultivation in large-scale open ponds. The first step in any domestication project is choosing algal strains that can be cultivated in both laboratory reactors and open ponds and for which genomic and genetic information is already available or could be readily developed. The growth characteristics of over a dozen algal strains obtained from culture collections and isolated from polyculture ponds were determined in the laboratory in triplicate 800 mL bubble column reactors. Cultures exhibiting the highest average volumetric productivities in the laboratory included several strains of Scenedesmus obliquus (DOE 0152-z, UTEX 393, DOE 0111), Desmodesmus armatus (UTEX B 2533), Desmodesmus sp. (DOE 1051, DOE 1357), Chlorella sorokiniana (DOE 1412) and a new Pediastrum sp. isolate. Several of these strains were subsequently cultivated in 3.3 m2 outdoor raceway ponds. Based on this data, DOE 0152-z, for which the full genome sequence became available recently (Starkenburg, S.R. et al., 2017, https://doi.org/10.1128/genomeA.00617-17), was selected as the initial target for enrichment cultures designed to select for strains with increased content and productivity of biofuel precursors (carbohydrates and triglycerides). Initial results obtained with laboratory reactors specifically designed for enrichment cultures will be presented. This project is supported by US Department of Energy (DOE) Bioenergy Technologies Office (BETO) Advanced Algal Systems Program, for Algal Biomass Yield Phase 2 (ABY2), Award DE-EE0007691 to MicroBio Engineering Inc.

BIOLOGY

Leveraging Omics Technoloiges for Species Domestication - Understanding Algae at the Systems Level to Drive Innovation

Monday, October 15 / 4:00 pm - 5:30 pm

Waterway 6, Level 2

Yang, Runqing [4:00pm]

South China University of Technology

Identification and Characterization of miRNAs in Coccomyxa subellipsoidea C-169 in Responds to CO2 Supplementation

Runqing Yang, Huifeng Peng, Dong Wei, Gu Chen* School of Food Sciences and Engineering, South China University of Technology, Guangzhou 510640, P.R. China*

As an oleaginous microalga, Coccomyxa subellipsoidea C-169 (C-169) is promising for renewable biofuel production. MicroRNAs (miRNAs) are master modulators of gene expression at the post-transcriptional level and are promising candidates in bioengineering modification. However, so far there is no report about the C-169 miRNA and their differential expression upon high CO_2 supplementation remained elusive. Through high-throughput sequencing of small RNAs from C-169 cultured in air (AG) or 2% CO_2 (CG), totally 127 miRNAs were identified in C-169, including 118 conserved miRNAs and 9 novel ones. In the comparison of CG/AG miRNA expression, twenty significantly differential expressed miRNAs were identified upon CO_2 supplementation, including thirteen upregulated and seven downregulated. The differential expressed data were verified through qRT-PCR. Then 388 genes were predicted as potential target genes, 320 for conserved miRNAs and 68 for novel miRNAs. The annotated target genes were significantly enriched in six KEGG pathways, including pantothenate and CoA biosynthesis, C5-branched dibasic acid metabolism, 2-oxocarboxylic acid metabolism, butanoate metabolism, valine, leucine and isoleucine biosynthesis and alpha-linolenic acid metabolism. When integrated with the target genes transcriptomic data, several miRNAs-target genes module were suggested with reversed regulation, such as miR319, miR6478, miR396 and csl-nmiR9 and their potential target genes. The pioneering identification of C-169 miRNAs and differential expressed miRNAs in responds to CO_2 supplementation lays the foundation for further miRNA research in eukaryotic algae and will contribute to the development of C-169 as an oleaginous microalga through bioengineering in the future. Keywords: Coccomyxa subellipsoidea C-169, CO_2 supplementation, miRNA, miR319, miR6478, miR396, csl-nmiR9

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Leveraging Omics Technoloiges for Species Domestication - Understanding Algae at the Systems Level to Drive Innovation

Monday, October 15 / 4:00 pm - 5:30 pm

Waterway 6, Level 2

Hovde, Blake [4:15pm]

Los Alamos National Lab

Insights into Haptophyte Algae from Genomic Analysis of Two Geographically Distinct Freshwater Chrysochromulina Species

Blake T. Hovde(1), Chloe R. Deodato(2), Robert A. Andersen(3), Shawn R. Starkenburg(1), Steven Barlow(4), Rose Ann Cattolico(2) 1)Los Alamos National Laboratory, 2)Department of Biology, University of Washington, 3)Friday Harbor Laboratories, University of Washington, 4)Department of Biology, San Diego State University

Recent studies have highlighted the extensive contribution haptophyte algae have toward global primary productivity and carbon sequestration. The high fatty acid content of these algae may play a role as a rich nutritional source for eco-cohorts and could be a viable source for biofuels products of productivity levels due to culture density can be enhanced. The haptophtyes in this study - two Chrysochromulina isolates - can grow mixotrophically and are osmotolerant. These two species described here, Chrysochromulina tobinii and Chrysochromulina parva, are small (~3 Î¼m) unicells that have two laterally inserted flagella, and a long haptonema that assists in prey capture. Unlike most isolates of this taxon, scales are absent in both the Golgi apparatus and on the exterior cell surface which makes them more suitable for production environments. The sequenced Chrysochromulina parva and Chrysochromulina tobinii haploid genomes are 65.7 and 59.1 Mb, respectively. Mixotrophic capability augments growth rate and lipid production, while a platform of genes associated with meiosis and DNA repair indicate the presence of a sexual cycle. Though geographically well separated, phylogenetic analysis suggests that fresh water Chrysochromulina isolates form a related clade. Mitochondrial genes lost to the nucleus include all extrinsic components of the nad complex, completing a punctate pattern of transfer that is observed among algal taxa. The chloroplast genome is gene dense and highly conserved. Chrysochromulina represents a new, tractable model organism for experimental studies on lipid biogenesis and other production relevant topics. Physiologically, this alga can be maintained both mixotrophically or photosynthetically, and the organism is amenable to osmotic manipulation. Additionally, the bacterial biome associated with Chrysochromulina is limited in size and manageable for additional studies.

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Monday, October 15 / 4:00 pm - 5:30 pm

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McKie-Krisberg, Zaid [4:30pm]

Brooklyn College of CUNY

Genomic Variation and Ploidy-plasticity in the Re-emerging Platform and Model Microalgal Species Scenedesmus obliquus.

Zaid M. McKie-Krisberg1, Shawn R. Starkenburg,2 James G. Umen3, and JÃ¼rgen E.W. Polle1,4 1 Brooklyn College of CUNY, Department of Biology, 2900 Bedford ave, Brooklyn, NY 11210, USA 2 Los Alamos National Laboratory, Bioscience Division, PO BOX 1664, MS M888, Los Alamos, NM 87545, USA 3 Enterprise Institute for Renewable Fuels, Donald Danforth Plant Science Center, 975 North Warson Rd., St. Louis, MO 63132, USA 4 The Graduate Center of CUNY, 365 Fifth Avenue, New York, NY 10016, USA

Genetic diversity has long been considered a key constituent of population stability. Despite the existence of ploidy variation as well as alternating haploid and diploid life stages common in higher plants, stable variation in ploidy within the closest relatives, the green algae, received little attention. Recently, several strains of Scenedesmus obliquus have been isolated that appear to represent stable haploid and diploid varieties within a single species. These different strains have been shown to vary in their response to specific light and temperature, and culture conditions, which provides evidence that the genetic ploidy variation has deterministic consequences on phenotypes among these S. obliquus strains. These preliminary findings prompted investigation of S. obliquus strains as part of a project exploring genome-wide comparisons, incorporating whole-genome sequencing of at a novel scale combined with high-throughput tools, like flow cytometry. Additional genomes will also provide the opportunity to increase the resolution of the genome at the chromosomal level, yielding possibility of additional scales of comparison in the future. We provide a discussion of our results indicating that genetic diversity at both the sequence level, and in terms of ploidy, both may provide mechanisms to increase genetic variation within the species. Our future work is focused on phenomics, meaning understanding the implications of genetic diversity on the phenotypes and adaptive radiation of the species through identifying parental genotypes of polyploid strains. Our studies contribute to the establishment of S. obliquus as a re-emerging model organism and a platform strain for robust growth with the potential to identify targeted varieties that are optimized according to the specific conditions.

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Monday, October 15 / 4:00 pm - 5:30 pm

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Hanschen, Erik [4:45pm]

Los Alamos National Laboratory

Genomic Comparison of Three Strains of Chlorella sorokiniana

Blake T. Hovde1, Erik R. Hanschen1, Christina R. Tyler1, Yuliya Kunde1, Karen Davenport1, Hajnalka Daligault1, Heriberto Cerutti2, Juergen Polle3, Shawn R. Starkenburg1* 1Bioscience Division, Los Alamos National Laboratory, Los Alamos, New Mexico, USAa; Department of Biology 2School of Biological Sciences, University of Nebraska-Lincoln, Lincoln, NE, USA 3Brooklyn College of the City University of New York, Brooklyn, New York, USAb*

Development of a viable algal cultivation system or biomanufacturing platform requires detailed knowledge of the platform strain(s), including its genetics and physiology. Furthermore, given the role of sexual reproduction in increasing variability, sexual reproduction/mating could be leveraged to artificially select for desirable traits. Using the sequenced genomes of three strains of Chlorella sorokiniana, we investigated their genetic diversity, the basis of sexual reproduction, photosynthesis, and secondary product synthesis. Though currently classified as strains of the same species, a significant disparity of gene content was identified, with each of the strains containing a large complement of strain specific genes (hundreds of genes per strain) as well as a high discrepancy of overall nucleotide identity. Preliminary investigation of the Chlorella epigenetic machinery suggests the presence of complex transcriptional regulation. With respect to photosynthesis, many genes previously thought to be required for photosynthesis (Viridicut gene set) are not found in these three strains of C. sorokiniana with minimal inter-strain variability. Using Chlamydomonas as a genomic positive control, we also inventoried the sex-related genes. Based on this comparison, C. sorokiniana has the genetic capacity/potential for sexual reproduction. Finally, we discovered a diverse yet conserved genomic repertoire of polyketide synthases (PKS) and NRPS/PKS hybrid genes in C. sorokiniana. Further analysis of the genetic similarities and differences between these and other Chlorella strains will enable their deployment for industrial applications.

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Monday, October 15 / 4:00 pm - 5:30 pm

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Barry, Amanda [5:00pm]

Los Alamos National Laboratory

Characterization of Plant Carbon Substrate Utilization by Two Microalgae

Amanda N. Barry1, Shawn Starkenburg1, Brian Vogler1,2, Nilusha Sudasinghe1, Joe Rollin3, and Sivakumar Pattathil4 1 Bioscience Division, Los Alamos National Laboratory, Los Alamos, NM 2 Colorado School of Mines, Golden, CO 3 National Renewable Energy Laboratory, Golden, CO 4 Complex Carbohydrate Research Center, The University of Georgia, Athens, GA: Current: Mascoma LLC

Significant effort has been made to maximize algal biomass productivity under photoautotrophic growth conditions; however, little progress has been made to discover and understand reduced carbon assimilation pathways or enzymatic degradation of complex carbon substrates in algae. We purport that utilization of raw plant-based carbon substrates in addition to photosynthesis (mixotrophic growth) for biochemical assimilation into biomass, biofuels, and bioproducts, can increase cultivation productivity and improve the economic viability of algal-derived biofuels. We demonstrate that two production strains of microalgae are capable of directly degrading and utilizing non-food plant substrates, such as switchgrass, for cell growth. Glycome profiling of plant substrates before and after addition to cultures demonstrates the utilization of xyloglucans. Genomic, proteomic and transcriptomic analyses revealed the identity of many enzymes that are hypothesized to be involved in complex carbohydrate degradation, including several family 5 and 9 glycosyl hydrolases. This work presents the first example of algae degradation and utilization of whole plant substrate, the putative genetic and molecular mechanism(s) behind this degradation, and the identity of potential glycosyl hydrolases that may be involved in plant deconstruction, paving the way for future designer engineering of plant carbon utilization to further improve productivity of algal production strains.

BIOLOGY

Crop Protection - Detection and Mitigation of Pathogens

Tuesday, October 16 / 10:30 am - 12:00 pm

Waterway 6, Level 2

Lane, Todd [10:30am]

Sandia National Laboratories

Innate and Designed Resistance to Algal Pond Crashes.

Todd W. Lane; Sandia National Laboratories, Nataly L. Beck; Sandia National Laboratories, Carolyn L. Fisher; Sandia National Laboratories, Pamela D. Lane; Sandia National Laboratories, James, D. Jaryenneh; Sandia National Laboratories

Research at Sandia National Laboratories has focused on three elements of crop protection that are critical to preventing or lessening the effects of pond crashes: 1, the identification of agents and the conditions under which they cause crashes 2, the development of technologies for the rapid detection of crash agents and 3, the development of pond operational strategies and countermeasures to prevent crashes. To facilitate this work, Sandia operates an Algal Testbed facility consisting of three 1000L ponds, housed under biocontainment, capable of simulating outdoor culture conditions and that can be used to cultivate the full range of algal species including GMOs. These ponds can be "crashed on demand" and represent a unique capability in the National Lab system. As part of the Development of Integrated Screening, Cultivar Optimization and Validation Research (DISCOVR) project, Sandia is testing candidate production strains for resistance to ingestion by grazers. In previous research under the ATP3 consortium we have identified grazers, parasites, and pathogens from freshwater and marine algal pilot ponds grown under seasonal and geographic variation. This information has informed the development of diverse panels of grazer species in both marine and freshwater systems which are now in cultivation at Sandia. We are evaluating the resistance, to these grazer panels, of promising production strains identified by the DISCOVR team. Grazer resistance assays are being carried out under simulated outdoor conditions at both laboratory and pilot pond scale at the Sandia Testbed. We will present the results of these experiments and efforts to identify potential algal production strains with the broadest innate resistance to grazing. In addition, we have previously reported the isolation and characterization of probiotic bacterial consortia that are capable of protecting algal cultures against rotifers. We now report the application of these methods and isolated consortia to additional grazer species.

BIOLOGY

Crop Protection - Detection and Mitigation of Pathogens

Tuesday, October 16 / 10:30 am - 12:00 pm

Waterway 6, Level 2

Poorey, Kunal [10:45am]

Sandia National Labs

Microbial Ecology Variation in Industrial Algae Cultivation Systems

K. Poorey : Sandia National Laboratories D.J. Curtis : Sandia National Laboratories C.L. Fisher : Sandia National Laboratories R.W. Davis : Sandia National Laboratories T.W. Lane : Sandia National Laboratories

For efficient biomass cultivation from microalgae and cyanobacteria in open cultivation systems, it is crucial to understand various parameters positively influencing the biomass productivity. We have observed that productivity and desired characteristics of the biomass have a great correlated with the microbial ecology in the cultivation ponds. Hence, it is crucial to study the microbial ecology and its dynamics over the cultivation runs for optimized industrial-scale cultivation of algae/cyanobacteria and quality. We have used next generation high throughput 16s/18s amplicon sequencing to characterize the ecology of multiple long-term cultivation runs for N. oceanica, C. vulgaris, cyanobacteria and polycultures from wastewater. We find, using machine learning approaches, that the quantitative measure of the pond ecology is correlated with other features measured from cultivation systems. Using ensemble predictive model, we have identified features in the dataset correlating with high yield and desired characteristics in the datasets. For BETO funded ATP3 project the trained ensemble machine learning model can predict pond crashes with greater than 87% accuracy and identify key members of microbiota both beneficial and harmful for optimized. Further using similar techniques characterized ecology in polyculture raceway ponds run with wastewater from CalPoly San Luis Obispo. We found key members in the pond ecosystem responsible for maintaining high productivity and, highly desirable, high settling behavior. We also track the changes in the microbial ecology during the long cultivation runs to study how the microbial community evolves and diverge in replicate ponds. Interestingly, over the course of cultivation run the microbial ecology of the replicated ponds diverged over time in taxonomic dimension and based on the geometry of the pond. We show that these data-driven approaches clearly increase our capacity to understand these complex systems and, we find that maintaining healthy industrial algal pond ecology is key for improving quality and productivity of biomass.

BIOLOGY

Crop Protection - Detection and Mitigation of Pathogens

Tuesday, October 16 / 10:30 am - 12:00 pm

Waterway 6, Level 2

Dempster, Thomas [11:00am]

Arizona State University

Pulsed Electric Field Processing for Microalgae Crop Protection

Thomas A. Dempster1, Henri Gerken1, Ian Roth2 and Michael A. Kempkes2 1Arizona State University, Arizona Center for Algae Technology and Innovation, Mesa, AZ, USA 2Diversified Technologies, Inc., Bedford, MA, USA

The Arizona Center for Algae Technology and Innovation (AzCATI) at Arizona State University (ASU), in cooperation with Diversified Technologies, Inc. (DTI), is investigating the application of Pulsed Electric Field (PEF) processing for predator control in microalgae cultures. We examined PEF processing as a low-cost, chemical-free method of microalgae crop protection via the reduction of microalgae predators. Ten different strains were subjected to a range of PEF conditions: pulse durations of 10, 20 and 40 and field strengths of 0, 1, 3, 5, 7.5, 10, 15, 20, 30, 35 and 39 kV/cm and to determine lethal conditions for each strain. These microalgae kill curves were used to determine the maximum treatment time and field strength not showing a detrimental effect on the microalgae. In theory, cultures could be treated up to these maxima to kill predators, but cause no harm to the algae. The following techniques were used to examine PEF processing effects and culture viability: 1) light microscopy, 2) spectrophotometric scans from 300 - 800 nm to evaluate pigment release resulting from the diminished integrity or lysis of cell membranes, 3) subjecting PEF-treated cultures to Sytox fluorescent microscopy to evaluate cell membrane permeability and nuclear staining, and 4) observing subsequent growth after streaking PEF-treated cultures on nutrient-rich agar plates and transferring treated culture into replete 800 ml glass columns. In addition, protein release and conductivity were measured for all conditions described above. Testing indicated that PEF treatment successfully killed rotifers, ciliates, amoeba and Poteriochromonas, at treatment times and field strengths that were non-lethal to all strains tested including Chlorella vulgaris, Scenedesmus acutus, Chlorella zofingiensis and Nannochloropsis oceanica. PEF treatment of predators appears to be a cost effective, chemical-free approach, which can be applied without damaging the microalgae itself. This effort is funded by USDA NIFA Phase II SBIR Grant 2017-33610-27016.

BIOLOGY

Crop Protection - Detection and Mitigation of Pathogens

Tuesday, October 16 / 10:30 am - 12:00 pm

Waterway 6, Level 2

Simkovsky, Ryan [11:15am]

University of California San Diego

Sniffing Out a Bad Pond: Mass Spectrometry-based Detection of Contamination

Simkovsky, Ryan Sauer, Jon Prather, Kimberly Pomeroy, Robert University of California San Diego*

Contamination of industrial-scale growth systems by pathogens, predators, and non-productive contaminating species continues to be a major obstacle to the robust and economically sustainable production of algal biomass and bioproducts. Appropriate management of these pests requires a sensitive and continuous monitoring system that can detect and identify contaminants and competitors as early as possible. In comparison to current detection methodologies, such as quantitative PCR or FlowCam monitoring systems, a mass spectrometry (MS)-based detection system is orders of magnitude more sensitive and can be readily automated for continuous monitoring of multiple production ponds. We have developed a chemical ionization mass spectrometry-based detection system capable of real time monitoring of volatile compound abundances in the air over an algal culture. Using this system, we have examined the headspace over healthy algal cultures throughout multiple growth phases, under abiotic stresses, and through culture crashes resulting from infecting the cultures with predators. The resulting data has allowed us to confirm previously characterized molecular signatures derived from breakdown pathways occurring in the culture liquid. These experiments have allowed us to expand our catalog of molecules that indicate the health of the algae or contamination, as well as to determine thresholds for detection of contaminants and the kinetics of culture crashes post-infection. Altogether, this research is rapidly advancing the development of a field-deployable instrument for monitoring contamination in algal cultures.

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Crop Protection - Detection and Mitigation of Pathogens

Tuesday, October 16 / 10:30 am - 12:00 pm

Waterway 6, Level 2

Fisher, Carolyn [11:30am]

Sandia National Laboratories

Probiotic Marine Bacteria Defend Microalgal Cultures in Field Trials

Carolyn L. Fisher, Pamela D. Lane, Mary Tran-Gyamfi, James D. Jaryenneh, Kunal Poorey, Todd W. Lane â€" Sandia National Laboratories, Livermore, CA

Pond crashes account for up to 30% loss of algae production, which drives up the economic barrier to biofuels. Previous lab-scale studies indicate that our protective microbial consortia have a positive impact on microalgaal culture although underlying mechanisms are unknown. Concurrently, we are investigating what microbial strains, natural products, and biosynthetic pathways are correlated with this protective effect in order to elucidate the mechanism of microalgae protection. We have also scaled up our lab-scale cultures and conducted outdoor 20L mesocosm trials with Microchloropsis salina in the presence of the protective consortia. By the end of the 40 day outdoor culture trial, we found that the cultures with the probiotic consortia present thrived while the axenic cultures experienced flocculation and were more susceptible to changing environmental conditions. Additionally, by the end of this outdoor trial, the bacterial consortia were still protective against marine rotifers in a lab-scale experiment, suggesting their stability within the co-culture. Similarly to past experiments, we found that there were fewer live rotifers and fewer rotifers carrying eggs in the algal-bacterial co-cultures. During the summer of 2018, we are scaling up to 1000L raceway pond trials in order to further investigate the biological and chemical differences at industry-scale culture sizes. We will be investigating the key biological and chemical differences, via Illumina MiSeq amplicon sequencing and Liquid-Chromatography/Mass Spectrometry (LC/MS), identified in the protective consortia co-cultures with algae. We plan to use these data to generate a simplified probiotic bacterial culture that will still confer protection from algal predation and will grow alongside the microalgae, aiding in robust algal growth and productivity. Development of a versatile bacterial system that protects microalgae from predation will be useful for protecting a variety of algae production systems and ultimately, driving down the cost of biofuel production.

BIOLOGY

Wastewater and Polycultures - Optimizing Productivity through Diversity

Tuesday, October 16 / 1:00 pm - 2:30 pm

Waterway 6, Level 2

Lodge, Jeffrey [1:00pm]

Rochester Institute of Technology

Use of Microalgae for Nutrient Reduction of Anaerobic Digester Effluents and Egg Processing Wastewater

Daniel Baah Rochester institute of Technology, Tim Snyder Rochester Institute of Technology
Ryan McMullan Rochester Institute of Technology Dr. Jeff Lodge Rochester Institute of Technology*

CH4 Biogas, Covington,NY has an anaerobic digester used to digest dairy manure, cheese whey, and yogurt whey to produce biomethane for electricity and heat. This facility produces 1.9 million gallons of pressed effluent per month with NH3 levels around 1900 ppm and PO4 levels around 600 ppm. These high levels persist even after treatment in a 3 lagoon system and are still too high for land application more than 2X per year. Our lab is investigating the use of microalgae to reduce N and P levels of the effluent such that the wastewater can be applied more often in an environmentally safe manner. Results show a significant reduction in N and P using a pilot microalgae tank onsite. Over 80% reduction has been achieved. A large triglyceride fraction of lipids has been found when the algae are grown on ADE. We have also found that the biomass can be used as a co-digestate for anaerobic digestion producing biomethane. Nearby in Clarence,NY, Kreher Egg produces two waste streams from egg production. One stream contains a detergent from egg wash and the second is wash water from hen houses. Our lab is testing microalgae to reduce N and P in both waste streams as neither can be land applied or sent to a WWTP. Preliminary results show that microalgae reduced N by 96% and P by 87% in 5 days using egg wastewater. Detergent containing wash water did not affect microalgae growth and further studies are being done to look at nutrient reduction in this waste stream. Microalgae treatment of ADE and egg processing wastewater may be a viable alternative to nutrient reduction and be used as a supplemental treatment process for treating various waste streams in Western NY.

BIOLOGY

Wastewater and Polycultures - Optimizing Productivity through Diversity

Tuesday, October 16 / 1:00 pm - 2:30 pm

Waterway 6, Level 2

Schramm, Stephanie [1:15pm]

University of Illinois Urbana-Champaign Department of Civil & Environmental Engineering

Development of Universal Stoichiometric Coefficients For Modeling Polyculture Cultivation Systems

Stephanie M. Schramm, Brian D. Shoener, Jeremy S. Guest All Authors: University of Illinois at Urbana-Champaign, Department of Civil and Environmental Engineering, Urbana, IL 61801, USA.

Treatment processes at water resource recovery facilities (WRRFs; a.k.a. wastewater treatment plants) are approaching the limit of technology for N and P removal. Algal technologies have immense potential to lower nutrient discharge while producing valuable coproducts such as animal feed, fertilizers, and bioenergy feedstocks. A critical challenge for the adoption of algal technologies, however, is the lack of mechanistic understanding of how to design and operate systems that reliably achieve effluent quality and biomass production targets for a given locality. The development of robust algal modeling platforms for wastewater treatment could overcome this barrier, but such platforms would need to accommodate reactor condition fluctuations and the inevitable biodiversity of wastewaters. At present, many existing algal process models rely on empirical stoichiometric parameters, making them difficult to translate across systems and locations. Alternatively, genome-scale models provide fundamental insight into specific species metabolisms, but genome-scale data are complex, difficult to manipulate, and cannot accommodate dynamic polycultures, making such models impractical for wastewater process engineering. To improve modeling capabilities and advance the reliability of algal treatment systems, generalizable model parameters are needed. The development of stoichiometric parameters -" like those used in the International Water Association's (IWA's) Activated Sludge Models (ASMs)" would bolster accuracy and the accessibility of algal process models. To this end this presentation will introduce universal stoichiometric coefficients for algal process modeling derived from the conserved enzymatic properties for seven algae species using 11 genome-scale models. The model parameters include yield coefficients for algae grown under various energy inputs (photoautotrophic, mixotrophic, and heterotrophic), nitrogen sources (ammonia, nitrate), and carbon sources (inorganic, acetate, glucose) as well as stoichiometric parameters for the accumulation of storage compounds (starch and lipids). Establishing universal stoichiometric coefficients based on conserved metabolic properties of algae will help promote the use of algal technologies by wastewater design engineers and utilities.

BIOLOGY

Wastewater and Polycultures - Optimizing Productivity through Diversity

Tuesday, October 16 / 1:00 pm - 2:30 pm

Waterway 6, Level 2

Jackson, Matthew [1:30pm]

Montana State University

Improved Productivity during Combined Wastewater Treatment and Algae Cultivation - Understanding Nitrogen Assimilation under Low and High Alkalinity Conditions

Matthew Jackson; Center for Biofilm Engineering, Chemical and Biological Engineering, Montana State University Ashley Berninghaus; Center for Biofilm Engineering, Chemical and Biological Engineering, Montana State University Daniel Peters; Center for Biofilm Engineering, Chemical and Biological Engineering, Montana State University Robin Gerlach; Center for Biofilm Engineering, Chemical and Biological Engineering, Montana State University (ABO member)

Affordable water and nutrient supplies remain to be limiting factors in the expansion of the current algae biofuel industry. The use of low quality waste streams, such as municipal and industrial wastewaters, has been considered as a potential alternative to the use of clean water and traditional fertilizers. However, wastewater streams are variable in their chemical make-up and therefore it is necessary to understand how differences in chemistry will affect algae cultivation and biomass composition. We investigated the effect of different nitrogen species (nitrate, ammonium, urea, and a combination of all three) on the growth and composition of two Chlorella species, C. vulgaris strain UTEX 395 and C. sorokiniana strain SLA-04. Strain SLA-04 was isolated from a high alkalinity environment and has been shown to be highly productive during high alkalinity culturing. High alkalinity culturing of microalgae is of interest as it increases the availability of dissolved inorganic carbon and has been shown to reduce the competition from other organisms. The effect of nitrogen species on culture productivity was compared for both organisms in low and high alkalinity growth media. Both organisms were able to grow under all nitrogen and alkalinity conditions. While high alkalinity culturing of UTEX 395 resulted in reduced productivity; SLA-04 grew similarly at low and high alkalinities. Acidification of the medium during cultivation with ammonium and off-gassing of ammonia at high pH values were identified as potential obstacles for cultivation using certain waste streams. To address these issues we explored HCO_3^- or KOH additions combined with a 5% CO_2 sparge for pH control. This has been successful at minimizing detrimental pH changes during cultivation with ammonium. Through this research we have improved the current understanding of the effects of nitrogen speciation in low and high alkalinity waste streams on algae growth and biomass composition. This work will aid in reducing the costs for project development using different waste streams for algae cultivation and conserve traditional fertilizers and clean water for more important uses.

BIOLOGY

Wastewater and Polycultures - Optimizing Productivity through Diversity

Tuesday, October 16 / 1:00 pm - 2:30 pm

Waterway 6, Level 2

Edmundson, Scott [1:45pm]

Pacific Northwest National Laboratory

Complete Water and Nutrient Recycling in Algal Biomass Production for Biofuels

Scott Edmundson, PNNL Robert Kruk, PNNL Kyle Pittman, PNNL Jordana Wood, PNNL Nicholas Schlafer, PNNL Michael Huesemann, PNNL Dan Anderson, PNNL Andy Schmidt, PNNL

Recycling nutrients downstream of the fuel conversion process of will be critical to sustainable biofuels, including algal-based fuels. We adapted the freshwater green alga Chlorella sorokiniana DOE1412, originally isolated in the National Alliance for Advanced Biofuels and Bioproducts (NAABB) consortium project, to grow on a brackish water medium (10 PSU) with all major nutrients (N, P, K, and Fe) derived from the solid and aqueous phase by-products of biocrude production via the continuous hydrothermal liquefaction (HTL) of Chlorella biomass. The adapted strain, C. sorokiniana DOE1412.HTL, was cultivated under climate simulated conditions in PNNL's Laboratory Environmental Algae Pond Simulator (LEAPS), simulating summer in Mesa, AZ, the geographical location of the Arizona Center for Algae Technology and Innovation (AzCATI). Biomass was harvested periodically from the LEAPS via continuous centrifugation and the supernatant was returned to the bioreactor to restart a successive growth cycle. Additional recycled nutrients derived from HTL processing were added at every growth cycle to provide sufficient N and P for approximately 500 mg/L of biomass. After running continuously for over 200 days, completing 40 harvest and growth cycles, no cultures crashes were observed, and biomass productivity averaged ca. 14 g·m-2·day-1 (n=172). We measured elemental contents in both the algal biomass and the recycled supernatant overtime. Biomass grown on recycled HTL by-products accumulated Co and Zn, likely due to the addition of trace metals, but most other elements remained constant in the biomass over time. The supernatant, in contrast, accumulated Co, Mn, Mo, Ni, S, and Zn. No indication of toxicity or progressive growth inhibition was observed throughout the course of the experiment. To the best of our knowledge, this is the longest report of continuously re-used water and recycled nutrients in algal cultivation to date.

BIOLOGY

Wastewater and Polycultures - Optimizing Productivity through Diversity

Tuesday, October 16 / 1:00 pm - 2:30 pm

Waterway 6, Level 2

Gerlach, Robin [2:00pm]

Montana State University

Maximizing the Benefits of Combined Algae Cultivation and Wastewater Treatment through a Better Understanding of Organic Carbon Utilization by Three Green Algae Species

Daniel Peters, Montana State University Matthew Jackson, Montana State University Robin Gerlach*, Montana State University*

Algae cultivation using low-quality waste streams such as municipal wastewater is of increasing interest due to the high demand (and potentially cost) of water and nutrients. Traditional fertilizers are energy intensive to generate or are limited in availability; similarly, the availability of high quality water is limited. In addition to the traditional nutrients required for photosynthetic metabolism, N and P, most low-quality waste streams include an organic fraction that can act as an additional, valuable carbon source for some algae strains capable of mixotrophic metabolism. We screened more than 100 algal cultures and compared their ability to grow photoautotrophically, mixotrophically, and heterotrophically. During this screening 27% of the strains evaluated had final mixotrophic cell concentrations that were greater than the sum of the phototrophic and heterotrophic conditions, suggesting that organic carbon metabolism and photosynthesis are working synergistically. The effect of OC on growth and biomass composition of three green algae strains, Chlorella sp. SLP5, Chlorella vulgaris UTEX 395, and Chlorella sorokiniana SLA-04 was investigated. Photoautotrophic (14:10 light cycle; no OC), mixotrophic (14:10 light cycle; 300 mg/L OC), and heterotrophic (no light; 300mg/L OC) growth conditions were evaluated in 1.5 L tube reactors. Biomass and total FAME accumulation appear to be equivalent or increase for these organisms under mixotrophic conditions; the lowest growth rates and biomass accumulation were observed under heterotrophic conditions, along with an increased susceptibility to contamination by heterotrophic organisms capable of utilizing the available OC in both the mixotrophic and heterotrophic conditions. This research will improve the algae community's ability to use waste streams for algae cultivation and remediate wastewaters simultaneously.

BIOLOGY

Novel Products from Microalgae: Making the Most of Biology

Tuesday, October 16 / 3:15 pm - 4:45 pm

Waterway 6, Level 2

Cheng, Jun [3:15pm]

Zhejiang University

Mutation and Domestication of Haematococcus pluvialis to Promote Biomass Growth and Astaxanthin Yield

Jun Cheng, Ke Li, Hongxiang Lu, Junhu Zhou, Kefa Cen State Key Laboratory of Clean Energy Utilization, Zhejiang University presenter: Jun Cheng email: juncheng@zju.edu.cn

In order to increase biomass yield and reduce culture cost of Haematococcus pluvialis with flue gas from coal-fired power plants, a screened mutant by nuclear irradiation was gradually domesticated with 15% CO_2 to promote biomass dry weight and astaxanthin yield. The biomass yield of mutant after 10 generations of 15% CO_2 domestication increased to 1.3 times as that with air. With the optimization of nitrogen and phosphorus concentration, the biomass dry weight was further increased by 62%. The astaxanthin yield induced with 15% CO_2 and high light increased to 87.4 mg/L, which was 6 times higher than that induced with high light in air. To elucidate the mechanism underlying the enhanced growth rate in the Haematococcus pluvialis mutated with 60Co-gamma rays and domesticated with 15% CO_2, transcriptome sequencing was conducted to clarify the carbon metabolic pathways of mutant cells. The CO_2 fixation rate of mutant cells increased to 2.57 g/L/d under 15% CO_2 due to the enhanced photosynthesis, carbon fixation, glycolysis pathways. Transcriptome sequencing and annotation was also performed on Haematococcus pluvialis mutant red cells induced with high light under 15% CO_2 to demonstrate why astaxanthin yield of the mutant was 1.7 times higher than that of a wild strain. Most significant differences were found in unigenes related to photosynthesis, carotenoid biosynthesis and fatty acid biosynthesis pathways. In vivo spatiotemporal dynamics of lipids and astaxanthin evolution in Haematococcus pluvialis mutant induced with 15% CO_2 and high light intensity were monitored with high spatial resolution in a nondestructive and label-free manner using single-cell Raman imaging. Astaxanthin intensity increased by 3.5 times within 12 h under 15% CO_2, and the accumulation rate was 5.8 times higher than that under air. Lipids intensity under 15% CO_2 was 27% higher than that under air. The lipids initially concentrated in chloroplast under 15% CO_2 due to an increase of directly photosynthetic fatty acid, which was different from the whole-cell dispersed lipids under air. Astaxanthin produced in chloroplast first accumulated around nucleus and then spread in cytoplasmic lipids under both air and 15% CO_2. The calculation results of kinetic models for lipids and astaxanthin evolutions showed that accumulation rate of lipids was much higher than that of astaxanthin in cells.

BIOLOGY

Novel Products from Microalgae: Making the Most of Biology

Tuesday, October 16 / 3:15 pm - 4:45 pm

Waterway 6, Level 2

Harvey, Patricia [3:30pm]

University of Greenwich, Faculty of Engineering and Science

Potential of New Isolates of Dunaliella salina for Natural β-carotene Production

Yanan Xu (1), Iskander M. Ibrahim (1), Chiziezi I. Wosu (1), Ami Ben-Amotz (2) and Patricia J. Harvey (1) (1) University of Greenwich, Faculty of Engineering and Science, Central Avenue, Chatham Maritime, Kent, ME4 4TB UK; (2) Nature Beta Technologies (NBT) Ltd, Eilat 88106, Israel; amiba@bezeqint.net p.j.harvey@greenwich.ac.uk

The halotolerant microalga Dunaliella salina has been widely studied for natural β-carotene production. We present biochemical characterization of three newly isolated Dunaliella salina strains DF15, DF17 and DF40 compared with D. salina CCAP 19/30 and D. salina UTEX 2538 (also known as D. bardawil) as part of a EU-funded project, KBBE.2013.3.2-02 the D-Factory: 368 613870. Although all three new strains have been genetically characterized as Dunaliella salina strains, their ability to accumulate carotenoids and their capacity for photoprotection against high light stress are different. DF15 and UTEX 2538 reveal great potential for producing large amount of β-carotene and maintained a high rate of photosynthesis under light of high intensity; however, DF17, DF40 and CCAP 19/30 showed increasing photoinhibition with increasing light intensity, and reduced contents of carotenoids, in particular ?-carotene, suggesting that the capacity of photoprotection is dependent on the cellular content of carotenoids, in particular β-carotene. Strong positive correlations were found between the cellular content of each of all-trans β-carotene, 9-cis β-carotene, all-trans α-carotene and zeaxanthin but not lutein in the D. salina strains. Lutein was strongly correlated with respiration in photosynthetic cells and strongly related to photosynthesis, chlorophyll and respiration, suggesting an important and not hitherto identified role for lutein in co-ordinated control of the cellular functions of photosynthesis and respiration in response to changes in light conditions, which is broadly conserved in Dunaliella strains. Statistical analysis based on biochemical data revealed a different grouping strategy from the genetic classification of the strains. The significance of these data for strain selection for commercial carotenoid production is discussed.

BIOLOGY

Novel Products from Microalgae: Making the Most of Biology

Tuesday, October 16 / 3:15 pm - 4:45 pm

Waterway 6, Level 2

Msanne, Joseph [3:45pm]

New Mexico Consortium

Engineering Microalgae to Produce Galactomannan Polysaccharides (Guar Gum)

Joseph Msanne and Shawn Starkenburg New Mexico Consortium, Los Alamos, NM*

In the present study, microalgae strains including Chlamydomonas reinhardtii and Chlorella sorokiniana were genetically modified to produce galactomannan polysaccharides, also known as guar gum, with a target yield more than 5% total biomass. Guar gum, originally derived from guar bean, is a commodity with a growing market. It is an edible agent used in a wide range of foods, while industrial grade guar gum is used in cosmetic, paper and pharmaceutical industries as a thickening agent. The polysaccharide is composed of galactose and mannose, with a linear chain composed of β1,4-linked mannose serving as the backbone to which galactose residues are linked at every second mannose, creating side chains. Cells were genetically-engineered by transformation using codon-optimized gene sequences that encode for the polymannan synthase, as well as the galactosyl transferase. We will report on current phenotyping efforts and the physiological impacts of the transgene insertion, quantification of guar synthesis and accumulation, and application of high performance liquid chromatography (HPLC) to determine the enrichment of galactose and mannose.

BIOLOGY

Novel Products from Microalgae: Making the Most of Biology

Tuesday, October 16 / 3:15 pm - 4:45 pm

Waterway 6, Level 2

Davis, Ryan [4:00pm]

Sandia National Laboratories

Cultivation and Utilization of Cyanobacterial Exopolysaccharide for Production of Bio-based Polymers

Ryan W Davis, Sandia National Laboratories, Livermore CA Eric Monroe, Sandia National Laboratories, Livermore CA Eric Sundstrom, Advanced Biofuels Process Demonstration Unit, LBNL Rocco Mancinelli, HelioBioSys Inc David Smernoff, HelioBioSys Inc

Development of polycultures has been identified as a potential means for overcoming several challenges facing scale-up of algae-based commodities that can displace petroleum but do not compete with food production. In this presentation, we will describe findings from our recent studies on cultivation of a marine cyanobacterial consortium in 1000L open algae raceways, gelation-based harvesting, and downstream conversion to bioplastic. In the consortium, three distinct cyanobacterial cultivars were combined to provide nitrogen fixation, photoprotection, and high rates of secretion of extracellular polysaccharides in support of a long-term bioproduct milking strategy. Each of the cohorts of the cyanobacterial consortium was cultivated individually at lab-scale for assessment of growth rate and other phenotypic variables as a function of light intensity and nitrate concentration in order to identify optimal algae raceway inoculation and maintenance strategies. Following the lab-scale investigations, the consortia were successfully cultivated with semi-continuous harvesting in pilot-scale environmental simulation open algae raceways for >160 days, achieving bioproduct concentrations >2 g/L consisting primarily of a variety of C5 and C6 monosugars, which were recovered using a low-cost gelation-based harvesting strategy. In addition to the notable stability of the consortium in open cultivation, measurements of culture density time course indicated insignificantly different log-phase specific growth rates at different levels of nitrate or carbon dioxide addition, which should have significant techno-economic and sustainability impacts for commercialization. Following recovery of the biomass and exopolymer, generation of cyanobacterial-derived bioplastic was demonstrated and performance characteristics were found to be similar to common biobased plastics, such as PLA. Initial technoeconomic analysis based on the product yield and corresponding biomass production, harvesting, and conversion costs indicate an Nth-plant model finished product cost of $600/ton.

BIOLOGY

Cultivation Practice Makes Perfect 2: Cultivation Strategies Towards Scaling Algae Biomass Production

Wednesday, October 17 / 10:45 am - 12:15 pm

Waterway 6, Level 2

Ganuza, Eneko [10:45am]

Heliae Development LLC.

Strategies for Mass Production of Mixotrophic Microalgae

Ganuza, E., Paolilli, K., Sellers, C., Amezquita, M. Microbiology Group, Heliae Development, LLC, Gilbert, AZ, USA

The benefits of combining heterotrophic and photoautotrophic metabolism to grow mixotrophic microalgae (i.e. productivities, titers) are well documented at small scale, but such an approach has rarely been applied commercially. Microbial contamination is an obstacle for scaling up of mixotrophic processes because the sugars used in such medium dramatically broadens the range of bacterial competition to which the reactor is exposed. Therefore, growth restrictive conditions that favor algae growth are required to exploit mixotrophy commercially. We screened several organic substrates in the green algae Micractinium inermum and observed that acetic acid conferred a competitive advantage over a wide range of bacterial contaminants. This led us to investigate the mechanisms of acetic acid toxicity in microalgae. We hypothesized that the acetate ion rather than the acid form is ultimately responsible for its toxicity and built a mathematical model that predicts the toxicity level in an algal culture. The physiological assumptions of the model were experimentally validated. Bacterial and algal response to acetate toxicity were measured and used to design a mixotrophic process in which acetate acts both as a substrate and a contamination controlling agent. This contamination control approach has led to what we believe is the scale up of the first industrial mixotrophic process.

BIOLOGY

Cultivation Practice Makes Perfect 2: Cultivation Strategies Towards Scaling Algae Biomass Production

Wednesday, October 17 / 10:45 am - 12:15 pm

Waterway 6, Level 2

Spierling, Ruth [11:00am]

California Polytechnic State University

A Comparison of Pure Culture and Polyculture Productivity in Outdoor Raceway Ponds

Ruth Spierling 1,2, Aubrey Davis 1,2, Sara Leader 1,2 , Mike Scott 1, John Benemann 2 , Tryg Lundquist 1,2 1 California Polytechnic State University, 2 MicroBio Engineering Inc.

Spontaneously developed algal polycultures in open ponds are selected by adaption to the prevailing environmental conditions and are expected to be more productive than cultures inoculated with single strains (Smith, V., and T. Crews, 2013 Algal Research 4:23-24; Narwani, A., et al., 2016, Environ. Sci. Technol., 50: 13142−13150). We operated in San Luis Obispo, California, from May 8,2017 to March 1, 2018, six 4.5 m2 and four 3.3m2 paddle wheel mixed raceway ponds at 0.3m depth, in replicate. Two ponds each were operated at a 2-day residence times with a spontaneous polyculture on two types of municipal wastewater: reclaimed wastewater (RWW) and primary clarifier effluent (PCE). Two ponds operated on a 2- to 4-day residence time (depending on culture density) with a pure culture of Scenedesmus obliquus (DOE 0152z) on RWW. In the remaining four ponds, additional pure culture strains were tested for shorter periods at 2 to 4-day residence times on RWW. Over six months, from May 8, 2017 to November 8, 2017, productivity, as g AFDW/m2-day (+/- one standard deviation), was 32.1 (+/- 1.8) for the polyculture grown on CPW, 20.5 (+/- 1.2) for the polyculture on RWW, and 14.6 (+/- 0.3) for the pure culture of S. obliquus (DOE 0152z). Productivities during the winter months were lower but followed the same trend. Results with other pure cultures grown on RWW for shorter periods were generally similar to those observed with S. obliquus. In summary, the polycultures grown on CPW were over a third more productive than on RWW, which, in turn, were about a third more productive than the S. obliquus ponds grown on the same RWW medium. The higher productivity of polycultures on CPW compared to RWW was due to the high organic content of that wastewater, resulting in additional mixotrophic algal and microbial heterotrophic growth. The higher productivity of the polyculture ponds compared to the pure culture could be attributed to the better adaptation of the former to the pond culture environment. Although polycultures can be more productive than single strains, applications could be limited where control over biochemical composition is important, as in biofuels production.
(This research was supported by the US DOE, Bioenergy Technologies Office, Advanced Algal Systems Program, “Algal Biomass Yield Phase 2” Award DE-EE0007691 to MicroBio Engineering Inc.)

BIOLOGY

Cultivation Practice Makes Perfect 2: Cultivation Strategies Towards Scaling Algae Biomass Production

Wednesday, October 17 / 10:45 am - 12:15 pm

Waterway 6, Level 2

Monroe, Eric [11:15am]

Sandia National Laboratories

Turf Algae Cultivation for Coupled Biofuel Production and Bioremediation of Agricultural Runoff

Eric Monroe - Sandia National Laboratory Lynn Wendt - Idaho National Laboratory Katie DeRose - Colorado State University Jason Quinn - Colorado State University Ryan Wesley Davis - Sandia National Laboratory

As the global population rises and agriculture continues to expand to support this growth, Harmful Algae Blooms (HABs) in lakes, rivers, and oceans caused by nutrient runoff from agriculture will be an increasing threat to public health and will have continue to large and lasting economic impacts. HABs have already had catastrophic impacts on a wide variety of environments and communities from coast to coast in the US, with many states such as New York, Ohio, and Florida launching large financial investments and R&D campaigns to monitor and understand the impact of these HABs as well as to reduce the amount nitrogen and phosphorus released that is the main driver of these events. This work details results from a research, development, and deployment effort to cultivate attached turf algae that utilizes the currently untapped supply of dilute nutrients for biomass growth and use of this biomass as a feedstock for biofuels or other bioproducts. Our results from a deployment in Imperial County, CA (which sources water from one of the most contaminated rivers in the US) demonstrate that this algae cultivation strategy can provide dramatic improvements in water quality including reduced nitrogen and phosphorus levels as well as uptake of hazardous heavy metals such as Selenium and Arsenic. Our results show that ash content is a key cost driver for the process since ash content in the harvested material can be over 80% of the dry weight; efforts currently underway to reduce ash from the harvested material and to prevent it from being incorporated into the biomass will be discussed. Furthermore, results from a variety of processing options for biofuel production from turf algal biomass will be discussed, as cultivation of attached turf algae offers the ability to couple biofuel production and environmental bioremediation of compromised surface waters to maximize value and improve process economics.

BIOLOGY

Cultivation Practice Makes Perfect 2: Cultivation Strategies Towards Scaling Algae Biomass Production

Wednesday, October 17 / 10:45 am - 12:15 pm

Waterway 6, Level 2

Liao, Wei [11:30am]

Michigan State University

An Integrated Algae Solution to Address Carbon Dioxide and Wastewater Challenges of the Power Industry

Sibel Demirer, Michigan State University Dave Pavlik, PHYCO2 LLC Susie Liu, Michigan State University Nathan Verhanovitz, Michigan State University Milton (Mitch) Smith, Michigan State University Angela Wilson, Michigan State University William Clary, PHYCO2 LLC Wei Liao, Michigan State University

The power industry in the U.S. withdraws approximately 71,000 million cubic meters of fresh water (1/3 of total fresh water withdrawal) and emits more than 1.8 gigaton of CO_2 (30% of the total CO_2 emissions) per year. New solutions are urgently needed to reduce/reuse the water and capture the CO_2. An algal-based solution was developed to synergistically integrate algal cultivation and biomass utilization with power plant operations to capture CO_2 and utilize the wastewater. A robust algal species selected from the Great Lake region was used as the strain to culture on flue gas and nutrient-containing boiler wastewater. A pilot system has been established at the Michigan State University power plant to directly take the flue gas and boiler water to carry out the algal cultivation. The algal biomass was used to produce carbohydrate-, protein-, and lipid-based chemicals. A detailed mass and energy balance was also conducted to delineate the integration of the algal cultivation with the power plant operations.

BIOLOGY

Cultivation Practice Makes Perfect 2: Cultivation Strategies Towards Scaling Algae Biomass Production

Wednesday, October 17 / 10:45 am - 12:15 pm

Waterway 6, Level 2

Johnson, Rick [11:45am]

InNow Water and Environmental Services

Recycling of CO2 Gas Through the Use of Algae Production

Joel Agner, Honda R&D Americas, Inc. Dan Sellars, Honda R&D Americas, Inc. Dr. David Bayless, Ohio University Kevin McGraw, Clearas Water Recovery Rick Johnson, InNow LLC, Water and Environmental Services

The beneficial use of algal technologies to reduce excessive nutrients in waste streams is gaining credibility with several full scale municipal and industrial applications under construction. Recently though, there has been a growing interest in the potential use of algal production to help reduce CO2 emissions. At the summer 2017 Algal Biomass Conference, a poster was presented which demonstrated that the production of algal biomass is a viable use of flue gas generated through the incineration of biosolids at the second largest wastewater treatment facility in Massachusetts (Upper Blackstone Water District located in Milbury, MA). This paper will discuss a program conducted through the support of Honda R&D Americas, Inc. to recycle CO2 emissions at its North American R&D facility in Raymond, OH. Part of a potentially larger program, this initial phase is focused on demonstrating that the use of algal production can be a viable component to a broader corporate objective of becoming carbon neutral. With the support of Honda R&D Americas, Inc. and the Ohio Water Development Authority, a public-private team was assembled to evaluate whether the use of algal production could achieve overall program objectives of carbon recycling at less than $100/ton of CO2 consumed. The discussion will focus on the overall program objectives, methodologies employed, results obtained, next steps and most importantly, the economics of this approach.

ENGINEERING & ANALYSIS

Beginning with the End in Mind: How Algae Applications Affect Growth Rates and the Cultivation System Design

Monday, October 15 / 1:45 pm - 3:15 pm

Waterway 1, Level 2

Bouchard, Josee [1:45pm]

Algenol Biotech, LLC

Biomass Production in an Advanced Photobioreactor-Based Biorefinery

Josée Bouchard, Yanhui Yuan, Ankush Karemore, Laura Belicka, Lisa Pickell, Allison DeNunzio, Diane Paradise, Caitlin Linder, George Meichel, Monica Brown, Kimberly Anderson, William Porubsky, Paul Roessler, Ron Chance16121 Lee Road, Suite 100, Fort Myers, FL, 33912

For over a decade, Algenol has been engaged in the design and production of photobioreactors (PBRs) for application in algal bio-refineries for ethanol and biocrude production. Over the recent years, Algenol has focused on the production of high value products. This talk describes the innovations in biology, cultivation, and engineering approaches which are used to take algae from the laboratory to the market. A description of the different production scales and various productivity levers used to optimize productivity will be included. In addition, the phenomenological model that allows good prediction of outdoor performance from small scale indoor experiments, as well as a general understanding of the optimum performance parameters for semi-continuous operation will be discussed.

ENGINEERING & ANALYSIS

Monday, October 15 / 1:45 pm - 3:15 pm

Waterway 1, Level 2

Pienkos, Philip [2:00pm]

National Renewable Energy Laboratory

Bringing the Outdoors In

Philip T. Pienkos, Martin Lynch, and Nick Sweeney National Renewable Energy Laboratory

In the past few years there has been a noticeable change in the adoption of indoor cultivation systems, shifting from constant temperature and non-natural illumination strategies to programmable systems that can better model outdoor cultivation conditions. These systems, which range from mass-produced commercial systems to custom-built systems, have greatly aided the algae community by enabling the ability to perform strain screening, evaluate productivity, and conduct physiological experiments with an eye towards extrapolation to outdoor cultivation. NREL has developed a number of custom-built PBR systems known as Simulated Algal Growth Environments (SAGE) using a variety of culture vessels allowing for operation at scales ranging from 50 mL to 2L. We have observed, however, that growth in the SAGE reactors does not match growth outdoors under similar conditions. In fact, growth rates and cell densities are typically much higher indoors than outdoors and compositional shifts caused by nutrient depletion occur much faster and to a greater extent. A recent exercise to model the cost/benefit of compositional shifts in deplete cultures with prolonged cultivation time has highlighted these differences. To address this problem, we have devised a simple and inexpensive PBR configuration that provides programmed temperature and lighting cycles to simulate outdoor growth along with adjustable culture depths that can be held constant throughout a growth experiment even with the removal of a number large samples taken for dry weight and compositional analysis. In this presentation we will compare growth data from this PBR with earlier iterations of the SAGE reactor and with outdoor open pond data, and show how these data can feed into the biomass composition cost/benefit model. Finally, we will provide some insights for development of cultivation strategies that mitigate the added cost of nutrient starvation for the production of high lipid algal biomass.

ENGINEERING & ANALYSIS

Beginning with the End in Mind: How Algae Applications Affect Growth Rates and the Cultivation System Design

Monday, October 15 / 1:45 pm - 3:15 pm

Waterway 1, Level 2

Manisali, Ahmet Yener [2:15pm]

University of South Florida

Continuous Cultivation of Microalga Nannochloropsis oculata to Isolate Value-Added Polar Lipids for Cosmetic Applications

Ahmet Y.Â Manisali (1) GeorgeÂ Philippidis (1, 2) Aydin K.Â Sunol (1) 1) Dept.Â ofÂ ChemicalÂ &Â BiomedicalÂ Engineering, UniversityÂ ofÂ SouthÂ FloridaÂ (USF) 2) PatelÂ CollegeÂ ofÂ GlobalÂ Sustainability,Â UniversityÂ ofÂ SouthÂ FloridaÂ (USF)Â

Algae, specifically microalgae, that are promising sources of natural ingredients owing to their cell mass containing polysaccharides, proteins, lipids, pigments, and vitamins have been the benign raw materials. Particularly the interest on phospholipids, a subgroup of polar lipids, has been on the rise due to them being the appropriate candidates to the pharmaceutical and cosmetics industry for various applications such as emulsifiers, liposome formers, solubilizers, wetting agents, and bioactive compounds. Phospholipids are currently extracted from food sources; however, this practice raises sustainability issues because of the competition with food. Microalgae can serve as a source of phospholipids on a more sustainable basis. To advance the status of microalgae bioproducts for cosmetics applications, the marine microalga Nannochloropsis oculata (N. oculata) was cultivated in a vertical flat panel photobioreactor (VFPPBR) in batch and continuous mode. Batch cultivation of N. oculata was performed to optimize the growth parameters, estimate its maximum specific growth rate (µmax), and determine its phospholipid productivity. Because the total lipid productivity is essential to increase the phospholipid productivity, optimization of volumetric microalgal biomass productivity in turn boosted up the overall lipid productivity. The measured µmax was utilized in selecting the dilution rate for designing and operating a VFPPBR-based continuous cultivation of N. oculata that was deemed to be more scalable and productive operation from a commercialization aspect. Cell harvesting via centrifugation was followed by solvent/pressurized solvent extraction to capture and isolate the microalgal polar lipids, specifically phospholipids. The experimental findings from continuous cultivation of N. oculata species, the robustness of the strain, and its polar lipid productivity, photobioreactor design, performance of the species in batch and continuous mode of operation, and green pathways for downstream processing to isolate, concentrate and fractionate microalgal phospholipids were analyzed and discussed.

ENGINEERING & ANALYSIS

Beginning with the End in Mind: How Algae Applications Affect Growth Rates and the Cultivation System Design

Monday, October 15 / 1:45 pm - 3:15 pm

Waterway 1, Level 2

Quinn, Jason [2:30pm]

Colorado State University

Implications of Mixing Energy at Photo-inhibiting Light Intensities for the Industrial Scale Design and Sustainability of Cyanobacterial Cultivation in Open Raceway Ponds and Flat-panel Photobioreactors

Carlos Quiroz-Arita, Kenneth F. Reardon, Peter Chen, Jason C. Quinn, Thomas H. Bradley Colorado State University, Fort Collins, CO 80523, USA

Turbulence mixing process governs the biological responses and life cycle energy efficiencies of cyanobacterial derived biofuels. The implications of turbulence mixing in the bioprocess were studied by cultivating Synechocystis sp. PCC6803 in open raceway ponds and flat-panel photobioreactors at industrially relevant mixing energy inputs and high incident radiations. Mixing energy inputs ranging from 0.03 to 1.97 W·m-3 were studied in this research. Photo-inhibiting incident radiations at 938 (± 84) and 1348 (± 84) µmol photons m-2.s-1 were used for cultivation of cyanobacteria in open raceway ponds and flat-panel photobioreactors, respectively. A well-mixed cyanobacterial growth model was developed and validated to determine the role of turbulence mixing in the light regime experienced by either single Synechocystis sp. PCC6803 cells or the cyanobacterial bulk. A comprehensive life cycle assessment (LCA) approach, incorporating experimentation, was developed to evaluate the impact of mixing energy inputs in the sustainability of the cyanobacterial derived biofuel systems. We have identified that the maximum growth rates, cyanobacterial biomass productivities, and Net Energy Ratios (NER), are enhanced at low mixing energy inputs, illustrating the importance of this study and novel approach to predict the performance of industrial systems from bench and pilot scale experimentation. The significance of this study is the establishment of mixing strategies to meet energy efficiency and sustainability goals by photoautotrophic derived biofuels facilities to maximize their assets.

ENGINEERING & ANALYSIS

Beginning with the End in Mind: How Algae Applications Affect Growth Rates and the Cultivation System Design

Monday, October 15 / 1:45 pm - 3:15 pm

Waterway 1, Level 2

Starkenburg, Shawn [2:45pm]

Los Alamos National Laboratory

Increasing Cultivation Yield and Stability with Rationally Designed Consortia

Shawn R. Starkenburg 1,2, Alina A. Corcoran2, Blake Hovdke1, Erik Hanschen1 1. Biosciences Division, Los Alamos National Laboratory 2. New Mexico Consortium*

The commercialization of algal biofuels will not be realized until major technical and economic barriers are overcome. As outlined in BETO's update to the National Algal Biofuels Technology Roadmap, there is a need to improve culture productivity and stability, as well as to better understand these metrics at commercial scales. In this project we attempt to address this key knowledge gap and increase yield of outdoor cultures through the rational design of consortia. Specifically, we aim to increase the productivity of Nannochloropsis cultures in open, outdoor, brackish cultivation systems through a stepwise process to design consortia consisting of multiple Nannochloropsis strains and growth-promoting bacteria. Previous research focused on consortia has resulted in successes and failures. We argue that past failures to engineer more productive and stable cultures has stemmed from two pitfalls: experimental approaches that employed haphazard inclusion of species into polycultures and technical limitations that prohibited screening of high numbers of consortia members. Here, we present our team's approach to overcome these limitations. Specifically, we describe our high-throughput screening processes by which we generate individual candidates for inclusion in consortia as well as tools generated through these steps. We also present results comparing the productivity of a Nannochloropsis monoculture to that of a candidate consortium. Finally, we outline our next projects steps. By focusing on rationally designed cultures and consistent biomass composition, we hope to generate an economically viable route to improve algal productivity and biofuel yield.

ENGINEERING & ANALYSIS

Navigating the Dual Role of Carbon as Pollutant and Critical Feedstock

Monday, October 15 / 4:00 pm - 5:30 pm

Waterway 1, Level 2

Benemann, John [4:00pm]

MicroBio Engineering Inc.

Carbon Supply in Large-scale Microalgae Biomass Production

John R. Benemann, MicroBio Engineering Inc.

After light carbon is the most important and expensive nutrient that must be supplied in large-scale photosynthetic microalgae cultivation for fuels, feeds and bioproducts generally. CO2 Carbon can be supplied from a variety of sources, including air, power plant flue gases, ethanol and other fermentations, biofuel conversion processes, anaerobic digestion and landfills, wastewaters, bicarbonate and even commercial (merchant) sources of CO2. Each source presents both opportunities and challenges, with merchant sources generally too expensive for large-scale, thus low cost, algal biomass production. Cost-effective transfer of air levels of CO2, at about 410 ppm, into algal cultures is a subject of ongoing research, but has not yet been demonstrated in practice. Processes currently being developed for concentrating CO2 from air may allow its use in microalgae cultivation, if cost projections of under $100/t CO2 can be achieved. Use of CO2 from power plant flue gases have been the main focus of research in this field, with many past and currently ongoing projects. However, typically such sources are very large-scale, with near-by land availability and limitations on piping distance for flue gas CO2 major limitations. CO2 capture and concentration, compression and piping would allow greater use of such resources, but at additional costs. Smaller-scale sources of more concentrated CO2, such as from fermentations, would be more cost-effective but are also limited by scale, location and other factors. Bicarbonate is used in China as a major source of C in commercial Spirulina production and has been proposed as a method to transport CO2 to algal cultures, but this would not be practical in large-scale cultivation. Finally, wastewaters can provide both organic and inorganic carbon for algal biomass production in waste treatment, water reclamation and nutrients recovery processes. In conclusion, CO2 supply for large-scale microalgae cultivation for biofuels, animal feeds and other commodities presents many challenges, but the many options available suggests that there will also be many site-specific opportunities for such applications. Results from prior and ongoing research by the author and colleagues will be presented.

ENGINEERING & ANALYSIS

Navigating the Dual Role of Carbon as Pollutant and Critical Feedstock

Monday, October 15 / 4:00 pm - 5:30 pm

Waterway 1, Level 2

Wilson, Michael [4:15pm]

UK CAER

Algae-Based Beneficial Re-use of Industrial Carbon Emissions: A Comparison of Algae Production Systems

M.H. Wilson, J. Groppo , D. Mohler, S. Kesner, M. Crocker Center for Applied Energy Research, University of Kentucky, Lexington, KY, USA J. Quinn Department of Mechanical Engineering, Colorado State University Fort Collins, CO, USA

Utilization of CO2 as a raw material for the production of biological-based products represents a promising alternative to other CO2 utilization technologies. In order to develop a cost-effective process that can convert CO2 from coal-fired flue gas to value-added products, our work focuses on microalgae-based CO2 capture, with conversion of the resulting algal biomass to a range of potential products. Against this background " and as part of an ongoing collaborative effort between the University of Kentucky, Colorado State University, Duke Energy and Algix" we are investigating a combined photobioreactor/pond cultivation strategy aimed at decreasing the cost of algae cultivation (and hence CO2 capture). Simultaneously, a utilization strategy is under development aimed at extracting maximum value from the produced algae biomass. Scenedesmus acutus, selected for its robust growth, tolerance to a wide range of pH values, as well as ease of harvesting and chemical composition, is autotrophically cultured in a system combining an innovative low-cost cyclic flow photobioreactor (PBR) with conventional raceway ponds. By leveraging a dual PBR/pond approach, we aim to boost pond productivity, while also reducing the down time associated with pond crashes. In this contribution we will present results from a study comparing algae cultivation in the PBR/pond system with conventionally operated ponds. Results from utilization studies aimed at the production of bioplastics, chemicals and biofuels and their impact on the overall techno-economic analysis of the process, will also be shared.

ENGINEERING & ANALYSIS

Navigating the Dual Role of Carbon as Pollutant and Critical Feedstock

Monday, October 15 / 4:00 pm - 5:30 pm

Waterway 1, Level 2

Beckstrom, Braden [4:30pm]

Colorado State University

The Cost of Microalgae-based Carbon Capture and Recycle

Braden Beckstrom; Colorado State University Michael H. Wilson; University of Kentucky Mark Crocker; University of Kentucky Ashton Zeller; ALGIX Jason C. Quinn; Colorado State University

A great need exists to combat the effects of climate change through paradigm shifts in CO2 emissions, utilization and sequestration efforts. Carbon Capture and Storage (CCS) of flue gas CO2 in underground geological features has been demonstrated, however, increased power plant energy demands (up to 40%) and corresponding consumer electricity price increases have limited the implementation of these systems. CO2 utilization through algae biomass has undergone extensive research, with most of the focus being on the production of renewable fuels. The economic feasibility of these biofuels is challenging due to their low value and their relatively high production costs. Consequently, major efforts have been undertaken to investigate the economic potential of co-products. These value adding co-products, such as animal feed, specialty chemicals, and nutraceuticals, greatly increase the value of the algae biomass, offsetting the cost of fuel production. In the case of durable bioplastics, algae also have the potential to sequester CO2. Bioplastics can be utilized in multiple products, including flexible foams, synthetic films and fibers that mimic their natural counterparts, food packaging films, mulch films, 3-D printing filament, and others. A large market of 335 million metric tonnes worldwide, combined with a relatively high product value (0.3-4 $/lb with an average value of $1.10 per pound), points to bioplastics being a promising avenue for carbon utilization. This project leverages engineering process models to analyze the economics ($/tonne CO2) and sequestration potential of a flue-gas fed algae production facility. Sub-process models are validated with experimental work across the entire algal value chain. Experimental data were obtained from fractionation and growth data specific to flue-gas fed biomass. Results show that bioplastics represent a cost-competitive avenue for CO2 utilization.

ENGINEERING & ANALYSIS

Navigating the Dual Role of Carbon as Pollutant and Critical Feedstock

Monday, October 15 / 4:00 pm - 5:30 pm

Waterway 1, Level 2

Eustance, Everett [4:45pm]

Swette Center for Environmental Biotechnology

Membrane Carbonation for Improved Carbon Capture Efficiency in Algal Cultivation

Everett Eustance, YenJung Sean Lai, Tarun Shesh, Bruce E. Rittmann; Biodesign Swette Center for Environmental Biotechnology, Arizona State University, Tempe, AZ.*

Current estimates indicate that CO2 will cost a minimum of $90/tonne of biomass, and therefore improving carbon capture efficiency is critical to reducing supply costs. Traditional CO2 delivery techniques utilize microspargers; however, due to the buoyant nature of CO2 bubbles and the short contact time in raceways it is nearly impossible to achieve high transfer efficiencies and is often reported at less than 40%. Multiple technologies and strategies have been developed to improve CO2 transfer efficiency including carbonation columns and CO2 sumps, but the scalability of these technologies may limit the implementation in large-scale operations. Membrane carbonation (MC) utilizes low pressures (<4 atm) and photosynthetic growth to create a CO2 concentration gradient to diffuse CO2 molecules across nonporous hollow membrane fibers. The diffusion of CO2 across the membrane mediates the transfer of CO2 between the gas and aqueous phases creating nearly 100% transfer efficiency into the culture medium. Although MC is a potential method for carbon delivery, the source of CO2 has a significant impact on its delivery rate and method of operation. MC has shown high transfer rates of CO2 into culture media when utilizing pure CO2, but the presence of inert gases such as air or water reduce the transfer rate of CO2 requiring different operating strategies. The assistance of a bleed valve and/or purge valve have been incorporated to remove inert gases. Purge valves using a sudden and short opening time can be used quickly evacuate inert gases from the fibers and has been identified as the best approach for high CO2 concentrations. Bleed valves, a slow steady flow through the fibers allows for a long contact time between the CO2 and the media and is best utilized for low CO2 concentrations. Both methods have shown to provide greater than 90% transfer efficiency into the liquid phase.

ENGINEERING & ANALYSIS

Navigating the Dual Role of Carbon as Pollutant and Critical Feedstock

Monday, October 15 / 4:00 pm - 5:30 pm

Waterway 1, Level 2

Viamajala, Sridhar [5:00pm]

The University of Toledo, Department of Chemical Engineering

Microalgae Cultivation in High-pH and High-alkalinity Media for High Productivity without Concentrated CO2 Inputs

Agasteswar Vadlamani, Brahmaiah Pendyala, Mohammadmatin Hanifzadeh, Sasidhar Varanasi, Sridhar Viamajala* â€“ University of Toledo Robin Gerlach*, Brent Peyton* â€“ Montana State University*

We will present recent results from our US Department of Energy sponsored effort through the Advancements in Sustainable Algae Production (ASAP) Program. Our project has focused on isolating and characterizing high-productivity microalgae strains that thrive in alkaline conditions. The microalgae are cultivated under conditions that simultaneously provide (i) a high pH (~10.2) to effectively scavenge atmospheric CO2 and (ii) a high alkalinity (>100meq) to maintain high, non-limiting bicarbonate concentrations (>30mM) for photosynthetic carbon fixation. Under these growth conditions, we will present results that demonstrate sustained high productivity (~20g/m2/d) of strain SLA-04 under outdoor conditions, even in the absence of supplemental CO2 input. Further, we will present a first-principles mass transfer model that we developed to estimate transfer of CO2 from ambient atmosphere into alkaline solutions. The experimental results are well supported by theoretical predictions from the model. Finally, we will present results to show that the cultures grow well in fresh water, high salinity waters and with a low input of synthetic fertilizers. The resulting low-N-content biomass (~3%) is favorable for biofuel production due to the higher relative proportion of carbohydrates and lipids. Overall, our project has addressed cultivation challenges related to (1) sourcing limitations and high cost of CO2 delivery, (2) high culture productivity while maintaining culture stability, and (3) minimization of nutrient inputs. Furthermore, in 2 years of outdoor experiments, the cultures resisted detrimental contamination and culture crashes, likely due to the high pH values.

ENGINEERING & ANALYSIS

Multi-Disciplinary Advances in Algae Culturing and Dewatering

Tuesday, October 16 / 10:30 am - 12:00 pm

Waterway 1, Level 2

Quiroz-Arita, Carlos [10:30am]

Colorado State University

Understanding Turbulence Mixing in Pilot Scale Open Raceway Ponds: An Experimental Fluid Mechanics and Computational Approach

*Carlos Quiroz-Arita (1,2) *, Patricia E. Gharagozloo (1), Myra L. Blaylock (1), Ryan Davis (1), Thomas Dempster (3), Thomas H. Bradley (2), John McGowen (3) (1) Sandia National Laboratories , Livermore, CA 94550, USA (2) Mechanical Engineering, Colorado State University, Fort Collins, CO 80524, USA (3) Arizona Center for Algae Technology and Innovation and the Algae Testbed Public Private Partnership, Mesa, AZ*

Turbulence mixing in pilot open raceway ponds and its implications in photoautotrophic growth are poorly understood. To understand the fluid mechanics of a pilot scale open raceway pond located in Colorado State University, Acoustic Doppler Velocimetry (ADV) was applied to obtain the velocity field in an Eulerian representation of the flow. Turbulence parameters were measured at low, mid, and high mixing energy inputs controlled by the paddlewheel. The experimental and dimensionless turbulence parameters were applied as boundary conditions for a computational fluid dynamic (CFD) model based on an open raceway pond affiliated with the ATP3 collaboration. The CFD turbulence mixing model is based on Reynolds Average Navier Stokes (RANS) equations that impact in the light regimes and respiration losses that algae experience and the resultant productivities in these raceway systems. To evaluate the implications of turbulence mixing in the photoautotrophic productivity at these open raceway pond scales, we have expanded our one-dimensional (1D) well mixed algae growth model to a three-dimensional (3D) algae growth model embedded into a CFD simulation. The state-of-the-art algae growth model incorporates dynamic responses that environmental light oscillations exert on Ribulose-1,5-bisphosphate carboxylase/oxygenase, known as RubisCO, which impact the biomass productivities in real-time. Additionally, our dynamic model solves a set of ordinary differential equations (ODE) consisting of growth functions dependent on incident radiation, temperature, and nutrients availability. Our research demonstrates that taking into account dimensionless turbulence parameters can reduce the uncertainty of CFD models in open raceway ponds, and our computational results have been validated using the experimental velocity measured at AzCATI during the ATP3 Unified Field Studies. We have then incorporated our 3D algae growth model with this validated turbulent flow to compare the predictive capability with respect to the 1D well-mixed dynamic algae growth model.

ENGINEERING & ANALYSIS

Multi-Disciplinary Advances in Algae Culturing and Dewatering

Tuesday, October 16 / 10:30 am - 12:00 pm

Waterway 1, Level 2

Sorenson, Carlise [10:45am]

University of Minnesota

Algal Assisted Nutrient Removal from Municipal Wastewater in a Sequential Batch Reactor

Carlise Sorenson, Carlos Zamalloa, and Bo Hu from the University of Minnesota - Twin Cities

The combination of bacteria and microalgae could enhance the removal of nitrogen and phosphorous while increasing the potential for resource recovery at lower energy consumption for aeration. This study evaluates the combination of nitrifying and denitrifying bacteria with microalgae in sequential batch reactor (SBR) at 15 ±2°C for treating real domestic wastewater. The microalgae-SBR was operated in cycles of 12 hours with anoxic and photo aerobic phases at a hydraulic retention time of 2.5 days. Continuous light was applied during the aerobic phase with minimal external air addition. Under these conditions, the nutrient removal efficiency of the microalgae-SBR is comparable to the activated sludge control with an additional 75% increase in soluble phosphorus removal seen in the microalgae-SBR. Furthermore, this system requires markedly less aeration during aerobic phases and therefore greatly reduces energy and cost of operation. The M-SBR was stable for a period of 60 days, did not required external addition of carbon, and reached dissolved oxygen values around 10mg/L. This research demonstrates the added benefits (limiting aeration needs and additional phosphorus removal) when utilizing bacteria and microalgae in concert to treat municipal wastewater.

ENGINEERING & ANALYSIS

Multi-Disciplinary Advances in Algae Culturing and Dewatering

Tuesday, October 16 / 10:30 am - 12:00 pm

Waterway 1, Level 2

Kishi, Masatoshi [11:00am]

Faculty of Science and Engineering, Soka University

Gas-permeating Bag Reactor for Energy Efficient Oxygen Removal in Microalgal High-density Culture

Faculty of Science and Engineering, Soka University, Tokyo, Japan. Graduate School of Engineering, Soka University, Tokyo, Japan.

Microalgae is widely applied to high-value commercial products such as neutraceuticals, cosmeceuticals, and feed. While high-density culture in a closed reactor is demanded for effective production of unialgal biomass, oxygen accumulation oftentimes limits the productivity. Currently, dissolved oxygen removal in most algal culture relies on costly aeration that inflates the total maintenance cost, and hence a low-cost oxygen removal is desired. Therefore, the current study proposes a bag photobioreactor whose one side is composed of gas-permeating microporous film, that enables low-energy dissolved oxygen removal from algal high-density culture.

Firstly, a flat-panel bag reactor with its one side composed of a microporous film was designed and constructed. The developed gas-permeating reactor had approximately 20 times higher oxygen mass transfer coefficient than common bag reactors without aeration. While mass transfer coefficient of gas-permeable photobioreactor was roughly 3.5-fold smaller than aeration, the energy consumption was calculated to be close to 20-fold less, demonstrating the energy-efficient dissolved oxygen removal. Using the developed gas-permeating reactor, the productivity of Arthrospira platensis was then evaluated under differing photon flux density between 100 and 800 µmol m-2 s-1. To simulate a large-scale production with limited energy consumption, the frequencies of aeration and circulation were reduced to 0.2/2 and 1/20 (min/min), respectively. The maximum productivity of 1.98 g-dry-weight (DW) L-1 d-1 was obtained with 325 µmol m-2 s-1 which was 1.5-times higher than that of conventional polypropylene bag reactor 1.31 gDW L-1 d-1, demonstrating the effective oxygen removal with the developed reactor. Finally, the developed gas-permeating photobioreactor was compared for its energy use with the conventional bag reactor. It was demonstrated that the energy consumption could be reduced 4 to 50-fold owing to the less requirement for aeration and circulation. These results demonstrated that the developed gas-permeating reactor can effectively remove dissolved oxygen and reduce the energy consumption for algal biomass production process.

ENGINEERING & ANALYSIS

Multi-Disciplinary Advances in Algae Culturing and Dewatering

Tuesday, October 16 / 10:30 am - 12:00 pm

Waterway 1, Level 2

Poole, Kyle [11:15am]

MicroBio Engineering

Improved Economics and Environmental Impacts from Bioflocculating Algal Cultures in Wastewater Treatment

Kyle Poole, MicroBio Engineering Neal Adler, MicroBio Engineering Dr. Tryg Lundquist, California Polytechnic State University Shelley Blackwell, California Polytechnic State University

MicroBio Engineering Inc (MBE) is currently finishing the Phase II period of their DOE funded small business innovation research project, Solid-Liquid Separation for Algal Systems. The focus of this research was to improve the economics and environmental impacts of an algal biofuels and wastewater treatment system by developing improvements in harvesting and dewatering techniques as well as developing methods for algal systems to provide consistent year-round treatment of municipal wastewaters. Experiments were performed at the Algae Field Station, San Luis Obispo (AFS-SLO) and the full-scale algal wastewater treatment plant in Delhi, CA. At AFS-SLO, annual average productivity goals were met (25 g/m2*d) and year-round treatment performance were demonstrated while simultaneously culturing naturally bioflocculating cultures, which yielded 93% 2-hr harvest efficiency. Harvested algae had an approximate AFDW solids concentration of 1%. High settling efficiencies and concentration by gravity to 1% eliminates the need for a pre-concentration step, typically performed by expensive microfilter systems (>$1M/MGD capital cost). Microfilter and screw press dewatering technologies were performed at Delhi. Screw pressed biomass was concentrated to 20% with the addition of coagulant chemicals. Multi-stage membrane thickening was also piloted on chemically treated algae yielding 11-14% solids concentration. Bioflocculated algae is currently being tested, and preliminary results indicate the ability to dewater biomass to higher concentrations (16%) in a single stage system. The reduced energy consumption and capital costs allowed by bioflocculated algae significantly reduce the cost of concentrating biomass to 20% AFDW. The findings from these experiments were incorporated into the MBE Environmental Sustainability and Process Economics (ESPE) model. Mass balances from the ESPE model were incorporated into an openLCA model for life cycle assessment with life cycle impact assessment performed using the US EPA's TRACI 2.0 methods. Preliminary results indicate reduced wastewater treatment costs as well as reduced environmental impacts. Additionally, the use of bioflocculating cultures significantly reduce the minimum biomass selling price (MBSP) by the removal of preconcentration steps, elimination and coagulant chemicals, and improved microfilter dewatering performance.

ENGINEERING & ANALYSIS

Multi-Disciplinary Advances in Algae Culturing and Dewatering

Tuesday, October 16 / 10:30 am - 12:00 pm

Waterway 1, Level 2

Avila, Nickolas [11:30am]

Montana State University

Quantifying Enhanced Mass Transfer of CO2 into High Alkalinity Algae Culture Medium

Agasteswar Vadlamani1, Nickolas Avila2, Matt Jackson2*, Mohammadmatin Hanifzadeh1, Brahmaiah Pendyala1, Sasidhar Varanasi1, Robin Gerlach2*, Sridhar Viamajala1* 1 The University of Toledo, Toledo, Ohio 2 Montana State University, Bozeman, Montana*

Microalgae are autotrophic organisms that fix carbon by utilizing free bicarbonate ions in solution as a readily available inorganic carbon source. Growing algae cultures in a high alkalinity, high pH (>10) medium has been shown by us to increase biomass productivity of appropriate algae strains. High pH and high alkalinity medium can simultaneously allow for a high rate of CO2 mass transfer from the atmosphere and provide non-limiting concentrations of bicarbonate in the medium for photosynthetic fixation. We developed a mathematical model describing this enhanced CO2 mass transfer by relating it to the hydroxyl ion concentration, diffusion constants, total alkalinity, equilibrium constants of the carbonate/bicarbonate equilibrium equations, and the volumetric mass transfer coefficient (kLa). All of the constants are well known from the literature and changes in the hydroxyl ion concentration are measured easily (as pH). Thus, the volumetric mass transfer coefficient can be estimated by fitting the data relating pH and time to the ordinary differential equation that describes the unsteady state mass transfer. In this work, we determined the volumetric mass transfer coefficient for the transport of atmospheric CO2 into paddlewheel-mixed alkaline open ponds by minimizing the sum of the square of the residuals between the experimentally determined pH versus time data and the model prediction via an algorithm developed in the programming language Python. This algorithm can handle large pH versus time data sets and finds the differential equation solution via a numerical ordinary differential equation solver in the SciPy software library of Python. Correlation coefficients between data and solutions are between 0.6341 and 0.9987 with a median correlation coefficient of 0.9830, using 7 sets of data measured over a period of 24 hours, having pH values between 9.95 and 10.55. This generally good fit is providing the basis for a science- and engineering-enabled approach to increase algal biomass productivity through high-alkalinity culturing of microalgae in the presence of atmospheric CO2.

ENGINEERING & ANALYSIS

Making the Most Out of Algae: Advances in Extraction, Processing and Conversion

Tuesday, October 16 / 1:00 pm - 2:30 pm

Waterway 1, Level 2

Halim, Ronald [1:00pm]

The University of Melbourne

Towards Sustainable Microalgal Biorefinery: The Induction of Autolytic Cell-wall Ingestion in EPA-rich Nannochloropsis PasteUnder Thermally Coupled Dark-anoxia Incubation

Ronald Halim (a,b,c), David R.A. Hill (a), Eric G. Hanssen (d), Paul A. Webley (a), Susan Blackburn (e), Arthur R. Grossman (b), Clemens Posten (c), Gregory J.O. Martin (a) (a) Algal Processing Group, Department of Chemical Engineering, The University of Melbourne, Victoria, 3010, Australia (b) Department of Plant Biology, Carnegie Institution for Science, Stanford University, California, 94305, USA (c) Institute of Process Engineering in Life Sciences, Bioprocess Engineering, Karlsruhe Institute of Technology, Baden-WÃ¼rttemberg, 76131, Germany (d) Advanced Microscopy Unit, Bio21 Molecular Science and Biotechnology Institute, The University of Melbourne, Victoria, 3010, Australia (e) The Australian National Algae Culture Collection, Commonwealth Scientific and Industrial Research Organisation, Tasmania, 7004, Australia

In this study, we present thermally coupled dark-anoxia incubation, a low-cost and low-energy treatment capable of inducing autolytic cell-wall thinning in microalgal cells. Using this method, we incubated highly concentrated paste (24±1 wt% solids) of Nannochloropsis cells in darkness at 38°C for 24 h. The simple treatment halved the thickness of the cell wall (from 29.9±7.1 nm to 17.0±4.0 nm) and, as a result, increased the susceptibility of the cells to mechanical rupture. High-pressure homogenisation (1100 bar) carried out on paste that had previously been incubated was able to rupture 72±9% of available cells (the same homogenisation was only able to rupture 41±3% of available cells in the untreated paste).

Under the treatment, Nannochloropsis cells activated fermentative pathways that catabolised intracellular sugar reserve, including cellulose in its cell wall (hence the cell-wall thinning effect), to generate the ATPs necessary for basal metabolism. During the treatment, we observed a reduction in the total cellular sugar content (from 17.3±3.7 to 12.6±2.6 wt% of biomass) with a corresponding multiple-fold increase in the secretion of organic acids as fermentation products (from 0.003±0.001 to 0.029±0.008 g total organic acid/g biomass). The fermentation process, however, did not degrade any of the cellular lipid storage. Detailed lipid analysis of the cells before and after incubation showed negligible changes in the level of total lipid, total transesterifiable (biofuel-convertible) lipid and EPA contents of the cells, staying constant respectively at 27.6±0.9, 12.9±1.1 and 3.8±0.5 wt% of biomass.

Thermally coupled dark-anoxia incubation is an attractive treatment that can be implemented as part of a microalgal biorefinery system to enhance cell rupture and reduce the energy requirement associated with biomass processing. The treatment exploits microalgal cells' biologically driven self-lysing

properties to thin their own wall and thus increase their susceptibility to mechanical rupture without introducing any decomposition to biofuel-convertible and ω3 lipid components.

ENGINEERING & ANALYSIS

Making the Most Out of Algae: Advances in Extraction, Processing and Conversion

Tuesday, October 16 / 1:00 pm - 2:30 pm

Waterway 1, Level 2

Kempkes, Michael [1:15pm]

Diversified Technologies, Inc.

Algal Extraction Enhancement with Pulsed Electric Fields

Michael Kempkes, Diversified Technologies, Inc. Dr. Ian Roth, Diversified Technologies, Inc. Dr. Thomas Dempster, AzCATI, Arizona State University Dr. Henri Gerken, AzCATI, Arizona State University Dr. Arunas Stirke, Center for Physical Sciences and Technology (Vilnius, Lithuania) / AzCATI, Arizona State University

Diversified Technologies, Inc. (DTI), in cooperation with the Arizona Center for Microalgae Technology and Innovation (AzCATI) at Arizona State University (ASU), is investigating the application of Pulsed Electric Field (PEF) processing on the extraction of high value commercial products, including nutraceuticals and lipids, from microalgae This paper will report on the results of this effort to date, and plans for future research. High value algal products today rely on slow and expensive solvent extraction processes, which typically require a drying step, to reach a commercial end product. These extraction processes are inherently energy intensive and expensive. PEF processing uses short, high voltage electrical pulses and a specially-designed treatment chamber to break cellular membranes. Our results show that PEF processing is much less expensive than drying, and enables wet extraction methods, which are faster and less expensive than conventional approaches. DTI and AzCATI are currently extending our initial assessment of PEF pre-extraction processing to a range of different algae strains, to assess both the ability of PEF processing to lyse (electroporate) these strains, the extraction enhancement by PEF pre-treatment, and the estimated costs of PEF treatment in high volume applications. Previous test results showed a consistent ability to impact the algae cells themselves, at costs as low as 2% of drying. This paper will update the results of our USDA work for the different algae strains tested, extraction performance, and plans for scale-up and commercial introduction of PEF processing for high value algae products. This effort is funded by USDA NIFA Phase II SBIR Grant 2017-33610-27016.

ENGINEERING & ANALYSIS

Making the Most Out of Algae: Advances in Extraction, Processing and Conversion

Tuesday, October 16 / 1:00 pm - 2:30 pm

Waterway 1, Level 2

Soto Sierra, Laura [1:30pm]

Texas A&M

Production of Protein Concentrates and Hydrolysates from the Microalgae Chlorella vulgaris: A Closer Look at the Economics.

Soto Sierra, Laura; Kulkarni, Sayali; Nikolov, Zivko. Texas A&M University

The need for developing alternative protein sources to meet future food demand has driven microalgae to re-emerge as a promising source. Considering its ability to produce quality protein, microalgae has been studied for the production of protein concentrates, isolates, hydrolysates, and bioactive peptides. Despite of its potential, current production methods still require optimization of processing conditions to ensure economic feasibility of algae products. Co-product extraction, such as carotenoids, together with protein has been proposed for increasing economic feasibility of algae platform. Nevertheless, scalable methods for the sequential extraction of proteins and other high value products are lacking. This study explored and optimized carotenoid extraction from Chlorella vulgaris and subsequent processing of pigment-extracted microalgae into protein concentrates and hydrolysates. Using SuperPro Designer, an economic evaluation of each process was performed and main strengths and bottlenecks were identified. Results showed that the extraction of high value carotenoids significantly increased economic feasibility of algae platform. Processing cost of concentrates was lower compared to hydrolysates. Biomass protein content and concentration factor during membrane filtration were the major parameters dictating the final cost of protein concentrates. Extraction of protein by hydrolysis efficiently released most proteins, significantly reduced green color of the extracts and increased protein value, but processing conditions and enzyme costs increased processing costs compared to concentrates. While protein concentrates displayed better functionality (emulsification), biological value and nutraceutical properties of protein hydrolysates were superior.

ENGINEERING & ANALYSIS

Making the Most Out of Algae: Advances in Extraction, Processing and Conversion

Tuesday, October 16 / 1:00 pm - 2:30 pm

Waterway 1, Level 2

Cuchiaro, Hunter [1:45pm]

National Renewable Energy Laboratory

New Method for Protein Analysis in Algae - Derivatization and Detection of Amino Acid O-Phthalaldehyde 3-Mercaptopropionic Acid (OPA-3MPA) Derivatives

Cuchiaro, H., Laurens, L. ML. National Renewable Energy Laboratory, Golden, CO 80401

The analysis of protein in algae is one of the most critical areas of analytical development needed to allow for commercial development of algal biomass for nutritional or other high value applications. Existing methodologies based on nitrogen conversion factors for total protein quantification are often adequate for rapid determination, but fail to take into account the amino acid variability between species and in biomass after conversion treatments. Earlier work has determined that different species of algae require a dedicated conversion factor, based on the nitrogen content entrained in the amino acids liberated from the biomass. Amino acid analysis until now has been limited to dedicated analytical laboratories, can be complex and are sometimes out of reach for rapid characterization of biomass. We have developed a simple spectrophotometric method, validated by HPLC-MS, to be used for primary amino acid quantification as a bulk measurement. This presentation covers the development, validation and interference testing of an OPA-derivation method on both standard reference amino acids as well as mixtures of amino acids, peptides and sugars, such as the mixtures generated by a combined algal processing acid treatment. We determined the amino acid content of 5 species of algae grown under controlled cultivation conditions in whole biomass as well as the acid treatment liquors.

DeRose, Katherine [2:00pm]

Colorado State University

Optimizing the Economics of Low Value Algae: Processing Based on Algal Composition and Dealing with Ash

Katherine DeRose, Colorado State University Ryan W. Davis, Sandia National Lab Fang Liu, Sandia National Lab Jason Quinn, Colorado State University

One of the major difficulties surrounding the potential use of algae for biofuels is the high upstream production costs. Major cost contributors can include capital costs, energy intensive dewatering systems and nutrient including carbon delivery costs. Two promising opportunities for improving the economic viability of algal based energy is: producing higher value co-products and exploring alternative production technologies. Algal Turf Scrubbers (ATS) are an exciting production platform which have been shown to be biologically robust and significantly lower capital, harvesting and nutritional costs compared to more traditional cultivation methods. Challenges to be overcome for ATS systems include low lipid, high protein and high ash content. Therefore, a new process was designed to better utilize the ATS algae. This process employs a proprietary protein targeted fermentation step, followed by Hydrothermal Liquefaction. Techno-economic analysis results show a minimum fuel selling price of $12.08 per gallon of gasoline equivalent (GGE). To improve the process economics, a sensitivity analysis was conducted to identify critical variables. Ash content was found to have major influence on the economics, so a study was conducted to identify the optimal de-ashing process. This study encompassed optimizing where in the process to incorporate de-ashing, evaluating technologies for their capital and operational costs, and assessing downstream effects of the procedure. Results show through integration of de-ashing, including environmental benefits, and improved processing performance results in a fuel product of $2.98 per gallon.

ENGINEERING & ANALYSIS

Cultivation Practice Makes Perfect 1: Updates from Testbeds and Consortia

Tuesday, October 16 / 3:35 pm - 4:45 pm

Waterway 1, Level 2

Huesemann, Michael [3:15pm]

Pacific Northwest National Laboratory

The Algae DISCOVR Project: Development of Integrated Screening, Cultivar Optimization, and Validation Research

Michael Huesemann and Scott Edmundson, Pacific Northwest National Laboratory Taraka Dale, Los Alamos National Laboratory Todd Lane, Jeri Timlin, and Thomas Reichardt, Sandia National Laboratory Phil Pienkos and Lieve Laurens, National Renewable Energy Laboratory

DISCOVR is a consortium project with four participating Department of Energy National Laboratories: Pacific Northwest National Laboratory, Los Alamos National Laboratory, Sandia National Laboratory, and the National Renewable Energy Laboratory. The overall objective of the DISCOVR project is to develop an integrated platform for standardized, deep characterization of high productivity and resilient microalgae strains, with the aim of delivering new performers for robust year-round outdoor cultivation. In this three year project cycle the DISCOVR team will characterize at least 30 selected strains in terms of their detailed growth characteristics (TIER I), evaluate 10 strains in terms of their seasonal areal biomass productivity, basic biomass composition, and resilience to biological stressors (TIER II), improve and further characterize 6 strains in terms of more detailed biomass composition and biological stress resistance in indoor ponds (TIER III), and test 4 strains in outdoor ponds (TIER IV) to provide inputs to lifecycle and techno-economic analyses (TIER V). The following results will be presented: a) measurement of the salinity tolerance and the maximum specific growth rates of 30 TIER I strains as a function of temperature, b) ranking of TIER I strains in terms of their potential as winter and summer seasons strains, c) quantification of areal biomass productivities of the top TIER I strains using PNNL's innovative Laboratory Environmental Pond Simulator (LEAPS) photobioreactors, using winter and summer season light and temperature scripts from the AzCATI testbed site in Mesa, Arizona, and d) quantifying the winter and summer season biomass productivity of the top TIER II strains in outdoor ponds in Arizona. In summary, the DISCOVR project is developing a standardized process for characterizing and comparing potential biofuels/bioproduct strains, with the goal of delivering high productivity strains to more rapidly meet BETO's goal of producing advanced biofuels at <$3 per gasoline gallon equivalent.

ENGINEERING & ANALYSIS

Cultivation Practice Makes Perfect 1: Updates from Testbeds and Consortia

Tuesday, October 16 / 3:35 pm - 4:45 pm

Waterway 1, Level 2

McGowen, John [3:30pm]

Arizona State University: Arizona Center for ALgae Technology and Innovation

Winter Season Strain Performance of Multi-year Outdoor Cultivation Trials in Support of the Department of Energy's State of Technology (SOT) Assessment for Algae Biofuels.

John A. McGowen, Jessica Forrester, Candyce Bair, Sarah Kempkes, Saran Chin, and Thomas Dempster, Arizona Center for Algae Technology and Innovation, Arizona State University.

The Algae Testbed Public Private Partnership (ATP3), a multi-institutional effort funded by the Department of Energy established a network of operating testbeds that brought together world-class scientists, engineers and business executives whose goal it was to increase stakeholder access to high quality facilities by making available an unparalleled array of outdoor cultivation, downstream equipment, and laboratory facilities. ATP3 utilized the same powerful combination of facilities and technical expertise to support TEA, LCA and resource modeling and analysis activities, helping to close critical knowledge gaps and inform robust analyses of the state of technology for algal biofuels. We used our facilities to perform coordinated long term cultivation trials producing robust, meaningful datasets from this regional network determining the effects of seasonal, environmental conditions. These data are critically important to support the modeling community and guide R&D towards the transformative goal of cost-competitive algal biofuels by 2022. For this presentation we will update specifically on winter seasonal data at the ASU AzCATI site looking at multiple seed train, nutrient management and operational strategies for improving pond cultivation performance (e.g., batch vs. semi-continuous cultivation, culture depth), thermal management, and different strains. We will present the winter seasonal performance for Monoraphidium minutum (26B-AM), and Scenedesmus acutus (LRB-AP-0401) across two seasons (2017 and 2018). In addition we will present on biomass compositional effects of the different strains/pond management strategies.

ENGINEERING & ANALYSIS

Cultivation Practice Makes Perfect 1: Updates from Testbeds and Consortia

Tuesday, October 16 / 3:35 pm - 4:45 pm

Waterway 1, Level 2

Vitale, Albert [3:45pm]

Commercial Algae Management, Inc./Commercial Algae Professionals, Inc.

Using Spirulina to Mitigate CO2 Production from a Large Scale Oil Refinery (A Case Study of the Current Project Underway at the Citgo Refinery in Aruba)

Albert Vitale - Commercial Algae Management, Inc.

In 2017 the government of Aruba along with partners Refineria Di Aruba, Citgo, Feyecon, TNO Caribbean, Commercial Algae and others completed the construction of the phase I pilot facility in Aruba to help to mitigate the Co2 produced in the newly reopened refinery. This refinery which during world war II was the largest in the world began construction in 1924. Over the years it was one of the most important refineries in the world and helped assure the allies victory over Nazi Germany providing the majority of the gas and oil used by the allies World War II's European campaign. In recent years the refinery changed hands several times and recently fell on hard times with it being largely mothballed and used as an oil trans-shipment point. In recent years the government of Aruba decided to purchase the refinery, retool it and retrofit it to process crude oil into heavy oil. A new pipeline will soon link crude producing wells in Venezuela with the facility in Aruba. The new facility also introduce new technology that allows the capture and cleaning of CO2 which will allow the use of algae biomass to consume CO2 produced from the refinery. The CO2 utilized at this facility is captured, cleaned and rendered 99.9% pure before being utilized for the production of the algae biomass. Initial markets include nutraceuticals, food colorants, skin and health products, The next phase of the project will commence later this year (prior to the 2018 Algae Biomass Summit) and eventually the project will encompass over 300 acres of large scale production primarily for CO2 consumption while creating eco friendly, healthy high value consumer products. In later phases the project will be expanded and additional types of commercially viable algae will be introduced and produced at the facility. while still providing for its primary goal of mitigating CO2 from the refinery. This presentation will discuss the facility, its goals, and the challenges and the future of the project going forward.

Lee, Choul-Gyun [4:00pm]

Inha University

Sustainable Marine Microalgal Biomass Production: An Update on Productivity Increase in Large-Scale Ocean Test-Beds

Hanwool Park1,2, Yonghee Cho2, Ki-Hyun Kim2, Jun-Ho Kim2, Sung-Mo Kang2, Injae Jung1, JaeHoon Park1,2, Yunwoo Lee1, Sang-Min Lim2, Choul-Gyun Lee1,2 1 Department of Biological Engineering, Inha University, Incheon 22212, Korea 2 National Marine Bioenergy R&D Center, Inha University, Incheon 22212, Korea*

Despite all the advantages of microalgal biofuels, there are quite a number of challenges to overcome before economic production of microalgal biofuel can be achieved. Most of the culture systems today would not be suitable for biofuel production. One of the possible solutions for some of these challenges is mass cultures in the ocean. A large-scale floating ocean cultures have several benefits: (i) lower CAPEX; (ii) no freshwater usage; (iii) relatively abundant seawater; (iv) ability to exploit the lower nutrient concentration in seawater; (v) no need to worry about evaporation; (vi) larger area to deploy; and so on. For the past two years, we have improved ion permeability of Selectively-Permeable Materials (SPMs) for our floating ocean culture system over 10 times by numerous tries and the overall biomass productivity has increased proportionally. The average biomass productivity of 20 g/m2/day using just seawater on our test-beds was achieved. Other recent progresses in the ocean test-beds and remaining challenges for sustainable marine microalgal biomass/biofuels production will be discussed based on our experience in Korea. Keywords: off-shore cultures, microalgae, biodiesel, sustainability, economic production

ENGINEERING & ANALYSIS

Cultivation Practice Makes Perfect 1: Updates from Testbeds and Consortia

Tuesday, October 16 / 3:35 pm - 4:45 pm

Waterway 1, Level 2

Laurens, Lieve [4:15pm]

National Renewable Energy Laboratory

Improving Biofuel and Bioproduct in Algae through Rewiring Algal Carbon Energetics for Renewables (RACER), a Consortium Overview

Laurens, L. ML.1, Peers, G. 2, Posewitz, M. C. 3, Knoshaug, E.P. 1, Reardon, K. F. 2, Pienkos, P. T. 1, McGowen, J. 4, Nagle, N. 1, Behnke, C.5 1 National Renewable Energy Laboratory, 2 Colorado State University, 3 Colorado School of Mines, 4 Arizona State University, 5 Sapphire Energy

Critically needed improvements in biomass and biofuel intermediate productivity can be made by addressing fundamental inefficiencies in algal carbon conversion efficiency (CCE) to biofuel feedstocks, cultivation performance, as well as the conversion to fuel intermediates. Algal photosynthesis is, at best, able to convert incident light energy to biomass at about a 5-7% carbon conversion efficiency, while downstream conversion to fuel intermediates in the current designed process currently falls 15-25% short of its maximum potential due to inefficiencies along the pathway. There is room for improvement to achieve much higher biomass and biofuel intermediate yields through manipulating the basic biological processes of photosynthesis and carbon sink metabolism in the cells and integrating the upstream cell biology with downstream conversion process improvements. This presentation will cover recent progress in the Rewiring Algal Carbon Energetics (RACER) project consortium. This work is focused on a means to address the above carbon conversion inefficiencies in a pathway from algal biomass to a trifecta of fuel intermediates in a coordinated and integrated manner with a goal to demonstrate both areal biomass productivity improvements by 64%, with an overall doubling of the fuel intermediate yields. The new algae biorefinery paradigm embodied in the RACER approach breaks open opportunities for algae engineering beyond efforts typically targeted solely at lipid content or improved light harvesting efficiency. We will present progress on parallel approaches applied to a single, commercially-relevant, productive strain Desmodesmus armatus (SE 00107) towards improved i) photosynthetic carbon conversion efficiency through elimination of wasteful diversion of energy during photosynthesis and increasing carbon flux through carbon assimilation by increasing the transitory carbon storage in the cells; ii) outdoor operation and nutrient management strategies and iii) fundamental operational efficiency of downstream conversion and extraction in a Combined Algal Processing approach to fuel and high-value product intermediates.

ENGINEERING & ANALYSIS

Designing Algae Systems that Meet the "Triple Bottom Line"

Wednesday, October 17 / 10:45 am - 12:15 pm

Waterway 1, Level 2

Davis, Ryan [10:45am]

NREL

2017 Algae Harmonization Study: Projections for Future Algal Biorefineries from Harmonized Modeling

ANL: Christina Canter, Jeongwoo Han, Qianfeng Li NREL: Ryan Davis (presenter), Jennifer Markham, Christopher Kinchin PNNL: Andre Coleman, Sue Jones, Mark Wigmosta, Yunhua Zhu

To present a more unified picture of the long-term future potential for algal biofuels and the goals that must be met to reach that potential, four algae modeling groups collaborated to harmonize respective models for resource assessment (PNNL), techno-economic analysis (NREL and PNNL), and life-cycle analysis (ANL) of algal biomass production and conversion processes. In contrast to prior harmonization studies that this group has previously conducted, which focused on establishing benchmarks attributed to current performance at the time, the primary intent of the present harmonization study was to project these models to forward-looking targets to reduce fuel costs and greenhouse gas emission profiles towards more viable levels, subject to specific location constraints imposed by resource assessment modeling and thus national-scale fuel output potential. Based on screening criteria constraints from the resource assessment model, 2.7 MM acres of total cultivation area were identified as being best suited for algal biomass production on fresh water and 7.1 MM acres on saline water cultivation, sited primarily across southern U.S. locations. The harmonization effort focused on CO2 sourcing and transport via carbon capture from existing flue gas point sources (primarily coal-fired power plants but with a number of other sources also included), as well as access to sufficient fresh/saline water resources to support cultivation water demands. The resulting biomass outputs were evaluated through two conversion pathways, and subsequently quantified through techno-economic and life-cycle models for their resulting fuel costs and greenhouse gas emissions, as well as modeled fuel yields and national scale fuel outputs. In contrast to prior modeling work typically focused on bulk flue gas pipeline co-location with power plants, the carbon capture and transport approach taken in this work identified substantially more biomass production potential on the order of 100-200 MM tons/year nationally, targeted to be produced generally below $700/ton (lower for freshwater cases). Based on evaluating these resulting biomass outputs through NREL's CAP conversion pathway, fuel cost curves versus national-scale fuel outputs were generated across varying scenarios for algal biorefinery coproduct markets to reduce fuel selling prices.

ENGINEERING & ANALYSIS

Designing Algae Systems that Meet the "Triple Bottom Line"

Wednesday, October 17 / 10:45 am - 12:15 pm

Waterway 1, Level 2

Chen, Peter [11:00am]

Colorado State University

Techno-economic Analysis of Potentially Cost-prohibitive Factors in Algal Biomass and Biofuel Costs

Peter Chen and Jason C. Quinn Department of Mechanical Engineering, Colorado State University, Fort Collins, CO

Techno-economic analyses of current algal biomass production technologies typically value biomass at $450 to $500 per dry ton of ash-free dry weight (AFDW). However, in order to make algal biomass production economically favorable, the purchase price needs to be reduced by more than half based on current conversion technologies. Often, the most significant factor considered in driving biomass cost down is through biomass productivity improvements. This study leverages a detailed open raceway pond (ORP) growth model and an algal biorefinery model to define a sustainable biomass cost and what is required to achieve this goal in terms of the growth system. Two downstream conversion pathways are considered in this bottom-up analysis: 1) Baseline: ORP coupled with a hydrothermal liquefaction (HTL) process to produce a biodiesel precursor and 2) High Value Pathway: ORP followed by a protein extraction with HTL of the residuals, which adds a high-value protein product to the analysis. Preliminary results with the baseline HTL process show that a minimum biomass selling price of $253/ton AFDW is required to meet the DOE goal of $3 per gallon of gasoline equivalent (GGE). Even as productivity is increased, oft-overlooked effects of other cost- or logistically-prohibitive factors, such as co-location of CO_2, open-channel fluid delivery, raceway pond liners, etc., can severely affect the viability of biomass production from a techno-economic standpoint. The results from this analysis illustrate where significant investment in realistically improving these parameters is required for algal production systems to reach the DOE milestone of $3 per GGE.

ENGINEERING & ANALYSIS

Designing Algae Systems that Meet the "Triple Bottom Line"

Wednesday, October 17 / 10:45 am - 12:15 pm

Waterway 1, Level 2

Hazlebeck, David [11:15am]

Global Algae Innovations

Techno-economic Analysis of Algal Production that Incorporates Global Algae Innovations' Radical Advances Throughout the Process

David Hazlebeck, Global Algae Innovations William Rickman, TSD Management Associates

Global Algae Innovations has developed radicial advances throughout the algal production process for economical production of commodities. Advances include contamination control, low cost carbon dioxide supply from flue gas, advanced open raceway design, the Zobi harvester, and low energy extraction and drying. These advances have been demonstrated in an 8-acre open raceway facility with all carbon dioxide supplied from flue gas from the adjacent power plant. This presentation will provide a techno-economic analysis of these radical advances when integrated into an open raceway facility for algal commodity production. The analysis will provide an evaluation of the cost of production and the value of the products separately so that the impact of technologies can be clearly elucidated. Various produce spectrums will also be considered since these can have a significant effect on the cost of production, particularly in lipid-protein content effects on cultivation and downstream processing. The presentation will also compare and contrast of the techno-economic analysis with the US Department of Energy State-of-Technology analysis and NREL design report as well as the soon-to-be released DOE harmonized techno-economic analysis of an approach to achieve economic production of biofuels. An evaluation of the differences in technical approach will be presented in terms of feasibility, strengths sand weaknesses, risks, and economics. The impact of scaling on cost, and the scalability of varous technologies will be addressed as well as the impact of variation in algal productivity throughout the year. Additionally, a sensitivity analysis of the opportunities for further cost reduction will be presented to highlight areas where additional research and technological advances would be most beneficial.

ENGINEERING & ANALYSIS

Designing Algae Systems that Meet the "Triple Bottom Line"

Wednesday, October 17 / 10:45 am - 12:15 pm

Waterway 1, Level 2

Kumar, Sandeep [11:30am]

Old Dominion University

Nutrients Recycling Towards Sustainable Large-scale Algae Biofuels Production: Perspectives and Closed-loop Material and Energy Analysis

Elena Barbera, Department of Industrial Engineering DII, University of Padova, Italy Eleonora Sforza, Department of Industrial Engineering DII, University of Padova, Italy Alberto Bertucco, Department of Industrial Engineering DII, University of Padova, Italy Sandeep Kumar, Civil and Environmental Engineering, Old Dominion University, Norfolk, Virginia, United States.

The supply and close loop management of nutrients is one of the great issues to a sustainable scale-up of microalgal biofuels production, as these photosynthetic microorganisms require large amounts of N, P and other micronutrients to grow, which turns into high fertilizers demand. Additionally, recovery and reuse of nutrients (particularly N & P) are a must to reduce the non-point pollution emanating from their release into water or air during the downstream processing steps to biofuels or bioproducts. Recently, strong research efforts have been addressed to the development of nutrient recovery and recycling techniques, to reduce the net amount of fertilizers required. One possibility is the recovery of N and P from the non-fuel fraction of the produced microalgal biomass, which can then be recycled to the cultivation system, in a closed-loop perspective. In this work, state-of-the art studies on nutrients recovery and recycling methods in microalgae processing from the last decade are critically analyzed, focusing on the most promising N and P recovery methods and respective yields, as well as on their subsequent use in algal cultivation and impact on algae productivity. Possible bioproducts exploitation is also taken into account. Perspectives of closed-loop material and energy balances on a large-scale are eventually provided by means of detailed process simulation using Aspen Plus software. Simulations are focused on two possible routes, namely anaerobic digestion and flash hydrolysis. The two technologies are compared in terms of fertilizers savings and energy return on investment ratio, highlighting advantages and drawbacks of both.

ENGINEERING & ANALYSIS

Designing Algae Systems that Meet the "Triple Bottom Line"

Wednesday, October 17 / 10:45 am - 12:15 pm

Waterway 1, Level 2

Bahekar, Roshni [11:45am]

Reliance Industries Limited

Life Cycle Assessment Study for Conversion of Wet Biomass to Biofuels Using Catalytic HTL

Roshni Bahekar, Avnish Kumar, Ramesh Bhujade Research and Development, Reliance Industries Limited, Navi Mumbai, India

Algae, with its potential for using abundant sunlight, green-house gas CO2, non-agricultural land, nonpotable water & faster growth is one of the most promising long-term sustainable source of energy and solution to energy security facing humanity today. Hydro-Thermal Liquefaction (HTL), a thermo-chemical conversion process converts biomass to oil using water as a solvent near supercritical conditions. It essentially mimics the natural process of oil and gas formation from biomass in few minutes instead of millions of years as taken by nature. It processes wet biomass containing as much as 80% water, does not require drying and also recovers water, nutrients, and co-products. With the technological advancement, HTL can be extended for converting other wet biomass to fuels. HTL pathway has significantly lower Green House Gas (GHG) emissions than most mainstream fuels which is one of the important parameter for process selection. A widely accepted method used to quantify environmental metrics is Life Cycle Assessment (LCA) which is particularly challenging for bio-based products due to uncertainties in modeling the natural biomass production process. Currently algal bio-crude is still undergoing research and development compared to the well-developed fossil crude industry and it is necessary to examine whether advances in algal biofuel production process can result in improvement of its environmental profile. To date, a limited number of LCAs have been conducted on HTL processing of algae and wet wastes. Most studies are based on lab or pilot data from batch processes and no publically available study has used data from a continuous system which would most probably be implemented at commercial scale. In literature, there are variations in Global Warming Potential (GWP) values, no details about power & chemicals emission factors used in studies and there is lack of data for Indian locations. This study presents LCA modelling of potential biofuel refinery systems with multiple biomass inputs to advance the understanding of GHG emission profiles of HTL processing with varying system configurations and at an Indian location. Comparison of GHG emissions from HTL process with other conventional wet-waste treatment processes has been performed. This study also aims to provide technological insights into the process design to make HTL technology more efficient.

COMMERCIALIZATION, FINANCE & POLICY

Policy, Finance, Education, and Risk Assessment

Monday, October 15 / 1:45 pm - 3:15 pm

Waterway 3, Level 2

McClung, Gwendolyn [1:45pm]

U.S. Environmental Protection Agency

U.S. EPA's Risk Assessments of Genetically Engineered Algae in Open Pond Testing

Gwendolyn McClung, Ph.D., Stephan Cameron, Ph.D., & Carolina PeÃ±alva-Arana, Ph.D. U.S. EPA, Office of Chemical Safety and Pollution Prevention, Office of Pollution Prevention and Toxics

The Toxic Substances Control Act (TSCA), amended by the Frank. R. Lautenberg Chemical Safety for the 21st Century Act (June 22, 2016), grants EPA the authority to regulate the manufacture, import, processing, distribution in commerce, use, and disposal of new chemicals which include new microorganisms. TSCA reviews Microbial Commercial Activity Notices (MCANs) for intergeneric microorganisms which are those that are formed by the deliberate combination of genetic material originally isolated from organisms of different taxonomic genera. For open pond testing of genetically engineered (GE) algae, the TSCA Experimental Release Application (TERA) is required. EPA conducts risk assessments on GE microorganisms under the paradigm Risk = Hazard x Exposure. To ensure EPA receives sufficient information and data to conduct a risk assessment, the Agency requests submitters provide descriptions of the recipient and donor microorganisms, a detailed description of the construction of the GE microorganism, potential human health and environmental effects, production volume, use information, potential worker exposures, environmental release protocols, potential environmental and general population exposures, as well as expected survival/persistence of the microorganism in aquatic and terrestrial ecosystems into which it may disseminate. The risk assessments for the two algae open pond TERAs that EPA has reviewed will be presented. The GE green microalgal species used in these experiments were Acutodesmus dimorphus and Chlorella sorokiniana.

COMMERCIALIZATION, FINANCE & POLICY

Policy, Finance, Education, and Risk Assessment

Monday, October 15 / 1:45 pm - 3:15 pm

Waterway 3, Level 2

Drage, James [2:00pm]

Algaculture Project

Funding Algae Companies and Projects in 2018

James Drage The Algaculture project and Algae Venture Capital

This has become something of an annual presentation (6 of the past 7 ABO Summits since 2011). Each year I talk about the basics that never change as well s the newest trends, tips and tricks to raising funding from investors. The focus is on venture capital and venture debt but we also touch on angel, strategic, and foreign investors, public markets, etc. After last years presentation in Salt Lake, and speaking with attendees, I realized that lack of investor funding in algae start-up and early stage businesses is still a major problem - more than a decade after algae supposedly became an industry. There is still too much dependence on large government grants and tax credits, which while important, shouldn't be required for this great industry. This year the presentation would focus on helping participants understand that mainstream professional investment capital is the fuel that every industry requires if it is ever going to become a mainstream professional investment. There are "must haves" that all professional investors look for and the presentation will present them and discuss how algae entrepreneurs and founders can impress them and improve the odds of getting funding. We will go quickly through the basics right through to advanced techniques to get funding and participants will leave with practical ideas to put into use. I will say that I believe this topic deserves to be a main stage presentation topic as the importance of funding seems to get lost in the science, government regulations etc. Not being a scientist I believe that the policy and interest more often follows the money than the other way around. We need to get more money into algae and that starts with helping equip the smart people in the industry, often academics, with better tools to get private and public funding.

Ramjohn, David [2:15pm]

AlgEternal Technologies, LLC

Opportunities and Challenges Facing Small and Micro Algae Enterprises: Facilitating Algae Entrepreneurship at Small Scales

David Damian Ramjohn--Chief Executive Officer, AlgEternal Technologies, LLC, 3637 West State Highway 71, La Grange, TX 78945, USA

Algae, specifically microalgae, possess natural characteristics that make them highly suitable to replace fossil hydrocarbons as a platform for sustainable economic activity. This potential has attracted significant private and public funds for research and development, dominated by large and sophisticated entities, in pursuit of commercially viable biofuels; however, the scale of operations necessary to achieve commercial success in biofuels is virtually impossible to achieve for Small and Micro Algal Enterprises (SMAEs). SMAEs should therefore focus on the non-biofuel fractions (low-hanging fruit) from microalgae if they are to successfully compete for a space in the algae biotechnology industry. If the fledgling algae biotechnology industry is to flourish and provide alternatives to the fossil hydrocarbon economic platform, then widespread algae entrepreneurship that challenges the stranglehold on petrochemicals, not biofuels, must be supported at the SMAE level. The success of SMAEs will contribute immensely to the algae biotechnology industry achieving the market penetration necessary for commercial success and acceptance of microalgae as more than a pipe dream or achievable only by the financially well-endowed. However, SMAEs typically are not sophisticated enough to navigate the labyrinths of Federal Regulations, Financial and Corporate Governance, or Intellectual Property Rights, and they lack the voice to influence Policy decisions to their favor. Having a brilliant idea about microalgae is seldom enough by itself to ensure that the idea will become commercially successful; SMAEs often find themselves deluged by the mundane administrative tasks and Corporate Governance issues, and discovery of unknown unknowns that usually result in failure and eventual loss of whatever brilliant idea sparked them into existence. This presentation shares the experiences of a startup in the microalgae industry and the significant learnings gained along the way, identifying major areas where SMAEs would benefit immensely from industry-wide support mechanisms, thus enhancing the competitiveness and possibility for success of the entire industry.

COMMERCIALIZATION, FINANCE & POLICY

Policy, Finance, Education, and Risk Assessment

Monday, October 15 / 1:45 pm - 3:15 pm

Waterway 3, Level 2

Bloxom, Jenna [2:30pm]

Colorado State University

From Pipette Dream to Political Powerhouse: Building Political Capital for Commercialization Success

Jenna Bloxom (M.A., ABD) --- Colorado State University

Poised to revolutionize industrial sectors ranging from effluent treatment to energy to aquaculture to skincare, algae biomass is as versatile as it is promising. The potential to displace conventional oils found in pipelines as well as culinary delights with sustainable, algae-derived alternatives, though, hinges upon an essential determinant that cannot be engineered in the laboratory: political capital. Political capital, characterized by leveraging public support to take a leadership role in creating policy agendas and influencing regulatory outcomes, is the imperative yet overlooked linchpin that will decide commercialization success in these diverse markets. Now is the time for the algae industry to prioritize the implementation of a proactive, cohesive, and long-term campaign to strengthen political capital and to develop a meaningful rapport with voters and consumers rather than continuing to trail behind political decision-making with reactive lobbying and discrete objectives. This presentation outlines several targeted strategies for a coordinated algae coalition to distinguish itself as an authoritative voice in the commercial and policy trajectories of the bioeconomy, proving that algae innovations are no longer pipe dreams but political powerhouses. Beyond a detailed analysis of the origins and applications of political capital, the discussion will explore specific tactics for algae-oriented corporations and organizations to better connect with the public, enhance political marketing, bridge gaps between shareholders and citizens, and compel advantageous legislative and bureaucratic actions.

COMMERCIALIZATION, FINANCE & POLICY

Policy, Finance, Education, and Risk Assessment

Monday, October 15 / 1:45 pm - 3:15 pm

Waterway 3, Level 2

Votaw, James [2:45pm]

Keller and Heckman, LLP

The Case For the Flexible Research Program TERA

James G. Votaw, Keller and Heckman, LLP

Large scale open pond R&D is an important and costly stage in the development of transgenic algae for open pond commercial applications. Promoters must develop appropriate agronomic techniques to achieve consistent high yield commercial production. More fundamentally, however, constructs must be trained to thrive outside the lab, and experience in the real world environment may indicate the need for additional trait modifications to adapt to the outdoor environment and achieve peak performance. With advancements in technology, the ability to monitor and modify target traits can be done very quickly. The practical challenge for developers is assuring that necessary regulatory approvals can keep pace and donâ€™t impede development. EPA rules exempt R&D work with new intergeneric algae in certain circumstances from full regulation under the Toxic Substances Control Act (TSCA). But these exemptions are risk-based, and they become more complex and inflexible as R&D moves to less controlled conditions. Open pond R&D with genetically engineered (GE) algae is subject to the most comprehensive government oversight and requires prior EPA approval of a TSCA Experimental Release Application (TERA). While open pond R&D warrants more pre-planning and oversight than fully contained tests, TERA application and review procedures will need to evolve with experience to be sufficiently flexible to meet the practical needs of large scale open pond R&D for TG algae. The talk will address this background and options for effective and practical oversight of large scale open pond R&D within existing legal authorities.

COMMERCIALIZATION, FINANCE & POLICY

Advancements in Photobioreactors

Monday, October 15 / 4:00 pm - 5:30 pm

Waterway 3, Level 2

Wintersteller, Fritz W. [4:00pm]

SCHOTT AG

Think Outside the Pond

Wintersteller, Fritz W., SCHOTT AG

Large tubular glass photobioreactors operate profitably since 20 years and industrial scale systems have been built recently or are under construction now. This presentation highlights the underlying reasons for the growing adoption of tubular glass systems by the algae industry. Tubular glass systems allow cultivations at high concentrations with high volumetric productivities. Production in closed systems is predictable and sustainable because of high bio-security and no evaporation of water. Glass maintains a high light transmission over many years of UV exposure and glass is generally recognized as safe by the FDA. Its smooth and hard surface almost prevents biofilm formation and allows for easy, scratch free cleaning without causing production downtime. The high initial investment is a myth and the lifetime of over 50 years results in much lower total cost of ownership than systems made of disposable materials that need to be replaced frequently. Finally, the presentation provides insights on the crystal clear benefits of tubular glass photobioreactors.

COMMERCIALIZATION, FINANCE & POLICY

Advancements in Photobioreactors

Monday, October 15 / 4:00 pm - 5:30 pm

Waterway 3, Level 2

Roebroeck, Eugene [4:15pm]

LGem

A Broad Range of Opportunities for Micro-algal Food Products

Dr. EugÃ¨ne J.A. Roebroeck and Sander H.E. Hazewinkel, LGem, The Netherlands

Production costs are essential in assessing the commercial potential of micro-algal products. In food markets micro-algal products can be positioned within a wide price range. In general market analysis reports food products are often positioned within a relative small price range on the value pyramid. Analysis of the prices of plant derived food products within a daily shopping basket in the supermarket however reveals a price range spanning three orders of magnitude. On dry weight basis retail prices of plant food products range from less than 1 to over 1000 US dollar per kilogram of dry weight. This seems unacceptably extreme, but consumers are apparently familiar to cope with these huge price differences. In analogy micro-algal products for food application can be successfully positioned at many different price levels. Although production costs is always an important issue, general statements on maximum acceptable cost price levels for marker introduction of micro-algae based food products are misleading and should be avoided. In 2007 LGem started with commercial scale production and sales of Nannochloropsis for applications in food supplements and food additives. Valuable years of practical experience allowed the development of a unique two-phase tubular photo-bioreactor. GemTubeTM PBRs are scalable systems which are easy to operate. Fouling and accumulation of dissolved oxygen are prevented, while power consumption is extremely low (< 100 W per m3 culture volume). Furthermore the patented design of the GemTubeTM PBRs allows easy drainage, CIP cleaning and stringent decontamination. Since 2012 LGem has delivered over 60 systems to customers around the globe developing many different micro-algal food products.

COMMERCIALIZATION, FINANCE & POLICY

Advancements in Photobioreactors

Monday, October 15 / 4:00 pm - 5:30 pm

Waterway 3, Level 2

Miller, Lanny [4:30pm]

Algenol Biotech, LLC

The Algenol Photobioreactor System: Evolution of Design and Performance

Lanny Miller, Oliver Ashley, Ron Chance, Bodie Drake, Paul Hill, Ed Legere, Ed Malkiel, Ricardo Pinedo, Scott Schuh, Kevin Sweeney, Matt Wivinus, Yanhui Yuan; Algenol Biotech, LLC.

Algenol has been engaged in the design and production of photobioreactors (PBRs) for application in algal bio-refineries for over a decade. The initial focus was on ethanol production from genetically engineered cyanobacteria, an application that dictated the choice of PBR over open pond cultivation. More recently the emphasis has evolved to biomass production for biofuels and higher value products where OPEX and CAPEX tradeoffs play an important role in the PBR array configuration and plant design. This talk will describe the evolution of the Algenol PBR system, including subject matter ranging from design cost and performance interactions to the practicalities of constructing a PBR manufacturing facility.

COMMERCIALIZATION, FINANCE & POLICY

Advancements in Photobioreactors

Monday, October 15 / 4:00 pm - 5:30 pm

Waterway 3, Level 2

Chance, Ron [4:45pm]

Algenol Biotech. LLC

The Algenol Photobioreactor System: Comparison to Pond-Based Systems

Ron Chance and Yanhui Yuan; Algenol Biotech, LLC.

Algenol has been engaged in the design and production of photobioreactors (PBRs) for application in algal bio-refineries for over a decade. The discussion here will focus on a comparison of PBR-based and pond-based systems for biomass production at various deployment scales ranging up to 2000 acres. That comparison will include biomass productivity comparisons between the Algenol PBR system and standard pond systems based on the Algenol Productivity Model and experimental results for Arthrospira platensis. The productivity advantage for PBRs basically offsets their increased costs versus ponds in our economic model, rendering PBRs much more competitive with pond systems than previously thought. Other advantages of PBRs over ponds, such as contamination control, will also be discussed.

COMMERCIALIZATION, FINANCE & POLICY

Advancements in Photobioreactors

Monday, October 15 / 4:00 pm - 5:30 pm

Waterway 3, Level 2

Wilson, Michael [5:00pm]

UK CAER

Demonstration and Scale-up of a Low-cost Photobioreactor for the Beneficial Re-use of Carbon Emissions

S. Kesnera, M.H.Wilsona, J. Groppoa , D. Mohlera, M. Crockera a Center for Applied Energy Research, University of Kentucky, Lexington, KY 40511, USA

Ongoing photobioreactor (PBR) development efforts at the University of Kentucky Center for Applied Energy Research have resulted in the design, prototyping, and scale-up of a unique system and operational strategy for cultivating microalgae. Specific goals have included minimizing capital and operating costs, while maintaining an environment conducive to rapid algae growth. A distinct characteristic of the cyclic flow PBR is the low energy requirement, enabling the application of these systems for the beneficial re-use of industrial carbon emissions. Mass produced and low cost materials were integrated with solenoid valves and microprocessors, to formulate a vertical cyclic flow photobioreactor capable of harnessing the benefits of closed systems, while limiting capital, maintenance, and energy costs. Since 2014, the reactor has been deployed and tested in real-world conditions at a coal-fired power station (Duke Energy's East Bend), and continually refined with regards to its operating strategy. Current PBR operations are located in Kentucky, Indiana, and Henan province in China. PBR licensing and development agreements were made with a company in Zhengzhou, China (Lianhenghui Investment Co.), to focus on the production, operation, and scale-up of cyclic flow systems for the commercial production of microalgae. In this contribution, we will discuss representative performance data and bioreactor design principles that have led to the operation of a 100,000-liter algae production system.

COMMERCIALIZATION, FINANCE & POLICY

Algae Applications in Water Treatment and Nutrient Recovery: Finding Downstream Markets

Tuesday, October 16 / 10:30 am - 12:00 pm

Waterway 3, Level 2

Okamoto, Kelvin [10:30am]

Gen3Bio, Inc.

Waste Microalgae as a Multifaceted Biofeedstock Through Enzymolysis

Dr. Kelvin T. Okamoto, Gen3Bio, Inc.

The goal of most microalgae extractions is to obtain a single core product such as biodiesel, astaxanthin or -glucans. Microalgae is an excellent source for these chemicals but unfortunately, this can leave over 95% of the algae biomass as waste. For microalgae obtained as a byproduct of wastewater treatment, flue gas remediation, natural water harvesting and other processes, the presence of such chemicals is often low to non-existent. Additionally, the extraction processes such as high pressure liquefaction (HPL) and hydrothermal liquefaction (HTL) degrades many of the cell components. Using HPL and HTL, it is difficult to produce biodiesel from the extracted lipids at a commercially competitive cost. To economically use microalgae, especially that obtained as a byproduct, more holistic extraction methods are needed. Such methods would extract the fats, sugars and proteins more completely as well as possibly provide the cell walls. These methods include ultrasound, supercritical CO2, pulsed electric fields and high acid or high alkaline solutions. Alternatively, Gen3Bio is commercializing an enzymolysis process for extraction of microalgae. This process has been demonstrated on several strains to readily, and cost effectively, extract and separate the sugars, fats and proteins. Each of these components can then be further converted to biobased chemicals that can then be starting materials for specialty chemicals in existing commercial pathways. The sugar byproducts of enzymolysis can be fermented to produce succinic acid, lactic acid, ethanol and numerous other specialty chemicals. Succinic acid itself can be used as an airplane deicer or as a flavoring agent or acidity regulator in food and can be a monomer to produce polybutylene succinate (PBS) and other bioplastics. Succinic acid can also be converted to 1,4-butanediol, maleic acid, 1,4-diaminobutane and several other specialty chemicals; these chemicals can then be further converted into other specialty chemicals or used as monomers themselves in bioplastics. During the presentation, a model will be presented which demonstrates the use of enzymolysis extraction technology to significantly increase the overall value per unit of biomass produced. Additionally, results for pilot scale trials will also be presented.

COMMERCIALIZATION, FINANCE & POLICY

Algae Applications in Water Treatment and Nutrient Recovery: Finding Downstream Markets

Tuesday, October 16 / 10:30 am - 12:00 pm

Waterway 3, Level 2

Gross, Martin [10:45am]

Gross-Wen Technologies

Slow Release Fertilizer from Wastewater Grown Microalgae

Martin Gross, Gross-Wen Technologies Xuefei Zhao, Gross- Wen Technologies Zhiyou Wen, Iowa State University

Algae grown on municipal was processed into slow release fertilizer pellets. This approach represents a simple low cost method to convert wastewater grown biomass into a salable product. The fertilizer was tested on tomato, corn, and marigold. It was found that the algae fertilizer outperformed off the shelf organic fertilizer and showed no significant difference compared to off the shelf synthetic fertilizers.

COMMERCIALIZATION, FINANCE & POLICY

Algae Applications in Water Treatment and Nutrient Recovery: Finding Downstream Markets

Tuesday, October 16 / 10:30 am - 12:00 pm

Waterway 3, Level 2

Gardner, Rob [11:00am]

University of Minnesota

Algae Biomass Production Using Dairy Wastewater for Livestock Feed Application

*Authors: Siane C. Luzzi1, Robert D. Gardner*1, Bradley J. Heins2 Institutions: 1University of Minnesota, St. Paul, MN, USA; Department of Bioproducts and Biosystems Engineering; University of Minnesota, St. Paul, MN, USA; Department of Animal Science.*

The removal of nutrients – in particular N and P – from wastewater is a growing regulatory need, and the use of algae may create a unique combination between dairy wastewater treatment and livestock feed application. This study aims to identify a wastewater dilution capable of producing considerable amounts of algae biomass and also to determine if additional CO_2 influences algal biomass productivity. The reactions described in this study occurred in hanging bags of 70L. The treatments were: control (only AM6 media and water), 1:30 (2.33L of wastewater and 67.66L of water) and 1:10 (7L of wastewater and 63L of water), and they were made in duplicates. The algae strain used in this study was isolated from the same wastewater lagoon where the wastewater for the dilutions was collected. Temperature and pH were monitored using an Apex system. Daily samples were collected from day 0 to 6 for analysis of cell growth, biomass, ammonium, and nitrate. Harvest occurred on day 4 for 1:30 and on day 6 for the control and 1:10. The biomass was centrifuged for 2 min at 6500xg. The statistical analysis was performed using SAS 9.4. Cell growth was significantly higher ($p < 0.05$) on days 5 and 6 when CO_2 was added. Cell growth was not different between treatments until day 4, when the control showed a higher growth than 1:10 and 1:30. On day 5, the control was only higher than 1:10. For biomass yield, there was no significant difference in adding CO_2. However, when comparing dilutions, 1:10 showed a significantly lower biomass yield than control on days 0, 1, 4, 5 and, 6. Biomass yield was higher for 1:10 on day 4 compared with 1:30. Bags with CO_2 added produced 333% more algae biomass in control, 14% more in 1:10 and 50% more in 1:30, compared with the bags without additional CO_2. Ammonium removal rates varied between 67.1% and 94.4% on both treatments (CO_2 added or not). Nitrate removal was higher for 1:30 (more than 90%), followed by 1:10 and control. The 1:10 dilution showed satisfactory algae biomass yield, which may be used for livestock feeding. Biofilm formation was observed, which caused variation in biomass measurements. Furthermore, the nutrient removal rates show that algae are capable of reducing the amount of nutrients in dairy wastewater. Keywords: algae; wastewater; algae biomass production; nutrient removal.

COMMERCIALIZATION, FINANCE & POLICY

Algae Applications in Water Treatment and Nutrient Recovery: Finding Downstream Markets

Tuesday, October 16 / 10:30 am - 12:00 pm

Waterway 3, Level 2

Thee, John [11:15am]

Clearas Water Recovery, Inc.

Food-Waste-to-Energy, Algae Wastewater Treatment and the Beauty of the Resulting Circular Economy - A Real World Case Study

Garrett Pallo, PE Vice President of Engineering and Technology Clearas Water Recovery, Inc. Art K. Umble, PhD, PE, BCEE Vice President Global Wastewater Practice Leader Stantec

The role of algae in the global circular economy of food waste to energy is rapidly growing and expanding. Each year, more than 1.3 billion tons of food is wasted or landfilled each year. This is equal to approximately 1/3 of all food produced. In the United States, we are only recovering approximately 3% of the total food that is wasted to landfills. We clearly can and must do better. Anaerobic digestion is making a resurgence because of the tremendous potential to produce high-quality and valuable biogas from food and other waste materials. However, while the anaerobic digester technology is effective at producing gas, it has the downside of producing a significant amount of waste products including high-strength nutrient liquid waste, solid waste (cake), and carbon dioxide. Algae-based wastewater treatment technologies, such as developed by Clearas Water Recovery, has become an enabling technology to the emerging and significant circular economy arising from the food-waste-to-energy market. Technologies, such as Advanced Biological Nutrient Recovery (ABNR), recovers the waste products from the anaerobic digester process and creates a valuable algal biomass coproduct. This coproduct is desirable and valuable to a number of industries including soil amendments, food and feed products, bioplastics, biofuels, and specialty chemical markets. This presentation will focus on a specific case study near Salt Lake City Utah where this circular economy is being made a reality. The combination of food-waste-to-energy, wastewater treatment, advanced biological nutrient recovery (algae), water recovery and reuse, and carbon dioxide recovery and sequestration are all at work at a single facility. The South Davis Sanitary District is proving that any wastewater agency can take advantage of these technologies and recovery resources in a cost effective manner.

COMMERCIALIZATION, FINANCE & POLICY

Algae Applications in Water Treatment and Nutrient Recovery: Finding Downstream Markets

Tuesday, October 16 / 10:30 am - 12:00 pm

Waterway 3, Level 2

Woertz, Ian [11:30am]

MicroBio Engineering, Inc

Bringing Microalgae from Niche Markets to Commodities

Ian Woertz, MicroBio Engineering Inc. Tryg Lundquist, MicroBio Engineering Inc. John Benemann, MicroBio Engineering Inc.

Significant government and private funding are being directed towards research and development of autotrophic microalgae for replacement of petroleum fuel. However, even with optimistic assumptions engineering models predict that algal biofuels are not cost competitive in the near future and that long-term research is required before that goal can be achieved. There are only a handful commercial microalgae companies that exist today, and they only sell to small niche markets for nutritional supplements, live aquaculture feeds, cosmetics, and colorants which have small volumes and high prices compared to commodity markets. In order reach the goal of competing in the commodity market as feed, food, and biofuel a gradual path of increasing productivity, implementing larger scale facilities, and expanding the algal species portfolio is required.

COMMERCIALIZATION, FINANCE & POLICY

What Can't Algae Do? New Markets

Tuesday, October 16 / 1:00 pm - 2:30 pm

Waterway 3, Level 2

Byrne, Thomas [1:00pm]

CarlsonSV

Tax Cuts and Jobs Act of 2017 Impacts and Planning Opportunities.

Thomas Byrne, CPA, CGMA, EDFP CarlsonSV LLP Tax Manager

The new tax provisions impact most taxpayers. The main theme of the bill was to provide businesses with lower overall tax in order to enhance business growth. The lowering of the corporate tax rates only impacted 6% of the businesses in the United States. The bill provides provisions such as Section 199A to enhance businesses operating as sole proprietors, s-corporations and partnerships. The presentation will focus on provisions of the tax bill that impact the after tax profits of business including new depreciation, Section 199A, the definition and utilization of qualified business income. There are also enhanced tax credits; adjustments to the alternative minimum tax; interest expense limitations and other provisions that will impact the strategic operations of your business. Thomas Byrne, CPA, CGMA, EDFP, is one of the biomass industry's experienced tax professionals. A Certified Public Accountant since 1979, Mr. Byrne provides expertise in business structure, tax consulting, feasibility studies, financial modeling, business plan preparation, equity meetings organization, startup management, and grant application. Mr. Byrne has a passion for the emerging algae-to energy-industry. His company, co-hosted the inaugural Algae Biomass Summit in November 2007 in San Francisco, California and the 2008 Summit in Seattle, Washington, which were the foundation for establishing the Algal Biomass Organization in 2008. Mr. Byrne was elected to the ABO's first Board of Directors and continues to serves as both a director and Board Secretary. CarlsonSV, LLP has been providing exceptional accounting, audit, tax, and consulting services to the Midwest area for over 60 years. From start-ups to established enterprises, businesses rely on accurate and insightful financial information in order to maintain profitability and capitalize on new opportunities. CarlsonSV's accounting services steer you closer to these goals with accurate recordkeeping and reporting, as well as support on financial issues such as initial accounting system set-up, cost containment, tax planning, investments, and employee benefit and profit-sharing plans. CarlsonSV serves businesses and organizations throughout a wide range of industries including but not limited to agribusiness, biomass, manufacturing, service etc.

COMMERCIALIZATION, FINANCE & POLICY

What Can't Algae Do? New Markets

Tuesday, October 16 / 1:00 pm - 2:30 pm

Waterway 3, Level 2

Traller, Jesse [1:15pm]

Global Algae Innovations

Development of a Low-cost Novel Algae-based Aquaculture Feed Product

Jesse Traller, Global Algae Innovations Frederic Barrows, USDA Agricultural Research Service (ret.), Aquatic Feed Technologies Aga Pinowska, Global Algae Innovations Rod Corpuz, Global Algae Innovations Dave Hazlebeck, Global Algae Innovations

Meat and dairy production will double and fish production will triple by 2050. Animal feeds play a leading role in the global food industry, and feed is the largest and most important component to ensuring safe, abundant and affordable animal proteins. Feed accounts for 40-60% of the production costs in aquaculture, so access to good quality feeds at reasonable prices is essential for success and profitability in the aquaculture industry. Most fish feeds contain a minimum level of fishmeal in order to ensure an optimal content of amino acids and other nutrients needed for fish growth and flesh quality. Global capture fisheries has been level for several decades, so alternative protein and omega-3 oil sources are needed. Microalgae sources of protein and omega-3 oil could be a tipping point for faster development of mariculture and change the role of some regions such as North America and Europe in global production.   Global Algae Innovations has developed economical, scalable, open pond microalgae production technology that will enable cost competitive production of microalgae for aquaculture feed. Global Algae has also isolated an algae strain that attains 71.4% protein and has an amino acid profile that compares favorably with fishmeal. Combining this strain with a high omega-3 diatom algae would provide a feed profile very similar to fishmeal, so it is likely be a very good aquaculture feed ingredient. Utilizing Global Algae Innovations low-cost production technology our high protein algae strain and high omega-3 diatom was grown at large-scale and further optimized for commercialization. Compositional analysis, fatty acid profiling, and rainbow trout digestibility trials at the USDA Agricultural Research Service further confirmed the potential of this new algal feed ingredient and will be discussed. Data has opened the door for longer-term production tests to generate key metrics needed to support scale-up and more extensive feed trials to validate the efficacy of the new algal feed ingredient.

COMMERCIALIZATION, FINANCE & POLICY

What Can't Algae Do? New Markets

Tuesday, October 16 / 1:00 pm - 2:30 pm

Waterway 3, Level 2

Griffiths, Hywel   [1:30pm]

Fermentalg

Moving Phycocyanin Production from Farming to Fermenters

Hywel Griffiths, Fermentalg Marion Champeaud, Fermentalg Axel Athane, Fermentalg Emma Caderby, Fermentalg Nicolas Andin, Fermentalg Adeline Le Monnier, Fermentalg Olivier Cagnac, Fermentalg*
**Presenting author*

The blue pigment phycocyanin is one of the success stories in the use of algal products to respond to increased consumer demands for more natural sources of food ingredients. Phototrophic production of this pigment by Spirulina, however, has certain disadvantages including seasonal variation in production, the potential for contamination with microcystins, and low productivity. At Fermentalg we have developed an alternative source of phycocyanin using an algae which can be grown at industrial scale in heterotrophic or mixotrophic conditions. By moving to production in fermenters we have been able to vastly improve productivity and ensure a consistent output with no danger of environmental contaminants. In addition the phycocyanin produced by this algae has certain physical characteristics that set it apart from that produced by Spirulina and provide real advantages for end users.

COMMERCIALIZATION, FINANCE & POLICY

What Can't Algae Do? New Markets

Tuesday, October 16 / 1:00 pm - 2:30 pm

Waterway 3, Level 2

Fulbright, Scott [1:45pm]

Living Ink Technologies

Transforming Algae into Next-generation Ink Products

Scott Fulbright- Living Ink Technologies Steve Albers- Living Ink Technologies Fiona Davies- Living Ink Technologies

Living Ink is a cutting edge biomaterials company transforming algae into sustainable printing ink. Currently, pigments within ink and coatings are derived from petroleum and are often toxic. Living Ink has developed a method to produce black pigments derived from algae. This pigment is a biodegradable and sustainable alternative to carbon black. The company currently has commercially viable Algae Ink formulations that are printed with commercial printers for end brands. Additionally, Living Ink is doing metabollic engineering to develop novel cyanobacteria that can produce cyan, magenta and yellow strains for colored Algae Ink.

COMMERCIALIZATION, FINANCE & POLICY

What Can't Algae Do? New Markets

Tuesday, October 16 / 1:00 pm - 2:30 pm

Waterway 3, Level 2

Henrikson, Robert [2:00pm]

Smart Microfarms

Adventures in Spirulina Microfarming

Robert Henrikson CEO Smart Microfarms

Robert Henrikson will talk story and share experiences, challenges and even some metrics growing spirulina in greenhouses in temperate climates and selling products in local markets. Alongside promoting, publishing and consulting in the algae industry for 40 years, his current company Smart Microfarms has operated a private research station in Richmond CA 2011-12, a microfarm testbed near Olympia Washington 2013-15, and since 2016, produces spirulina year round in the San Francisco Bay Area. SpiruSource fresh, frozen and dried spirulina products are sold primarily in the greater SF Bay Area, Los Angeles and online. Forget all those failed algae biofuel big business models, the trend to keep your eye on is the proliferation of algae microfarms. Entrepreneurs and NGOs are setting them up all over the world for innovative, high value products. Why is this happening? Soon fresh locally grown spirulina is coming to a region near you. (Did you know there is even a microfarmer in Northern Vermont?) Review a checklist of desirable qualifications for an algae microfarmer. Spoiler Alert: The three most important things to entertain a successful algae business: 1) Marketing. 2) Marketing. 3) Marketing.

COMMERCIALIZATION, FINANCE & POLICY

Industry Updates: Life Beyond the Test Tube

Tuesday, October 16 / 3:15 pm - 4:45 pm

Waterway 3, Level 2

Teegarden, Rob [3:15pm]

Orlando Utilities Commission

Carbon Utilization - Florida's Potential Pathway and Processes for Converting to the Bioeconomy - Research and the Prospects for Collaborating Across the Energy, Water and Agriculture Sectors

Tryg Lundquist, Micro Bio Engineering; John Benemann, Micro Bio Engineering; Erin Jenkins, Orlando Utilities Commission

Producing transportation bio- fuels can be among the ways OUC and Florida innovate and adapt to a future carbon managed world. Recycling waste nutrients and partnering with agriculture offers a surprisingly wide range to produce valuable renewable bio products, from chemicals and fuels to animal feeds and bio fertilizers. New businesses founded on the recycling of carbon/ nutrients as inputs for creating large scale biomass feedstocks will make such renewable bio products more affordable in Florida. Already a variety of biomass feedstocks can be used to produce energy (including transportation fuels) and bio-based products. The US Dept. of Energy Bioenergy Technologies Office (DOE-BETO) has focused on the development of cellulosic feedstocks derived from non-food-based feedstocks, such as agricultural residues, woody biomass from forest thinnings, municipal solid wastes and even energy crops (energycane, switchgrass, etc.) DOE-BETO is also developing microalgae as a source of feedstocks for biorefineries able to produce biofuels, chemicals and animal feeds. Microalgae are a diverse group of primarily aquatic microscopic plants. OUC has partnered with the MicroBio Engineering Inc., the University of Florida and others to tackle one of the world's most pressing and difficult problems carbon capture and utilization with microalgae. Research over the past 2 years by the OUC and partners, assisted by a grant from DOE National Energy Technology Laboratory (NETL), has been investigating methods to capture and utilize the SEC coal - fired flue gas to grow and process algal biomass into renewable biofuels and higher value animal feeds. Developments in process technology, gas separation, materials science requires increase of the current scales of innovative and multi-disciplinary approaches across the water, energy and food sectors for utilizing carbon. Investments in the bio economy - US federal agencies have invested billions of dollars into such research - proves that biomass grown on marginal nonfood farm lands and blended with nutrients from surrounding communities may be successfully developed and play a significant role as feedstock for new industries and agri - businesses of the future. The State of Florida is well positioned with ideal location and climate for algal biomass production and develop a commercially viable bio economy.

COMMERCIALIZATION, FINANCE & POLICY

Industry Updates: Life Beyond the Test Tube

Tuesday, October 16 / 3:15 pm - 4:45 pm

Waterway 3, Level 2

Corpuz, Rodney [3:30pm]

Global Algae Innovations

Global Algae Innovations Technology and Commercialization Update

David Hazlebeck, Rodney Corpuz, and Aga Pinowska Global Algae Innovations William Rickman, TSD Management Associates

Global Algae Innovations is focused on technology development and scale-up for algal commodity production. Radical advances developed to-date include contamination control, low cost carbon dioxide supply from flue gas, advanced open raceway design, the Zobi harvester, and low energy extraction and drying. These advances have been demonstrated in an 8-acre open raceway facility with all carbon dioxide supplied from flue gas from the adjacent power plant. This presentation will provide an update on technology development and potential for commercialization. Results for various unit operations will be presented along with a discussion of the needs and opportunities for additional development. These advances will be contrasted with prior state-of-the-art approaches as well as other emerging technologies. Areas of focus this year with exciting results for presentation include advances in carbon dioxide supply, low energy drying and extraction, and new cultivation methods for improved productivity as well as for faster lipid formation.

COMMERCIALIZATION, FINANCE & POLICY

Industry Updates: Life Beyond the Test Tube

Tuesday, October 16 / 3:15 pm - 4:45 pm

Waterway 3, Level 2

White, Rebecca [3:45pm]

Qualitas Health, Inc.

Planet-based Nutrition -- Algae Agriculture and the Future of Farming

Rebecca L. White, Qualitas Health, Inc.

Enabling sustainable food production is not just about providing sufficient calories, but also about providing the protein, essential fats, and other nutrients required for good health. Algae has the potential to fill this increasing need for sustainable, intelligently farmed nutrition. Before algae can live up to its promise, we must focus on developing algae as a crop from implementing agricultural practices, methodologies and mindsets, to amending regulations for inclusion of algae AND we need to educate consumers about the benefits of algae nutrition. Qualitas Health is a privately-held company developing high-value vegetarian nutritional products, such as Omega-3 oils and protein, from Nannochloropsis. Qualitas uses sunlight, renewable wind energy, using non-arable land, non-potable salt water and low-energy processes to farm Nannochloropsis in the desert Southwest. Through our production of renewable, algae-derived nutritional products and ingredients, we aim to realize the inherent potential of algae as an essential source of food and nutrition through scalable and sustainable production. The story of our brands, including iWi protein, speaks to the challenges, opportunities, and importance of algae's role in the future of feeding our world.

COMMERCIALIZATION, FINANCE & POLICY

Industry Updates: Life Beyond the Test Tube

Tuesday, October 16 / 3:15 pm - 4:45 pm

Waterway 3, Level 2

Weir, Jeremy [4:00pm]

Commercial Algae Management, Inc / Commercial Algae Professionals, Inc.

Challenges and Opportunities with Large-scale Commercial Organic Vegan Microalgae Production

Albert Vitale - Commercial Algae Management, Inc./Commercial Algae Professionals, Inc. Jeremy Weir - Commercial Algae Management, Inc./Commercial Algae Professionals, Inc.

One of the fastest growing areas of the algae industry is the production of high value nutraceuticals. In this area is one of the most challenging production niches. Commercial Scale production of high value algae biomass that meets both organic and vegan certification. In addition to the limits on the use of the most common chemicals used in the industry in organic cultivation the addition of the vegan certification means that no animal based or derived materials can be utilized. This creates particular challenges when one considers the limitations on the bioavailability of nutrients and other key growth contributors. Commercial Algae has been working with some of the largest producers in the organic vegan nutraceutical markets to increase the productivity, quality and cost effectiveness in the large scale (100 acres plus) of these profitable niche algaes and high value components. We will discuss the challenges and some of the solutions that can arise as well as the regulatory issues and certifications that govern these markets. Additionally, we will discuss a case study where Commercial Algae and its production partner were able to almost triple the production of the algae biomass at scale and the processes, and developments it used to achieve these successes. Lastly, We will discuss the opportunities in these areas and the market outlook over the next few years in what is arguably one of the most profitable opportunities in the algae biomass industries.

COMMERCIALIZATION, FINANCE & POLICY

Industry Updates: Life Beyond the Test Tube

Tuesday, October 16 / 3:15 pm - 4:45 pm

Waterway 3, Level 2

Al Sahtout, Haydar [4:15pm]

Saudi Aquaculture Society

Will the Concept of "Mega, Eco - Industrial ALGAE Parks"� Be the Key to "The Commercialized Algae Industry Growth and Sustainable and Affordable Algae Products"�?

Haydar H. Al Sahtout Adviser Saudi Aquaculture Society

Will the Concept of Mega, Eco - Industrial ALGAE Parks� be the key to The Commercialized Algae Industry Growth and Sustainable and Affordable Algae Products? Abstract: Despite positive perception about the future of the Algae Industry, and despite high optimism about Algae's potentials, and despite the extensive research and huge investments made in the last decade, and the numerous exciting achievements occurred at laboratory, pilot and demonstration scales, attempts to translate such small-scale successes into large commercial projects have not been successful as desired. So far, almost all commercialization projects have yet to produce significant quantities of Algae on a continuing basis and are yet ready to promote sustainable and affordable Algae Products. Industry investigations identified the key technical and non-technical challenges that are preventing the Algae industry from moving forward towards Economically Viable production of Algal. But so far, none of the feedback from the industry suggested the importance of the Mega, Eco - Industrial ALGAE Parks� Concept, were Vertically Integrated, Innovative, Circular Economy Base, Algae Industry Clusters� are accommodated, and none has investigated the reasons behind the absence of such development globally. The proposed (MEIAP) shall offer many important and significant benefits, including being low or free waste and pollution zones, resulting in offering exceptional levels of efficiency, profitability and ease of doing commercially viable and sustainable business. Each cluster hosted within (MEIAP) will focus on a key primary sector within the Algae Industry, and each Cluster would consist of interrelated organizations within the same fields of the Industry, including specialized suppliers, service providers, trade associations, academic institutions, R&D and technology transfer centers, standards-setting agencies, think tanks, vocational training providers, etc. The gathering of the collective expertise within the industry and related activities at each of the Clusters within (MEIAP) will enable each organisation to benefit from such situation as the neighbourhood's pool of expertise and resources shall be available and affordable to deal with. The physical proximity of these players shall encourage interaction and promotes the exchange of ideas and expertise. Haydar H. AL Sahtout

PRODUCTS & MARKETS

Macroalgae: From Sea to Supermarket – Finding a Route from Research to Consumers

Monday, October 15 / 1:45 pm - 3:15 pm

Waterway 8, Level 2

Gao, Song [1:45pm]

Pacific Northwest National Laboratory

Development of the Ocean NOMAD (Nautical Off-shore Macroalgal Autonomous Device) for Low-Cost Production of Biomass for Foods, Feeds, and Fuels

Michael Huesemann, Scott Edmundson, Zhaoqing Yang, Taiping Wang, Andrea Copping and Song Gao, Pacific Northwest National Laboratory Jason Quinn, Colorado State University Jascha Gulden, Reliance Laboratories Geoff Wood, Composite Recycling Technology Center Thomas Mumford, Marine Agronomics, LLC

We will present results regarding the design and techno-economics of a transformational Nautical Off-shore Macroalgal Autonomous Device (NOMAD), which is a free-floating sensor-equipped carbon-fiber seaweed longline (5 km) that is envisioned to be released from a seeding vessel far offshore the United States West Coast and collected by harvesting boats after six months of southbound journey (ca. 1500 km) along nutrient-rich ocean currents. By continuously releasing seeded NOMADs, our proposed seaweed cultivation system is in effect a 1500 kilometer long, interrupted seaweed line capable of generating a similar magnitude of biomass as a 1000 ha farm. Our NOMADs are scalable by many orders of magnitude. Free-floating lines will be used to avoid anchoring costs and the failures of earlier offshore growth trials. High-strength, extremely durable, recycled carbon fiber will be employed to minimize capital costs, longline degradation and failure, and risks to marine life. The NOMADs will be equipped with buoys with GPS sensors to track their positions and with accelerometers and underwater light sensors to estimate, in real time, the biomass yield to optimize harvesting time. The longline will be seeded with a binary culture of Nereocystis luetkeana (bull kelp) and Saccharina latissima (sugar kelp). State-of-the-art hydrodynamic modeling will be employed to design the NOMAD, and to identify offshore locations for release and harvest that result in optimum biomass yields as the NOMAD travels in nutrient-rich currents. To minimize labor costs, fully automated high-speed seaweed seeding and harvesting machines will be designed, built, and performance tested. A new adhesive vegetative seaweed rope seeding procedure will also be evaluated. Pending availability of ARPA-E Phase II funding, the entire NOMAD concept will initially be field tested at the permitted PNNL research site in Sequim Bay, Washington, and later on the Strait of Juan de Fuca, Washington.

PRODUCTS & MARKETS

Macroalgae: From Sea to Supermarket – Finding a Route from Research to Consumers

Monday, October 15 / 1:45 pm - 3:15 pm

Waterway 8, Level 2

Yarish, Charles [2:00pm]

University of Connecticut

Opportunities, Challenges and Future Directions of Open Water Seaweed Aquaculture in the USA

**Charles Yarish, University of Connecticut J.K. Kim, Incheon National University S. Lindell, Woods Hole Oceanographic Institution M. Stekoll, University of Alaska Southeast S. Augyte, University of Connecticut S. Umanzor, University of Connecticut D. Bailey, Woods Hole Oceanographic Institution J-L. Jannink, Cornell University X. Mao, Cornell University K.R. Robbins, Cornell University M. Marty-Rivera, University of Connecticut B. Smith, GreenWave Organization G.H. Wikfors, NOAA, NMFS, NEFSC S. Pitchford, NOAA, NMFS, NEFSC L. Roberson, Marine Biological Laboratory E. Ask, DuPont Nutrition and Health D. Mangelli, C.A. Goudey & Associates C.A. Goudey, C.A. Goudey & Associates*

After more than three decades of effort by scientists, industry, state and federal agencies, seaweed aquaculture is now considered an environmentally responsible practice and offers new opportunities for expansion in US coastal waters. With the nursery technologies developed at the University of Connecticut, the cold-water brown seaweeds, Saccharina latissima and S. angustissima have been successfully cultivated in open water farms in the Northeast. After out-planting juvenile kelp (< 1mm), we have found that our cultivated kelp grew as much as 7.0 m in length and yielded up to 24 kg FW per meter after 6 months (Dec.-May) in Long Island Sound and the Gulf of Maine with a plant density of 400 plants per meter. Similar yields have been found in the Gulf of Alaska. Seaweed aquaculture provides ecosystem services by removing excess nutrients (carbon and nitrogen) from ecosystems and thereby improves water quality, potentially reducing ocean acidification. The kelp aquaculture in Northeast America can remove up to 180 kg N per hectare per year, and 1800 kg C ha per hectare per year, respectively, depending on the spacing of the longlines. Seaweeds have significant value as foods for human consumption and agriculture as organic fertilizers, animal feeds, nutraceuticals, and cosmeceuticals. Seaweed aquaculture may now offer other new opportunities with the planned expansion into the Exclusive Economic Zone with the ARPA-E (US DOE) MARINER Program. With improvements in productivity, kelp and other seaweeds could potentially be a viable feedstock for biofuels. ARPA-Eâ€™s and our goal is to develop tools and a pathway toward low-cost (< $80/DWT) seaweed feedstock that could supply 10% of US transportation fuels. There are now unique opportunities for phycologists to work with ocean engineers, plant breeders and others to develop and apply advanced breeding technologies that will increase growth and improve thermal tolerance for open water farm systems.

Macroalgae: From Sea to Supermarket – Finding a Route from Research to Consumers

Monday, October 15 / 1:45 pm - 3:15 pm

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Perry, Beau [2:15pm]

Blue Evolution

Blue Evolution's North American Seaweed Products: The Journey from Farm to Shelf

Beau G. Perry CEO Blue Evolution

Seaweed's star is rising. Consumed mainly in Asian countries for millennia, these crops have only been commercially cultivated at scale in recent decades. As the industry spreads across the globe in the 21st century- both in terms of markets and production- new seaweed companies, species, farm technologies and products are quickly emerging. In North America, seaweed consumption is rapidly increasing, mainly due to the proliferation of snack products marketed to US consumers. Younger generations are especially receptive to seaweed as a common food component. The bulk of the initial spike in seaweed sales has come in the form of Nori sheets, made from red algae of the Porphyra genus. This is the same material used in sushi rolls, easily supplied in large volumes and repurposed as snack products from existing supply chains in Korea, Japan and China. Whereas 90% of US seafood products imported, seaweed products are closer to 100% due to a lack of domestic production. Over the last decade a new seaweed farming industry has begun to emerge, however, beginning with offshore kelp in New England. Much of that product is blanched and frozen, then sold into the culinary and food service sectors. Blue Evolution is a California-based seaweed business featuring a vertically-integrated supply chains for farmed seaweed in both Alaska and Baja, Mexico. It has bio-prospected a variety of new local species for cultivation, established both onshore and offshore farming models, pioneered processing systems and developed consumer and culinary/food service offerings. Its first line of products consists of wheat pastas infused with a green seaweed ("sea lettuce") ingredient. The ultimate goal is to create a seaweed farming capacity that is linked to a portfolio of foods goods designed to satisfy North American consumer preferences. As a company working across the spectrum of commercialization from wild seaweed to finished products, Blue Evolution has unique insights into the broad sets of challenges and opportunities surrounding the development this new industry. These include market identification, applied aquaculture research, scaling of production, nutrition, quality, food safety and driving consumer adoption.

PRODUCTS & MARKETS

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Nyvall Collen, Pi [2:30pm]

Olmix

Seaweed as a unique source of sustainable solutions

Pi Nyvall Collen , Olmix Herv Balusson, Olmix

We are entering a new era of agricultural production. This new cycle requires increasing technical skills, more natural solutions and fewer pesticides, antibiotics and chemical products. We must do better with less. For Olmix seaweeds are one of the solutions and have become our key innovative and sustainable resource as they grow without the need for arable land or fresh water and allow to recirculate nutrients from the sea to land. Seaweeds also have a wide range of applications, for framers, for agro business and for consumers at they participate to improve: plant performance in an natural way, improving stress resistance and drought tolerance while reducing the need for chemical fertilizers, pesticides and fungicides animal well-being with seaweed products allowing to reduce the use of antibiotics the human health capital with applications in products without egg, without gluten The Olmix company, founded in 1995 by Herv Balusson, have specialized in the extraction of opportunistic seaweed producing massive strandings on the Breton and Vende coasts in France. After harvest and washing the seaweed are extracted in a dedicated modulable seaweed biorefinery, and the produced algal extracts are stabilized into semi-finished products and used for the formulation of final products for animal and plant health and nutrition and placed in an integrated value chain from the resource to the consumactor.

PRODUCTS & MARKETS

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Monday, October 15 / 1:45 pm - 3:15 pm

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Evans, Franklin [2:45pm]

Acadian Seaplants Ltd.

Tasco®, a highly effective functional feed supplement for animals made from the macroalga, Ascophyllum nodosum.

F.D. Evans, Acadian Seaplants Ltd.

On labels, seaweed feed products are listed as “dried seaweed meal” or “dried kelp meal” but without further details as to the specific species or composition of the marine plant. This has led to considerable confusion in the industry as to effectiveness and bioactivity associated with different sources of seaweeds. To avoid confusion this review will concentrate on the seaweed product most researched and cited in the scientific literature, Tasco®, a high-quality ingredient manufactured from the macroalga, Ascophyllum nodosum. Research findings show that in monogastric animals, Tasco® exerts its effects primarily through a mix of complex polysaccharides (52% DM) that act as prebiotics with a potency five-fold greater than inulin. In addition, Tasco® is a rich source of phlorotannins (7% DM) that work in synergy with the prebiotic polysaccharides to selectively depress pathogenic microorganisms that cause disease and digestive problems. Together, these components stimulate positive aspects of gastrointestinal tract health that improve stress resistance, promote animal growth and enhance immune competency. Not only has it been shown that Tasco® upregulates immune associated genes in the host animal, improving disease resistance, but it also downregulates metabolic pathways in pathogenic bacteria, reducing their virulence and disease-causing ability. In ruminant animals, new research has determined that Tasco significantly reduces populations of archaea. Archaea are primitive bacteria with the unique ability to generate energy by reducing CO_2 to methane. This methane gas, produced by ruminant animals, significantly contributes to feed inefficiencies as well as to greenhouse gas emissions. In a trial involving rumen cannulated sheep, Tasco® significantly ($P< 0.001$) reduced archaea populations from 8.70 ($\log_{10}$) in Control animals to 8.12 ($\log_{10}$) in the Tasco® treatment. In ruminants, Tasco® not only has the potential to increase animal health and productivity but to also mitigate the climate change damage caused from methane emissions.

PRODUCTS & MARKETS

Trailblazers: Algae Innovators Making Waves in Food and Health

Monday, October 15 / 4:00 pm - 5:30 pm

Waterway 8, Level 2

Bromley, Philip [4:30pm]

Virun Nutra-Biosciences

Algae, The Challenges and Solutions in Finished Product and Process Formulation

Philip Bromley, Virun Nutra-Biosciences

Algae offers an alternative source for producing dietary supplement ingredients, healthy food additives, pharmaceutical ingredients (active constituents) compared to synthetic methods or unsustainable sources. Different types of Algae produce different types of active constituents. VIRUN is a company that largely formulates and manufactures finished dietary supplements and food products that contain Algae derived active constituents in the form of fatty acids and other non-polar compounds. For example, DHA Omega 3 and Astaxanthin, both derived from different sources of Algae. The challenge VIRUN faces with many Algae derived active constituents are making palatable, finished, consumer products that are stable. The demand for such active constituents in healthy, consumer products are increasing and having solutions to fulfill this demand is somewhat shorthanded. VIRUN will discuss their Intellectual Property with over 80 patents and patents-pending that utilize novel technologies to produce finished, consumable products, containing Algae derived active constituents, that are great tasting, stable, natural and sustainable.

PRODUCTS & MARKETS

Trailblazers: Algae Innovators Making Waves in Food and Health

Monday, October 15 / 4:00 pm - 5:30 pm

Waterway 8, Level 2

Itsygin, Simon [4:45pm]

Czar Salt

Innovative Sea Salt Products Infused with Algae and Other Natural Sources

Simon Itsygin, Czar Salt

Salt (sodium chloride) is the most essential compound in the human body. Sodium chloride is involved in regulating the fluid balance and also absorbs and transport nutrients, maintains blood pressure, and transmits electrical signals throughout the nervous system. Meanwhile too much sodium in our diet can have negative health consequences (high blood pressure, swelling, etc.). Review of publications related to salt daily usage is provided; a tendency for reducing a daily salt usage was specified. Methods of reducing consumed sodium chloride without a taste sacrificing are discussed. Rock salt and sea salt comparison is shown, and recommendations for use are done. Sea salts from the ecologically protected Lagoon of Cuyutlán on the Pacific Coast of Mexico were selected as the healthiest products. These salts are harvested and manually produced according to ancient technologies. The certified organic sea salts have a lower concentration of sodium chloride (85-95%) and don't contain plastic and other poisonous substances. The innovative method of enrichment of the organic sea salts with algae products and other natural sources was suggested. The technology, based on the creation of diverse salt-substance combinations, provides for an increasing line of innovative salt products. The final salt products (branded as Czar Salt) contain beneficial substances integrated into salt crystals, resulting in vivid colors and high stability. Infused into salts crystals, the healthy natural ingredients (vitamins, minerals, carbohydrates, proteins, flavonoids, oils, etc.) partly or completely cover the human demand for these substances and provide new health effects. These benefits come with daily consumption of salt enriched with our healthy nutrients. The main health benefits of Czar Salt products include supporting the immune system, maintaining a healthy circulatory system; managing blood pressure and cholesterols in healthy ranges; improving digestion, vision, skin and bone health; enhancing cognitive functions, etc. Various examples of the new healthy sea salts are presented.

PRODUCTS & MARKETS

Algae for Animals: Feed Applications Go Global

Tuesday, October 16 / 10:30 pm - 12:00 pm

Waterway 8, Level 2

Hansen, Bernie [10:30am]

GreatO Feed

The POWER of greatO

Bernie Hansen, Co-Founder, greatO

NBO3 Technologies LLC, located in Manhattan, Kansas, is a pioneer in the low-cost, efficient delivery of essential fatty acids to animals to improve animal growth, performance and reproduction. By balancing these important long and mid chain Omega-3 fatty acids via the greatOindexer, NBO3 innovated a proven science-based measure of animal health and performance. Harnessing the power of Algae used via NBO3â€™s patented process, NBO3 will launch our greatO family of feeds in early 2019 for all animal markets. greatOfeeds not only improve animal health, performance and reproduction but reduce or eliminate the use of antibiotics. More importantly, utilizing greatOfeeds as part of daily animal ration nutrition, consumers will now enjoy scientifically-proven, better-for-you greatOfoods for use in all consumer protein, dairy and pet food markets improving world-wide consumer health via balancing their Omega 6 to 3 ratio through daily day-part protein consumption.

PRODUCTS & MARKETS

Algae for Animals: Feed Applications Go Global

Tuesday, October 16 / 10:30 pm - 12:00 pm

Waterway 8, Level 2

Wickersham, Tryon [10:45am]

Texas A&M AgriLife Research

Algae Flakes to Beef Steaks

Tryon Wickersham, Texas A&M AgriLife Research

Sustainability of algal derived products is to some extent dependent on successful placement of co-products into a market of sufficient scale and value. Inclusion of agricultural coproducts in beef cattle diets is a common practice that capitalizes on the capacity of ruminants to upcycle, add value to, nutrients for human consumption. Accordingly, evaluating the utility of beef cattle as a potential market for post-extraction algal residue is a logical extension of existing practices. Three questions were posed and answered: What is the nutritional value of post-extraction algal residue? How does post-extraction algal residue affect beef flavor, tenderness, and fatty acid profile? Are consumers affected by the inclusion of post-extraction algal residue? While this project evaluated only one source of post-extraction algal residue in one type of livestock feeding system the thought process and research methodologies are easily be extended to other algal products and coproducts and livestock feeding systems.

PRODUCTS & MARKETS

Algae for Animals: Feed Applications Go Global

Tuesday, October 16 / 10:30 pm - 12:00 pm

Waterway 8, Level 2

Sarker, Pallab [11:15am]

Dartmouth College

Towards sustainable aquafeeds: Creating a fish-free feed for Nile tilapia (Oreochromis niloticus) using microalgae and co-products

Pallab K. Sarker1, Anne R. Kapuscinski1#a, Ashley Y. Bae1,#a, Emily Donaldson1,#b, Alexander J. Sitek1,#c Devin S. Fitzgerald1, Oliver F. Edelson1, Hannah M. Nash1 1Environmental Studies Program, Dartmouth College, Hanover, NH 03755, USA 1#aCurrent address: Environmental Studies Department, University of California, Santa Cruz, CA 95060, USA 1#bCurrent address: Juris Doctor/Master of Environmental Law and Policy Program, Vermont Law School, South Royalton, VT 05068, USA 1#cCurrent address: Department of Biological Sciences, University of New Hampshire, Durham, NH 03820, USA*

Aquaculture is the world's fastest growing food sector, now supplying 50% of seafoodand Nile tilapia is the second most farmed fish worldwide and a key driver of US and global consumer demand for farmed fish. Unfortunately, protein and oil ingredients for commercial aquafeeds currently come from environmentally unsustainable sources: fishmeal (FM) and fish oil (FO) from wild-caught forage fish such as sardines, and corn and soy from large farms with nutrient laden agricultural runoff. Aquafeeds now use over 70% of the world's fish meal and fish oil from unsustainably-sourced forage fish. Microalgae products may provide a more sustainable path for the aquafeed industry. Recently, we reported similar growth, feed conversion, and survival between tilapia fed a diet replacing 33% of FM with a protein-rich and EPA-rich microalga Nannochloropsis oculata co-product and tilapia fed a conventional diet (Sarker et al 2018). Although co-product has high protein content and highest digestibility of lysine and EPA, its higher levels of anti-nutrients may have depressed digestibility of other nutrients and tilapia growth at the higher co-product inclusion levels. We are now treating the co-product with specific enzymes to improve the nutrient digestibility, at least when it is used as the sole microalga to replace fishmeal. We then drew upon the above results to develop a high-performing fish-free feed (full substitution of FM and FO) for tilapia by combining co-product and DHA-rich microalga Schizochytrium sp an important breakthrough in the field. Fish fed the fish-free diet displayed significantly better growth and protein efficiency ratios than fish fed conventional diets with FM and FO; and no significant change in FCR and survival rates among all diets. The fish-free feed yielded the highest DHA content in fillets. We are now studying various marine microalgae and co-products for developing fish-free and crop-free feeds for tilapia.

PRODUCTS & MARKETS

Algae: Soil Savior? Terrestrial Applications for Algae Biomass

Tuesday, October 16 / 1:00pm - 2:30pm

Waterway 8, Level 2

Jauregui, Edgard [1:00pm]

Heliae Development, LLC

Phycoterra®, the key for sustainable agriculture

Edgard F. Jauregui, Heliae Development, LLC

In the past ten years, Heliae has been investigating microalgae and discovering its potential for multiple applications and innovative products that are useful for the world. Interestingly, Heliae has developed a conventional and an organic whole cell microalgae product, PhycoTerra, with application in sustainable agriculture. These innovative products can be applied directly to soil and plants; and have demonstrated benefits in plant growth, soil health, crop yield and crop quality. This presentation will address some of the trials performed with these products and their positive effects in plant agriculture.

PRODUCTS & MARKETS

Algae: Soil Savior? Terrestrial Applications for Algae Biomass

Tuesday, October 16 / 1:00pm - 2:30pm

Waterway 8, Level 2

Ramjohn, David [1:15pm]

AlgEternal Technologies, LLC

Algae: Soil Savior? Terrestrial Applications for Microalgae

David Damian Ramjohn AlgEternal Technologies, LLC 3637 West State Highway 71 La Grange, TX 78945, USA

Microalgae occupy the base of the food web in any ecosystem in which they occur, aquatic or terrestrial; microalgal populations in soil have been estimated to range from 10,000 to 100,000 by the Food and Agriculture Organization of the United Nations. Terrestrial microalgae occur in virtually all soil types, in every geographic region and climate across the globe, yet are perhaps some of the least known and studied species in the group when compared to aquatic species. Some of the known roles/activities of microalgae in soils include, inter alia: oxygenation; water retention; secondary metabolite activities; nutrient recycling; nitrogen fixation; mineral solvents; food for heterotrophic organisms; soil formation and stability; carbon sink; biological indicator; and bioremediation. The cumulative benefits of microalgae in soil remain undescribed and unquantified and the overall importance of microalgae in soil is still poorly understood; they are often overlooked or treated superficially when soil ecology and ecosystems are discussed. If soil is accepted to be the foundation of basic terrestrial ecosystem function, then the importance of soil to the health of the planet and by extension, to human health, cannot be over-emphasized. It can be further posited that microalgae are the foundation of soil ecosystem function. In the context of soil health as it relates to agriculture and food production, water pollution reduction, reduction of leaching, and increased carbon sequestration/reduced carbon emissions, microalgae's contribution to healthy soil ecosystems cannot be dismissed: healthy soil ecosystems = healthy soils = healthy ecosystems = healthy planet = healthy humans. The reintroduction of healthy algal populations to soils delivers significant benefits to human beings, not the least of which is helping planet Earth remain hospitable to our species.

PRODUCTS & MARKETS

Algae: Soil Savior? Terrestrial Applications for Algae Biomass

Tuesday, October 16 / 1:00pm - 2:30pm

Waterway 8, Level 2

Cloud, Ben [1:30pm]

Beem Biologics, Inc.

Opportunities for Algae Biomass in Commercial Crop Production

Ben Cloud Chief Operating Officer Beem Biologics, Inc.

Commercial agriculture worldwide is shifting at an increasing rate towards sustainable practices and inputs that promote soil health and sustainability. There is a significant opportunity for algae biomass as an ingredient in biofertilizer and biostimulant products that promote soil health and optimize crop performance. My presentation will consist of 10-slides and oral comments on the following points: 1. Prioritizing natural nutrient cycling over synthetic/chemical fertility practices 2. Understanding crop fertility and the shift to sustainability 3. Historic and global trends in food production and methods 4. Why algae biomass? 5. Functions as an ingredient in biofertilizer and biostimulant formulations 6. Regulatory issues and challenges nutrient or soil amendment 7. Potential market value for algae biomass in fertility and stimulation 8. Using algae biomass to rebalance CO_2 in the atmosphere and reverse climate change I welcome any comments or suggestions to adjust or improve this presentation to meet the objectives of the ABO. Thank you,   * Please Note: I have presented to the ABO Summit on previous occasions as CEO of Phyco BioSciences, Inc.. I remain CEO of Phyco which has licensed an algae biomass formulation called Cyanoblend to Beem Biologics, Inc. for use as a fertilizer ingredient. I am a co-founder and COO of Beem Biologics, Inc which develops and manufactures biological products for the crop protections industry.

PRODUCTS & MARKETS

Algae, Recycled Carbon and Advanced Biofuels: Prospects for 2020 and Beyond

Tuesday, October 16 / 3:15 pm - 4:45 pm

Waterway 8, Level 2

Kerby, Mike [3:30pm]

ExxonMobil Research and Engineering Company

Advances in Algae Biofuels

Mike Kerby

Global demand for transportation fuels is projected to rise by nearly 30 percent through 2040, and accelerating the reduction in emissions from the transportation sector will play a critical role in reducing global greenhouse gas emissions. Advanced biofuels have the potential to increase energy supplies and reduce emissions. The partnership between ExxonMobil and Synthetic Genomics (SGI) was first announced in 2009 and since that time we have been researching and developing oil from algae to be used as a renewable, lower-emission alternative to traditional transportation fuels. Work continues toward developing strains of algae that demonstrate significantly improved photosynthetic efficiency and oil production through selection and genetic engineering of higher-performance algae strains. A key objective of this collaboration has been to increase the lipid content of algae while decreasing the starch and protein components without inhibiting the algaeâ€™s growth. Here, we describe how we expanded the genetic toolkit available for microalgae and doubled lipid productivity of two algae species. This key milestone in our advanced biofuels program confirms our belief that algae can be very productive as a renewable energy source with a corresponding positive contribution to our environment. While the breakthrough is an important step, the technology is still many years from potentially reaching the commercial market and further improvements not only in carbon partitioning to lipid, but also overall photosynthetic biomass productivity are still required. In March of 2018 we announced a new phase of our research program with SGI. We are beginning research to improve our understanding of outdoor algae growth systems as well as the downstream aspects of harvesting and extraction. This collaborative project is located in the Imperial Valley of California where SGI owns algae ponds and has established expertise in farming of the algae. The companies will be able to better understand the fundamental engineering components necessary for scaling up the technology for potential commercial deployment.

PRODUCTS & MARKETS

That's Made of Algae? The New Wave in Algae Biomaterials Innovation

Wednesday, October 17 / 10:45 am - 12:15 pm

Waterway 8, Level 2

Fulbright, Scott [10:45am]

Living Ink

Developing novel pigmented algae for the use in the ink, printing and colorant industries

Scott Fulbright- Living Ink Steve Albers- Living Ink Fiona Davies- Living Ink

Living Ink is an innovative biomaterials company transforming algae into pigments for a variety of industries, including ink. Approximately nine billion pounds of ink is produced annually around the world. Ink is predominantly made of petroleum or inorganic chemicals mined from the earth. For example, carbon black is commonly used in traditional ink, which is derived from petroleum, not biodegradable, and toxic for humans. At Living Ink, we are developing renewable, biodegradable and safe pigments using algae and cyanobacteria as feedstock. We are developing cyanobacteria cells capable of generating cellular pigments for a color spectrum of cyan, magenta, yellow and black. This project is developing a unique process in which extraction of pigments/dyes is not necessary, thus saving energy and reducing cost. Using cyanobacteria cells as pigments creates a renewable source of biomass for bio-products, as these organisms leverage sunlight, carbon dioxide, wastewater and land otherwise unsuitable for conventional agriculture to rapidly generate biomass.

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Waterway 8, Level 2

Hunt, Ryan [11:00am]

ALGIX

Bloom Foam: Transforming Green Water into Green Products

Ryan W. Hunt, ALGIX

ALGIX commercialized the Bloom Foam technology and built a vertical supply chain from ponds to products. The supply chain for Bloom Foam uses algae growth that converts water and air pollution into protein-rich renewable biomass. Bloom Foam is an algae biomass infused with a polymer elastomer to create bio-composites for foam sheet, insoles, midsoles, outsole, and sandals. Bloom Foam can now be found in athletic, casual and functional products launched by leading footwear and sporting good brands.

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Waterway 8, Level 2

Mancinelli, Rocco [11:15am]

HelioBioSys, Inc

Cyanobacterial production of biopolymers for the production of bioplastics and cosmetics

Rocco L. Mancinelli, David T. Smernoff HelioBioSys, Inc.

HeliobioSys uses a consortium of marine cyanobacteria to produce biopolymers that can be used in the bioplastics and cosmetics industry. Our consortium has advantages over algae and cellulosic crops, including, (1) high photosynthetic efficiency; (2) ability to obtain nitrogen from the atmosphere; (3) excretion of biopolymers; (4) simplified downstream processing and (5) resistance to predation. Combined with their rapid growth rates these traits represent a novel crop capable of addressing the challenges of sustainable production of non-food based industrial feedstock. At Sandia National Laboratory we demonstrated remarkable system stability, resilience and biomass/EPS production in 1,000 L open growth systems. This results in important cost savings in the cultivation of aquatic organisms, and improves the commercial viability of biomaterial production from cyanobacteria. Cyanobacterial extracellular biopolymers have the potential to replace a variety of fossil-fuel derived commercial products. To that end we are investigating its material properties to develop commercially-relevant applications for bioplastics and cosmetics, as a replacement for the polluting and non-degradable petroleum derived microbeads, and thin films for packaging. Additionally, completely non-toxic sunscreens are not currently available, but are highly desired by consumers and cosmetic manufacturers. We are actively investigating the UV absorbance, anti-oxidizing (anti-ageing) and moisturizing properties of our biopolymers and derived hydrogel material. All of these investigations require more detailed understanding of the underlying material properties

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That's Made of Algae? The New Wave in Algae Biomaterials Innovation

Wednesday, October 17 / 10:45 am - 12:15 pm

Waterway 8, Level 2

Callaghan, Tessa [11:30am]

AlgiKnit

Transforming the Fashion Industry with Sustainable Textiles Derived from Kelp

Aleksandra Gosiewski - AlgiKnit, Aaron Nesser - AlgiKnit, Asta Skocir - FIT, Tessa Callaghan - AlgiKnit, Theanne Schiros - FIT, Columbia University

AlgiKnit is a biomaterials company integrating science and design into sustainable textile production. Addressing the ecological damage caused by the fashion industry, AlgiKnit is creating rapidly degradable yet durable yarns derived from a seaweed called kelp. We envision the next generation of sustainable, wearable and ethical materials, produced within a closed-loop life cycle. With a focus on marine health and fashion circularity, AlgiKnit strives to create better material alternatives for designers, consumers, and the world. The yarns are made using plant and algae based biopolymers, negating the need for harmful chemical usage throughout production. Designed to fit into the existing textile ecosystem, AlgiKnitâ€™s yarns readily absorb pigments using sustainable dye methods, reducing the need for excess chemical and water usage.
