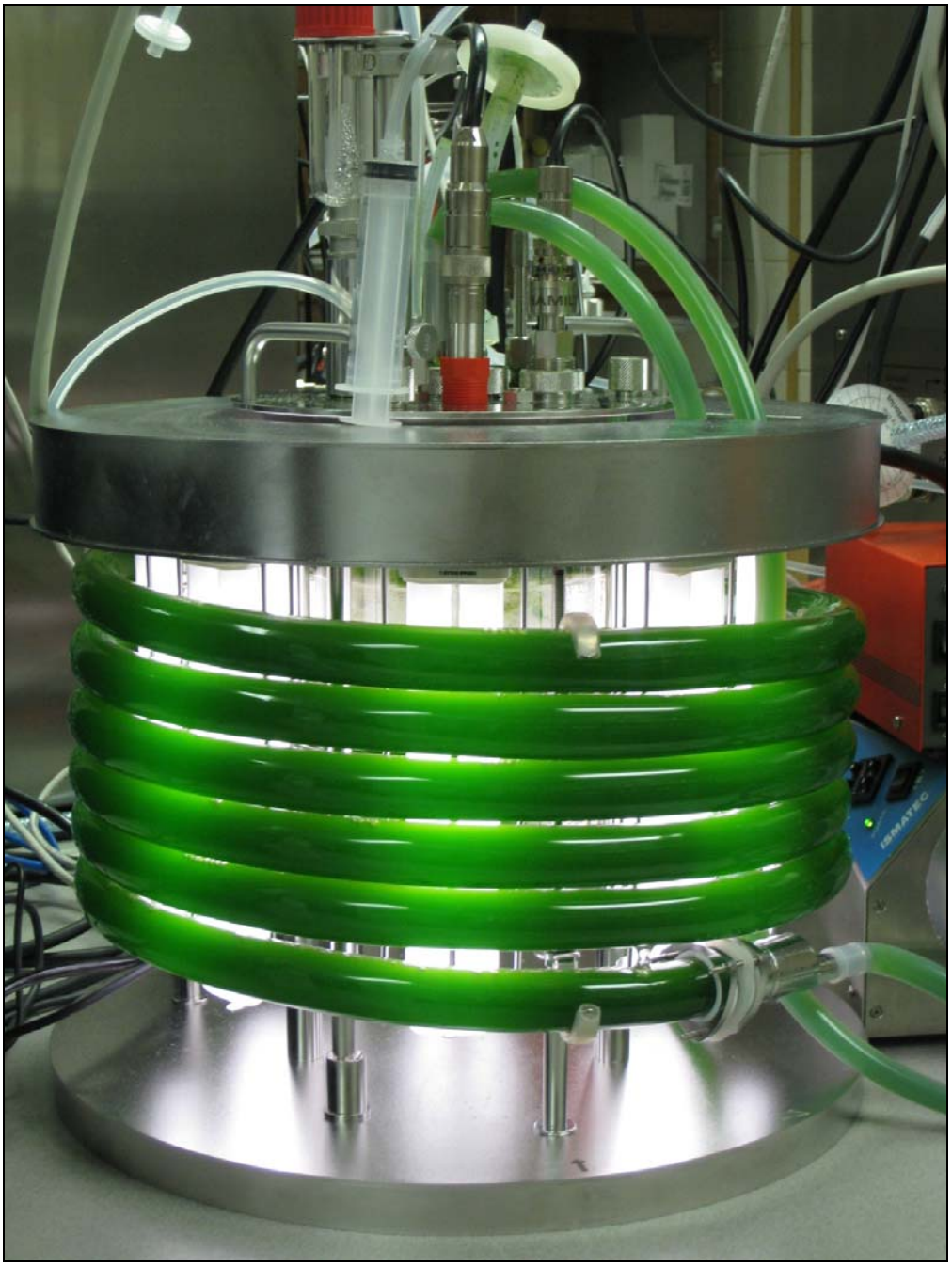
UGA Biorefining & Carbon Cycling Program

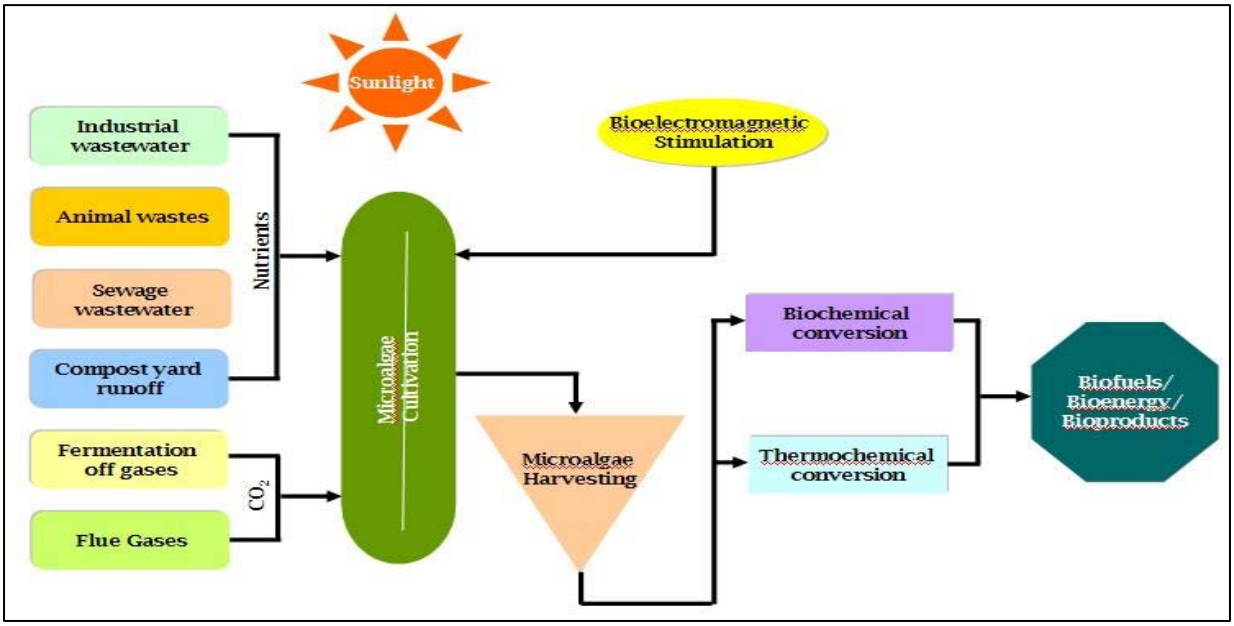
Microalgae Bioenergy Research



www.biorefining.uga.edu
http://biorefinery.uga.edu/biomassdevelopment.html

UGA Microalgae Bioenergy Research Program

The Department of Biological and Agricultural Engineering initiated The Microalgae Bioenergy Program under the Department of Energy (DOE) sponsored Biorefining and Carbon Cycling Program (BCCP) in January 2007. This research program is truly a multidisciplinary research endeavor involving expertise of scientist from various fields such as phycology, microbiology, agriculture, aquaculture, mechanical, chemical and process engineering, physics, and animal sciences to develop cost effective front and back end commercial scale technologies to produce algae biofuels from marine and fresh water microalgae and macroalgae. Ongoing research includes developing algae production, harvesting, and conversion technologies at the bench and pilot scales. Conversion technologies being studied include pyrolysis, liquefaction, gasification, catalytic conversion, fermentation, and transesterfication.



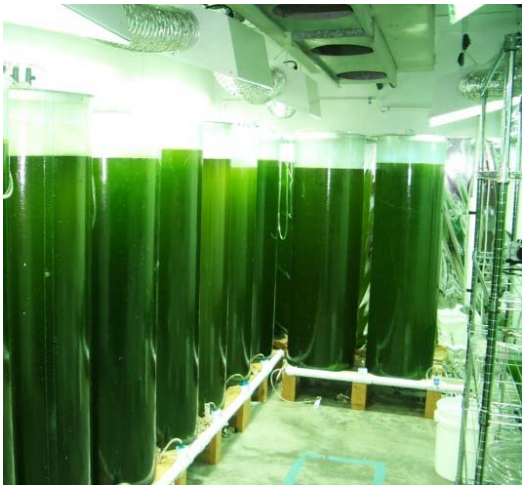
RESEARCH OBJECTIVES

- To develop a combined biotechnological system for processing/treatment of agricultural and industrial wastes such as wastewater and flue gases for production of microalgae biomass.
- Determine the optimal growth conditions for enhanced growth and lipid production
- Enhance growth rate and lipid production using novel technologies such as bioenergetic stimulation
- To develop cost-effective large-scale microalgae cultivation systems.
- To develop technologies for harvesting algal cells and extraction and conversion of lipids/ biohydrocarbons into biodiesel or bio-oil.
- Examine the algal biomass for production of value added products
- To conduct LCA, technical, and economic analysis of renewable energy and biofuel production from algae biomass as feedstock.

Sartorius Photobioreactor

Growth Chamber

Growth chamber

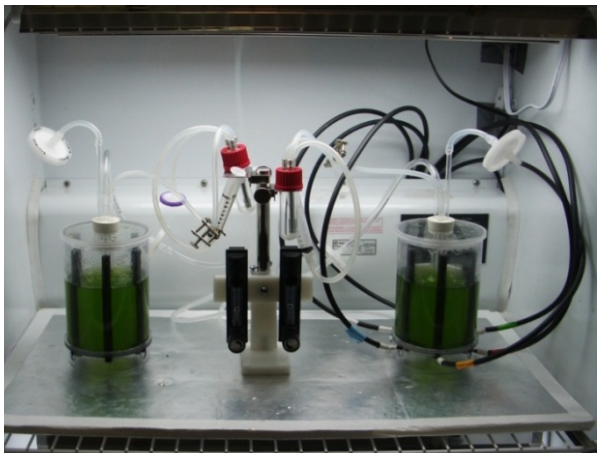


Vertical Photobioreactors

More in depth focus:

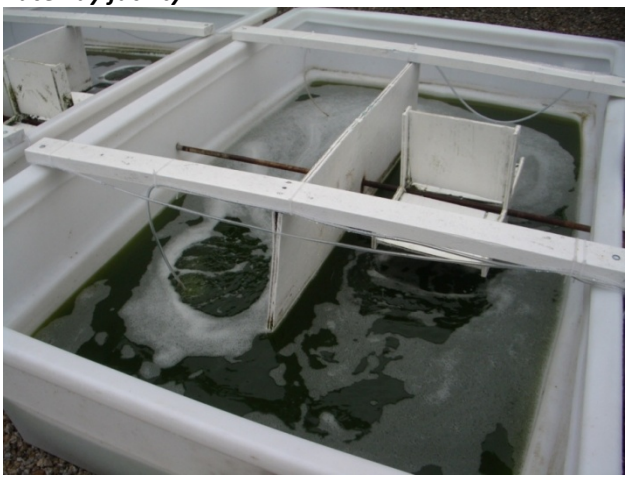
1. Utilization of industrial, agricultural, aquaculture and municipal wastewaters and livestock industry wastes such as poultry litter for biomass production
2. Isolating and identifying suitable photo and heterotrophic microalgal strains from different habitats for biofuel production
3. Developing novel carbon capture and delivery technologies
4. Enhancing algal biomass productivity through biological nitrogen fixation
5. Developing low cost advanced fiber flocculation and electroflocculation technologies for harvesting algal cells
6. Improving lipid extraction efficiency through explosive decompression technology
7. Developing advanced non chemical lipid extraction methods
8. Design and Engineering of novel low cost reactor configuration for mass cultivation of algae
9. Developing low cost technologies for ethanol production from algal biomass
10. Developing Biomethane production and up-gradation technology using algal biomass feedstock to replace conventional transportation liquid fuels

Bioenergetic Stimulation set up



Bioenergetic Stimulation incubator

Raceway facility



Bench Scale algae ponds

CO_2 Supply System for Algae Pilot Plant

Microalgae Grants

TITLE	FUNDING AGENCY	DURATION
1. Improving cost effectiveness of algae-lipid production through advances in nutrient delivery and processing systems.	Unites States Department of Energy (DOE)	2008-2010
This current proposal aims at developing novel and innovative approaches for nutrient delivery and supply, and biomass processing systems for harvesting oil extraction and value addition. The project also addresses various barriers impacting cost and performance effectiveness of lipid productions from algae. Apart from developing low cost cultivation and processing technologies, the outcome of this project will help to establish integrated algae biorefineries in the future for the production of biofuels and other value added products from algae.		
2. Carrot Waste Anaerobic Digestion for Biogas Production	Ascend Engineering, Inc	2008
This project aims at establishing proof of concept for biogas production from methane capture from carrot waste.		
3. Microalgae Based Biofuels production using carpet industry wastewater: An integrated approach for environmental sustainability in carpet industries.	State of Georgia, Traditional Industries Program for Polymer, Fiber, and Fabric Products	2008-2009
This proposed project will survey various types of algae cultivation systems such as open raceway and circular ponds, plastic and polybag reactors, etc. and evaluate the best two cost effective cultivation systems for mass production of algal biomass using carpet industry wastewater. Also this project will quantify the impacts of magnetic and electromagnetic fields to enhance productivity that can increase algae growth, photosynthetic efficiency and lipid production as well documented in the literature but never researched with algae.		
4. Microalgae mediated biodiesel production using carpet industry wastewater phase I: Bench scale screening and optimization studies.	Industry; Dalton Utilities	2007-2009
This project aims at establishing the proof of concept for production of algae biofuels from mixed consortium of native flora in carpet industry wastewater.		

5. 5. U.S.-Mexico Universities Training, Internships, Exchanges, and Scholarships (TIES) Partnership Initiative project on "Integrated Waste Management with Energy Production for Increased Competitiveness of the Livestock Industry in Northeast Mexico"	United States Agency for International Development (USAID) in partnership with Higher Education for Development (HED)	2007-2009
This project targets technology and business policy relating to integrated waste management that is cost-effective and will provide additional income through co-product generation from waste treatment. Research focuses on methane capture from a mixed consortium of animal wastes and algae for the production of biogas. Currently UGA hosts two internship students and one Master's student in collaboration with the TIES grant.		
6. Development of feedstock specific anaerobic consortia for biogas generation from food waste	Georgia Centers of Innovation Research and Commercialization	2008-2009
This project intends to analyze different types of food wastes based to optimize biogas generation potential.		

Industry Partners & Other Collaborators

Dalton Utilities: Located in Dalton, Georgia, they are providing the utility services that keep the Carpet Capital of the World running. From fiber optics to innovations in wastewater treatment, it brings the latest technology to the community. http://www.dutil.com/

Carpet and Rug Institute: Based in Dalton, Georgia, the Carpet and Rug Institute (CRI) is a nonprofit trade association representing the manufacturers of more than 95 percent of all carpet made in the United States, as well as their suppliers and service providers. It coordinates with other segments of the industry, such as distributors, retailers and installers, to help increase consumers' satisfaction with carpet and to show them how carpet creates a better environment. (Jeff Carrier- Sustainability Manager) http://www.carpet-rug.org/index.cfm

Eau Plus, Inc.: Located in London, United Kingdom, , Water4life is committed to the development of products that do not harm our environment, are organically grown, free from contaminants, toxins and preservatives, and bring real measurable benefits to the consumer. We are working on a D2 product and a spring water with a high concentration of seaweeds that looks and tastes like water. (Tom Brudenell-Bruce) http://www.eauplus.co.uk/press-release.htm

Ascend Engineering, Inc : Located in Aiken South Carolina, the mission of Ascend Engineering Inc. (AEI) is to provide cost effective and value added engineering services for cleansing and treatment of Water Resources using state of the art technologies without causing any harm or adverse effect to the environment. Another mission of AEI is to develop and engineer processing systems for production of Green Renewable Energy Sources such as Ethanol and Bio-diesel. http://ascendengineering.net

Alterra: Privately held Alterra Bioenergy Corporation is headquartered in Macon, Georgia. It manufactures and distributes biofuels to traditional fuel distributors, as well as trucking and construction companies, railroads, mining companies, the marine industry, governmental agencies and U.S. military organizations. Alterra Bioenergy is not only committed to the production and distribution of Biodiesel but also importing, educating and enabling other businesses to start their own distribution and production services. http://alterrabioenergy.com/index2.html

Georgia Centers of Innovation Research and Commercialization: Providing access to university level research, product commercialization, industry networking, investor and funding services in Georgia. http://www.georgiainnovation.org/

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Graduate Student Research

Ryan W. Hunt
B.S. Physics
M.S. Bio & Ag Engineering

It has been well established that electromagnetic fields are capable of eliciting bioeffects in many biological systems. A number of bioprocesses could be successfully integrated with electromagnetic or electrochemical processes and stimulation, if properly engineered. Currently, the bioengineering of microbiological systems, such as microalgae and yeasts, are of interest for biofuel applications and technologies. The idea that electromagnetic forces have a fundamental role in the mechanisms of organization and transport in biological systems is supported by the indirect and direct measurements of electromagnetic fields around living cells. Exposure to exogenous can influence enzyme activity, gene expression, DNA conformation, cell growth, and cell death in biosystems. Research has been initiated to detect, analyze and tailor the response of micro-organisms to external electromagnetic fields and signals. Our project is dedicated to interact with the endogenous bioelectromagnetic systems which could lead to dramatic advancements in biological sciences and bioengineering applications.

Nisha Vaidyanathan
BS Biotechnology, SRM University, India

Engineering systems and technologies current project goals:

- To identify species of benthic algal communities (attached algae), develop a growth pattern and enhance its lipids production.
- To develop a reactor model for the growth of attached algae thereby making it a stabilized culture system for large scale production of lipids.
- To establish parameters affecting the growth of attached algae with respect to lipids productivity thereby developing an understanding of its behavior.

Kevin Lee
B.S. Ecology and Biology

The fermentation technologies branch of Biorefining Program is integral to the overall goal of pioneering engineering solutions to our oil-based economy. Current research is focused on further understanding the fermentation process and its application to bioenergy, in a cost efficient, economically sensitive fashion. Current project goals:

- Continuing to increase the scientific understanding of the ecological mechanisms and interactions occurring in anaerobic systems using computer modeling.
- Optimization of anaerobic digestion processes by elucidating and controlling various system parameters.

- Developing biological systems which use anaerobic digestion for the production of methane from various agricultural and industrial waste streams.
- Working with the principles of anaerobic digestion to decrease toxicity of and generate methane from black liquor, a kraft mill effluent.

Sarahi Garcia
B.S. Microbiology
Universidad Autonoma de Coahuila
Torreon, Mexico
TIES Master's Student at UGA

Fermentation technologies- current project goals:

- To isolate and characterize, novel acid-tolerant methanogens for use in anaerobic digestion systems.
- To develop a consortium for the production of methane from carrot waste.
- To use computer modeling of anaerobic systems to predict the bacterial consortium that optimizes system processes, most importantly methane production.
- To use and develop novel techniques for the analysis of microbial ecology of anaerobic systems.
- To create a catalog of pure cultures containing the various microbes present in anaerobic systems for use in reactor optimization.

Gerardo Martinez Castro
B.S. Microbiology
Universidad Autonoma de Coahuila
Torreon, Mexico
TIES Internship at UGA

The area around Torreon in Coahuila, Mexico, which is known as Comarca Lagunera, is the biggest milk-producing region in Mexico, with an estimated 500,000 cows. It generates one million tons of cattle manure per year, and huge amounts of methane emissions, which is of great environmental concern. Anaerobic digestion is an economically attractive waste treatment practice through which both pollution control and energy recovery can be accomplished. The resulting mixture of methane and CO2 can be used as a renewable fuel.
A preliminary study on anaerobic co-digestion of dairy manure and algae for biogas production was conducted. It was found that the proportion of algae in the treatments increased the biogas production; but it affected the methane concentration in all treatments. The biogas production was maximum in reactors inoculated with rumen fluid followed by adapted inoculum. However, the maximum methane concentration was observed in the following treatments; 90% dairy manure + 10% algae, 80% dairy manure + 20% algae, 70% dairy manure + 30% algae with adapted inoculum.

Please visit *www.biorremlaguna.blogspot.com* or *www.biorefinery.uga.edu* to view research posters.

Christian Espino Lopez
B.S. Microbiology
Universidad Autonoma de Coahuila

Torreon, Mexico
TIES Internship at UGA

Objective: To determine the feasibility of an anaerobic co-digestion of dairy manure and algae in varying combinations to produce biogas and observe the effects of addition of algae on methane production.

Results: Reactors fed with increasing proportions of algae in dairy manure enhanced the biogas production in all the treatments. However, a decrease in methane concentration in the biogas was observed in the reactors fed with increasing proportions of algae in dairy manure. Biogas production increased from treatments containing 70% Dairy manure + 30% Algae, to 100% Algae in uninoculated reactors and reactors inoculated with rumen inoculum. Similar trend was observed in the treatments containing 60% Dairy manure + 40% Algae to 100% Algae in the reactors inoculated with adapted inoculum. Inoculation with rumen fluid showed a better biogas production than uninoculated reactors and reactors added with adapted inoculum in most of the treatments, except in the reactors having 90% Dairy manure + 10% Algae, 80% Dairy manure + 20% Algae and 70% Dairy manure + 30% Algae where adapted inoculum performed better. The maximum methane concentration was 74.3%, 68% and 58% for 90% Dairy manure + 10% Algae, 80% Dairy manure + 20% Algae, 70% Dairy manure + 30% Algae fed reactors, respectively. Average methane concentration was 70.9% and 38.2% in 90% Dairy manure + 10% Algae and 10% Dairy manure + 90% Algae treatments respectively in the reactors inoculated with rumen inoculum. Treatments containing 10% Dairy manure + 90% Algae with rumen inoculum resulted in 46.5% decrease in methane concentration.

Please visit *www.biorremlaguna.blogspot.com* or *www.biorefinery.uga.edu* to view research posters

Patrick Raber

If algae are to be used as a medium to create biofuel or used for water treatment applications, it is important to fully understand the behavior of different strains subjected to multiple growing conditions to assess which strain has maximum biomass potential. In collaboration with Dr. Senthil Chinnasamy, the project has been designed to monitor algae growth under varied nutrient conditions. The first stage of the project will allow algal cultures to grow at controlled nitrogen levels and monitor biomass lipid levels. Moving forward the project will introduce multiple nutrient adjustments and include continuous analysis of the algae samples for carbohydrates and lipids, (using the Soxhlet extraction method,) as well as calculating total algal biomass.

Vandana Murthy

This project is the evaluation of poultry litter and nitrogen fixing microbes as low cost nutrient sources for the production of biofuels from microalgea..The first objective is to improve biomass productivity of microalgae using nitrogen and phosphorus extracted from poultry litter, and to optimize the amount of convertible energy from carbohydrates and lipids produced by a specific strain of microalgae. The secondary objective is to test the effect of nitrogen fixing cyanobacterium (*Nostoc sp* /*Anabaena sp*)/BGA and plant growth promoting rhizobacterium, *Azospirillum brasilense*, individually and in combination, to improve the productivity of microalgae.

Publications & Conference Papers

1. *Chinnasamy,S.* and Das, K.C. 2008. Microalgae Biomass Production Using Industrial Wastewater, Institute of Biological Engineering 2008 Annual Conference, Chapel Hill, NC, Mar 6-9, 2008.
2. *Chinnasamy,S*, Hunt, R.W. and Das, K.C. 2008. Bioprocessing of Industrial Wastewaters for Renewable Biomass Production using Microalgae, International Workshop on Bioprocess Engineering, SRM University, Chennai, India, Feb 7-9, 2008
3. Hunt, R.W., *Chinnasamy,S.* and Das, K.C. 2007. Microalgae based biodiesel production using poultry litter, Presented at the "Incredible anaerobes – from physiology to genomics to fuels". The Georgia Center, University of Georgia, March 2-3, 2007
4. Kinetic study of catalytic decomposition of paper mill sludge, paulownia wood and micro algae using Thermo Gravimetric Analyzer (TGA). U. Jena & K.C. Das, Presented at ASABE 2008. Online at
5. www.biorefinery.uga.edu
6. Biostimulation Effects of Electromagnetic Fields on Living Cultures for Biotechnology and Bioenergy Applications: Time and Topological Aspects. R. Hunt. Presented at Driftmier Engineering Center 2008. Online at www.biorefinery.uga.edu
7. Second Annual Bioenergy Awareness Days, Washington D.C., June 19 2008. Poster online at www.biorefinery.uga.edu

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