

**Biodiesel Research at Eastern Regional Research Center, Wyndmoor, Pennsylvania  
Fats, Oils and Animal Coproducts Research Unit  
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**Alternative feedstocks and production technologies:** *Most of the cost of biodiesel is in the feedstock. There are abundant low-cost alternatives to refined vegetable oils that—with application of appropriate technology—can fill America’s growing demand for the fuel.*

- In situ transesterification: Conceived, and are developing, a new method (‘in situ transesterification’) for the direct synthesis of biodiesel from lipid-bearing materials.
  - o The attractive potential abilities of this method to eliminate hexane use in oil extraction, and to reduce biodiesel production cost, have led to requests for collaborative investigation of this method from the private and public sectors (ADM, Super Soy Feeds [WI], Pulsewave Technologies [CO], Custom Extruding [MN], Crown Iron Works [MN], and Minnesota Ag. Utilization Research Inst.). A CRADA is under development with ADM.
  - o The potential of this method to provide a new type of animal diet component (lipid depleted spent meal exiting the process) has led to collaborations with the ARS Fish Culture Experiment Station (ID), Ohio State U. Poultry Dept., and R. L. Stroup Inc. (OH). Soy feedstock provided by Cargill and Perdue Farms.
  - o The potential inherent in this new technology caused Unit researchers to be invited to describe it before the Governing Board of the National Biodiesel Board. At annual research planning meetings sponsored by NBB, in situ transesterification has lately been the sole new biodiesel production technology discussed.



*top to bottom: soy flakes, DDGS, meat & bone meal*

- Biodiesel from soapstock
  - o In collaboration with Cargill (CRADA) and Runyon Industries (TN), developed new methods for the production of biodiesel from soapstock, an underutilized byproduct of edible oil refining. Conducted process optimization, quality validation testing, and, with university collaboration [CO School of Mines], heavy duty engine testing. The developed process was implemented by collaborator Runyon, resulting in the sale of greater than 1 million pounds of product to date.



*soapstock and resultant biodiesel*

- Low value refined lipids as biodiesel feedstocks
  - o Produced biodiesel from underutilized low-cost animal-derived lipids, including tallow, lard, chicken fat and restaurant grease. Characterized resulting fuel and conducted small-scale engine testing on site. CRADA with NCAUR, the rendering industry technical group Fats and Proteins Research Foundation, and the U. of Illinois to further explore emissions properties at the latter location’s engine test lab.



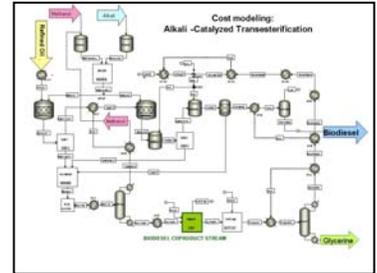
*tallow and resultant biodiesel*

- Waste-stream lipids and the technology for their conversion to biodiesel
  - o Team member with Philadelphia Fry-O-Diesel (PA) in the successful development of technology and pilot and production facilities for the synthesis of specification grade biodiesel from restaurant trap grease. Pilot technology in validation phase at this time.
  - o Conceived, facilitated, planned, and presently participating with Philadelphia Fry-O-Diesel Co. on the conversion to biodiesel of an 800-pound keynote butter sculpture produced for and displayed at the 2007 Pennsylvania Farm Show. This dovetails nicely with the Food and Renewable Fuels theme of that Show, and has received local and national press attention. The study was coordinated with and approved by PA Secretary of Agriculture D. C. Wolff and ERRC’s Center Director.



*trap grease and resultant biodiesel*

- Renewable catalysts for biodiesel production
  - o Examined the use of enzymes, both free and immobilized, as catalysts for the production of biodiesel from oils, fats, and other rendered materials such as restaurant grease. The progress demonstrated led to a request by Novozyme Inc. (Denmark) to employ their lipases in producing an immobilized enzyme bioreactor for biodiesel production from high free fatty acid fats and oils. The bioreactor method has advantages of less byproducts and less energy use.
- Process simulation and cost engineering of biodiesel production
  - o ERRC researchers and its cost engineers developed detailed models on biodiesel production. The models incorporate the chemistry, engineering, capital, feedstock, and operating costs to present the public with a realistic picture of the economic feasibility to produce the fuel. The models have been distributed to more than 60 requestors, mainly from the private sector, in the first year. They are being used not only to do economic feasibility studies for potential producers, but also as illustrative tools in professional lectures, guides by college students, and college teaching tools, especially in engineering departments.

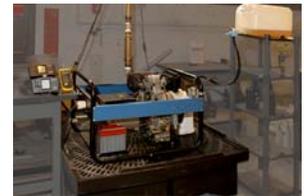


process simulation/cost analysis

**Fuel properties:**  $NO_x$  emissions have been the one property of biodiesel that has challenged claims of the environmental benefits of this fuel. The problems have been most identified with the extent of unsaturation in the fuel and feedstock; soy oil, with its high polyunsaturation, was particularly vulnerable to this challenge.

- Developed  $NO_x$ -reducing fuel additives for biodiesel, demonstrating their effectiveness in an on-site emissions-instrumented diesel engine, and in collaboration with DOE-National Renewable Energy Lab (NREL, CO) engine emissions team.

on-site diesel engine with emission monitoring capabilities

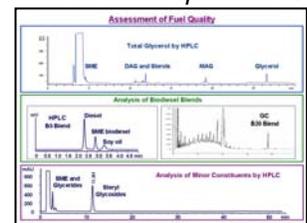


- Results of ongoing collaboration between ERRC and NCAUR (Peoria) on how biodiesel properties relate to the amount of unsaturation in the biodiesel molecule has enticed the National Renewable Energy Laboratory, DOE, Golden, CO, to conduct heavy duty engine testing on these fuels.

**Biodiesel quality—meeting industry specifications.** The biodiesel industry is very sensitive to the need for quality products. It has set its own standards and promoted those of ASTM. Accurate yet simplified analytical techniques are needed for lab and field assays. Newly surfacing problems with trace impurities have also demanded more specific test methods.

- Identified species present in biodiesel samples from engine failure events. Allowed the industry to identify the causes of engine failure and producers to modify their technologies to generate reliably high quality fuels. Among requesters of assistance have been private sector cooperators and such public sector entities as the PA Turnpike Commission and the MN Agricultural Utilization Research Institute.

testing total glycerol, blend levels, minor constituents



- Developed rapid methods for measuring biodiesel blend levels that also can be used to measure residual oil levels in biodiesel fuels and blend levels in biodiesel/petrodiesel blends. The Technical Director of the National Biodiesel Board (who is also the Head of the ASTM Committee on Biodiesel Quality) is using detailed information following a visit to ERRC to discuss the methods, and to distribute them to potential field users for evaluation.



testing instrumentation

**New markets for glycerol byproduct of biodiesel production.** Rising production of biodiesel has meant a growing glut of the glycerol (glycerin) coproduct and thus a growing urgency for new uses for the material.

- The use of crude biodiesel glycerol as a carbon and energy source in the microbial production of poly(hydroxyalkanoate) polymers, and--with a private-sector CRADA partner--biosurfactants (sophorose and rhamnolipids) is being investigated.



fermentations fed by glycerol

- Working with Rohm & Haas Co. under a USDA/DOE Green Chemistry Program grant to investigate the incorporation of biodiesel glycerol into new adhesive and elastomer products.

**Intact oils as burner fuel.** Biodiesel's focus has been for use in vehicular engines. Stationary heaters (boilers, etc.) also use petroleum products and alternatively could burn not only biodiesel but--with appropriate engineering—intact oils and fats as well.

- In collaboration with Clean Burn Technologies [PA] and Laughing Stock Farms [ME], are investigating intact triglycerides, particularly used cooking oils, as burner fuels.

*used cooking oil as heating fuel*



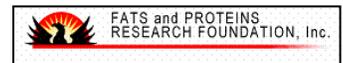
**A source of technical expertise:** Our scientific and managerial staff have been invited to lend their expertise to numerous public meetings, citizen's group events, and stakeholder/customer workshops.

- At the request of the PA Department of Agriculture, Unit researchers and Center Director are participants in the PA Governor's Energy Council meetings.
- Several ERRC researchers participated in the Animal Tissue Biomass Workshop at the Energy Institute at Penn State University. At this workshop, stakeholders from animal agriculture and the energy industry evaluated issues surrounding the use of animal tissue (including fat) for fuel.



- On request, provided guidance, expertise, and methods to researchers at Penn State University, as they built a biodiesel production module into their undergraduate engineering curriculum.

- Staff scientists are members of the research committee of the rendering industry's Fats and Proteins Research Foundation (Alexandria, VA). This committee advises the foundation on the relevance and validity of research proposals sent to it. A significant portion of these proposals addresses the use of animal fats in biodiesel and other energy applications.



- By request, provided advice, expertise, and methodology to United Biofuels, York, PA, allowing them to set up a more rigorous analytical capability. This allowed improvement of their production operation and an increase in product consistency and quality.

- A group member has been twice invited by the Regional Economic Development District Initiative (REDDI) of South Central PA to serve as co-organizer and session presenter in Renewable Energy Symposia. REDDI Targets urban and rural economic development projects, with strong links to agriculture and particular focus on the biofuels sector.



- Invited to establish a collaboration between ARS and GOSNIOKhT, a Russian research facility, to plan research on biodiesel production. ERRC, NCAUR, and GOSNIOKhT researchers together designed the first project on biodiesel in Russia; the project was ultimately funded by the Canadian government.

- The Unit leader and another Unit scientist served on a committee that helped to set research priorities for the new Animal Co-Products Research and Education Center at Clemson University. The "virtual" Center is the only such U.S. entity on animal coproducts; its focus offers opportunities for collaboration, particularly as it studies the re-engineering of the rendering process and the use of the fat stream from the process for production of biofuels.



- Based on their recognized expertise in biodiesel research, Unit researchers have been invited to join a research consortium led by GreenFuels Inc. (CO). Progress in the planned collaborations will bring to reality the vision of algal-based biofuels (particularly replacements for military jet fuel JP-8).

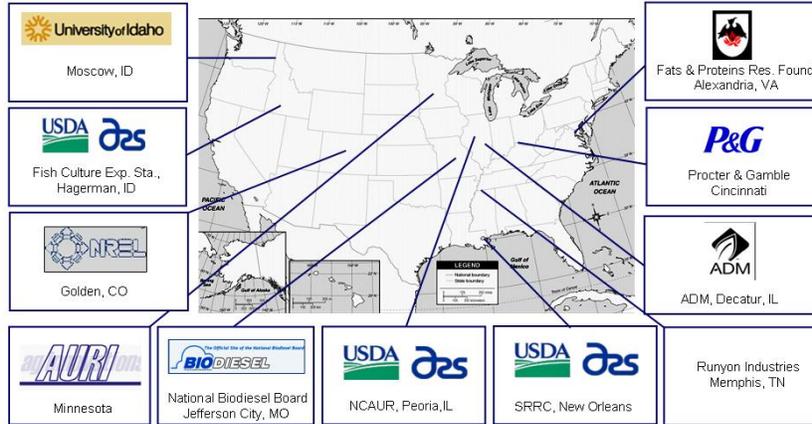
- Collaborated with Changing World Technologies (CWT; PA) to demonstrate the feasibility of producing biofuel from soybean soapstock (residue from soy oil refining) using CWT's thermal conversion technology for transforming organic materials into liquid and gaseous fuels and carbon black. CWT's process offers an alternative to ERRC's successful technology for conversion of soapstock to biodiesel.

- To foster community awareness of biodiesel, group members have actively participated as speakers before local panel discussions on alternative energy. The community activities were organized by a Pennsylvania Assembly representative and attended by Federal, State, and local officials, stakeholders, the public, and the press.

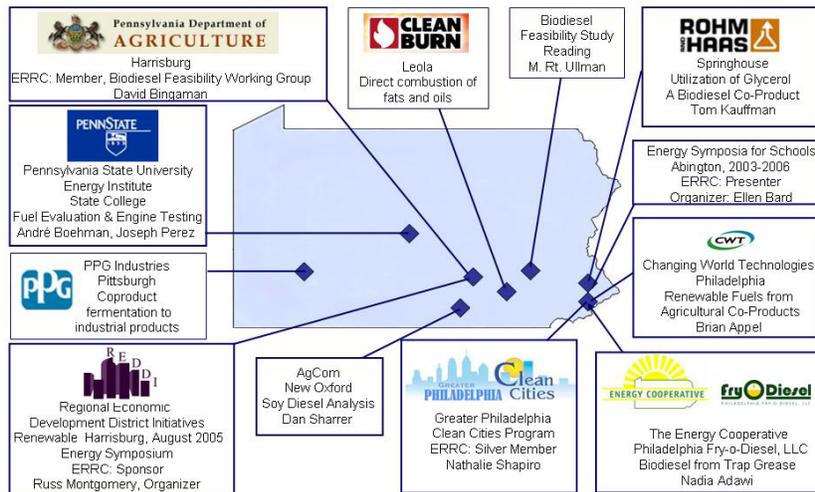


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**Biodiesel and Related Biofuels: American Collaborations**  
 (other than Pennsylvania)



**Pennsylvania Collaborations**



**Biodiesel and Related Biofuels: Worldwide Collaborations**

