S-1075 Multistate Regional Project

The Science and Engineering for a Biobased Industry and Economy

2020 – 2021 Annual Report

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S1075 Chair for 2020-2021

Executive Summary

The annual report was compiled from individual station reports submitted by station representatives including outcomes and impacts against the S1075 objectives, outputs, impacts, and target audiences. For a detailed description of each individual objective and task, see the project statement available on the NIMSS database website.

Project Objectives & Tasks

The objectives and tasks of the S1075 project are:

OBJECTIVE A. Develop deployable biomass feedstock and supply knowledge, processes and logistics systems that economically deliver timely and sufficient quantities of biomass with predictable specifications to meet efficient handling, storage and conversion process requirements

Task 1: Identify and evaluate biomass type and availability for selected geographic regions based on economic, agronomic, and climate conditions

Task 2: Characterize feedstock physical and chemical properties throughout the supply chain

Task 3: Develop harvest, pre-processing, handling, densification, storage, and transportation methods for specific biomass feedstock end-users

OBJECTIVE B. Research and develop technically feasible, economically viable and environmentally sustainable technologies to convert biomass resources into chemicals, energy, materials in a biorefinery methodology including developing co-products to enable greater commercialization potential

Task 1: Develop and assess technologies to produce valuable products from lipids and residuals from lipid processing

Task 2: Develop and assess technologies to produce valuable products from cereal grains, other starchy crops and food waste

Task 3: Develop and assess biological conversion technologies to produce valuable products from carbohydrates in cellulosic biomass

Task 4: Develop and assess technologies to produce valuable products from lignin

Task 5: Develop and assess thermochemical conversion technologies to produce valuable products from cellulosic biomass

Task 6: Integrate thermochemical and biological conversion processes to produce valuable products from lignocellulosic biomass

OBJECTIVE C. Perform system analysis to support and inform development of sustainable multiple product streams (chemicals, energy, and materials) and use the insights from the systems analysis to guide research and policy decisions

Task 1: Develop system models and data to assess sustainability of integrated conversion platforms

Task 2: Develop integrated system models to configure, analyze and optimize bioenergy and

biofuel production systems

Individual Stations Submitting Reports:

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Outcomes related to Objective A. [Develop deployable biomass feedstock and supply knowledge, processes and logistics systems that economically deliver timely and sufficient quantities of biomass with predictable specifications to meet efficient handling, storage and conversion process requirements]

Minnesota

We continued to develop methods to utilize animal wastewater for production of biomass that can be used as biofuel feedstock and food products. We are taking a closed loop system approach consisting of AD, algae cultivation, and hydroponic cultivation. A major improvement in AD process is the development of vacuum assisted stripping process that can effectively remove ammonia nitrogen and hydrogen sulfide, effectively reducing the inhibition of AD by ammonia and sulfur compounds and hence improving the methane yields and fast nutrient removal, resulting in effluent more suitable for algae and vegetable growth. An ongoing project is to demonstrate a complete system that streamlines all the processes for a continuous operation.

New Jersey

Develop a multitrophic aquaculture system that is also growing macroalgae using vertical structures. The system is used to assess the feasibility and economic viability of such systems.

New York

We are continuing to build a database demonstrating the yield potential for switchgrass and miscanthus on wetness-prone marginal soils in New York. While a manuscript is in progress, a brief summary of the yields from fall harvest 2020 indicated that the new Liberty switchgrass variety is outyielding Shawnee (11 vs. 8 dry tons/ha (Mg/ha), both with 70 kg/ha N as ammonium sulfate). Shawnee without N yielded 6 tons/ha, and the fallow grassland control yielded 2.5 tons/ha. Giant miscanthus (cv Illinois) continued to show vulnerability to extended deep ponding, with little to no yield in those areas. Areas on the field only slightly less saturated had yields in excess of 10 tons/ha, and areas without ponding (but still somewhat poorly drained) yielded greater than 20 tons/ha. No fertilization was used on miscanthus, demonstrating a significant yield potential as long as deep off-season ponding can be avoided.

North Dakota

The energy involved in biomass logistics, especially the infield biomass aggregation, is highly significant. Therefore, a simulation study was conducted to determine the energy (fuel consumption) involved in biomass bales infield aggregation logistics using tractors and automatic bale pickers – and this research was published in "Biomass and Bioenergy." Extending the energy involvement to total economics research to the whole forage production, involving all the field activities, a "Forage Economics Calculator – A web tool," which uses the developed infield biomass models, is developed and good progress has been made – and this work is in progress and will be reported in next cycle. Energy in bale aggregation: Infield bale aggregation is essential for bale removal and preparing the field for subsequent crops, which can be more efficiently performed using the modern automatic bale picker (ABP) that supports multiple bales/trip (BPT) than commonly used tractors. But the energy involved in the bale aggregation logistics using ABP has not been thoroughly evaluated. Therefore, the energy involved in the bale aggregation, in terms of fuel consumption, was studied for different logistic scenarios using a tractor (control) and ABP through a user-developed simulation program in R. Different variables such as field areas (8 to 259 ha), biomass yields (3–40 Mg ha−1), four outlet locations, and five equipment speeds (6.6–10.5 km h−1) using realistic equipment turning paths were used in the simulation. The "Nebraska Tractor Test" and "fuel efficiency" methods were considered for the fuel consumption. Fuel consumption for the ABP (8–259 ha) with 8 BPT on an average decreased by 72 % and 53 % compared to a tractor with 1 and 2 BPT, respectively. Field area, biomass yield, and BPT were the most influential variables affecting logistics

distance; while, field area, biomass yield, BPT, and equipment speed affecting the operation time and fuel quantity. Convenient prediction models (multi-variate nonlinear) for logistics distance, operation time, and fuel quantity, using the influential field variables, produced very good fits ($R2 \geq 0.98$). The study recommends an ABP with a capacity of 8 BPT, which can also handle 11 BPT, is efficient considering the logistics energy.

Ohio

We focused on analyzing the logistics, costs and emissions for different feedstocks for the biobased industries, which included corn stover, Taraxacum kok-saghyz (TK) (an alternative rubber crop), pennycress and hemp. We evaluated the techno-economic and life cycle greenhouse gas emissions of implementing the three near-term practical strategies for improving the corn stover supply chain, which included reducing stover supply chain, bale supply quantity, and quantities of in-field machineries. With these strategies, the benchmark cost ($95.9/metric ton (t)), energy use (11%), and greenhouse gas emissions (58.4 kg CO2e/t emissions) associated with the supply of corn stover could be reduced by 34–35%. We also evaluated the techno-economics and greenhouse gas emissions associated with a novel corn stover harvest and post-harvest logistics method which involves harvesting the whole-plant corn. Our preliminary estimates show that the corn stover delivered cost and greenhouse gas emissions can be reduced by more than 30% through this method. Logistics and preprocessing of hemp were analyzed. Hemp for cannabidiol shows huge economic potential, however due to fluctuating market prices and high production cost, there is greater risk. The techno-economics of the production, harvest and post-harvest logistics of pennycress as a renewable jet fuel feedstock was evaluated. Estimated total cost for the pennycress production and logistics was 170–230 $/t. We are currently developing and analyzing the logistics systems for TK rubber dandelion.

Pennsylvania

Co-PI: Tom Richard Outcomes: In support of Objective A, continued to work on the modeling feedstock production and harvesting strategies that spatially identify and efficiently manage economically marginal subfield areas. We improved and validated a high resolution biophysical and economic model to identify unprofitable areas and identified market pathways to profitably convert this land to perennial biomass production. We are also characterizing risks associated with feedstock and supply chain uncertainties along the value chain. Co-PI: Jude Liu Outcomes: Started a new USDA-NIFA SAS project in 2020. Worked on biomass harvesting mechanical and field efficiency. A master thesis on “dynamic cutting strength of miscanthus stalk using a high-speed test device” was completed and met the degree requirements.

South Dakota

1. Utilize biochar to develop smart control release nitrogen fertilizers for sustainable biomass and food production. Received a total of $110,000 to support the research from USDA NIFA through Sungrant Center in FY20/21. 2. Published a peer-review paper for the biochar-based control release fertilizer in May 2021. 3. Supported 3 M.S. 1 PhD, and 2 undergraduate students for research in the projects.

Tennessee

Dr. Hayes (TENNESSEE) showed that the performance of a plastic mulch film prepared from a blend of the biopolymers polylactic acid and polyhydroxyalkanoate is equally as effective as commercially available biodegradable mulch films for the production of vegetables and specialty crops. The mulch film serves as an effective barrier to weeds and is biodegradable when tested according to standardized testing methods. Dr. Abdoulmoumine (TENNESSEE) analyzed 110 hardwood residue samples collected across the southeast and are generating a database of the natural variability of properties that affect performance. We have developed and are refining thermochemical conversion process models to evaluate the impact of feedstock chemical and physical variability on the conversion performance. Dr. Womac (TENNESSEE) oversaw the development of a biomass-supply-logistics, first-generation cotton-module builder and loader

constructed at a model scale to enable biomass testing of module formation factors and the stability of the module during loading. Similitude process provided the scientific basis to create “pi terms” to examine similarity between the model and prototype (full-scale) systems. Initial results emphasized the need to build the module with many shallow layers of chopped biomass, such as switchgrass, to create stable modules during loading processes.

Texas

Texas A&M University (TAMU) AgriLife Research (AgriLife), through the research effort of Dr. Capareda has initiated the logistics studies to design a 1 million gallon per year (MGY) bioethanol refinery using cellulosic at its Rellis Campus facilities in the Bryan-College Station area. The primary feedstock is high tonnage hybrid sorghum and other cellulosic wastes within 20 mile radius of the university campus. Project outcome is the biomass mix to satisfy the requirement of the facility.

Washington

Understanding effects of shapes and sizes of biomass feedstocks on pretreatment is important in order to achieve low cost production of sugars from lignocellulosic biomass. In this study, hardwood (e.g. Poplar wood) and softwood (e.g. Douglas fir) feedstocks with four different particle sizes comminuted by two methods (hammer milling and rotary shearing) were used to investigate effects of different biomass shapes and sizes on the effectiveness of hot water and dilute acid pretreatment as well as the sequential enzymatic hydrolysis. The hot water and dilute acid pretreatment of Poplar and Douglas fir with four particle sizes using two cutting methods were investigated. Results showed that biomass species and cutting methods have stronger impacts on pretreatment yields than particle size. Also, results of enzymatic hydrolysis after hot water pretreatment and 1% (w/w) dilute acid pretreatment indicated the significant roles of particle sizes and cutting approaches in enzymatic hydrolysis yield. It was found that sugar yields were comparable among substrates with four particle sizes using two cutting methods. Although shards shaped (hammer milling) biomass particles showed slightly higher sugar yields for similar particle sizes, the crumbling cutting approach achieved comparable sugar yields as hammer milling. Interestingly, the rotary shear cutting showed 5-15% higher sugar yields in enzymatic hydrolysis. Additionally, the energy consumption of crumbling was three times less than traditional hammer milling. Biomass particles with 12-30/16-40 mesh size could achieve similar combined sugar yields as finer particle size substrates. This study provides more insights in advancement of biomass preprocessing methods and pretreatment methods. In addition, the rotary shearing comminution method led to comparable sugar yields by pretreatment and enzymatic hydrolysis while it consumed three times less energy in comparison with the traditional hammer milling method. Further study on the morohology of the biomass particles and its relationship with mass and heat transfer is needed to better understand the underline mechanisms.

Wisconsin

A study was completed on manure storage management in conjunction with shared Anaerobic Digestion system to identify opportunities for smaller farms to produce biogas economically. Studies were initiated looking at whole corn (stalk and ear processing) followed by at plant separation for improved logistics for ethanol production.

Outcomes related to Objective B. [Research and develop technically feasible, economically viable and environmentally sustainable technologies to convert biomass resources into chemicals, energy, materials in a biorefinery methodology including developing co-products to enable greater commercialization potential.]

Alabama

We have several projects for the investigation and development of sustainable technologies for the conversion of biomass to bioenergy and biochemicals. 1) In one project supported by DOE, Dr. Yi Wang's lab is engineering Clostridium strains for fatty acid ester production. Then the fatty acid esters produced using the engineered strain from corn stover hydrolysates will be evaluated as a bioblendstock for diesel fuel. One engineered strain could produce butyl acetate up to 20.3 g/L, which is highest that has ever been report for microbial production fatty acid ester. The results has recently been published on Nature Communications (Feng et al. 2021, Nature Communications. 21:4368) 2) Brendan Higgins has developed an algal-bacterial process for the treatment of anaerobic digestate and conversion of the nutrients into algae. These algae are then fed to zooplankton to create a natural, protein-rich fish feed. This system directly recycles nutrients from agricultural wastes back into the food production system. This project was funded in May of 2020 by NIFA. In the past year, two papers were published on this topic – one related to pretreating digestate for improved algae growth rates and one related to Daphnia zooplankton cultivation on wastewater-grown algae. 3) B. Higgins is developing (in collaboration with others) an algal-bacterial process to treat poultry processing wastewater so that it is safe to use in hydroponic irrigation. Nutrients in this wastewater are partially sequestered by algae, generated a small biomass stream for potential valorization. However, most nutrients are used by plant crops. This project was funded in January of 2021 by NIFA. 4) B. Higgins is the PI (with Sushil Adhikari as the Co-PI) of a recently-funded NSF REU site focused on converting biological waste materials into products of value. This project starts 9/2021. 5) Dr. Sushil Adhikari is developing a process for renewable hydrogen production through fluidized-bed gasification of coal-biomass-plastics mixture. The coal will be bituminous coal, the biomass will be southern pine and the plastics will be exclusively household waste plastics. The project has recently been funded by DOE (Fossil Energy office).

California

Research was conducted on conversion of the cheese whey to a high value product lactobionic acid (LBA) using the pretreated wheat straw as the substrate. We have utilized the *Neurospora crassa* strain which naturally produces cellobiose dehydrogenase (CDH) to achieve the conversion. However, *N. crass*a strain does not produce laccase when it was gown on wheat straw, which was found to be able to assist CDH with electron transfer and improve the LBA yield from lactose. Cycloheximide was found to able to induce laccase production when it was added to the fermentation broth. The fermentation conditions such as cycloheximide addition time and amount, fermentation temperature were optimized. The LBA production from lactose in cheese was successfully achieved. The final titer of LBA was about 37g/L, he yield was 90%, and the productivity was 1g/L/hour. Research was conducted to produce polyhydroxyalkanoates (PHA) from cheese processing byproduct by using Haloferax mediterranei. Poly(3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV) is co-polymer in PHA family with outstanding plastic properties among various types of biodegradable polymers. In addition to experimental research, An industrial-scale PHA production system using cheese byproducts as feedstock was designed and analyzed for the material flows and economics. Byproduct streams from a cheese plant, with an input of 168.7 metric ton/day (MT/day) lactose, were used as the feedstock. SuperPro Designer was used as the software for the process design and economic modeling. Three scenarios with different processes for the treatments of used enzyme and spent medium were investigated and the major factors that influence the overall economics were identified. The simulated system produces 9700 MT/year PHBV with assumed PHA yield of 0.2 g PHBV/g lactose and an overall process efficiency of 87%. The breakeven price of PHA was found to be sensitive to the lactose price. The scenario with enzyme reuse and spent medium recycling achieved the lowest breakeven price among others, which can be less than 4 $/kg PHA based on the de-lactosed permeate (DLP) unit price. The study suggests utilizing dairy derived feedstocks has the potential to make PHA competitive in the bioplastic market, which could be beneficial to both dairy and bioplastic industries.

Hawaii

Su Lab investigated alternative feedstocks, especially lipid-based feedstocks. The investigation resulted in

developing plant-based oils as an effective carbon source, as well as a biocompatible solvent for efficient extraction of oleochemicals such as astaxanthin secreted by the yeast Yarrowia lipolytica. Genetic and modeling tools have been developed to further the strain engineering and metabolic engineering analysis. These efforts will greatly advance our ability to use yeast biorefinery to produce high-value oleochemicals from abundant and underutilized lipid feedstocks. In another bioconversion project, Su lab developed a low-cost bioreactor with a novel mixing mechanism to support scalable microbial fermentation for producing value-added products from locally sourced waste feedstocks. This new bioreactor technology not only enables large-scale fermentation at a low cost but also requires only low-skilled workers to operate the bioreactor. Using this bioreactor, Su lab can produce yeast biomass at kg scale (dry cell mass) per batch per reactor unit from local papaya fruit waste, and the resulting yeast biomass can partially replace fishmeal to support tilapia aquaculture. Su lab also initiated a project to investigate the use of papaya seed waste as a renewable biofumigant to provide a sustainable solution for managing soil-borne phytopathogens. If successful, this technology will be valuable not only to sustainable agriculture, but also to circular bioeconomy. Khanal's Lab has been working on the use of black soldier flies (BSF) to convert organic wastes including food wastes and agri-residues into BSF larvae for both animal feed and biodiesel production. We have been successful in maintaining native colony of BSF, developing effective mating chamber and producing larvae on diverse organic wastes/residues. We are currently working on process automation and scale-up, with a goal of developing zero waste insect-based biorefinery for valorization of waste and biofuel production. Khanal's Lab has also been working on innovative anaerobic digestion (AD) biorefinery for highly complex feedstocks. The AD biorefinery concept have been developed using lignocellulosic feedstock to convert hemicellulose into biogas and cellulose and lignin into multiple products via thermochemical conversion. In another AD research, Khanal's Lab has employed ORP-based microaeration for anaerobic digestion/co-digestion of agri-residues, sewage sludge and food wastes. By combining reactor performance results, mass balance analyses, microbial community characterization data, and bioenergetics evaluation, an alternative pathway of volatile fatty acids conversion through synergistic association of anaerobic and facultative microorganisms, bypassing syntrophic reactions typically found in anaerobic digestion processes, has been demonstrated. This novel operational strategy can be applied as an effective process control approach for full-scale AD system at high organic loading rates, and offers significant economic and logistical merits. Khanal's Lab continues to work on nitrogen transformations in aquaponics. Our study examines nitrogen utilization efficiency (NUE) under different hydraulic loading conditions, and pathways of nitrogen transformations via nitrogen-stable isotope and microbial community analyses. This study also looks at nitrous oxide (N2O), a highly potent greenhouse gas emission, and its subsequent contribution to global climate change. We have further expanded this research to incorporate nanobubbles technology to improve the productivity of fish and organic produce, and bioponics to include organic wastes as a nutrient source for food production. Du lab has been working on the lipid metabolism in photosynthetic organisms including plants and microalgae, as well as lipid biosynthesis and turnover in soil fungi and bacteria. A particular interest of the Du lab is to under the dynamic of the membrane and storage lipids and the role of lipid metabolism in development and stress response. Du lab is also interested in using engineering and synthetic approaches to produce valuable bio-products in microalgae and establish co-production systems with synthetic consortia of algae, bacteria, and fungi.

Illinois

Development and validation of time-domain 1H-NMR relaxometry correlation for high-throughput Phenotyping method for lipid contents of lignocellulosic feedstocks The bioenergy crops such as energycane, miscanthus, and sorghum are being genetically modified using state of the art synthetic biotechnology techniques to accumulate energy-rich molecules such as triacylglycerides (TAGs) in their vegetative cells to enhance their utility for biofuel production. During the initial genetic developmental phase, many hundreds of transgenic phenotypes are produced. The efficiency of the production pipeline requires early and minimally destructive determination of oil content in individuals. Current screening

methods require time-intensive sample preparation and extraction with chemical solvents for each plant tissue. A rapid screen will also be needed for developing industrial extraction as these crops become available. In the present study, we have devised a proton relaxation nuclear magnetic resonance (1H-NMR) method for single-step, non-invasive, and chemical-free characterization of in-situ lipids in untreated and pretreated lignocellulosic biomass. The systematic evaluation of NMR relaxation time distribution provided insight into the proton environment associated with the lipids in the biomass. It resolved two distinct lipid-associated subpopulations of proton nuclei that characterize total in-situ lipids into bound and free oil based on their "molecular tumbling" rate. The T1T2 correlation spectra also facilitated the resolution of the influence of various pretreatment procedures on the chemical composition of molecular and local 1H population in each sample. Furthermore, we show that hydrothermally pretreated biomass is suitable for direct NMR analysis unlike dilute acid and alkaline pretreated biomass which needs an additional step for neutralization. Production of xylose enriched hydrolysate from bioenergy sorghum and its conversion to β-carotene using an engineered Saccharomyces cerevisiae A new bioprocess has been developed that allows for producing β-carotene from the xylose portion of bioenergy sorghum. Bioenergy sorghum was pretreated in a pilot-scale continuous hydrothermal reactor followed by disc refining. Xylose was extracted using low-severity dilute acid hydrolysis. A xylose yield of 64.9% (17.4 g/L) was obtained by hydrolyzing at 120 °C for 5 min with 2% sulfuric acid. The xylose-enriched syrup was separated and concentrated to either 32 g xylose/L (medium-concentrated hydrolysate, MCB) or 66 g xylose/L (high-concentrated hydrolysate, HCB). The non- (NCB), medium-, and high-concentrated xylose syrup were neutralized and fermented to β-carotene using Saccharomyces cerevisiae strain SR8B, which had been engineered for xylose utilization and β-carotene production. In HCB, MCB, and NCB cultures, the yeast produced β-carotene titers of 114.50 mg/L, 93.56 mg/L, and 82.50 mg/L, which corresponds to specific yeast biomass productions of 7.32 mg/g DCW, 8.10 mg/g DCW, and 8.29 mg/g DCW, respectively. Balancing sugar recovery and inhibitor generation during energycane processing: Coupling cryogenic grinding with hydrothermal pretreatment at low temperatures Pretreatment of lignocellulosic biomass at high temperatures or with oxidizing chemicals generate various inhibitors that restrict the efficient bioconversion of sugars in subsequent steps. The present study systematically investigates individual and combinatorial effects of pretreatment parameters on the generation of inhibitors. A plot between pretreatment temperature and inhibitor revealed optimum pretreatment temperature for energycane bagasse i.e., 170 °C beyond which total inhibitor production increased exponentially. No inhibitor production was observed on mechanical processing i.e., disk milling/cryogenic grinding of biomass. Evaluation of response surface regression exhibited that biomass solids loading has a significant effect on inhibitor generation at higher temperatures. The concentrations of certain inhibitors such as acetic acid, furfurals, and HMF increased more than 3-folds on doubling the solids loading. Furthermore, a novel low-severity approach of low-temperature hydrothermal pretreatment coupled with cryogenic grinding for lignocellulosic biomasses has been introduced which improved sugar yields while maintaining a low inhibitor concentration. Response surface methodology guided adsorption and recovery of free fatty acids from oil using resin The presence of free fatty acids interferes with the conversion of plant oils to biodiesel. Four strong and weak base resins were evaluated for the removal of free fatty acids (FFA) from oil. Amberlite FPA 51 showed the highest adsorption capacity of FFA. A ratio of resin to fatty acid concentrations above 1.875 was sufficient for 70% adsorption. A two-step washing of resin using hexane and ethanol recovered recovered approximately 67.55% ± 4.05% of the initially added fatty acid.

Iowa

Value-addition to light corn steep liquor (CSL), a coproduct of corn wet milling was done through fermentation in producing antifreeze recombinant proteins (AFPs). CSL and thin stillage was utilized as growth media for recombinant *Lactococcus lactis*. A plasmid construct that had AFP III codon-optimized for expression in *L. lactis* was created. The AFP III sequence was cloned into a shuttle vector to make an expression vector that produced recombinant AFP III in *L. lactis*. Media was optimized with a combination of additives and trace elements; Additives and trace elements increased the optical density at

OD600 by more than 40%, indicating the growth of wild type as well as recombinant *L. lactis* strains when compared to control without any additives. The CSL-based media consisting of 50% (v/v) light steep, and disodium-β-glycerophosphate (DG), tryptone (T), ascorbic acid (AA), iron (Fe), zinc (Zn), and magnesium (Mg) was found to be the best-optimized media for further production of AFP. Supercooling of recombinant supernatant after growth indicated a depression to -10□C before crystallization initiated compared to -0.5□C for no-inoculation control and -4.5□C for wild type *L. lactis*, indicating presence of AFP proteins.

Kansas

1. Summary: We improved wet adhesion of plant protein (soybean, sorghum, cottonseeds) based adhesives modified with depolymerized lignin. We also developed the technologies to convert cellulosic biomass and waste materials in to biofuels and chemicals with improved yield and efficiency and technologies to treat and valorize the black liquor and hydroliquefaction wastewater for value-added products. 2. Outputs: 9 peer-reviewed journal articles were published. 6 meeting presentation and invited presentation were delivered. 2 patent disclosures were submitted. 3. Activities: 4 invited presentations were delivered in the international conferences. 4. Milestones: 1) Improved wet adhesion of plant protein-based adhesives through development of protein and lignin polymers; 2) developed new pretreatment method to increase biomass conversion efficiency; 3) Identified marine protists that be able to treat and valorize hydrothermal liquefaction wastewater; and 4) improved black liquor lignin upgrading to high-value products with marine protists.

Kentucky

1) Storage and valorization of hemp hulls and floral material for long term stability and feed supplement applications: The current hemp industry is based on the production of essential oil that is extracted from the floral material of the crop. Essential Oil processors often deal with low density non-uniform feedstocks. By pelleting the hemp floral material, the increased bulk density and uniform shape would increase the operational range of extraction facilities and lead to automated handling. The goal of this project is to determine the ideal moisture content for the pelleting process by examining pellet features: PDI (pellet durability index), compressibility, uniformity, energy consumption, bulk density, equilibrium moisture content, angle of repose, and retention of chemical compounds during long term storage. 2) Exploration of lignin-based super absorbent polymers (hydrogels) for soil water management and as a carrier for Rhizobium: The main goals of this project are to develop lignin-based hydrogels that can be applied to soil to improve soil hydraulic properties i.e. soil water retention and soil hydraulic conductivity. As part of the main goals of the project, machine learning models will be developed to estimate hydraulic conductivity of different textures of soil when they are amended with lignin-based hydrogels. Several studies have succeeded in encapsulating beneficial microorganisms using different carriers e.g. peat, cellulose, starch, alginate etc. However, lignin-based hydrogels have yet to be extensively tested as carriers of Rhizobium which could be applied to soil. Thus, the final part of this project will investigate the feasibility of using lignin-based hydrogels for microencapsulation of Rhizobium. 3) Enzymatic synthesis of esters on spatially confined lignin nanospheres in aqueous media: This study attempts to build a spatially confined hydrophobic environment to allow enzymatic condensation reaction in aqueous solution. Firstly, a colloidal cationic nanospheres suspension was synthesized from lignin. Then, commercial lipases were mixed with the colloid to form the enzyme-nanosphere complexes, and finally entrapped in calcium alginate and dried to form durable beads. Been spatially confined within a hydrophobic nano-scale volume and protected from the outer environment by the alginate beads, the immobilized lipase can catalyze condensation reaction and support direct esters synthesis in aqueous solution. This technique could facilitate the collecting of volatile fatty acids (VFAs) from dark fermentation broth by converting VFAs to extractable esters directly in aqueous solutions. 4) Lignin derived antimicrobial compounds: Corn stover lignin from a biorefinery was oxidatively depolymerized using an environmentally benign organic oxidant, peracetic acid, into a bio-oil that has selective antimicrobial properties against LAB and not yeasts. The resulting bio-oil demonstrated up to

90% inhibition of commercially sampled LAB (including antibiotic-resistant strains) at 4 mg/ml with no inhibition against an industrial yeast strain. These antimicrobial properties of the bio-oil are attributed to larger unidentified lignin oligomers, compared to monolignols, that have a membrane damaging mode of action. Using the bio-oil (4 mg/ml) during simultaneous saccharification and fermentation (SSF) of raw corn starch showed no inhibition of enzymatic activity, and in LAB contaminated fermentations the bio-oil treatments showed an 8% increase in ethanol yields at higher bacterial contamination ratios (l:100 yeast to LAB, CFU/ml). This study illustrates the efficacy of using lignin bio-oil as an antibiotic replacement during fuel ethanol fermentation and demonstrates the highly selective antimicrobial properties of lignin oligomers, which creates a viable lignin valorization strategy for biorefineries." (this work has been accepted as a journal article in Green Chemistry) 5) Extraction of micro- and nano-plastic particles from water using hydrophobic natural deep eutectic solvents: Deep eutectic solvents are a recently discovered solvent composed of a hydrogen bond donor and hydrogen bond acceptor and have been proposed as a cheaper alternative to ionic liquids. Hydrophobic varieties of natural DES (NADES) have been used as extractants in liquid-liquid extractions. The aim of this study is to investigate the relationship between three NADES and micro- and nano-plastics in a liquid-liquid extraction system. The results show that all three NADES extracted plastic particles in the range of 55%-83% with varying rates of extraction. The conclusions from this study are that the plastic particles have a higher affinity for NADES than water and may extract at different rates, but the maximum percentage of plastic particles extracted does not vary significantly.

Massachusetts

Research continues to expand our understanding of fungal degradation mechanisms that can be employed in woody biomass conversion processes. Research continues on understanding non-enzymatic mechanisms involved in brown rot decay that open the structure of woody biomass at the nanoscale in advanced of enzymatic action. We have expanded our research to explore how wood is digested in marine environments, as unknown, yet important degradation terrestrial biomass, also occurs in our oceans via the action of marine borers. We also have expanded research into understand of how other degradative (and plant pathogenic) fungi use similar non-enzymatic mechanisms to initiate wood decay in living woody tissue.

Michigan

Engineering Tools for Modeling of Polar Fluids (Lira). Improved spectroscopic methods for study of alcohols in hydrocarbons (e.g. alcohols in petroleum) provides association constant values for alcohols. Presented work on ethanol-gasoline fuel evaporation. Continuing collaboration with NREL and PNNL. Demonstration of fitting spectroscopic data to obtain association constants. Electrocatalytic hydrogenation (ECH) (Saffron). Mapped multiple reaction mechanisms for aryl akyl ether cleavage via aqueous ECH, which is important for upgrading pyrolysis bio-oils that contain lignin-derived products. Two reviews were published discussing ECH, one on lignin upgrading and the other on model compound upgrading.

Minnesota

We continue to improve microwave assisted gasification and pyrolysis. Our research has been focused on development and evaluation of catalysts and catalytic cracking and reforming of volatiles to produce both fuels and chemicals/materials. Our new catalytic cracking at atmospheric pressure was found very effective. We are also investigating processes to convert non-condensable gas to high value carbon materials including graphite and nanotubes. The hydrogen produced from this process can be used for catalytic cracking.

Missouri

A peer reviewed paper was published to review systems and techniques designed, developed and operated over a 20 year period to test catfish and shrimp production systems employing co-culture of tilapia

(*Oreochromis niloticus*) and brine shrimp (*Artemia*) to remove, concentrate, and convert microbial solids into animal biomass and/or concentrated sludge. A technique entitled “tilapia enhanced sedimentation” is evaluated for use in converting algae into concentrated fertilizer and fish-flesh. Alternatively, brine shrimp are used to harvest and convert microbial solids into a potential fishmeal replacement.

Nebraska

Pretreatment of corn stover using three different ionic liquids and three different deep eutectic solvents was examined in terms of lignin extraction and sugar yield from enzymatic hydrolysis. The ionic liquids resulted in more lignin extraction than the deep eutectic solvents, and the greatest lignin extraction was achieved with the ionic liquids cholinium glycinate and cholinium lysinate. The sugar yields after enzymatic hydrolysis for corn stover pretreated with either cholinium glycinate or cholinium lysinate were similar. Cholinium glycinate has a lower viscosity and is cheaper to produce, so this ionic liquid was chosen for further study.

New Jersey

Survey the state of micro-algae and macroalgae and the various products produced using these feedstocks. The survey will also identify successful industries that commercialize their technologies and produce products for the food, pharmaceutical, and cosmetic industries.

North Dakota

The demand for carbon-based chemicals has rapidly increased due to a diversified market economy. One specific parameter that asserts an attractive, economical solution to biorefinery viability is the solid loading rate of the substrate within the pretreatment and enzymatic hydrolysis for sugar production. The main goal of this research was to evaluate high solid loadings strategies to minimize costs in biorefinery. Our result showed that the pelletization allowed increased pretreatment solid loadings up to 40% while still obtaining glucose yields above 90% and xylose yields above 85% following pretreatment with 18% aqueous ammonia at 90 ºC for 4 hrs. Enzymatic hydrolysis was performed with variable loadings of 10%, 20%, and 30% (w/v) using different reactors. Hydrolysis with gravimetric rolling design produced significantly higher sugar yields at 20% and 30% hydrolysis loadings. We developed low energy, bench-scale mixing method that offers a simple, effective way to replace the large, complex mixing systems commonly required for high solid hydrolysis. Finding new value-added products to utilize dried distillers' grains with solubles (DDGS) would benefit the biorefinery. We used sieve and air aspirator to fractionate DDGS into high protein and high fiber, which could contribute additional economic benefit. A high protein and low fiber fraction will have extra oil recovery potential and a greater value as animal feed for non-ruminants. On the other side, a high fiber fraction will have more potential to build composite materials. Protease and cellulase enzymes were tested either individually or in combination with the heavier fractions of DDGS and resulted in 18-20% more oil than the original DDGS. More than 90% of the oil was recovered from the heavier fraction of DDGS using ethanol at 30ºC with 30% solid loadings. Ethanol bio-refineries may use these findings to recover oil as no significant changes are required in the ethanol plant's design. The lighter fraction of DDGS was used as a multifunctional filler in wheat straw particleboards. Particleboards made with 25% DDGS loading and 75% wheat straw attained good mechanical properties, reduce the phenol-formaldehyde resin use by 50%, and save almost 40% on the raw material cost. The inclusion of DDGS fiber for composites materials would significantly benefit the industry that relies on petroleum-based products. As the production of hemp fiber increases, there will be more hempseed available for other uses. Hempseed has 25-35% oil and the oil that can be used for biofuel, bioresin, and cosmetic industries. Hemp oil has a dark green color from pigments like chlorophyll a and b, and carotenoids. These pigments may have a significant effect on the downstream biofuel and bioresin processes, hence reducing yield. Also, the dark color may not be appealing to end-users. 200 g of hempseed oil was degummed at four citric acid concentrations 0.1%, 0.15%, 0.2%, and 0.25% (m/m) at 60 ˚C. The amount of gum removed after degumming was quantified. The amount of gummed removed increased as the concentration of citric acid increase. The degummed sample was bleached at three

bleaching earth amounts (5%, 7%, and 10%) w/w at 120 ˚C. The color of the bleached samples was analyzed before and after bleaching. Analysis showed that there was a light benefit in color after 7% bleaching earth. Many bioprocessing depends on costly enzymes to break down macromolecules like starch and protein to their respective fermentable monomers. One strategy to reduce costs is to recycle enzymes by attaching them on nanoscaled supports for easy recovery and reuse. We have produced biomimetic cellulosomes and magnetic nanobiocatalysts containing cellulases for hydrolysis of lignocellulosic materials. The biomimetic cellulosomes can be recovered with membrane. The reuse of the recovered biomimetic cellulosomes can reduce enzyme requirement in subsequent hydrolysis by 60%. The magnetic nanobiocatalysts are equally recoverable and reusable, though, with reduced efficacy. We are currently working on developing multifunctional nanobiocatalysts that will contain both amylase, amyloglucosidase and protease for the hydrolysis of soybeans. Bale net wraps are made of non-biodegradable plastics and accumulate and form stomach blockage when consumed by animals. Therefore, edible bale net wrap production, with similar properties to conventional bale net wrap, is a desirable solution. Corn components (starch, oil, zein, and fiber) are suitable for making edible biomaterials with poor mechanical properties. We hope to overcome these challenges by using biochemical processes to linearize and then crosslink corn-biopolymers to form a composite suitable for making edible bale net wrap. This work is in progress and will be reported in the next cycle.

Ohio

We performed organic waste valorization, primarily through anaerobic digestion and hydrothermal carbonization of the digestate produced to produce hydrochar and utilize the hydrochar as adsorbents. We evaluated the performance of using hydrochar for adsorbing dyes in water and as soil amendment. Results showed that hydrochar can adsorb more than 90% of the methylene blue dye at 200 ppm concentrations in the wastewater.

Oklahoma

(1) Biological conversion of syngas and CO2 to alcohols and fatty acids (Atiyeh and Huhnke) Dr. Atiyeh's team continued the development of gas fermentation for the conversion of syngas and CO2 into biofuels and biobased products. We have characterized three new syngas fermentation strains (Strain A, Strain B and Strain C) and compared them with Clostridium carboxidivorans P7 and C. ragsdalei P11 for production of C2-C6 products from CO2. All strains converted CO2 into alcohols and fatty acids. New strains A, B and C produced more butanol and hexanol from CO2 than strains P7 and P11. More acids were produced from CO2 by strains P7 and P11. New strains A, B, C have the potential to produce C4-C6 compounds from CO2. Further investigation of enzyme activity can determine the variation in metabolic functions towards production of C2-C6 compounds from CO2. One paper was published in peer-reviewed journal.

(2) Novel biocatalytic conversion of biomass to butanol (Atiyeh) Dr. Atiyeh's team from Oklahoma State university and Ohio state University has been developing butanol production process with high yield and carbon conversion using novel biocatalysts. In one project, the team has developed a process for butanol production using genetically modified strains that are tolerant to lignocellulose derived microbial inhibitory compounds (LDMIC). LDMICs such hydroxymethylfurfural, furfural and phenolic. These compounds are generated during pretreatment of lignocellulosic biomass. We used an LDMICs tolerant Clostridium beijerinckii (Cb) by overexpressing aldo/keto reductase (AKR) to produce butanol from non-detoxified switchgrass hydrolysate. The Cb_AKR strain produced about 22% more solvents than wild Cb. We also estimated the cost of butanol produced using the Cb_AKR strain for a production facility making 30 million gallons butanol per year. In another project, we examined microbial pretreatment of plant biomass for efficient saccharification and butanol production. We are investigating the feasibility of using a consortia of bacteria and fungi for the pretreatment of switchgrass. Fungi-alone and Bacteria-Fungi coculture degraded four-fold more biomass than bacteria-alone or control. One paper is in review in peer-reviewed journal.

Pennsylvania

Co-PI: Tom Richard Outcomes: Continued to investigate microbial conversion of biomass into methane and carboxylic acids through various modes of anaerobic mixed culture fermentation, with a strong emphasis on mechanical cotreatment (milling during fermentation, mimicing the rumination and cud-chewing of a cow). Characterized the microbiomes and identified several organisms that appear to tolerate the stress of milling. Co-PI: Ali Demirci Outcomes: The project to produce hydrolytic enzymes production from distillers dried grains with solubles (DDGS) for cellulosic biomass hydrolysis for biofuels and other uses have been continued. In this study, it was proposed that DDGS can replace the high-cost feed-stocks to produce these enzymes. To achieve this goal, this phase of the study evaluated Therefore, this study was undertaken to evaluate the effect of salts (KH2PO4, CaCl2·2H2O, MgSO4·7H2O, FeSO4·7H2O, CoCl2·6H2O, and MnSO4·H2O), peptone, and yeast extract on enzyme secretion by four different Aspergillus niger strains and to optimize the nitrogen source for maximum enzyme production. The optimization of all three nitrogen sources improved both cellulase and hemicellulase production in the DDGS-based media. In a different study, further evaluation and the commercialization of vitamin K production via microbial fermentation have been started. The objectives are to validate batch and fed-batch fermentation modes in the bench-top biofilm reactors and determine the optimum conditions in continuous strategies for maximum productivity with high enough titer to be economically viable in a commercial manufacturing process; finally to scale-up the biofilm reactor to 30-L pilot-scale and to study the most efficient scale up strategies including geometry, optimizing oxygen transfer rate, shear rate, mixing time and air bubble residence time. Co-PI: Howard Salis Outcomes: mRNA degradation is a central biological process that takes place inside all cells and yet biological engineers do not have the ability to control this process when engineering organisms. To overcome this challenge, we have developed a new biophysical model to predict and control mRNA decay rates in bacteria, which enables rational engineering and optimization of organisms (e.g. synthetic metabolic pathways) to maximize the bioconversion of waste products into valuable biorenewable chemicals. The biophysical model takes into account the mRNA's sequence, structure, and translation rate in order to predict how quickly RNase enzymes will bind to the mRNA and degrade it. The model was developed and validated by characterizing over 60,000 rationally designed genetic systems using a massively parallel assay. The developed model enables biotech researchers and engineers to control this biological process, which is necessary to reliably engineering biological systems with desired functionalities. Co-PI: Stephen Chmely Outcomes: We have continued testing 3D printed composite materials. Our group is currently developing insights into dispersing TEMPO-oxidized cellulose nanofibrils (TOCNFs) into commercial resins to enhance their mechanical properties, including strength and toughness. In addition, we have used the cellulosic-enhanced lignocellulosic fractionation (CELF) method to isolate lignin from switchgrass. After modifying this material, we have incorporated it into new soybean oil-containing resins for 3D printing by stereolithography. These new blends show enhanced mechanical properties when compared to the unadulterated soybean resin. Finally, we have begun a project to 3D print biocompatible hydrogels to be used as tissue scaffolds for bone regeneration. This is a collaborative project with the University of Tennessee and funded by Sun Grant to study how we can use renewable cellulose fibers to enhance the elastic modulus of these scaffolds. Our hypothesis is tuning the modulus of the scaffolds will cause the stem cells used to differentiate into bones (stiff modulus) or nerves (flexible modulus), and we can tune this variability by incorporating either cellulose nanocrystals (CNCs) or TOCNFs. Co-PI: Juliana Vasco-Correa We are developing a hybrid system based on anaerobic digestion and hydrothermal carbonization for converting agricultural waste into biogas and char-like products. This year, we designed and model a system for dairy farms waste. In another project, we are designing solid-state bioreactors to mitigate agricultural greenhouse gas emission, envisioning a biobased system that can be commercialized as a product and that benefits economically from carbon markets.

South Dakota

1. Extract celluloses from corn stover using mechanical homogenization methods. 2. Develop nano-

composites from different biomass feedstocks (sawdust and corn stover) for biosensor applications in smart food packaging. 3. Development of thermoset resins from corn based chemicals. $ 25,000 supported by NCGA. 4. Value Added Novel Bio-Resins from soybean. $78,000 supported by SD Soybean research and Promotion Council. 5. Supported 3 M.S. 2 PhD, and 3 undergraduate students for research in the projects. 6. Published 2 peer-reviewed papers and 3 presentations in conferences in FY20/21.

Tennessee

Dr. Li's group (TENNESSEE) has explored the modification lignin with poly(□-caprolactone) as a promising approach to valorize industrial low-value lignins. The synthesized lignin-grafted-polycaprolactone has shown significantly improved compatibility and dispersion in acetone, chloroform, and toluene due to the hydrophobic polycaprolactone segments introduced onto the lignin. This study provides extra information on lignin valorization in the form of synthesizing lignin-based copolymers for innovative applications. Dr. Hayes (TENNESSEE) formed bicontinuous microemulsion-based delivery systems composed of biobased oils (e.g., isopropyl myristate and limonene) for delivery of antimicrobial peptides to chronic wounds.

Texas

The TAMU 1 MGY biorefinery is a model designed for a circular economy whereby carbon capture technologies will be researched. TAMU is working with POET for the final design and construction of the refinery that is functional for wide range of research while generating revenues on the sale of commercial-grade bioethanol. All carbon will be recycled with a thermal conversion facility based on fluidized bed gasification systems designed by Dr. Capareda for power generation and the production of biochar which will be incorporated in the TAMU farm for direct carbon sequestration. Electrical power production will be used by the facility through net metering system. Carbon footprint work is also planned and implementation of full life cycle analysis (LCA) and techno-economic analysis (TEA) of all technologies to be developed. In the future, the system will transition from bioethanol to other high value biofuels such as biobutanol. Texas A&M is the home of hybrid sorghum varieties and the genome for the sorghum plant has already been developed by key research personnel on campus.

Washington

Flowthrough pretreatment provides valuable insight into the fundamentals of deconstruction of plant biomass. In this study, the potential softwood degradation pathways under water-only and alkali conditions were determined by elucidating the deconstructed biomass-derived products at 0–270 °C for 2–10 min at a flow rate of 25 mL/min with water-only or alkaline at the initial pH of 8, 9, 11, and 12, respectively. The results indicated that the initial pH value was a convenient indicator along with the severity parameter to control the biomass degradation through the pH < 9 and the pH ≥ 9 pathways. Up to 100% of hemisugars, 90% of cellulose, and 70% of lignin were derived from softwood under pH < 9 at severity parameter log R0 around 5.5, respectively. On the contrary, at pH 12, the degradation resulted in pretreated hydrolysate rich in monomeric and oligomeric phenolic products as well as glycolic acid, acetic acid, and formic acid from carbohydrates. The two-dimensional 1H–13C heteronuclear single-quantum coherence (HSQC) nuclear magnetic resonance (NMR) analysis revealed that nonoxidative degradation at initial pH values lower than 9 mainly cleaved the majority of β-O-4 and preserved most β–β and β-5/α-O-4 linkages in lignin, whereas at pH 12, substantial original aromatic ring structures survived further degradation.

The valorization of non-sugar compounds from biorefinery wastes to biofuels and bioproducts is an attractive but challenging strategy to improve the carbon efficiency of the entire biorefinery process for economic competitiveness. In this work, *R. jostii* RHA1 showed an excellent metabolic and catabolic capacity to degrade various non-sugar compounds, which are common in pretreated biomass hydrolysates, including vanillin, vanillate, furfural, 5-HMF and acetate. Different kinetics, specific

growth rates and lipid yields, when utilizing these compounds were observed and compared, suggesting the strain's metabolic complexity and preference on carbon routing to growth or lipid biosynthesis. The catechol branch of the β-ketoadipate pathway showed higher efficiency in catabolizing benzoate than in the catabolism of vanillate by the protocatechuate branch, and appears to be preferred by R. jostii RHA1. Although acetate was rapidly consumed, it was less favorable for lipid production compared with benzoate. The highest lipid content (0.46 g lipid g−1 CDW) with predominance of C16:0 and C17:0 fatty acids was promoted by the presence of 5-HMF using benzoate as the main carbon source under nitrogen-limited conditions. As 5-HMF was not utilized by *R. jostii* RHA1, the mechanism of increasing lipid production could possibly be related to the redox regulation of lipogenesis. The oxidation of furfural and 5-HMF was observed and supported by NMR results, indicating new possibilities of furan valorization by *R. jostii* RHA1. This study provides a further understanding on the conversion of mixed or individual lignocellulose-derived compounds to lipids by *R. jostii* RHA1, facilitating its application to biofuel production using all of carbon source from biomass.

Wisconsin

Several studies were completed demonstration LiCl and LiBr as ionic salt systems to dissolve and degrade biomass to enable component separation. Studies were conducted demonstrating the use of biological pretreatments to reduce sulfur emissions during anaerobic digestion. Several studies were conducted to improve processes for nanocellulose and hydrogel production.

Outcomes related to Objective C. [Perform system analysis to support and inform development of sustainable multiple product streams (chemicals, energy, and materials) and use the insights from the systems analysis to guide research and policy decisions]

Alabama

B. Higgins is engaged in process model development (mass balance and nutrient transformation) and life cycle assessment of the aquaponics facility at Auburn University. The outcome of this effort is to identify “hot spots” within the system that could benefit from improvements that reduce the environmental footprint of the facility. The efforts have also identified unit operations that contribute most to losses of nutrients and water. One manuscript has been submitted for publication on direct greenhouse gas emissions from the aquaponics facility and have two other articles ready for submission (awaiting acceptance of the first article). Yi Wang is working with collaborators to perform the Life Cycle Analysis (LCA; EcoEngineers in Des Moines, Iowa) and Techno-Economic Analysis (TEA; Dr. Haibo Huang from Virginia Tech) on the fatty acid ester production process. The results provides essential evidence that demonstrates the sustainability and economic viability for the bioprocess for ester production.

California

Work continued on integrated systems modeling and spatial analysis as part of the development of a decision support application to determine optimized supply chains for electricity and fuels from biomass. The modeling approach includes spatial mapping of forest resources in California, including dead and dying stock that represent significant fire hazard, coupled with GIS estimations of transport distances and costs, technoeconomic modeling of feedstock processing and conversion, lifecycle environmental assessment, and distribution costs for product delivery into final demand. A web-compatible version of the FRCS model was developed for forest biomass harvesting cost analysis. Lifecycle data were translated to web-compatible files and an LCA model written for direct integration into the web application. Geospatial resource data were assembled for the Sierra Nevada region of California with a transportation model overlay. A substation data layer was added to estimate costs of

electricity delivery into the grid infrastructure for overall product lifecycle cost estimation.

Illinois

Improving technical and economic feasibility of water based anthocyanin recovery from purple corn using staged extraction approach High anthocyanin concentration in the pericarp, and bioethanol coproduction from remaining fractions make purple corn an attractive source for anthocyanin extraction. Water-based anthocyanin recovery would provide 'natural' anthocyanin extract with diverse applications in food industry. However, low anthocyanin recovery with water-based extraction is not economically feasible on a commercial scale. The objective of this study was to investigate various approaches for increasing water-based anthocyanin recovery from purple corn and assessing techno-economic feasibility of these process options for commercial scale application. Anthocyanin recoveries of 48.6, 68.6, 77.9 and 66.8 % with single-stage, two-stage, three-stage, and two-stage countercurrent water-based extractions, respectively, from pericarp, were higher than recoveries (30.8 %) with process conditions used in previous studies. Single-stage extraction with corn flour had 46.1 % higher anthocyanin yield than single-stage extraction with pericarp due to low pericarp yields. Annual ethanol and anthocyanin yields for plants processing 1113 MT purple corn/day were between 35.2 and 36.3 million gal and 496 and 795 MT, respectively for processes modified for water-based anthocyanin extraction, compared to 42 million gal for the conventional process. Capital costs for modified processes ($97.4–101.4 million) were higher than the conventional process ($87.2 million). Due to the high value of anthocyanins, ethanol production costs for modified processes ($0.98 to 0.48/gal) were lower than the conventional process ($1.34/gal). Internal rate of return for modified technologies was 1.9–3.1 times that of the conventional process, indicating an improvement in economic performance. Anthocyanin extraction process with three-stage anthocyanin recovery had the highest profitability among the processes. Technical and economic feasibility of an integrated ethanol and anthocyanin coproduction process using purple corn stover The coproduction of high-value anthocyanin extract in the cellulosic ethanol process would diversify the co-product market, increase revenue, and potentially improve the economics of the process. The high anthocyanin concentration in the cob and structural carbohydrates in residual stover make purple corn stover an attractive source for anthocyanin and ethanol coproduction. This study aimed to develop simulation models for processes integrating ethanol production and anthocyanin extraction using purple corn stover, to evaluate their techno-economic feasibility, and to compare their performance with the conventional ethanol production process using corn stover. The annual ethanol production for plants processing 2000 MT dry feedstock / day was 148.6 million L/year for the integrated processes compared with 222.6 million L/year for the conventional process. Anthocyanin production in the modified processes using dilute acid-based and water-based anthocyanin extraction processes was 1779 and 1099 MT/year, respectively. Capital investments for the integrated processes ($448.1 to $443.8 million) were higher than the conventional process ($371.9 million). Due to high revenue from anthocyanin extract, the ethanol production cost for the integrated process using acid-based anthocyanin extraction ($0.36/L) was 34.5% lower than conventional ethanol production ($0.55/L). The ethanol production cost for the integrated process using water-based anthocyanin extraction ($0.68/L) was higher than conventional ethanol production due to low ethanol and anthocyanin yields. The minimum ethanol selling price for the integrated process using acid-based anthocyanin extraction ($0.65/L) was also lower than the conventional process ($0.72/L), indicating an improvement in economic performance.

Iowa

Technoeconomic models of anaerobic digestion were evaluated for biogas production from the swine manure. Iowa's livestock produce over 50 million tons of wet-basis manure each year. Biogas production from the manure can provide additional income to farmers, reduce greenhouse gas emissions, control odors, and provide a renewable energy source. Despite these benefits, biogas production is rarely deployed at swine farms. We have explored the economics of various AD systems to better understand the reasons for low deployment, as well as the benefits that might be realized via

several additional steps, including: (1) cleaning and injection into the natural gas grid, (2) amending manure with biomass, and (3) digester centralization. We have created and shared publicly (ASABE meeting presentation, upcoming manuscript) a static, spreadsheet-based technoeconomic model that allows examination of these scenarios and combinations thereof. Core findings included that distributed, farm-scale digesters are not competitive with natural gas prices in Iowa but that some centralized production scenarios can be competitive with natural gas prices when fertilizer value and RIN credits are considered.

New Jersey

Survey the state of micro-algae and macroalgae and the various products produced using these feedstocks. The survey will also identify the importance of the bio-refinery and plausible structures that yield the potential of viable economic outcomes.

Ohio

Technoeconomic analysis was conducted for three biobased products: novolac resin, lactic acid, and renewable jet fuel. Techno-economics of producing novolac resin by partially substituting petroleum-derived phenol with the phenolic compounds in bio-oil obtained from fast pyrolysis of pine chips in the U.S. was analyzed. The study estimated the minimum selling prices for biomass-based novolac resin for 25,000 and 100,000 t capacities to be $1,585/t and $1,250/t, respectively, which are lower than the current market price range of the fossil-based novolac resin production ($1,700-3,200/t). Techno-economics of producing lactic acid from corn grain using three fermentation pathways based on bacteria, fungi and yeast was evaluated for 100,000/t production capacity. Costs of lactic acid production using corn grain were $1,181/t, $1,251/t and $844/t, for bacteria, fungi and yeast, respectively, which was comparable to lactic acid production costs using petroleum sources. Techno-economic feasibility of renewable jet fuel production from pennycress through hydroprocessing technology was evaluated. Minimum selling price of renewable jet fuel from pennycress was estimated to be $1.2/L, which was comparable to the minimum selling price of renewable jet fuel from similar oilseeds, including soybean and canola, but higher than the petro-based jet fuel.

Oklahoma

(1) Life cycle assessment of switchgrass to jet fuel via a novel co-fermentation of sugars and CO2 (Atiyeh) Dr. Atiyeh's team compared the life cycle environmental impacts of petroleum and corn-based butanol and jet fuel production pathways to those from switchgrass using traditional ABE fermentation and co-fermentation of sugars, CO2 and H2 into butanol. Switchgrass to jet fuel pathway via co-fermentation route has lower 100-year Global warming potential (GWP-100, expressed in CO2e/MJ) when compared to fossil fuel pathways. One paper was published in peer-reviewed journal.

(2) Comparative Life Cycle Assessment of Gasification and Landfill for disposal of Municipal Solid Wastes (Kumar): Disposal of Municipal solid wastes (MSW) remains a challenge to minimize its impacts on the environment and human health. Landfill, currently the most common method used for MSW disposal, occupies land space and lead to soil and air emissions. Gasification, an alternative MSW disposal method, can convert waste to energy, but also lead to soil and air emissions and is a more extensive operation. In this study, a comparative life cycle assessment (LCA) of the two disposal methods (landfill and gasification) has been studied to understand impacts on environment and health. The LCA was conducted following the ISO 14040 standards with 1 ton of MSW as the functional unit. The life cycle inventory was obtained from GREET database, published journals and technical reports. The impact assessment was done using TRACI 2.1 and categorized into nine groups. The LCA revealed that landfill is a higher contributor in global warming (1,280 kg CO2 equivalent from landfilling vs. 56.3 kg CO2 equivalent from gasification), smog formation (372 kg O3 equivalent from landfilling vs. 101 kg O3 equivalent from gasification) and human health cancer (1.63E-05 CTU-cancer

from landfilling vs. 8.79E-5 CTU-cancer from gasification). The results showed that the negative environmental impacts of MSW landfilling can be primarily attributed to the fate of leachate and LFG while those of the MSW gasification can be attributed to the disposal of its solid residues.

Pennsylvania

Co-PI: Tom Richard Outcomes: Continued experimental and modeling efforts to understand and enhance system-level opportunities to find synergies between profitable on-farm biomass production, advanced conversion technologies, and innovative market products. Intensified academic and private sector collaborations on the ecosystem service valuation of perennial energy grasses and energy winter crops for water quality in the Chesapeake Bay region as well as the Upper Mississippi Basin watersheds in Iowa. We continued to quantify carbon offset benefits in forest and cropland bioenergy systems. Co-PI: Juliana Vasco-Correa We are developing a superstructure-based analysis of emerging routes for lignin valorization, that allow is to rapidly compare technologies in terms of economic and environmental performance. This year, we have developed a database of lignin valorization process, a superstructure, and a preliminary non-linear model. In another project, we also have performed techno-economic and life-cycle assessments of the process of using hydrothermal carbonization to valorize anaerobic digestate from dairy farms. Co-PI: Christine Costello Outcomes: Two large projects have started this year, C-CHANGE, funded by USDA NIFA and ECO-CBET, Transforming the Nitrogen Economy, funded by NSF. I have been developing research questions and approaches with team members to provide modeling support, particularly to support decision-making, to these projects. Recent publications represent a range of modeling approaches and suggestions for new and combined approaches to understanding and communicating to stakeholders about the impacts of decisions made individually and collectively.

Texas

The planned TAMU biorefinery is designed to begin researching on net zero greenhouse gas emissions. The facility will showcase carbon-negative chemicals, fuels and materials solutions that will be shared with producers, refiners and blenders to meet their requirements in a economical and sustainable manner. Future planned research include conversion of biochar into valuable materials such as activated carbon, graphene, capacitors and the like. Chemicals production research will expand to produce biobutanol, high value organic acids, building block chemicals and many more. The university (TAMU) has also began evaluating its carbon footprint in order to develop a roadmap for sustainability studies. Dr. Capareda has initiated these studies and reported an annual CO2eq emissions for the university based on its power production energy usage and the carbon footprint for TAMU Athletics. The group is planning to cut down greenhouse gas emissions by around 7% each year following Kyoto Protocol and provide yearly offsets. The planned biorefinery will also contribute to the yearly carbon offset targets.

Washington

The sustainability of renewable fuels from biomass heavily depends on the utilization of lignin for fungible products, where biological lignin valorization has recently opened new avenues for competitive biorefineries. Despite the significance, current biorefinery designs yield lignin with inadequate fractionation and low yield of converted products, yet substantial changes of current biorefinery design to focus on lignin could jeopardize carbohydrate efficiency and lead to high capital costs. We hereby designed a set of ‘plug-in processes (PIP)’ to integrate with five leading pretreatments and carried out systemic performance analysis. The new biorefinery design effectively achieved substantial improvement of lignin bioconversion, synergistic enhancement of carbohydrate processing, and comprehensive advancement of biorefinery profitability. First, PIP has improved lignin dissolution, where dilute sulfuric acid (DSA), steam explosion pretreatment (SEP), liquid hot water (LHW), and ammonia fiber expansion (AFEX) achieved most significant increases and generated more than 70.2%, 65.6%, 56.2% and 81.5% soluble lignin compared with sodium hydroxide pretreatment (SHP), respectively. Second, PIP has synergized higher carbohydrate efficiency by 89.7%, 94.9%, 80.1%, 96.8%, and 84.2% for DSA, SEP, LHW, AFEX and SHP, respectively. Third, the PIP substantially improved lignin processibility as

compared to lignin waste streams directly out of pretreatments. The PHA concentration reached 2.2, 4.5, 2.3, 3.2, and 3.6 g/l for the PIP with DSA, SEP, LHW, AFEX, and SHP, respectively. Fourth, the mechanistic studies indicated that PIP depolymerized the lignin to low weight molecules and functionalized the lignin with more phenolic hydroxyl and carboxyl groups, which further enhanced the solubility and reactivity of lignin and improved biological processibility. The new biorefinery design with PIP could transform lignocellulosic biofuel in several ways. First, the PIP simultaneously improved the carbohydrates and lignin conversion in a biorefinery. The synergy effectively addressed the dilemma of lignin- or carbohydrate-first scenarios and represented a balanced approach for biorefinery advancements. Second, the techno-economic analysis (TEA) suggested that the PIP enabled minimum PHA selling price (MPSP) at $9.58/kg, $6.82/kg, $8.32/kg, $6.18/kg, and $11.99/kg for DSA, SEP, LHW, AFEX, and SHP, respectively. The results highlighted the potential for PIP to achieve commercial production of PHAs as a co-product of cellulosic ethanol, in particular, for AFEX and SEP. Third, PIP achieved lignin chemistry for efficient bioconversion along with integration with current pretreatment technologies, minimizing the requirement of the additional units, amortizing the capital investment, and optimizing the total capital cost. Overall, PIP has the potential to transform biorefinery design toward profitability and sustainability.

Wisconsin

Several studies were completed quantifying the environmental impacts of biochar production systems and use for prevent nutrient runoff and water degradation.

Impacts

Alabama

1) Developed new bioprocess for biofuel and biochemical production; 2) Secured federal grants for further biomass and biochemical research, education and outreach; 3) Develop connections and collaborations with colleagues from other institutions and stations.

California

Conversion of cheese whey waste and wheat straw for lactobionic acid production can lower the cost of lactobionic acid production and reduce waste. Conversion of food and other organic waste into Polyhydroxyalkanoates (PHA) will lower the cost of PHA production, making the PHA more affordable as biodegradable plastics. The development of the forestry biomass decision support application directly addresses Objective C/Task 2 to inform the development of sustainable product streams and to help guide research and policy decisions. California in particular, but the western U.S. more generally, has experienced disastrous wildfires in the past several years that call for more extreme management strategies that benefit from the availability and development of bioenergy and bioproduct industries and improved decision tools to support feasible project development.

Hawaii

Current work from the Su lab helped to advance our understanding of how underutilized renewable lipids can be utilized as an alternative carbon feedstock for producing useful biobased products. That study along with studies on innovative bioprocessing of locally sourced fruit wastes have an important positive impact on sustainable valorization of agricultural wastes/byproducts and transition into a circular bioeconomy. Khanal’s Lab has been actively involved in renewable energy, environmental biotechnology, waste-to resources research with focus on sustainability. Several of the funded projects were through close collaboration with members of S1075. Du lab has developed an efficient bio-flocculation method that can significantly reduce the cost of harvesting microalgae and produce feedstocks for biodiesel and nutraceuticals. Development of novel gene editing toolkits like CRISPR for microalgae will improve production of high-value products.

Illinois

Developed processes to recovery vegetative lipids from biomass Developed analytical methods to identify lipids in biomass Recovered high-value coproducts from biomass

Iowa

1. Higher-value biochemicals/biobased production through fermentation can add to circular bioeconomy utilizing lower-value waste/ coproducts leading towards sustainable products 2. Deployment of biogas production from animal manure through anaerobic digestion can be competitive with natural gas prices when fertilizer value and RIN credits are considered

Kansas

The enabling technologies of utilization of agriculture feedstocks and by-products developed for biobased materials and bioenergy are critical to our sustainable economic development. The new knowledge generated can be useful reference to both academia and industries in the field.

Kentucky

Through the support of S-1075, seven graduate students (including three minority and two female students) were trained. The research outcomes were presented at international conferences and published as journal articles. The results of antimicrobial and plastic extraction related study lead to two patents/patent applications.

Massachusetts

We have 10 refereed publications that have come out in 2020-2021 showing the advance of our research on woody biomass and degradation mechanisms. A primary focus has been expansion of the research we have pioneered on the chelator-mediated Fenton (CMF) mechanism that is used by brown rot fungi. Other research groups at JBEI (Joint BioEnergy Institute), Sandia Labs, and Lawrence Berkeley National Lab are now advancing and patenting research on the CMF mechanism for efficient conversion of lignin. Example: Kent et al. Green Chemistry. DOI: 10.1039/C7GC03459H . We consider this as a successful transfer of the fundamental mechanisms we have discovered to practical application for biomass conversion.

Michigan

Collaborations are continuing with PNNL and NREL on fuels.

Minnesota

Production of current major biofuels, i.e., biodiesel and ethanol, is competing with food and feed demands, prompting the need to use non-food biomass feedstock for biofuel production. Our work on pretreating animal manures to produce effluent suitable for microalgae and vegetables to grow would have significant impact on alternative biomass production. Thermochemical conversion of lignocellulosic biomass feedstock is a platform which can provide short and mid-term solutions. The major challenges for thermochemical conversion are the poor quality and stability of the products. Our work on microwave assisted catalytic conversion of biomass and plastic wastes has improved the yield and quality of bio-oil and syngas. These outcomes have positive impacts on the overall technical and economic performance of thermochemical conversion technologies. Our research projects many students and other researchers. Many of our findings have found their way in the classroom teaching and outreach also.

Missouri

Publication of invited book chapter providing knowledge to fish and shrimp farmers enabling co-products and biofuels from intensive and super-intensive aquaculture production

Nebraska

A bienzyme lignin depolymerization system using aryl alcohol oxidase and lignin peroxidase was developed. The combination of these enzymes resulted in decreased lignin molecular weight as opposed to the control with no enzymes.

New Jersey

The multitrophic aquaculture system, which focuses on cold-water fish and the use of chillers, is of interest to the industry. The survey is useful in understanding the current state of the technologies and plausible paths and supply chains being developed.

New York

A paper summarizing switchgrass and miscanthus establishment and yields on marginal soils is nearing completion for submission in 2021. It covers harvest data from 2012 through 2020, and demonstrated significant yield potential on low-quality soils.

Ohio

Opportunities to collaborate with researchers from different institutions. Assembling expertise from wide range of researchers on solving related problems of common interest.

Oklahoma

Global generation of municipal solid waste (MSW) is predicted to reach over 2.2 billion tons/year in 2025. Landfilling and incineration, the two most common conventional techniques for MSW processing, negatively impact public health. One of the studies developed and demonstrated electricity generation by co-gasification of two underutilized resources: MSW and agricultural biomass. Biochars from various sources were used in medium formulation that enhanced ethanol and butanol production from syngas, which was reported in four journal papers. Results are part of three patents on the syngas fermentation technology developed.

Pennsylvania

Having the ability to rapidly assess emerging conversion technologies toward developing systems that are economically and environmentally sustainable. Implementation of economically viable and sustainable processes is urgent due to three converging issues: decrease in productive agricultural land; using unsustainable methods to clear land for agricultural production and increasing world population. These intersecting problems is so vast that constructive solutions can only be developed and implemented through collaborations. Replacing existing petroleum-based energy and products with those that are stemming from biomass and other agricultural products will require research and development. Incorporation of renewable polymers in materials used for additive manufacturing will provide the materials are generally less expensive than those derived from petroleum, so there would be an immediate cost benefit. Furthermore, LCAs and TEAs will be great tools to achieve these tools.

South Dakota

1. Provided opportunities of education and research training for graduate (6 M.S. 3PhD) and undergraduate (5) students in the projects. 2. Disseminated new technologies and knowledge to public and stakeholders through publishing 3 peer-reviewed papers and 6 presentations in FY20/21.

Tennessee

The impact is to reduce the risks associated with the deployment of biomass supply/logistics and conversion technologies. Reducing this risks is based on creating biomass supply chains that yield predictable quality and quantity of raw ingredients for conversions that produce positive economic outcomes for the served sectors and industries. To do this, TENNESSEE tackles a wide range of problems involving improved field production, enhanced identification of biomass properties, alternative logistics

supply systems, and improved conversion processes.

Texas

The following are the list of impacts related to involvement with S1075. 1. Assist with pre-commercialization of TAMU thermal gasification technology by developing commercial-sized systems and assisted with commissioning 2. Development of new advanced research in the development of biomass-based biomaterials such as activated carbon and graphene materials from agricultural and waste bio-char for manufacture of advanced bio-materials such as capacitors, semi-conductors, adsorbents and filters and graphene ink for 3D printers 3. Power generation from biofuels (bioethanol, biogas and biodiesel) from sweet sorghum, high digestibility grain sorghum and high tonnage sorghum, waste oil and net meter the electrical power to the grid while developing smart grid systems. 4. Development of advanced pyrolysis research for purified carbon production. 5. Life cycle analysis (LCA) of all chemicals, biofuels, biomaterials and other related technologies that are integral part of the TAMU biorefinery.

Wisconsin

The S1075 meeting and contacts were used to share research ideas, reviewers, and keep abreast of research innovation.

Target Audience

Alabama

1. Academic researchers and university/college students. 2. Engineers, Scientists, Industries, and Policymakers. 3. K12 students

California

The target audience includes stakeholders involved in the deployment of biofuel systems and researchers participating in biofuel and bioenergy investigations. The research findings and decision support tools can be used by extension and other academic investigators, government policy makers, and private developers to develop and disseminate knowledge about possible environmental impacts and economic implications for biofuel systems and to assist in specific policy and investment decisions. In addition, researchers in the field can use insights of the work to further advance the methods and approaches for enhanced decision support and sustainability assessment.

Hawaii

Biobased industry, farmers, processors, scientists, and policy makers

Illinois

Biofuels Companies, Industrial Biotech Companies

Iowa

Biochemical/ bioproducts companies, Corn wet-millers, animal farms, scientific community and general public

Kansas

Crop growers, farmers, companies will be the immediate beneficiaries of the investigation by finding new applications of soybean meals, oils and its derivatives for adhesives and coatings, agricultural feedstock processing industries, resin and biobased fuel related industries. Oilseeds and biomass related farmers and industries will also benefit from this study to find a way to utilize their products. The general public will benefit from the results, because biobased adhesives and fuels are environmentally friendly. In addition, the findings from this project will advance the bioadhesives and biofuel knowledge base and stimulate

future developments within the biobased adhesive and biofuel industry. In addition, biomass and bioenergy industries will be the immediate beneficiaries of the advanced technologies for biofuel production.

Kentucky

Target audiences include the biofuel and bioproduct research community, the farmers and processors, biotechnology industry.

Massachusetts

Other Researchers and Scientists. Technical Experts in the Bioconversion Field. Students.

Michigan

Academic and Industrial Professionals

Minnesota

Our research findings were publicized to the academic community through peer-reviewed publications and conference presentations. On-site demonstrations were conducted to showcase our results to a broad range of audiences including academic researchers, government officials, funding agencies, students, entrepreneurs, and the general public. Some research findings were brought to classroom teaching. Graduate and undergraduate students were involved in the research projects.

Missouri

Utilization of co-culture of filter-feeder organisms such as tilapia and brine shrimp to harvest, concentrate, and convert algal and bacterial solids into concentrated sludge or animal biomass offers potential to provide value-added products from integrated aquaculture operations in a more environmentally friendly practice.

Nebraska

Bioproducts researchers and industry

New Jersey

Academia Practitioners, Industry, General public

New York

Producers, advisors and researchers interested in low-input, highly productive perennial grass biomass feedstock plants that tolerate marginal soils.

North Dakota

Agricultural producers, biofuel and biomass processors, biofuel investors, other researchers, university students

Ohio

The target audiences for this reporting period were scientists, engineers, and representatives from academia, industries and agricultural commodity groups attending professional scientific conferences, meetings, and workshops.

Oklahoma

Scientists, engineers, graduate students, postdoctoral fellows, product developers, and the public.

Pennsylvania

The target audiences for this research include a) the science and engineering research community, b)

biomass processing companies ranging from small start-ups to large multi-national companies, c) policy analysts and decision makers, and d) potential biomass producers and the general public. Stakeholders include state and national organizations, state and federal agencies, companies and industry consultants. There is also strong public interest in understanding the environmental impacts of the biomass production and processing technologies as well as comparisons to conventional petroleum-derived products. These various stakeholders are being engaged through ongoing extension education programming that includes public presentations, short courses, websites (www.bioenergy.psu.edu, eXtension, and NEWBio.psu.edu), scientific journal articles and extension publications. The project results will be benefit biomass producers, the bioprocessing/fermentation industry and the rural public in general as a result of production of value-added products and bioenergy from raw agricultural products or by-products.

South Dakota

The target audience include: 1). Undergraduate and graduate students: Undergraduate students are targeted through lab classes and/or summer internship programs. The research program will help them prepare for graduate school or a career in biomass production or processing. Graduate students are targeted by directly participating in research activities for their thesis/dissertations. These students will get professional training to prepare them for their careers, in not only in academia, but also agriculture, food, energy, and biorefinery industries. 2). Farmers and biomass producers: This audience is targeted because biomass feedstocks will be supplied by farmers. They are targeted through formal and informal classroom instruction (many undergraduate students will choose agriculture, food, energy, and biomass production as an occupation) and extension/outreach activities. 3). Public and customers: This audience is targeted because the biomass-derived materials and products developed from the research will ultimately be used by public and customers. The customer's needs, likes, and acceptance should be considered in the research. This audience is targeted through publications of research results, conferences or workshops, website, and extension/outreach activities.

Tennessee

Academia, universities, some related industries Vegetable and specialty crop growers, agricultural plastic manufacturers, scientific community Biomass producers, Production Consultants, logistics managers, conversion managers

Texas

Academic Research Personnel, Practicing Engineers, Extension personnel, Ranchers and Agriculturists, Students and Teachers, Private Investors

Washington

This research-based experiential learning and teaching can help our society to foster future leaders in industry, academia and government in developing sustainable clean technology to produce bioenergy and bioproducts for demands vital to our future. The problems associated with the bioprocessing of biomass to fuels and chemicals are among the most interdisciplinary areas and are true blend of science, technology, engineering and mathematics (STEM).The proposed education program will provide a rich environment to teach K-12, undergraduate and graduate students a general strategy to define and solve open-ended problems that should be valuable to them in dealing with complex real problems as well as develop students' multidisciplinary team working skills. Throughout the project, data relevant to the above hypothesis will be collected through student surveys, science project products, and interviews in order to establish the progress of teaching modules' success at improving the engagement of student participants in STEM learning and their attitudes towards science and STEM careers as well as their working skills. In addition, our studies will be guided by our industrial partners and government agencies to provide valuable data and facilitate near term commercial use. The

postdoctoral and graduate student researchers supported by the project were involved in all aspects of the proposed studies, and had cross-training opportunities in multi-disciplinary research area as different subfields, including lignin chemistry, catalytic chemistry, biomass pretreatment, synthetic chemistry and biology, and chemical process design. They took the lead on experimental design, setup, and data analysis.

Wisconsin
Researchers (industrial and academic) working in the bio-economy to sustainable produce products and energy from biomass resources.

Related Publications

Alabama

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Wang, Q., B.T. Higgins. 2020. Life Cycle Assessment of Microalgal Production from High Strength Anaerobic Digestate Effluent. Presented at the Annual International Meeting of American Society of Agricultural and Biological Engineers. July 12-15, Virtual forum.

Kalvakaalva, R., B.T. Higgins, D. Blersch, D. Wells, T. Hanson, M. Smith. Life Cycle Assessment and Mass Balance Nutrient Modeling of a Pilot Scale Aquaponics System at Auburn University. ACLCA Conference. September 22-24, Virtual forum.

J. Zhang, J. Feng, P. Wang, Y. Wang. Genome engineering tools development and metabolic engineering of solventogenic clostridia for biofuel and biochemical production. 2021 Institute of Biological Engineering (IBE) Annual Conference (Virtual). April 9-10, 2021.

Y. Wang. Towards energy, environment and health nexus: understanding and manipulating biosystems using metabolic engineering and synthetic biology approaches. International Symposium on Microbiology: One Health 2021 (Virtual). May 12-14, 2021. (Invited talk)

J. Feng, J. Zhang, M. Cao, Z. Shao, I. Borovok, Y. Wang. Rational engineering of Clostridium for

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Y. Wang, J. Feng, S. Guo, M. Haefner, J. Zhang, Y. Wang, C.T. Avedisian. Combustion of butyl acetate as an alternative additive to petroleum fuels. 36th Annual Meeting, American Society of Gravitational and Space Research. Virtual Forum, November 5-6, 2020.

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Adjuik, T. A., Nokes, S. E., Montross, M. D., & Wendroth, O. (2021). Lignin-based Hydrogel for Water Retention in Silt Loam Soil. In 2021 ASABE Annual International Virtual Meeting (p. 1). American Society of Agricultural and Biological Engineers.

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Massachusetts

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Minnesota

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Salzer, M., and Nahar, N. 2021. High Solids Pretreatment and Enzymatic Hydrolysis of Pelleted Corn Stover with Improved Sugar Yields. ASABE Annual International Meeting, Virtual Conference, July 12-16.

Salzer, M., and Nahar, N. 2021. Investigating High-Solid Pretreatment and Enzymatic Hydrolysis Strategies using Corn Stover to Reduce Biorefinery Costs. 3rd Annual Gamma Sigma Delta Symposium. April 22.

Subhashree, S. N., Igathinathane, C., Liebig, M., Halvorson, J., Archer, D., Hendrickson, J., and Kronberg, S. 2020. Energy consumption of tractors and automatic bale pickers for biomass bales infield aggregation. ASABE Paper No. 2000449. ASABE 2020 Annual International Meeting, July 13–15, 2020, Virtual & On Demand.

Subhashree, S. N., Igathinathane, C., Hendrickson, J., and Archer, D. 2020. A review on drought-based decision tools applicable to forage production and management. ASABE Paper No. 2000560. ASABE 2020 Annual International Meeting, July 13–15, 2020, Virtual & On Demand.

Subhashree, S. N., Igathinathane, C., Hendrickson, J., Archer, D., Liebig, M., Halvorson, J., Kronberg, S., Toledo. D. 2020. Webtool demonstration – Forage Economics Calculator. North Dakota Stockmen's Association Annual Board of Directors Meeting. December 2, 2020.

Wilson, P., Sarker, N.C., and Monono, E. 2021. Optimizing Hempseed Oil Degumming and Bleaching Processes. ASABE Annual International Meeting, Virtual July 12-16, 2021.

Ohio

A. Shah. 2021. A novel whole-plant logistics system for biobased industry. ASABE Annual International Meeting 2021, July 12-16, Virtual.

A. Khanal, A. Shah. 2021. Evaluating storage characteristics of whole-plant corn for biobased industries. ASABE Annual International Meeting 2021, July 12-16, Virtual.

A. Khanal, A. Shah. 2021. Techno-economic analysis of hemp production and logistics in the U.S. ASABE Annual International Meeting 2021, July 12-16, Virtual.

H. Stockham, A. Khanal, A. Shah. 2021. Physico-thermal properties of co-pelletization of agricultural and municipal wastes. ASABE Annual International Meeting 2021, July 12-16. Virtual.

H. Stockham, A. Khanal, A. Shah. 2021. Techno-economic evaluation of alternative fuel use analysis of co-pelletization of agricultural residue and plastic waste for cement production. ASABE Annual International Meeting 2021, July 12-16. Virtual. Objective B:

J. Vasco-Correa, L. Huezo, A. Shah. 2021. Hybrid biorefinery integrating anaerobic digestion and hydrothermal carbonization. International Conference for Bioresource Technology for Bioenergy, Bioproducts & Environmental Sustainability (BIORESTEC). May 17-19, virtual.

S. Sivaprasad, A. Manandhar, A. Shah. 2021. Fixed-bed continuous remediation of methylene blue dye using hydrochar derived from sewage sludge digestate. The CFAES Annual Research Conference 2021. The Ohio State University. April 5-7, virtual. [Poster]

A. Khanal, A. Shah. 2021. Techno-economic comparison of hemp production and processing for grain, Cannabidiol (CBD) and fiber. The CFAES Annual Research Conference 2021. The Ohio State University. April 5-7, virtual. [Poster]

S. Sivaprasad, A. Manandhar, A. Shah. 2020. Adsorptive removal of dyes using char derived from anaerobic digestate. The CFAES Annual Research Conference 2020. The Ohio State University. April 24,

virtual. [Poster]

A. Khanal, A. Shah. 2020. Techno economic analysis of biobased novolac resin production. The CFAES Annual Research Conference 2020. The Ohio State University. April 24, virtual.

L. Huezo, A. Shah. 2020. Techno-economic analysis of a combined anaerobic digestion and hydrothermal carbonization system. The CFAES Annual Research Conference 2020. The Ohio State University. April 24, virtual.

A. Khanal, A. Manandhar, S. Adhikari, A. Shah. 2020. Techno economic analysis of biobased novolac resin production. Hayes Graduate Research Forum, February 28. The Ohio State University, Columbus, OH.

S.H. Mousavi-Avval, A. Shah. 2020. Techno-economics and life cycle environmental impacts of renewable jet fuel production from pennycress. Hayes Graduate Research Forum, February 28. The Ohio State University, Columbus, OH.

Pennsylvania

Liu, J. 2021. Opportunities and Challenges in Developing an Industrial hemp based Products System. University and Industry Consortium (UIC) Spring Meeting, June 22-24, 2021, Fort Collins, CO (Invited panel speaker; postponed from 2020 Spring due to COVID-19).

Jones, S., J. Reisterer, A. Demirci, D.E. Oruc. 2020. Utilization of wastes of wine industry for the production of human lysozyme by fed-batch fermentation. 42nd Symposium on Biomaterials, Fuels and Chemicals. Abstract # 41685.

Iram, A., D. Cekmecelioglu, and A. Demirci. 2020. Optimization of nitrogen sources to produce cellulase and xylanase enzymes in Distillers' Dried Grains with Solubles-based medium. Northeast Agricultural and Biological Engineering Conference (Virtual).

Iram, A., D. Cekmecelioglu, and A. Demirci. 2020. Salt and Nitrogen amendment for the cellulase and xylanase production using Distillers' Dried Grains with Solubles-based medium as the Feedstock. Northeast Agricultural and Biological Engineering Conference (Virtual)

Cassar, J., Bright, L., Patterson, P., Mills, M., Demirci, A. 2020. Pulsed ultraviolet light processing for microbial reduction of table and fertile shell eggs. Northeast Agricultural and Biological Engineering Conference (Virtual).

Cassar, J, M. Mills, and A. Demirci. 2020. Comparison of static and conveyer pulsed ultraviolet light systems for microbial reduction on chicken thighs. Northeast Agricultural and Biological Engineering Conference (Virtual).

Hu, H., J. Catchmark, and A. Demirci. 2020. Study of pullulan additives and a novel co-culturing fermentation for bacterial cellulose nanocomposite production. Northeast Agricultural and Biological Engineering Conference (Virtual).

Iram, A., D. Cekmecelioglu, and A. Demirci. 2020. Enhanced production of cellulase and hemicellulase in DDGS-based media by optimizing nitrogen source and salts. Future of Bioenergy and Biorenewables Workshop. Penn State Center for Biorenewables and Penn State Extension. Penn State University. (Virtual).

Demirci, A. 2020. Enhanced production of cellulase and hemicellulase in DDGS-based media by optimizing nitrogen source and salts. Future of Bioenergy and Biorenewables Workshop. Penn State Center for Biorenewables and Penn State Extension. Penn State University. (Virtual).

Iram, A., A. Demirci, and D. Cekmecelioglu. 2021. Biofilm Bioreactors: a novel strategy for current microbial MK-7 fermentation production. Virtual ASABE Annual Meeting.

Berenjian, A., A. Demirci, and E. Mahdinia. 2021. Optimization of growth parameters and media for vitamin K (MK-7) production by Bacillus subtilis. Virtual ASABE Annual Meeting.

Babusci, J., and Chmely, S. 2021. Catalytic Transfer Hydrogenolysis for Sustainable Transformations of Lignin. Annual Spring Meeting of the American Chemical Society, American Chemical Society, Online and Virtual.

Moose, N., Arya, A., and Chmely, S. 2021. 3D Printing Stronger and Tougher Objects with Lignin-containing Resins for Stereolithography. Gamma Sigma Delta Annual Research Expo, Penn State Gamma Sigma Delta, Penn State University, University Park, PA.

Wu, Y., Gonzalez, C., Chmely, S., Vasco-Correa, J. 2021. A systematic analysis and comparison of lignin valorization approaches using superstructure optimization. ASABE Annual International Meeting. Virtual, July 11-14. Oral Presentation.

Wu, Y., Gonzalez, C., Chmely, S., Vasco-Correa, J. 2021. Superstructure optimization as a system approach to identifying optimized pathways for lignin valorization. ACS Annual Green Chemistry & Engineering Conference. Virtual, June 14-18. Poster.

Vasco-Correa, J., Huezo, L., & Shah, A. 2021. Hybrid biorefinery integrating anaerobic digestion and hydrothermal carbonization. International Conference for Bioresource Technology for Bioenergy, Bioproducts & Environmental Sustainability (BIORESTEC). Virtual, May 17-19. Oral presentation.

Wu, Y., Gonzalez, C., Chmely, S., Vasco-Correa, J. 2021. Trends in Lignin Valorization Approaches Using Superstructure Optimization. International Conference for Bioresource Technology for Bioenergy, Bioproducts & Environmental Sustainability (BIORESTEC). Virtual, May 17-19. Poster.

Peacock, H. V., Vasco-Correa, J. 2021. Life-cycle assessment of integrated anaerobic digestion with hydrothermal carbonization. Penn State Undergraduate Research Expo. University Park, PA, April 14-16. Poster.

Vasco-Correa, J., Huezo, L., & Shah, A. 2021. Integrating anaerobic digestion and hydrothermal carbonization for the development of a hybrid biorefinery. IBE Annual Conference. Virtual, April 9-10. Oral presentation.

Peacock, H. V., Vasco-Correa, J. 2021. Life-cycle assessment of integrated anaerobic digestion with hydrothermal carbonization. Gamma Sigma Delta Research Expo, University Park, PA, March 23. Poster.

Costello, C. 2021. Life Cycle Assessment: Past, Present and Future. Millennium Café. Materials Research Institute. Penn State. Penn State University, University Park, PA.

Costello, C. Life Cycle Analysis in the Bioeconomy. 2021. The Future of Bioenergy and Biorenewables. Penn State University, University Park, PA.

Chowdhurry, Z.U. Md., Algren, M., J.S. Richter, A.E. Landis, and C. Costello. 2021. Estimating nitrogen and phosphorous flows embodied in manufactured foods and per capita nutrient footprints in the United States. International Symposium on Sustainable Systems and Technologies (ISSST).

Algren, M., T.T. Burke, Z.U. Md Chowdhurry, C. Costello, and A.E. Landis. 2021. Assessing the potential of phosphorous loss mitigation strategies to eliminate both net anthropogenic phosphorous inputs and mineral P demand in the United States. International Symposium on Sustainable Systems and Technologies (ISSST).

South Dakota

Lin Wei*, Yajun Wu, Zhisheng Cen, Emmanuel Arkon-Mensah, Surbhi Gupta. 2021. Applications of different control release fertilizers in corn greenhouse trials, Paper #: 2100091. ASABE Annual International Meeting, online virtual conference on July 12-16, 2021.

Robiul I. Rubel, Lin Wei*, 2021. Improve biochar-based control release fertilizer's performance by coating multiple layers of polylactic acid, Paper #: 2100092. ASABE Annual International Meeting, online virtual conference on July 12-16, 2021

Lin Wei*, Robiul I. Rubel, Kasiviswanathan Muthukumarappan. 2021.Plasma-enchance chemical deposition system for future graphene deposition. Paper #: 2100095. ASABE Annual International Meeting, online virtual conference on July 12-16, 2021

Nadee Kaluwahandi, Lin Wei, Kasiviswanathan Muthukumarappan*, 2021. Inactivation of E. coli and quality change in beef using cold plasma. Paper #: 2100867. ASABE Annual International Meeting, online virtual conference on July 12-16, 2021.

Nadee Kaluwahandi, Kasiviswanathan Muthukumarappan, Lin Wei*, 2021. Effect of cold plasma on inactivation of E. coli, Salmonella cerro, Salmonella, and Enterotoxigenic E. coli, and quality change in beef. IFT 2021 annual meeting, online virtual conference on July 19 – 23, 2021.

Nadee Kaluwahandi, Kasiviswanathan Muthukumarappan, Lin Wei*, 2021. Effect of cold plasma on inactivation of E. coli and quality change in beef. IFT and Honor Society of Phi Tau Sigma, University of Minnesota Chapter, Speedy Science™ 2021, online virtual conference on March 26, 2021.

Tennessee

Mi Li . Invited talk: Insight of biomass recalcitrance reduction and lignin valorization. Oregon State University, Oct. 2020, Virtual.

Mi Li. Invited talk: Structural variation in biomass: recent advances and their significance to reduced biomass recalcitrance and lignin valorization. Auburn University, Oct. 2020, Virtual.

Mi Li. Invited talk: Synthesis and characterization of lignin-grafted-poly(ε-caprolactone) from different biomass sources. International Congress on Sustainability Science & Engineering (ICOSSE '20), Aug 3-5, 2020, AIChE Virtual.

D.G. Hayes [invited presenter], Biobased Surfactants: Overview and Recent Trends, Future of Surfactants Conference, Boston, 23-24 September 2021 (moved from 2020 due to the pandemic)

AB Gilmore [poster presenter], AF Astner, DG Hayes, SM Schaeffer, Characterizing Biodegradable Plastic Mulch Fragment Distribution through the Soil Profile in an East Tennessee, Agroecosystem, Soil Science Society of America Virtual Conference, November, 2020.

Y Yu [poster presenter], M Flury, DG Hayes, AF Astner, Transport of Biodegradable Plastic Mulch in Unsaturated Porous Media, Soil Science Society of America Virtual Conference, November, 2020.

Y Yu [presenter], HY Sintim, DG Hayes, AF Astner, M Flury, Release of TiO2 Nanoparticles and Mulch Fragments from Biodegradable Plastic Mulch during Degradation, Soil Science Society of America Virtual Conference, November, 2020.

D.G. Hayes (invited), Expanding Opportunities for Oil Palm as a Feedstock for Biobased Surfactants, Future-Proofed Palm Oil Conference (virtual), 16 Dec 2020

Madrid, B. (speaker), S. Wortman, D.G. Hayes, J.M. DeBruyn, C. Miles, M. Flury, T.L. Marsh, S.P. Galinato, K. Englund, S. Agehara and L.W. DeVetter. 2021. End-of-Life Management Options for Agricultural Mulch Films in the United States. Poster presentation. American Society for Horticultural Science (ASHS) Annual Conference. Aug. 5- Aug. 9. Denver, CO.

A.F. Astner (speaker), D.G. Hayes, H.M. O'Neill, B.R. Evans, S.V. Pingali, V.S. Urban, T.M. Young, Mechanical formation of biodegradable micro- and nano-plastics used for environmental studies in agricultural ecosystems, Salzburg Conference for Smart Materials, 16-17 September 2021 Kuchl, Austria

A.F. Astner (speaker), D.G. Hayes, H.M. O'Neill, B.R. Evans, S.V. Pingali, V.S. Urban, K. C. Littrell,

Impact of convective transport on the agglomeration and dispersion of biodegradable nanoplastics in sediments measured via small-angle neutron scattering (SANS) and ultra-SANS (USANS), Salzburg Conference for Smart Materials, 16-17 September 2021 Kuchl, Austria

Texas

Beeravalli, Vijayalaxmi, Nanjappa Ashwath, Sergio Capareda, Mohammad Rasul, Masud Khan and Basavaraj Patil. 2021. Ranking the Feedstocks Using Neural Network-Bases System for Biofuel Production. 2021 6th International Conference for Convergence in Technology (12CT), Pune, India, April 02-04, 2021. 978-1-7281-8876-8/21/$31.00 © 2021 IEEE: DOI:10.1109/12CT51068.2021.9418218.

Washington

Zhangyang Xu, Joshua Heyne, Mark Feng, David Daggett, Karl Seck, and Bin Yang. "Minimization of Jet Fuel Emissions via Optimization of J-A1 Fuel with The Lignin Based Jet Fuel Compositions and Processing", 2021 JCATI Symposium, Seattle, WA, April 12, 2021.

Xiaolu Li, Weijun Qian, Yuanqiao Pu, Bin Yang* "Persulfide and Polysulfide-Induced Posttranslational Protein Modifications in Oleaginous", AIChE annual virtual meeting, Nov. 18th, 2020.

Fritia, Jiang Liu, Bin Yang* "Effects of Biomass Ash and Ash-Forming Elements on Biomass Pretreatment and Enzymatic Hydrolysis", AIChE annual virtual meeting, Nov. 17th, 2020.

Zhangyang Xu, Chunmei Pan, Xiaolu Li, Naijia Hao, Arthur J. Ragauskas, Yuanqiao Pu, Bin Yang* "Enhancement of Polyhydroxyalkanoate Production by Co-feeding Lignin Derivatives with Glycerol in Pseudomonas Putida KT2440", AIChE annual virtual meeting, Nov. 18th, 2020.

Bin Yang. "Lignin-Based Drop-in Jet Fuel Hydrocarbons". Thermal and Catalytic Sciences Symposium, October 5th, 2020, Richland, WA

Fnu Fitria, Jian Liu, Praveen K. Thallapally, , Jay Grate, B. Peter McGrail, and Bin Yang. "Surface Acoustic Wave Sensor for Refrigerant R32 Leak Detection". Virtual Summer Symposium at PNNL, August 20th, 2020.

Xiaolu Li, Tong Zhang, Matthew J. Gaffrey, Ronald J. Moore, Bin Yang, Wei-Jun Qian. "Direct detection of protein polysulfidation in macrophages under endoplasmic reticulum stress conditions". Virtual Summer Symposium at PNNL, August 20th, 2020.

Zhangyang Xu, Leah Stevenson, Bin Yang, J. Timothy Bays, John R. Cort. "Functional Group Characterization and Carbon-Type Analysis of Fossil- and Biomass-Derived Hydrocarbon Fuels via Heteronuclear Two-Dimensional NMR Spectroscopy with a Hydrocarbon Chemical Shift Database". Virtual Summer Symposium at PNNL, August 20th, 2020.

Wisconsin

Zheng Li, Xiao Zhang and Xuejun Pan. Demethylation of lignin in inorganic ionic liquid. 2020 AIChE Annual Meeting, November 15-20, 2020.

Tao Wu, Ning Li, Xuejun Pan, and Sheng-Li Chen. Homogenous hydrolysis of cellulose catalyzed by solid acid in inorganic ionic liquid. 2020 AIChE Annual Meeting, November 15-20, 2020.

Kamalakanta Sahoo, Matthew J. Dunlop, Richard Bergman, Bishnu Acharya, Troy Runge. Lifecycle assessment of wood-based and tunicate-based nanocellulose; ACLCA 2020, Madison, WI, US (September 22, 2020)

Theses and Dissertations

Alabama

Rohit Kalvakaalva, MS thesis, 12/2020. "Process Modeling and Life Cycle Assessment of a Large Pilot-

Scale Aquaponics Facility at Auburn University."

Peyton Goodling, MS thesis, 7/2021. "Development of a predictive model for taste and odor episodes in regional drinking water reservoirs."

Morgan Thomas, MS thesis, 7/2021. "Spatial and temporal investigation of taste and odor-producing microorganisms in Lake Saugahatchee."

California

Barzee, T. 2021. Processing and Utilization of Anaerobic Digestate as Biofertilizer for Production of Crops and Microalgae. PhD Dissertation. University of California, Davis

Poltorak A, 2021 Conversion of lactose to lactobionic acid using the engineered Neurospora crassa strain MS Thesis. University of California, Davis

Kentucky

Kalinoski, Ryan, "CHARACTERIZING AND PREDICTING THE ANTIMICROBIAL PROPERTIES OF LIGNIN DERIVATIVES" (2020). Theses and Dissertations--Biosystems and Agricultural Engineering. 76. https://uknowledge.uky.edu/bae_etds/76

Lopez, Gary, "Densification of hemp floral material and its effect on retention of cannabinoids", MS Thesis, in progress

Vin-Nnajiofor, Makua, "CHARACTERIZATION AND UPGRADE OF ENDOCARP BIOMASS DERIVED LIGNIN TO VALUE ADDED PRODUCTS" (2021), Theses and Dissertations--Biosystems and Agricultural Engineering. 79. https://uknowledge.uky.edu/bae_etds/79

Michigan

Das, Sabyasachi. Ph.D. dissertation. "Investigation into the electrocatalytic hydrogenation of pyrolysis bio-oil : economic, life cycle and kinetic analysis." 2020.

Minnesota

Renchuan Zhang, Ph.D. Bioproducts and Biosystems Engineering, January, 2021. Thesis: An innovative thermal-vacuum stripping assisted thermophilic anaerobic digestion process and system for complete utilization of liquid swine manure.

Nan Zhou, Ph.D. Bioproducts and Biosystems Engineering, April, 2021. Thesis: Catalytic microwave-assisted pyrolysis for energy production from biomass and plastic wastes.

Nebraska

Liu, E. 2020. Microbial production of lignin-degrading enzymes from genetically engineered Aspergillus nidulans and enzymatic depolymerization of lignin. Ph.D. Dissertation. Lincoln, NE: University of Nebraska. 177 p.

North Dakota

Hammed, A. 2021. Process development for effective, recoverable and reusable magnetic nanobiocatalysts for biomass hydrolysis. Doctoral Dissertation. North Dakota State University.

Regmi, S. 2021. Manufacturing low-density particleboards from wheat Straw and distiller's dried grains with solubles. Master's thesis. North Dakota State University.

Huda, S. 2020. Increased oil recovery from distillers dried grains with solubles and whole stillage. Master's thesis. North Dakota State University.

Ohio

Seyed Hashem Mousavi Avval. 2020. Techno-Economic, Energy and Environmental Life Cycle Analyses of Renewable Jet Fuel Production from Pennycress. Ph.D. The Ohio State University.

Luis Huezo Sanchez. 2020. Technical, economic, and carbon dioxide emission analyses of managing anaerobically digested sewage sludge through hydrothermal carbonization. Ph.D. The Ohio State University.

Natalia Zappernick. 2020. Techno-economic analysis of a Tilapia-Lettuce aquaponics system. M.S. The Ohio State University.

Shyam Sivaprasad. 2021. Remediation of methylene blue dye using hydrochar derived from anaerobically digested effluent of sewage sludge. M.S. The Ohio State University.

Pennsylvania

Grace E. Vezeau. 2021. Automated Design of Genetically Encoded Biosensors. Ph.D. Dissertation. Pennsylvania State University, University Park, PA.

May, D Cotreatment Enhanced Anaerobic Digestion of Lignocellulosic Biomass. M.S. Thesis. Pennsylvania State University, University Park, PA.

South Dakota

Zhisheng Cen, M.S. thesis titled: Develop bio-based control release fertilizers.

Washington

Xiaolu Li. 2021. “Fundamentals of Bioconversion of Biorefinery Wastes to Lipids by Rhodococcus Strains” PhD Thesis, Washington State University, Richland, Washington, May.

Wisconsin

A Mandalika, Enabling Biorefineries Through Biomass Component Valorization Ph.D. 2020 University of Wisconsin--Madison

D. Ho, Application of White-Rot Fugus on Dairy Manure to Improve Biogas Yield M.S. 2021 University of Wisconsin--Madison

Synergistic activities

Alabama

1) Dr. Yi Wang collaborates with the Virginia station; we work together to obtain a DOE grant and submit several other grant applications. Wang also provided the engineered strains for their project for the PI at the Virginia station. 2) Investigators serve on the review panel for several grant agencies in United States.

California

Collaboration was carried out with the researchers from Kansas State University and University of Maryland.

Hawaii

Su lab is actively collaborating with Professor Yinjie Tang at the Washington University in St. Louis in the State of Missouri, on the development of yeast-based biorefinery for converting lipid feedstock to high-value oleochemicals. Additional collaborations involved collaborators from the State of Hawaii, including Mr. Ryan Kurasaki (bioprocess control), Professor Koon-Hui Wang and Professor Tao Yan (papaya seed based biofumigant). There is also an international collaboration with Prof. Jeong-Woo Choi at the Sogang University in Korea on nanobiotechnology research. Khanal’s lab is actively collaborating

with the following national and international collaborators: *Prof. Karthik Chandran, Columbia University: Nitrogen Transformations in Aquaponic *Prof. Lutgarde M. Raskin, University of Michigan: Microbial Community Analysis in AD System Digesting Cellulosic Biomass *Prof. Ganti S. Murthy, Oregon State University: Techno-economic Analysis of Bioenergy System *Dr. Kaushlendra Singh, Western Virginia University: Biochar Applications for Sustainable Agriculture *Dr. Deb Jaisi, Delaware University: Chemical Characterization of Biochars for Sulfide Removal from Biogas *Prof. Sushil Adhikari, Auburn University: Integrated Anaerobic Biorefinery and Thermochemical Conversion *Prof. Jeffrey Tomberlin, Texas A& M University: Black Soldier Flies (BSF) for Organic Waste Valorization.

Kentucky

UK researchers have worked with researchers at 12 states including Kansas, Louisiana, Ohio, Virginia, Vermont, Florida, Idaho, North Carolina, Nebraska, Michigan, Mississippi, Tennessee on joint proposals and publications

Massachusetts

USDA Forest Products Laboratory. Oak Ridge National Laboratory. Virginia Polytechnic Institute and State University.

Minnesota

We collaborated with investigators at South Dakota State University, Washington State University, Mississippi State University, Stanford University, Berkeley Lab — Lawrence Berkeley National Laboratory, and Resynergi Inc. in research and grant writing activities. We established external partnerships with agencies and companies including Minnesota Metropolitan Council Environment Services, Holistic Health Farms, Forsman Farms, and Minesga.

Missouri

Cooperative Research with Mississippi State University and National Warm-water Aquaculture Center at Stoneville Mississippi to develop water quality sensing systems to improve zero discharge aquaculture production

New Jersey

NC1034

Ohio

Collaborated with the researchers from numerous institutions for proposals and papers related to all three S1075 objectives.

Pennsylvania

Co-PI serves as Deputy Technical Director of the DOE's National Risk Assessment Partnership for geologic carbon storage (consortium of five DOE National Labs (2011-present) as well as serves as co-chair of the National Council for Science and the Environment's Energy Education Community of Practice (2017-present). A major agricultural equipment company CNH provided field harvesting equipment and operator team for the field studies. In addition, Idaho National Lab provided field supplies and analyzed field crop samples. Co-PI (Dr. Costello) co-chaired three sessions of the International Symposium on Sustainable Technologies, June 2021. These sessions included curated presentations about methods and case studies of sustainability assessment of systems, e.g., life cycle assessment focused on waste management, bioprocesses, and nutrient cycling from leading research universities and federal research laboratories. Co-PI (Dr. Chemely) has been working with investigators at the University of Tennessee Institute of Agriculture (UTIA) and the University of Tennessee College of Veterinary Medicine (UTCVM).

Tennessee

Collaboration with Oak Ridge National Laboratory Collaboration with Kansas State University Collaboration with Auburn University Collaboration with Nanjing Forestry University (China)

Texas

1. Working with POET on the design and construction of a 1 MGY biorefinery 2. Working with Iogen on Net Zero Carbon Economy 3. Working with Genencor and Dupont on development of lignocellulosic enzymes for bioethanol production