AC 2012-3861: UMES STEM FACULTY, STUDENTS, AND STAFF COLLABORATE TO ADDRESS CONTEMPORARY ISSUES RELATED TO ENERGY, ENVIRONMENT, AND SUSTAINABLE AGRICULTURE

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UMES STEM FACULTY, STUDENTS, AND STAFF COLLABORATE TO ADDRESS CONTEMPORARY ISSUES RELATED TO ENERGY, ENVIRONMENT AND SUSTAINABLE AGRICULTURE

Abstract

"The Bio-Fuel, Sustainability, and Geospatial Information Technologies to Enhance Experiential Learning Paradigm for Precision Agriculture Project", recently funded by the United States Department of Agriculture (USDA) extends the environmental stewardship archetype of the preceding project titled "Environmentally Conscious Precision Agriculture: A Platform for Active Learning and Community Engagement" (completed in September 2011). The initial phase of the project to demonstrate the production of biodiesel using waste vegetable oil (WVO) from campus dining services has been successfully executed by a team of UMES students . Under the supervision of the project leaders, the students have worked in teams to collect, dewater, and filter the WVO; supported the acquisition of supplies and installation of the biodiesel processor; performed necessary titration and laboratory tests on the WVO to determine appropriate amounts of chemicals (sodium hydroxide, methanol, and sulfuric acid) to be used with a batch of WVO in the processor for the esterification and transesterification reactions; and operated and monitored the 48 hour biodiesel production and washing cycle of the processor. Besides biodiesel the process produces glycerin as byproduct. The glycerin has been used to produce soap successfully by the students. Students have also tested 'gelling' tendency of different blends of biodiesel and are currently working with the UMES farm manager to identify and appropriately modify farm equipment for biodiesel use. Students are also working with the university safety office to refine safety considerations to comply with OSHA and municipality requirements. Students will be involved in managing broader logistics of scheduling the processor operation for biodiesel production and utilization, based on needs of the farm equipment. The project team plans to refine the processing of glycerin by-product to improve the aesthetics, fragrance, and other qualitative parameters of the soap so that they may sell it for possible fund-raising efforts for selected student organizations.

1.0 INTRODUCTION

Agricultural needs and environmental concerns are of utmost importance in the rural setting of UMES and its proximity to the Chesapeake Bay and has been the motivation behind the "Precision Agriculture" project on campus [1]. Precision farming practices have allowed integration of geospatial information technology which has helped improve nutrient management and crop yields on campus. The environmentally friendly paradigm of the project is synergistic with the "green" initiatives of UMES and University System of Maryland (USM) and has led to the cooperation with UMES dining services and physical plant to produce bio-diesel from used cooking oil. Processed bio-diesel will be used to run farm equipment that currently use conventional petroleum diesel. Under the supervision of the project leaders the students are coordinating the entire logistics of this rather complex operation involving dining services, physical plant, and farming staff. The rich learning outcomes associated with this active learning activity is outlined in Figure 1 using the "Kolb's Experiential Learning Cycle [2]". Use of biodiesel with the farm equipment reduces the carbon foot print of the campus as biodiesel is a carbon neutral cleaner burning fuel and a more efficient transportation fuel compared to petroleum diesel[3].

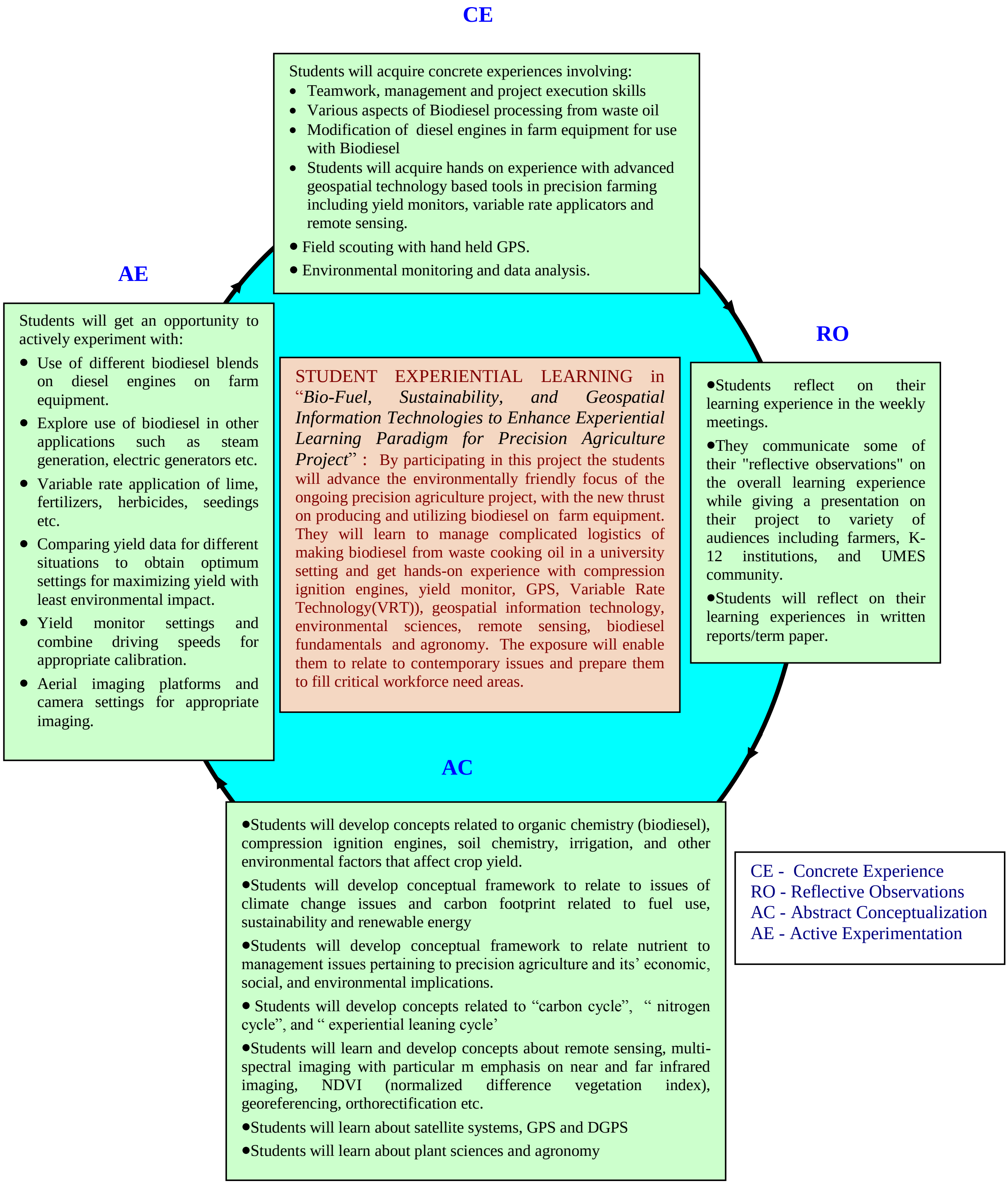
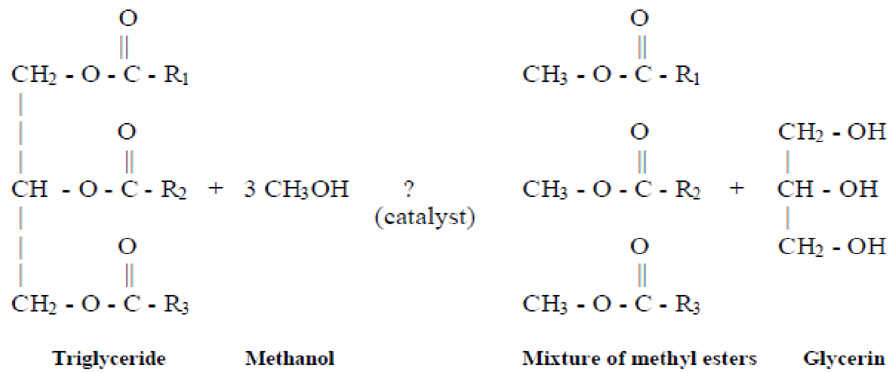


Figure 1: Kolb's Experiential Learning Cycle adapted for the Biofuel Project

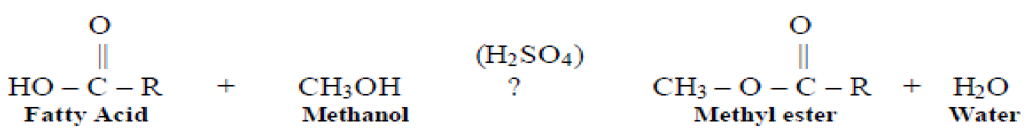
2.0 CHEMISTRY OF BIODIESEL FROM USED COOKING OIL

Straight Vegetable Oil (SVO) can produce "*biodiesel*" by chemically reacting the SVO directly with an alcohol such as *methanol*, in the presence of a catalyst such as *sodium hydroxide* or *lye*. The product of the reaction is a mixture of methyl esters, which are known as *biodiesel*, and glycerol, which is a byproduct. The process is known as *transesterification.* Transesterification reaction is shown in the equation below [4,5]:



where R1, R2, and R3 are long hydrocarbon chains.

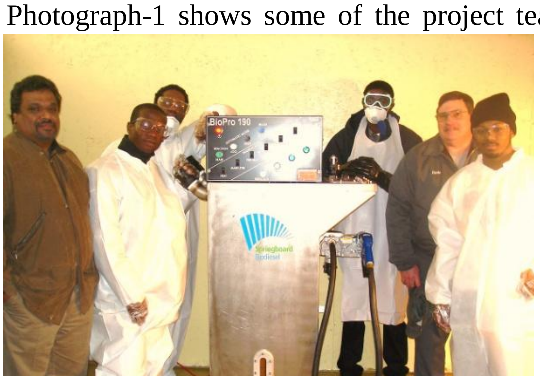
Waste Vegetable Oil (WVO), however, typically contains significant amounts of free fatty acids (FFAs). As such an acid catalyst such as *sulfuric acid* is used to *esterify* the FFAs to methyl esters to avoid forming soaps that can inhibit biodiesel production from WVO. The *esterification* reaction is shown in the equation below [4,5], where R represents generic long chain hydrocarbons that are present in SVO or WVO.



The BioPro 190 automated biodiesel processor acquired by the project team, automates the esterification, transesterification [4,5], and the washing and drying phases of the production process that integrates safe handling of chemicals (methanol, sulfuric acid, and catalyst (NaOH or KOH)) and delivers high quality ASTM grade biodiesel [6] that can even be pumped from the unit directly into the vehicle for use.

3.0 OUTLINE OF BIODIESEL PRODUCTION USING BIOPRO 190 AND IN THE LABORATORY

Photograph-1 shows some of the project team members with the BioPro190 processor. The unit uses roughly 50 gallons of filtered dewatered waste vegetable oil, 10 gallons of methanol (99.9% pure), 3.54 lbs of lye (sodium hydroxide, 98% pure or better), and 190 mL of sulfuric acid (93% pure or better) to produce roughly 50 gallons of biodiesel over a 48-hour cycle. The process produces about 10 gallons of glycerin as a byproduct. Photographs 2 through 6 show various stages of the process executed by the student participants. At first the students coordinate with the "University Dining Services" to collect the WVO in a 55 gallon drum (Photograph -2). The 55 gallon drum is then transported to the processing facility with the help of farm personnel. A 400 micron



Photograph-2: Project team with BioPro190 filter is used to trap some of the particles from the WVO. Subsequently, the WVO is heated to a temperature of around 220°F to dewater the oil. During the first processing cycle in the winter of 2010/2011, the last aspect posed a significant challenge to the project team. The Biopro 190 is installed in a non-airconditioned well ventilated facility close to the UMES farm shop. The student participants quickly realized that they will have to properly insulate the 55 gallon drum (Photograph-3) and use two 1200 Watt band heaters to raise the oil temperature in a reasonable time-frame, to the desired level, against the ambient temperature that averaged around 40° F. Some of the engineering students that participated in this endeavor will be able to draw from this experience when they take courses such as Thermodynamics and Heat Transfer in future. The filtered and dewatered WVO is finally pumped into the BioPro190 for conversion to biodiesel. Student participants poured measured amounts of sulfuric acid, lye, and methanol to activate the esterification and transesterification reactions. Photographs 4 and 5 show students pouring lye (NAOH) and pumping methanol using a hand pump through appropriate ports in the BioPro 190. The reaction is facilitated by continuous agitation in the processor. At the end of the reactions, biodiesel and glycerin separates out into layers. The heavier density glycerin settles at the bottom of chamber in the BioPro190 and is collected into a separate container (Photograph 6). The biodiesel remains in the processor and goes through an automatic washing cycle with water to remove the excess chemicals followed by a drying cycle to remove water.

Photograph-2:WVO Collection Drum

Photograph-3: Insulated WVO Collection Drum

Besides producing biodiesel using WVO with the BioPro 190 on a relatively large scale, some student participants in the project also worked with the project leaders to conduct the biodiesel production in a laboratory setting (Chemistry Lab in the Department of Natural Sciences at UMES) using WVO, as well as several varieties of SVO in small portions using a kit acquired from a commercial vendor [7]. The laboratory procedure parallels the process outlined above. When working with WVO in a laboratory setting the titration process is conducted carefully using a few drops of the WVO using Phenolphthalein or any other titration agent with KOH or NAOH to determine the percentage of Free Fatty Acids (FFAs). This helps to determine the amount of sodium or potassium hydroxide (NAOH or KOH) and methanol to

Photograph-4:Students Pumping methanol in BrioPro190

Photograph-5:Student Pouring NAOH in BrioPro190

Photograph-6: Student taking out glycerin from BrioPro190 be used for the transesterification reaction. Following the reaction the glycerin is separated by gravity. The biodiesel is manually washed using distilled water and subsequently dried as usual. Photograph 7 shows a UMES student participant working in the laboratory to make biodiesel.

Photograph-7:Student making biodiesel in Lab

4.0 MAKING USE THE GLYCERIN-BYPRODUCT

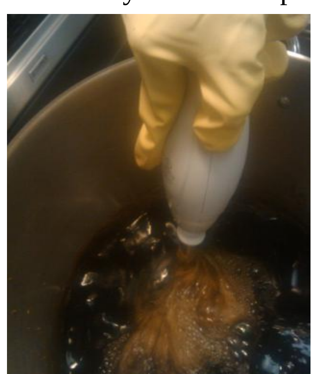
The project team is considering variety of uses of the glycerin that is obtained as byproduct in the biodiesel production process. Preliminary efforts of producing soap using some of the glycerin have been successfully executed by the project team. Other uses of glycerin for making fire-place pellets and liquid soap are also being considered. The soap making process is simple and can be summarized in the following steps:

(i) A measured amount of glycerin is heated to 180 ^{0}F over medium heat in non-aluminum pot.
(ii) Fatty acid (Lauric acid) is added to the glycerin and mixed thoroughly.
(iii) Sodium Hydroxide (NaOH) is dissolved in distilled water to create Lye solution.
(iv) The Lye solution is slowly added to glycerin mixture, and stirred gently.
(v) The mixture is then stirred gently using immersion blender until "tracing" occurs.
(vi) Essential oils are added to make natural scented soap.
(vii) Soap is then poured into mold and allowed to harden for about 24 hours.
(viii) The soap slab is finally unmolded and cut into bars.

Photographs 8 through 11 captures significant steps followed by the student participants for making soap.

Photograph-8: Stirring fatty acid into melted Glycerin

Photograph-9: Adding Lye solution to Glycerin mixture



Photograph-10: Stirring mixture using blender, tracing visible

Photograph-11: Cutting unmolded soap into bars

5.0 SYNERGY WITH NBB PROJECT AND FUTURE PLANS

The efforts described above were initiated with the award of the USDA grant "The Bio-Fuel, Sustainability, and Geospatial Information Technologies to Enhance Experiential Learning Paradigm for Precision Agriculture Project". Subsequently, a collaborative proposal led by Cornell University involving UMES, Delaware State University, Ohio State University, and PACE University titled "Northeast Bio-energy and Bio-products (NBB) Education and Development Institute" has also been approved by the AFRI program of USDA. Some of the project leaders including the primary author that lead the former project are participating in the NBB project on behalf of UMES. The broad goal of the NBB project is to raise awareness of the process of producing ethanol, biodiesel, and other bio-energy products from a variety of feedstocks and to promote their benefits with regard to sustainability, carbon footprint, energy independence, and climate change issues. Educational outreach with regard to commercialization of other bio-based products and their impact on the bio-economy of the future also forms a significant component of the NBB project. The UMES team will focus their developmental effort on biodiesel from WVO, SVO and algal oil in concert with the project partners within the broader scope of the project.

One of the key aspects of the NBB project is for each partnering institute to run a one week summer academy for K-16 teachers and community outreach groups with supporting material from partnering universities. The synergy of the bio-fuel endeavor initiated earlier at UMES with the NBB project, supported a variety of activities at the summer institute at UMES for the NBB project. These activities included using a biodiesel kit to produce biodiesel in laboratory setting, a tour of the BioPro190 biodiesel processing facility, as well as a tour of “Greenlight Biofuels” a commercial biodiesel production endeavor from used cooking oil in the “Princess Anne Industrial Park” in close proximity to UMES campus, and a soap making activity using glycerin. Several experimental runs to produce soap in UMES laboratory by student participants in the bio-fuel venture initiated with prior USDA funds helped the team to put together a soap making kit using glycerin obtained from the biodiesel production process with the BioPro190. These kits were utilized effectively in the one week summer institute for the NBB project.

The project leaders have encouraged all “STEAM” (science, technology, engineering, agriculture, and mathematics) majors at UMES to participate in these efforts and are exploring involvement of interested business, human ecology, and fine-arts students to address some of the new dimensions of the project. Some of the human ecology faculty and students have expressed a desire to work on packaging and marketing the soap produced during the project execution and the fine-arts faculty would like to involve their students to decorate the walls of the BioPro190 biodiesel processing facility. Maryland Space Grant Consortium has provided supplementary support for interested undergraduate students, particularly from the underserved population to get involved. The broader scope of the project includes use of biodiesel, a carbon neutral energy source, for use with farm equipment and as an alternative transportation fuel to address climate change and sustainable energy related issues. In this regard a basic assessment of the fuel needs of farm equipment that run of biodiesel has been done and is shown in Table 1.

Table 1: Estimated fuel use of tractors, mowers, and combine/harvester.

Vehicle-Make & Model	Type	Gallons per Month												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Cost-Retrofit
New Holland TR86	Harvester	0	0	0	0	0	120	120	0	120	240	120	0	$550.00
International Truck 1800	Farm Truck	40	200	40	40	40	100	100	40	200	400	100	40	$365.00
John Deere 4230	Tractor	0	0	25	60	60	30	60	30	30	30	0	0	$365.00
Ford 4600	Tractor	0	10	20	10	30	30	0	20	10	0	10	0	$365.00
Ford 5640	Tractor	0	0	0	0	20	20	20	20	20	20	0	0	$365.00
Ford 8770	Tractor	0	0	100	60	70	0	0	0	0	0	0	0	$455.00
John Deere 2950	Tractor	0	0	0	30	60	0	0	0	60	0	0	20	$365.00
Ford CM 272	Mower	0	0	20	40	40	40	20	20	20	20	0	0	$120.00
Toro Zmaster	Mower	0	0	0	15	10	25	5	40	20	5	0	0	$120.00

The overall management, production planning, storage and other logistics will be worked out by the participating students. Furthermore, the project will continue to address use of remote sensing and advanced geospatial information technology tools to optimize use of nutrients, water, and other resources for efficient production agriculture practices [1] that are critical to provide food for a growing population on the planet in a sustainable fashion.

6.0 ACKNOWLEDGMENT
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