

Advancing Bio-Based Chemicals and Next-Generation Fuels from Montana's Agricultural Crops

Third Quarterly Report

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Montana State University-Northern

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Introduction

With the steady decline of manufacturing employment in Montana and as the search for alternative energy sources continues, industrial oilseed crops pose a unique opportunity in addressing these issues. This collaborative research effort between Advanced Fuels Center, Montana State University Northern (AFC-MSUN) and Montana State University Billings (MSUB) aims at establishing and maintaining a biorefinery utilizing Montana-grown industrial oilseed crops. If a local facility can process industrial oilseeds, such as camelina and carinata, and is able to pay producers a competitive price, there is potential for an oilseed-based biorefinery that will boost Montana’s manufacturing employment and will meet industries’ greener portfolio. The establishment of this biorefinery will provide sustainable growth in Montana’s agriculture and manufacturing industry in two ways: [a] the research is expected to generate numerous Montana jobs and will allow the investment to be leveraged by attracting businesses and [b] the research can address the federal government’s thrust of utilizing alternative energy sources to achieve a cleaner environment. This report covers all activities performed from March 1, 2016 to May 31, 2016.

Personnel Recruitment and Employment

Montana State University Northern

Five undergraduate research assistants were hired to assist the leads with their respective tasks. An Energy Corps through the AmeriCorps Program was appointed to help the leads in the catalyst research, outreach, and education. During this reporting period, the Director of AFC-MSUN took another position. The following are brief biographies for all AFC-MSUN researchers and staff supporting the project activities.

<p><i>Randy L. Maglinao, PhD</i> <i>Lead Principal Investigator</i> Dr. Randy Maglinao earned his degree of Doctor of Philosophy in Biological and Agricultural Engineering at University of Idaho in 2011. His research interests are converting industrial oilseed crops and glycerol to value-added chemicals and next-generation fuels, scaling chemical processes to pilot-scale production, and heavy-duty engine emissions and performance of different fuels and additives.</p>	
<p><i>Eleazer P. Resurreccion, PhD</i> <i>Principal Investigator</i> Dr. Eleazer Resurreccion obtained his Doctor of Philosophy degree in Civil Engineering from University of Virginia in 2013. His interest is on the area of renewable energy and environmental sustainability, particularly in the nexus of energy-water systems. He utilizes an interdisciplinary systems approach that combines novel technology, environmental restoration, and economics to address challenges pertinent to these systems in an innovative manner. The application of these areas in industrial ecology allows him: (1) to perform both lab-scale investigations and multi-scale modeling of environmentally-conscious processes and (2) to implement environmental-economic modeling for policy analyses.</p>	

Joynal Abedin, PhD

Principal Investigator

Abedin obtained his PhD in synthetic/organometallic chemistry from University of Montana, Missoula under the supervision of Professor Edward Rosenberg in 2002. His research areas are on heterogeneous Grubbs catalyst and bio-based polymers.



Alexandra Jones

Energy Corps | Chemist

Alexandra Jones graduated from Washington and Lee University in May of 2015 with a Bachelor of Science in Chemistry. She began her work at the Center in August of 2015 as a Montana State Energy Corps Service Member. She contributes to research in catalyst development as well as much of the science, technology, education, and mathematics (STEM) outreach activities. Alexandra believes in equal education opportunities for all students and in the critical nature of teaching STEM skills.



Keith Richardson

Performance Engineer

Keith Richardson has over 40-years of experience in automotive, aircraft, motorcycle, agriculture, construction and mining equipment repair maintenance and design. Keith designed, and then supervised the building and assembling of those tractors engineer for Big Bud Tractors starting in 1975. Keith has extensive experience in designing tractors, prototype power trains, hydraulic systems, and electrical systems. He also designed earth moving scrapers as well as several other equipment needs for railroads.



Brody Dahlman

Senior Ag Operations Technology Student

Brody Dahlman was born and raised southeast of Dutton Montana on his family farm and ranch. He graduated from Dutton/Brady High School in 2013 as class salutatorian. He is attending Montana State University Northern pursuing a bachelor's degree in Agriculture Operations Technology with a minor in Farm Mechanics. Brody plans on graduating in 2017 from MSUN and returning to the family farm and ranch to continue the family tradition as he is a 5th generation Dahlman and has already begun to build his own cattle herd.



Chazley Hulett

Senior Biology Student

Chazley Hulett was born and raised in Havre, Montana. He graduated from Havre High school in 2011 and started attending MSUN in 2014 where he is currently studying Biology. After graduation Chazley plans to pursue higher education in healthcare professions.



Drew Randall

3rd Year Biology Student

Drew Randall was raised in Lewiston, Idaho. A passionate wrestler, Drew is studying biology in hopes of becoming a physician's assistant. He is entering his third year and will resume wrestling after a yearlong break due to a sports-related injury.



Lane Urick

Senior Civil Engineering Technology Student

Lane Urick attended high school in Great Falls, Montana. He is currently entering his senior year at MSU Northern as a Civil Engineering Technology major. He plays football for the Northern Lights and hopes to join the military as an engineering technician.



Montana State University Billings

Seven undergraduate research assistants were recruited to assist with MSUB activities. Two students will be working for credit as part of course PPT 292 - Independent Studies Bio-Based Chemicals and Fuels. Five other students will be working part-time for pay within the scope of the grant. Students earning credit are not paid. Brief bios for all MSUB researchers supporting the project follow.

Andrew D. Sullivan

Principal Investigator / MSUB Team Leader

Andy is the Process Plant Technology Instructor at City College. He holds a B.S. in Chemical Engineering from MIT, and has 20 years of operations and technical experience in refining at ExxonMobil. His research interests focus on process operations excellence, operator training, and renewable fuels process design and optimization.



Cody Dayley

2nd Year Process Plant Technology Student

Cody is the 2016 Student Employee of the Year for his service as the Process Plant Laboratory Technician, a position he has held since fall 2015 under the Federal Work Study program. He has an entrepreneurial spirit and brings a high level of enthusiasm and skill to everything he does. He has interest in starting a biofuels business and in developing advanced training tools for processing industries.



Adam Goodburn

2nd Year Process Plant Technology Student

Adam plans on pursuing an Engineering Degree after completing his AAS in Process Plant Technology. He works as a machinist and brings a high level of knowledge and practical skills to his work at City College. He has interest in advanced process control and was selected to present his work on a self-balancing robotic platform at the 2016 Research and Creativity Conference at MSUB.



Garth Webster

2nd Year Process Plant Technology Student

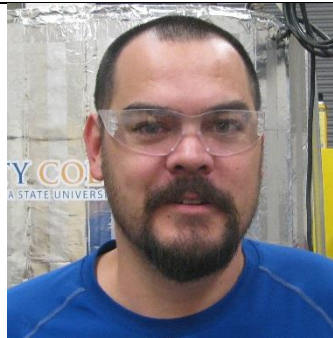
Garth plans to work in the refining sector when he graduates with an AAS in Process Plant Technology. He brings a background in agriculture that benefits his research at City College.



Paul Bledsoe

1st Year Process Plant Technology Student

Paul is serving as a Process Plant Laboratory Technician under the Federal Work Study program. He has worked in hard rock mining and brings considerable computer experience to his work at City College. He has interest in renewable fuels, and is designing and retrofitting a vehicle to operate on 100% vegetable oil.



Greg Howick

1st Year Process Plant Technology Student

Greg has served in the Navy and in the Air National Guard as an Avionics Technician. He plans to use his skills in the Refining sector when he graduates with an AAS in Process Plant Technology.



Jason Kills Pretty Enemy

1st Year Process Plant Technology Student

Jason is an enrolled Crow tribal member. He is a member of the Whistling Water Clan and a child of the Greasy Mouth. He graduated from Plenty Coup High School and has spent a few semesters at Haskell Indian Nations University located in Lawrence, KS and Little Big Horn College located in Crow Agency, MT. Jason has experience in wild land fire-fighting as a crew and engine boss. He plans on working as a Process Plant Technician in the Billings Montana area.



Equipment Purchased

Montana State University Northern

The team identified a need for more efficient purification of samples in order to better utilize staff time in the lab. A request to acquire a CombiFlash™ Flash Chromatographer was submitted and was approved. With the purchase of the instrument, the team is able to automatically and consistently collect pure samples.

Montana State University Billings

The following equipment has been received at MSU Billings City College:

- Buskirk Engineering PM605 pellet mill
- 12' pellet cooling conveyor
- 10" wide vibratory screener
- 60" paddle mixing auger
- 10 cubic foot surge tank

Motor control equipment was ordered in May and has been received at City College. Remaining equipment and supplies to order include:

- 4 multi-fuel pellet stoves
- Bacharach ECA 450 Environmental Analyzer
- Smoke Tester Kit

Progress Towards Meeting Milestones

Task 1: Life Cycle Analysis (LCA) and Techno-Economic Assessment of Green Diesel and Bio-jet Fuel (Lead: E.P. Resurreccion, eleazer.resurreccion@msun.edu). Evaluate the environmental life cycle analysis (LCA) impacts and techno-economic feasibility of green diesel and bio-jet fuel (next-generation fuels) and high-value added chemicals (bio-based chemicals).

Key Milestones

- a) Development of a thorough unit process analysis and life cycle inventory of the entire camelina-to-next-generation fuels/bio-based chemicals process chain. (Timeline: July 1, 2015 to July 2016)
- b) Comparative assessment of "cradle-to-gate" life cycle impacts of camelina-to-next-generation fuels/bio-based chemicals. (Timeline: July 1, 2016 to January 1, 2017)
- c) Evaluation of tech-economic feasibility of camelina-to-next generation fuels/bio-based chemicals via life cycle costing (LCC). (Timeline: January 1 to July 1, 2017)

Activities to Date

The life cycle analysis framework has been partially developed. The results will be presented at the American Center for Life Cycle Assessment (ACLCA) on September 2016 in Charleston, SC. The researchers were also selected to participate in the 2016 Chemical Life Cycle Collaborative (CLiCC) Workshop administered by the Institute of Energy Efficiency, UC Santa Barbara on June 25th, 2016. Additionally, a proposal has been submitted to the National Science Foundation-Innovations at the Nexus of Food, Energy, and Water Systems (NSF-INFIEWS) on March 2016. This proposal is a collaboration between MSUN and Old Dominion University (ODU), Norfolk, VA. MSUN has fostered a relationship with ODU because the institution has developed a novel and efficient oil extraction method from oilseed.

Task 2: Production of Camelina-Derived Alkylated Aromatics as a Blend Component to Aviation Gasoline (Lead: R.L. Maglinao, randy.maglinao@msun.edu). Propose and validate the mechanism of producing high-octane number chemicals (e.g., alkylated aromatics) from camelina.

Key Milestones

- a) Validation of the mechanism of producing high-octane number chemicals from camelina. (Timeline: July 1 to December 1, 2015)
- b) Optimum ratio of camelina-derived alkylated aromatics and unleaded avgas with desired anti-knock value identified. (Timeline: December 1, 2015 to October 1, 2016)
- c) Certification of the newly-formulated unleaded avgas. (October 1, 2016 to June 30, 2017)

Activities to Date

The results of the Task 2 research was presented at the 107th American Oil Chemists' Society (AOCS) Annual Meeting & Expo in Salt Lake City, UT last May. During the conference, the team established connections with universities and federal agencies. The resulting collaborations are moving forward on writing future grant projects. Different reaction conditions to maximize octane boosting chemicals are currently being investigated. The team is also working on developing a formula to predict octane number rating of blends of known pure hydrocarbons.



MSUN Participants to the 107th AOCS Conference

Task 3: Development of Heterogeneous Grubbs Catalyst for Biomass Conversion (Lead: M.J. Abedin, md.abedin@msun.edu). Develop a novel and robust heterogeneous Grubbs catalyst that achieves efficient conversion of natural oils to next-generation fuels and bio-based chemicals.

Key Milestones

- Synthesis of a silica-supported polymeric Grubbs catalyst for olefin metathesis of natural oils. (Timeline: July 1, 2015 to June 30, 2016)
- Synthesis of a novel silica-supported Grubbs catalyst for olefin metathesis of natural oils. (Timeline: July 1 to December 31, 2016)
- Comparative analysis of the two heterogeneous Grubbs catalysts. (January 1 to June 30, 2017)

Activities to Date

Despite minimal progress with milestone *a* due to staff transition, the Energy Corps Chemist has reinvented the catalyst synthesis for milestone *b*. A CombiFlashTM Flash Chromatographer is being used to improve the purity of intermediates for a better quality catalyst.

Task 4: Design of an Optimum Process Configuration and Economic Analysis for Medium- and Large-Scale Pelletizing Plants for Camelina Meal (Lead: A. Sullivan, andrew.sullivan3@msubillings.edu). Develop and prepare a design study documenting an optimum process configuration and economic analysis for medium- and large-scale pelletizing plants for camelina meal (next-generation fuels).

Key Milestones

- Development of an optimized process for fuel pellet production from camelina meal and manufacture a range of pellet compositions to verify producibility. (Timeline: Summer 2016)
- Testing of products in a range of commercially-available multi-fuel pellet stoves and identification of potential markets to determine product price including a fish food for export. (Timeline: Winter 2016)

- c) Preparation of study design for 40,000 to 500,000 ton per year pelletizing plant with economic analysis. (Timeline: Summer 2017)

Activities to Date

Student support of the project was off to a strong start beginning the week of May 14, 2016. They have achieved two important steps necessary in achieving the first milestone.



Howick, Kills Pretty Enemy, and Songstad condition camelina for pressing



Goodburn and Webster operate the Kern Kraft Oil Prince 20F

The first step was the further improvement of our camelina pressing operations. The results of this work are documented in the student made video at the following link (https://www.youtube.com/watch?v=7Ozvd_nOQP0). Students have identified and corrected pressing inconsistencies due to breaks in operations. Seed moisture analysis followed by conditioning has been included resulting in high oil yields. Next phase will consist of automation of the conditioning process, optimization of oil press parameters, and escalation of camelina meal production for pelletizing research.

The second step was the design of a pelletizing plant motor control system. The new facilities include six 3-phase motors ranging from 0.25 to 4 horsepower. Next phases will involve the establishment of a control system and its integration to the pelletizing process.

Other work this quarter included development of plans for a mobile pelletizing plant. It will facilitate future field demonstrations and allow the opportunity to test other biomass sources. Additionally, collection of high quality grass clippings continues this season. We have collected approximately 400 lbs of dry grass clippings and expect to gather another 200 lbs.



Bledsoe and Dayley evaluate design options for motor control system

Expenditures

MSU Northern	Expenditures to Date
Personnel Services	\$290,148. ⁷⁴
Operations	\$68,185. ⁰¹
Equipment	\$14,935. ⁸⁵
MSU Billings	
Personnel Services	\$1,656. ⁰⁰
Operations	\$1,197. ⁰⁰
Equipment	\$24,982. ⁰⁰
TOTAL	\$401,104.⁶⁰
Percent Spent	50.14%