April 1998 • NREL/SR-580-24433

Biodiesel Research Progress 1992–1997

K. Shaine Tyson, Editor

Prepared by

Information Resources, Inc.
Contract #: ACG-7-17046-01

Dyncorp Information & Engineering Technology
Contract #: YAH-5-15099-01

National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, Colorado 80401-3393
A national laboratory of the U.S. Department of Energy
Operated by Midwest Research Institute
for the U.S. Department of Energy
Under Contract No. DE-AC36-83CH10093

Acknowledgments

By IRI

Information Resources, Inc. gratefully acknowledges its sponsor at the U.S. Department of Energy, Dr. Raymond Costello and its technical monitor, Dr. K. Shaine Tyson, at the National Renewable Energy Laboratory. IRI also thanks Janine Finnell of DynCorp for her cooperation and patience in completing this project. The principal authors of this report wish to express their sincere gratitude to the endless support and guidance of Steve Howell and Alan Weber of MARC. Likewise, Bev Thessen, Information Manager for the National Biodiesel Board, deserves recognition for indulging the numerous questions and report requests necessary to complete a task of this order.

Finally, a special thanks goes to all those who willingly participated in this collection effort.

By DynCorp

The authors would like to acknowledge the efforts of Alan Weber, MARC-IV, who graciously provided input on a large number of the U.S. Department of Agriculture biodiesel project. A thanks also goes to David Pizzano of DynCorp's Energy Programs Group who helped to format the project information as well as review the document. Dr. Rene Tshiteya, Director, Planning and Analysis Center, assisted in reviewing and providing guidance as needed on the project.

I. Introduction and How to Use This Report

A. Introduction

Since the oil shortage during the late 1970s, the United States has imported more than $50 billion of oil annually, or 52% of its demand. Two-thirds of U.S. refineries have closed. Air pollution remains a threat to human health. Climate change has surfaced as a global concern requiring legally binding solutions. The U.S. farm economy continues to struggle for sovereignty.

For these reasons, the U.S. Department of Energy (DOE) Office of Fuels Development began evaluating the potential of various alternative fuels, including biodiesel, as replacement fuels for traditional transportation fuels. Biodiesel is derived from a variety of biological materials from waste vegetable grease to soybean oil. This alkyl ester could be used as a replacement, blend, or additive to diesel fuel.

This document, funded by DOE, is a comprehensive summary of relevant biodiesel and biodiesel-related research, development, demonstration, and commercialization projects completed and/or started in the United States between 1992 and 1997. This document was designed for use as a reference tool to those evaluating biodiesel's potential as a clean-burning alternative motor fuel. It encompasses federally, academically, and privately funded projects.

DOE chose to review the past 5 years of research for the following three reasons. Research before 1992 revolved largely around vegetable oil, rather than esterified oil, as a direct replacement for diesel fuel. Further, alkyl ester research and development in the United States began with the formation of the National SoyDiesel Development Board (now called the National Biodiesel Board [NBB]) in 1992. More importantly, DOE anticipates that this compilation will serve as a foundation for the evolution of a 5-year strategy for biodiesel development and improve coordination for future research.

B. How to Use This Report

This report is a summary of biodiesel research completed from 1992 through 1997. To help the readers access the information included in this summary document, we have organized the subject matter by a number of search mechanisms.

The Table of Contents is the best place to begin. It contains headings and page numbers for all projects included in the report. Additional information on projects, papers, or sponsoring organizations can be found in the indexes. The indexes are broken down into three categories by Project Title, Paper Title, or Sponsoring Organization.

For information on a specific topic, begin by searching the Table of Contents. The projects are divided into sections and subsections. However, be aware that some projects may fall into more than one category. To find a project that fits into this classification, go to the lead page of that section or subsection for a list of papers that have been cross-referenced to that category.

The index section is helpful if the name or approximate name of the project or paper is known. Although paper and project titles are often similar, both indexes should be checked in case the larger project has a different name than its primary paper.

The indexes are user friendly and very helpful for those with limited time. However, there is no substitute for taking the time to "thumb" through the entire document. The information included in this report is just a taste of the vast array of interesting work being done in the field.

As the authors sought input to this report, they were amazed by the sheer volume of projects in the area of biodiesel, with more than 350 projects identified. In earlier stages, the document was organized by project sponsors, but with the recommendation of NBB, the authors decided to organize it by topic to make it more useful to the reader. Seven categories of research were identified, including biodiesel production; fuel characteristics; engine data; regulatory and legislative activities; commercialization activities; economics and environment; and outreach and education. Numerous subcategories were further developed to guide a reader interested in more focused topics through the report; e.g., the engine data category is divided into emissions, durability, and maintenance activities. Overall, the largest volumes of biodiesel projects were conducted in the areas of biodiesel fuel properties, emissions data, and commercialization/ demonstration activities.

Although we have worked to make this report as comprehensive as possible, the following caveats apply. Time and budget constraints in any report require authors to set deadlines regarding additional submissions to finalize project data. In addition, despite our best efforts to seek input from leading biodiesel experts, inevitably in a document of this nature, some projects may be overlooked to the massive quantity involved.

As this report will be provided on a web site, we are examining the possibility of adding new project information as it becomes available. We invite you to contact the webmaster to express your opinion on whether it would be useful to update and expand upon this report as more biodiesel research is conducted in the future.

Project Title:

Biodegradation of Synthetic Diesel

Background: This program involves the extension of methodologies for evaluating oil spill protocols for conventional petroleum products to the special case of biodiesel. The biodiesel and biodiesel blends will be tested under oxic and anoxic conditions in three environments: marine, freshwater, and soil microcosms. The disappearance of the biodiesel materials will be monitored using protocols previously developed for determining the effects of bioremediation agents on petroleum products. The rates of degradation will followed by loss of target compounds and by following oxygen uptake and/or by carbon dioxide evolution. GC/MS will be used to measure material decomposition.

Objectives:

- Develop a methodology to evaluate the biodegradability of biodiesel materials in oil spill environments.
- Determine biodegradability under varying environmental conditions of microcosms, e.g., aerobic and anaerobic.
- Develop methodologies to assess the biodegradability of biodiesel.
- Characterize marine and sulfate-reducing bacterial isolates that degrade biodiesel.
- Screen new bacterial isolates for the degradation of both biodiesel and petroleum diesel.
- Determine biological and chemical dynamics for biodiesel blends.
- Investigate biodiesel degradation and biodiversity in storage tanks.

Status: September 1993-August 1996.

Accomplishments:

- Completed the characterization of the aerobic and anaerobic biodiesel degrading species isolated from fresh water.
- Tested sulfur compounds (e.g., sulfate, sulfite, and thiosulfate) as alternative electron acceptors for anaerobic degradation.
- Began studies on the characterization of the biodegradation pathway and initiated studies on dynamics of biodiesel blends.
- Tested sulfate, thiosulfate, and sulfite as alternative electron acceptors in the anaerobic degradation of biodiesel.
- It appears that sulfate, sulfite, or thiosulfate cannot be used as a terminal electron acceptor when well-aerated freshwater samples were used as inoculum.
- Sulfate and biodiesel did support growth when anoxic samples were used as inoculum and cautions were taken not to aerate the sample.

Participants: Duquesne University

Sponsoring Organization(s): U.S. Department of Agriculture-Cooperative State Research, Education, and Extension Service

Point of Contact: John Stolz, Department of Biological Sciences, Duquesne University, Pittsburgh, PA 15282, phone 412.396.6333.

Papers:

Buzzell, J. and J.F. Stolz (1995). "Pseudomonas Oleovorans Is a Gamma Proteobacterium." Int, J. System. Bac. (under revision).

Follis, Paige, J. Buzzell, G. Floro, R. Donofrio, W. M. Griffin, and J. F. Stolz (1995). "Aerobic and Anaerobic Biodegradation of the Methyl Esterified Fatty Acids of Soy Diesel in Freshwater and Soil Environments." *Appl. Environ. Microbiol.*

Additional Information: CRIS Accession No.: 9163215

Project Title:

Toxicity of Particulate and Semi-Volatile Emissions from SME and Biodiesel Blended Fuels

Background: One group of toxicologically important compounds that may be present in diesel, and potentially in biodiesel exhaust emissions, are PAHs and their substitute derivatives nPAHs. Some PAH and nPAHs are potent mutagens and carcinogens in laboratory animals and in humans. This research may be very timely as the current suit against California refineries and trucking associations progress, which charges that diesel exhaust emissions are a health hazard. Previous research on RME and REE indicates that biodiesel may reduce the toxic nature of petroleum exhaust. NREL took advantage of several ongoing engine tests to collect data for this project.

- CIFER portion of the project: This project takes advantage of ongoing research under the **Multi-Feedstock Biodiesel Project**, by placing a separate subcontract with CIFER to perform additional research. This project is designed to add funds to CIFER to perform the additional emissions analysis. Specifically, this project requires CIFER to include cold transient tests, C1-C12 and aldehyde speciation, and additional particulate sample collection for bioassay analysis while conducting research to support the Multi-Feedstock Biodiesel Project. All biodiesel tested in this portion of the project are 20% biodiesel and 80% test diesel blends.

- NBB and Caterpillar portion of the project: NBB is working cooperatively with Caterpillar to collect emission data from a 3406 D test engine at Caterpillar's Peoria, IL laboratory. NREL will support the the University of California-Davis staff time and expenses necessary to collect sufficient quantities of particulate and SOF emissions for bioassay analysis. NBB and Caterpillar will be collecting speciated emission data (PAH, nPAH) to support health effects research. Only neat SME is tested in this part of the test.

- University of California-Davis: UCD will conduct chemical analyses on the particulate and vapor emissions from SME from the Caterpillar testing as well as conduct bioassay tests to determine the mutagenic potential of the particular emissions. USDA will also conduct bioassay analyses on the biodiesel blends used in the Multi-Feedstock project, which include: yellow grease, tallow, lard, soy, and acidulated soapstocks.

Objective: To develop a body of data for submission to EPA that describes the chemical and biological characteristics of vapor- and solid-phase particulate emissions to support the registration of biodiesel under 40 CFR 79, Section 211 (f) "Registration of Fuels and Fuel Additives."

Status: The project has just been initiated and will run through September 1998.

Accomplishments:

NBB and Caterpillar project:

- The testing was completed on two Cummins 1988 L10 engines joined in tandem. The test runs for 125 h on a cycle that alternates between driving and motoring of each engine. The pass/fail criteria for this test are based on carbon and lacquer deposits (CRC) rating) on the injector plunger, as well as loss specification of the complete injector.
- Based on the results from the Cummins L10 Injector Deposit Test, the use of 20% biodiesel blended with various petrodiesel fuels increases injector deposits. However, adding commercially available detergency additive can reduce the deposit formation to the

equivalent level experienced with neat petrodiesel. Further testing is required to procure an additive that can be blended with the petrodiesel and biodiesel mixture to reduce deposits levels to within the passing range on the L10 Injector Deposit Test.

Participants: Colorado Institute for Fuels and Engine Research, Colorado School of Mines, National Renewable Energy Laboratory, University of California-Davis; and MARC-IV Consulting, Inc.

Sponsoring Organization(s): U.S. Department of Energy Office of Fuels Development, Caterpillar Inc.

Point of Contact: Dr. K. Shaine Tyson, National Renewable Energy Laboratory, 1617 Cole Blvd., Golden, CO 80401, phone 303.275.4616, fax 303.275.4675, e-mail tysonk@tcplink.nrel.gov.

Papers:

"Health-Related Emissions from Various Biodiesel Blends in a DDC Series 60 Engine," forthcoming.

"Bioassay Analysis of Biodiesel Produced from Low Value Feedstocks," forthcoming.

"Chemical and Bioassay Analysis of SME PM Emissions from a Caterpillar 3406/435 HP," forthcoming.

IV. Engine Data

Also see the following projects:

Multifeedstock Biodiesel Project

Technology for Efficient Use of Agricultural **Resources**

Project Title:

2-Cycle Engine 200 Hour EMA Test with Hydrogenated Soy Ethyl Ester (HySEE)

Background: In adding to the body of literature on biodiesel performance, this study was undertaken to develop data on 2-cycle engine use of HySEE as a lubricant.

Objectives: The objective of this project was to determine whether the bio-lubricant HySEE could be used in small two-cycle engines. The University of Idaho conducted the 200-h Engine Manufacturers Association engine test.

Status: Project completed December 31, 1995

Accomplishments: Six fuels were evaluated and a final report was produced.

Participants: University of Idaho

Sponsoring Organization(s): Pacific Northwest and Alaska Regional Biomass Energy Program

Point of Contact: Dr. Charles L. Peterson, Department of Agricultural Engineering, University of Idaho, Moscow, Idaho 83844; phone208.885.7906, fax 208.885.8923, e-mail peterson@novell.uidaho.edu.

Papers:

Screening Test for Rape Ethyl Ester 2-Cycle Oils. February 15, 1996.

Project Title:

Alternative Fuels and Lubricants from Rapeseed

Background: Production, processing, engine testing, and fuel properties will be used to determine application of rapeseed as a potential engine fuel.

Objectives:

- Determine problems associated with the use of RME in commercial use such as material compatibility, storage life, handling problems, and low-temperature operation in on-road and off-road vehicles.
- Develop a process of REE comparable to RME.
- Determine performance, durability, and possible engine modifications for optimizing efficiency of engines fueled with both REE and RME.
- Determine the performance of the RME and REE fuels in engine injector coking tests, EMA engine test evaluation cycles, and long-term endurance tests.
- Investigate biodegradability, emissions, and other environmental advantages of RME and REE in comparison to No. 2 diesel fuel.
- Develop criteria for RME and REE fuel standards and standard test procedures, which can be used to ensure manufacturers of a consistent quality of rape oil-based fuels.
- Investigate the potential of biodegradable, rape oil-based lubricants and hydraulic oils.

Status: Project initiated in January 1994 and is scheduled to be completed by January 1998.

Accomplishments:

- The on-farm biodiesel plant expressed 22,500 kg of rapeseed in 1996 resulting in 9,710 L of oil. More than 18,900 L of biodiesel, all but 2,000 L with ethanol, was produced, of which 6,358 L was from used oil and 6,124 L for our joint project with Yellowstone Park. Biodiesel produced from the used hydrogenated soy oil is usable as a fuel but has a high PP, making it a challenge for use in cold weather.
- Tests are continuing with three of the on-road vehicles; the 1992 Ford has reached 76,985 miles, the 1994 Dodge 56,852 miles, the 1995 Dodge about 60,000 miles and the 1992 diesel vehicle operated by IDWR, completed the 100,000-mile milestone. Cummins Engine Co. evaluated the engine which showed less deposits and the engine which showed less deposits and wear than a similar engine operated on diesel. Two items showed some distress. The front and rear oil seals were hardened slightly. Varnish was apparent in the injector pump.
- Acute oral toxicity limit tests showed that RME and REE (biodiesel) had LD50 values greater than 5,000 mg/kg when administered once orally to albino rats and acute dermal toxicity tests showed LD50 values greater than 2,000 mg/kg when administered once to the clipped, intact skin of albino rabbits. The biodegradability and biodegradation rates of several biodiesel fuels in the aquatic environment show that all biodiesel fuels are readily biodegradable. After 28 days, all biodiesel fuels were within the range: 77%-89% biodegraded; diesel fuel was only 18% biodegraded.

Participants: Department of Biological and Agricultural Engineering, University of Idaho

Sponsoring Organization(s): U.S. Department of Agriculture-Cooperative State Research, Education, and Extension Service

Point of Contact: Dr. Charles L. Peterson, Department of Agricultural Engineering, University of Idaho, Moscow, ID 83844, phone 208.885.7906, fax 208.885.8923, e-mail peterson@novell.uidaho.edu

Papers:

Hammond, B.L. (1996). "Performance and Durability Testing of Diesel Engines Using Ethyl/Methyl Ester Fuels." An unpublished MS thesis, Dept. of Biol. and Agr. Engr., University of Idaho, Moscow, ID.

Peterson, C.L. and D.L. Reece (1996). "Emissions Characteristics of Ethyl and Methyl Ester of Rapeseed Oil Compared with Low Sulfur Diesel Control Fuel in a Chassis Dynamometer Test of a Pickup Truck." Trans. of the ASAE 39(3)-805-816.

Peterson, C.L., D.L. Reece, J.C. Thompson, S.M. Beck and C. Chase (1996). "Ethyl Ester of Rapeseed Used as a Biodiesel Fuel - A Case Study." *Biomass and Bioenergy* 10(5/6):331-336.

Peterson, C.L., D.L. Reece, B.L. Hammond, J.C. Thompson and S.M. Beck (1997). "Processing, Characterization and Performance of Eight Fuels from Lipids." *Applied Engr. in Agr.* 13(I):71-79.

Peterson, C.L. and D.L. Reece (1996). "Emissions Testing with Blends of Esters of Rapeseed Oil Fuel with and without a Catalytic Converter." SAE Paper No. 961114. SAE, Warrendale, PA.

Peterson, C. L.; Hammond, B. L.; Reece, D. L. (1996) "Engine Performance and Emissions with Methyl and Ethyl Esters of Rapeseed Oil." *Proceedings of the Third Liquid Fuels Conference,* September 15-17, Nashville, TN. Liquid Fuels and Industrial Products from Renewable Resources, pp.116-127.

Thompson, J. C.; Peterson, C. L.;, Reece, D. L.; Beck, S.M. (1996) "Two Year Storage Study with Methyl and Ethyl Esters of Rapeseed" *Proceedings of the Third Liquid Fuels Conference,* September 15-17, Nashville, TN. Liquid Fuels and Industrial Products from Renewable Resources, pp.104-114.

Additional Information: CRIS Accession No.: 9164150

Project Title:

Identification of Chemical Changes Occurring during the Transient Injection of Selected Vegetable Oils

Background: A number of engine experiments indicate that vegetable oils used as fuels for diesel engines create durability problems in many of these engines. The direct durability problems include nozzle coking, engine deposits, and lube oil dilution. The indirect problems include ring sticking, scuffing of the cylinder liners, injection nozzle failure, and lubricant failure due to polymerization of the vegetable oil. Most experience indicates that the durability problems are more severe in direct-injection engines than in the indirect-injection engines.

Objectives:

- Determine whether the vegetable oils change chemically during the diesel type of injection into a high-temperature, high-pressure environment of nitrogen.
- Determine the nature of the chemical changes, if detectable, and identify any new compounds formed during the process.

Status: 1993

Accomplishments:

- Major changes in the chemical makeup of vegetable oils occur during injection. These consist of fractures of the large molecules and the formation of lower molecular weight compounds.
- The IR analyses indicate the presence or formation of free carboxylic acid, trans-olefins, cis-olefins and terminal olefins.
- The analyses of the transesterified and esterified samples indicate that the polyunsaturated fatty acids are most affected by the injection process. It appears that the lower molecular weight materials result from breakdown of the linoleic and linoenic acids.
- The chemical changes that occur during the injection process could account for the unexpected spray characteristics of the vegetable oils.

Participants: Southwest Research Institute

Sponsoring Organization(s): U.S. Department of Agriculture

Point of Contact: Thomas W. Ryan III, Southwest Research Institute, 6220 Culebra Road, San Antonio, TX 78238-5100, phone 210.684.5111, fax 210.522.3496.

Paper(s):

Ryan, T.W.; Bagby, M.O. (1993). "Identification of Chemical Changes Occurring during the Transient Injection of Selected Vegetable Oils." *New Developments in Alternative Fuels and Gasolines for SI and CI Engines (SP-958)*, March 1-5, Detroit, MI. SAE # 930933. Warrendale, PA: Society of Automotive Engineers, pp. 201-210.

Project Title:

Industrial Agricultural Products Center

Background: This is a broad-based project with a component on biodiesel research. Research activity includes in the areas of starch-based plastic foams, plant protein films, and tallow and soybean oil processing and use as biodiesel. Industrial uses of beef tallow are being assessed along with processing technologies, ester properties, and biodiesel emissions and engine performance.

Objectives:
- Identify niche markets for industrial use of agricultural-based products.
- Improve and develop conversion processes as needed for specific product isolation and use.
- Provide technical, marketing, and business assistance to industries.
- Coordinate agricultural industrial materials research at the University of Nebraska-Lincoln.

Status: Project initiated in July 1993 and is scheduled to be completed by September 1998.

Accomplishments:
- A Cummins N14-410 engine was operated on 12 fuels produced by blending methyl tallowate, methyl soyate, and fuel ethanol with No. 2 diesel fuel. Peak rates of heat release for all fuels were less than for No. 2 diesel fuel. When methyl tallowate was blended with No. 2 diesel fuel, the shift in the location of peak heat release was away from TDC, whereas the addition of ethanol to the blend shifted the location toward TDC. Ignition delay slightly decreased when methyl tallowate was blended with diesel fuel. However, ignition delays were not affected by the methyl tallowate or ethanol contents of the blends. The charge temperature decreased with decrease in diesel content of fuel blends. The indicated mean effective pressure and maximum rate of pressure rise values for all fuel blends were less than for diesel fuel.

- It was concluded that the fuel blends used in this study would have no detrimental long-term effects on engine performance, wear, and knock. Mixtures of starch (25% amylase), ethylene glycol, and concentrated sulfuric acid were extruded in a Brabender laboratory conical-twin-screw extruder with postextruder reactor modifications. Temperature, ethylene glycol-starch mole ratio, and screw speed were permuted to enhance the yield of glycosides. Optimum process conditions of 160ºC, 20-rpm screw speed, and mole ratio of 3 with a static mix and cooler gave 91% yield of glycosides.

Participants: Industrial Agricultural Products Center, University of Nebraska

Sponsoring Organization(s): U.S. Department of Agriculture-Cooperative State Research, Education, and Extension Service

Point of Contact: Milford Hanna, Director, Industrial Agricultural Products Center, 211 LW Chase Hall, University of Nebraska-Lincoln, Lincoln, NE 68583-0730, phone 402.472.1624.

Papers:

Ali, Y. and Hanna, M.A. (1997) . "In-cylinder pressure characteristics of a D.I. heavy-duty diesel engine on biodiesel fuel." SAE Technical Paper Series 971683. State of Alternative Fuel Technologies--1997, pp. 143-151. SAE International, Warrendale, PA.

Ali, Y. and M.A. Hanna (1996). "Durability testing of diesel fuel, methyl tallowate and ethanol blend in Cummins N14-410 engine." Trans. of the ASAE. 39 (3): 793-797.

Ali, Y., M.A. Hanna, and J.E. Borg (1996). "Effect of alternative diesel fuels on heat release curves for Cummins N14-410 diesel engine." Trans. of the ASAE. 39 (2): 407-414.

Ali, Y., M.A. Hanna, and J.E. Borg (1996). "In-cylinder pressure characteristics of a CI engine using blends of diesel fuel; and methyl esters of beef tallow." Trans. of the ASAE 39( ):799-804.

Ali, Y., M.A. Hanna (1996). Durability testing of diesel fuel, methyl tallowate and ethanol blend in.

Ali, Y., M.A. Hanna, J.E. Borg (1996). Effect of alternative diesel fuels on heat release curves fo.

Ali, Y., M.A. Hanna, J.E. Borg (1996). In-cylinder pressure characteristics of a CI engine using bl.

Bhatnagar, S. and M.A. Hanna (1996). Effect of Talc on Properties of Corn Starch Extrudates. Starke. 48.

Ghorpade, V.M. and M.A. Hanna (1996). Mechanical Properties of Soy Protein-Polyethylene Ribbon and Film.

Ryu, D., S.K. Katta, L. Bullerman, M.A. Hanna, and A. Gennadios (1996). Microbial Stability of Methyl.

Subramanian, K. and M.A. Hanna (1996). Glycol glycosides synthesis by reactive extrusion with a stat.

Additional Information: CRIS Accession No.: 9161844

Project Title:

Monitor Biodiesel Use in Selected Tactical Vehicles at Yuma, Arizona

Background: A biodiesel fuel evaluation was performed on various U.S. Army tactical wheeled vehicles from March 1994 through March 1995 at the U.S. Army Yuma Proving Ground. Testing was conducted to compare vehicle system performance when the vehicles were operated with a 80%/20% JP-8/biodiesel fuel blend instead of neat (or 100%) JP-8 fuel. The vehicle types under test included the Commercial Utility Cargo Vehicle, High Mobility Multipurpose Wheeled Vehicle, M939A2 Series of 5-Ton Truck, Heavy Expanded Mobility Tactical Truck and the M915A2 Truck-Tractor.

Objective: To collect data and evaluate the relative performance of a 80/20 JP-8/biodiesel blend fuel mixture compared to neat-JP-8 and DF-2 fuels in different wheeled vehicle systems.

Status: Program was funded in FY 1993 and completed in FY 1995.

Accomplishments:

- Preliminary vehicle testing at Yuma Proving Ground has been completed.
- Research found that biodiesel in a 20% blend with JP-8 reduces emissions and enhances acceleration.

Participants: U.S. Army Tank - Automotive and Armaments Command

Sponsoring Organization(s): U.S. Department of Agriculture-Cooperative State Research, Education, and Extension Service

Point of Contact: Carmela Bailey, USDA-CSREES, 910 D. Street, SW, Aerospace Bldg. 8th Floor, Washington DC, phone 202.401.6443

Papers:

Lucas, W. Materiel Test Directorate. U.S. Army Yuma Proving Ground, Yuma, Arizona. "Summary Test Report for the Biodiesel Fuel Evaluation for the U.S. Army Tactical Wheeled Vehicles, Volume I of Series." Prepared for the U.S. Army Tank-Automotive and Armaments Command , Warren, MI and U.S. Army Test and Evaluation Command, Aberdeen Proving Ground, MD. May 1995. TECOM Project No. 1-EG-095-000-028.

Project Title:

Power, Emissions, and Bioresponse of Biodiesel in a Marine Environment

Background: The use of biodiesel in an unmodified, commercially available marine diesel engine was tested under dynamometer-controlled load conditions.

Objective: To contrast engine performance and potential effect on the environment when the engine was fueled with 100% SME (biodiesel) versus 100 No. 2 petroleum diesel (petrodiesel).

Status: Completed

Accomplishments:

- The four-cylinder, turbocharged, intercooled direct-injection diesel engine produced from 2% to 7% less power when fueled with biodiesel.
- The production of CO was significantly reduced and soot was reduced by using biodiesel.
- Biodiesel produced greater power than petrodiesel when the engine was operated at full throttle at speeds less than 2650 rpm.
- Dosed water with biodiesel exhaust at 50% engine load setting resulted in "no-detect" in PAHs.

Participants: University of Tennessee

Sponsoring Organization(s): NBB, Tennessee Agricultural Experiment Station, and Volvo-Penta

Point of Contact: Ms. Bev Thessen, National Biodiesel Board, P.O. Box 104898, Jefferson City, MO, 65110-4898, phone 573.635.3893, fax 573.635.7913, e-mail biodiesel@sockets.net.

Paper(s):

Womac, A. R.; Stange, R, J.; Crouch, J. A.; Easterly, C. (1996) " Power Emissions, and Bioresponse of Biodiesel in a Marine Environment". *Proceedings of the Third Liquid Fuels Conference,* September 15-17, Nashville, TN. Liquid Fuels and Industrial Products from Renewable Resources, pp.177-190.

A. Emissions

Also see the following projects:

Biodiesel Fuels--Vegetable Oil/Alcohol Blends

Biomass-Derived Alternatives in High Performance Snowmobile Engines: A Snowmobile in the Park

Bi-State Development Agency Alternative Fuel Bus Testing of 10 Buses

Clean Air Partners--Biodiesel Water Shuttles at Logan Airport

Demonstrate and Promote Biodiesel as a Transportation Fuel

Demonstrate Biodiesel in Commuter Trains and Buses

Developing Yellow Mustard (Sinapis Alba L.) Cultivators Suitable for Biodiesel Production in the United States

Development of Rapeseed Biodiesel for Use in High-Speed Diesel Engines

Expanded Rapeseed Ethyl Ester (REE) Demonstration and Testing, and Cooperative Development of Hydrogenated Soy Ethyl Ester (HySEE) Biodiesel

Over-the-Road Heavy-Duty Diesel Engine Operational Demonstration

Rapeseed Oil as a Fuel for Agriculture

Second Workshop: Commercialization of Biodiesel, Environmental and Health Benefits

Twin Cities, Minnesota Biodiesel Pickup Truck Demonstration

Use of Vegetable Oil as Fuel for Compression Ignition, Internal Combustion Engines

Project Title:

Agricultural and Rural Transportation Systems

Background: There is a small component on biodiesel in this project although the project's main focus is on examining structural changes in the U.S. grain transportation and marketing infrastructure.

Objective: The project's objective related to biodiesel was to evaluate the practicality and economic potential for using biodiesel fuelsto reduce particulate levels in mines to meet new EPA and OSHA standards.

Status: Project initiated in October 1994 and scheduled to be completed by September 1997.

Accomplishments:

- Completed joint project with the University of Minnesota Center for Biodiesel Research evaluating the practicality and economic potential for using biodiesel fuels to reduce particulate levels in mines to meet new EPA and OSHA standards. Blends of 0%, 30%, 70%, and 100% biodiesel and regular diesel were compared to systems using catalytic converters and/or filters for lifetime net present value and annual variable costs to meet various PM levels in two model mines.
- Although technically feasible, we found that at current levels of more than $3.00/gal, biodiesel fuel is not economical. However, at costs of less than $2.50, biodiesel would be considered by coal mines and by metal mines if less than $2.00.

Participants: Applied Economics, University of Minnesota

Sponsoring Organization(s): Applied Economics, University of Minnesota, U.S. Department of Agriculture-Cooperative State Research, Education, and Extension Service

Point of Contact: J.E. Fruin, Applied Economics, University of Minnesota, St. Paul, MN 55108, phone 612.625.8720.

Papers:

Fruin, J. E. "The Transportation Industry in Rural America." In press, *The Encyclopedia of Rural America.*

Fruin, J. and D. Halbach (1996). "The Influence of Rural Road Quality on Vehicle Fuel Consumption." *1996 Semisesquicentennial Transportation Conference,* May 13-14, Iowa State University Center for Transportation Research and Education.

Additional Information: CRIS Accession No.: 9164964

Project Title:

Biodiesel Blends in a DDC Series 60 Engine at High Altitude

Background: Not available.

Objective: To examine regulated emissions for neat soy-based biodiesel with commercial No. 2 diesel fuel using a 1991 model DDC Series 60 heavy-duty diesel engine.

Status: July 1994-August 1994

Accomplishments:

- Thirty-one transient tests were conducted on both fuels. The diesel reference fuel was tested before and after each blend to permit corrections for engine drift. One cold and three hot runs were made for each fuel. Cold, hot, and composite regulated emissions were reported.
- Biodiesel significantly decreased HC, CO, and particulate emissions, but increased NO_x emissions.
- The data were analyzed to predict blend-diesel modifications necessary to produce NO_x neutral blends relative to the commercial diesel.

Participants: Colorado School of Mines and National Renewable Energy Laboratory

Sponsoring Organization(s): U.S. Department of Energy Office of Heavy Vehicle Technologies

Point of Contact: Michael Graboski, Colorado School of Mines, Colorado Institute for Fuels and Engine Research, Golden, CO 80401, phone 303.273.3246 or 303.299.3143, fax 303.299.3142.

Papers:

Graboski, M.S. (1994). *Emissions from Biodiesel Blends and Neat Biodiesel from a 1991 Model Series 60 Engine Operating at High Altitude.*

Graboski, M.S., J.D. Ross, R.L. McCormick, and B.K. Bailey (1994). *Transient Emissions from No. 2 Diesel and Biodiesel Blends in a DDC Series 650 Engine.* In preparation, to be submitted to SAE.

Project Title:

Bioblended Fuel for Use in Light-Duty Compression Ignition Engines

Background: The intention for this project was to develop baseline performance information on biodiesel use in this type of engine.

Objectives: Examine the blending of biodiesel fuel with ethanol to form a bioblended fuel for use in light-duty compression ignition engines. The project examined engine/fuel performance in the areas of emissions, fuel economy, driveability, durability, and cost of operation. Primary testing was done on an engine dynamometer. The secondary testing was involved the use of a chassis dynamometer where a research vehicle was evaluated using the bioblended fuel. Depending on how the first two phases looked, road testing for driveability, durability, and fuel economy made up the final phase of the research.

Status: FY 1995-FY 1996

Accomplishments:

- The contractors found general improvement in the emissions with blends of biodiesel and ethanol compared with petroleum-based diesel. Levels of HC emissions were lower with blends of biodiesel, especially during open throttle conditions. 100% biodiesel yielded a 71.4% drop in HC emissions.
- Levels of NO_x emissions generally increased with increased concentrations of biodiesel when blended with No. 2 diesel; however, as the concentration of ethanol in the mix increased, the levels of NO_x decreased.
- Particulate emissions were reduced by 81% over No. 2 diesel with a blend of 15% ethanol and 85% biodiesel.
- In addition, no compatibility problems were identified with fuel system components at any concentration of biodiesel, of ethanol. However, some cold start problems and reduced fuel economy were identified.

Participants: Mankato State University

Sponsoring Organization(s): Great Lakes Regional Biomass Energy Program

Point of Contact: Drs. Bruce Jones & Kirk Ready, Mankato State University, P.O. Box 8400, Mankato, MN 56002-8400, phone 507.389.6700.

Papers:
Draft Report: *Bioblended Fuel for Use in Light-Duty Compression Ignition Engines.*

Project Title:

Biodiesel Steamboat Test on the Ohio River

Background: The purpose of this study is to test the operational and emissions levels of a cleaner fuel on the Ohio River.

Objective: To develop and test a biodiesel steamboat operating under normal conditions on the Ohio River with help from PUC of Ohio and the University of Cincinnati.

Status: September 1995-November 1995.

Accomplishments:

- A steamboat operating on diesel, a 50/50 biodiesel/diesel blend and 100% biodiesel was tested.
- The steamboat was measured for CO and particulates while operating under loaded conditions.

Participants: Public Utilities Company and University of Cincinnati

Sponsoring Organization(s): Public Utilities Company, University of Cincinnati

Point of Contact: Bill Manz, Public Utilities Commission, 77 S. High Street, 26th Floor Columbus, OH 43215, phone 614.466.7429; Claude Eggleton, Public Utilities Commission, phone 614.466.7707, e-mail claude.w.eggleton@ohio.gov; Carl Tucker, Public Utilities Commission, phone 614.752.9838; Dan Durbin, University of Cincinnati, 5559 Foxrun Court, Cincinnati, OH 45239, phone 513.542.0795, e-mail daniel.durbin@uc.

Paper: Two videos and report to be released in the summer of 1997.

Project Title:

Biodiesel Use in Underground Metal and Non-Metal Mines

Background: As a result of the OPEC crisis, a significant amount of research on biodiesel and other domestically produced fuel was conducted by universities and government agencies. The general conclusion at that time was that biodiesel was a technically acceptable substitute, replacement, or blending stock for conventional petroleum diesel, but that its costs were prohibitive compared to petroleum-based diesel fuel. Concern about the health impacts of diesel fuel exhaust and proposed regulations has spurred the recent activities to commercialize biodiesel in North America and opened doors for its use in confined areas such as underground mines.

Objective: To outline the benefits and costs of biodiesel use in underground mines.

Status: May 1997

Accomplishments:

- The use of biodiesel in underground mines is an easily implemented control strategy, which has been demonstrated to reduce diesel PM and other diesel emissions.
- Biodiesel significantly reduces the Ames mutagenicity of diesel particulates.
- Biodiesel complements diesel and aftertreatment technologies and can be used as a stand-alone strategy or in combination with these future technologies.
- Biodiesel use provides other benefits to society such as reducing CO_2, reducing dependence on foreign petroleum, and creating domestic manufacturing jobs.

Participants: MARC-IV Consulting, Inc

Sponsoring Organization(s): MARC-IV Consulting, Inc, Consulting

Point of Contact: Alan Weber, MARC-IV Consulting Inc., 402 Oak Street, Ashland, MO 65010, phone 573.657.5537, fax 573.657.1058, e-mail aweber@marciv.com.

Paper(s):

Howell, S.; Weber, J.A. (1997). *Biodiesel Use in Underground Metal and Non-Metal Mines.* Kearney, MO: MARC-IV Consulting, Inc.

Project Title:

Biofuels Research

Background: Biofuels, made from agricultural crops, have the potential for making significant contributions toward achieving environmental, energy security, and increased demand for agricultural commodities goals. Additional emission and engine performance data about ethanol and ethanol blends need to be obtained and the benefits that will result from their increased use need to be provided to representatives of the biofuels industry, engine manufacturers, and state and federal agencies developing regulations.

Objectives:

- Conduct emissions and engine performance tests using a range of ethanol and gasoline blends with specific emphasis on NO_x and VOCs in the exhaust gases.
- Cosponsor working conferences on ethanol and biodiesel issues.
- Evaluate promising technologies for reducing the cost of biofuels production and provide limited support to enhance selected technologies.

Status: December 1996

Accomplishments: Funds under this project were previously distributed to the Eastern Regional Research Center for Biofuels Research.

Participants: U.S. Department of Agriculture-Agricultural Research Service, Eastern Regional Research Center

Sponsoring Organization(s): U.S. Department of Agriculture-Agricultural Research Service, Beltsville, Maryland

Point of Contact: Jill Statka, Agricultural Research Service, Eastern Regional Research Center, 301-504-5100

Papers: None available at this time.

Additional Information: CRIS Accession No.: 9146500

Project Title:

Chemical and Biological Characterization of Emissions from a Biodiesel-Fueled Underground Mining Diesel Engine with and without an Oxidation Catalytic Converter

Background: Very few comprehensive studies have been conducted on vegetable-based fuels, such as methyl soyate or biodiesel fuel, on engines designed for use in underground mining operations. Even less information is available on the impact of biodiesel fuels on toxic emissions such as PAHs, nPAHs, and mutagenic activity. The purpose of this study was to provide some of the detailed emission information necessary to evaluate the impact of using a biodiesel fuel on potentially health-related emissions from a diesel engine typical of those used in underground mining operations.

Objectives:

- Measure the toxic emissions, particularly PAHs, nPAHs, and mutagenic activity as well as alkaline-equivalent HC distribution in the particle and vapor phase samples obtained from an underground mining engine operated under transient conditions with three fuels with and without OCCs as control devices.
- Evaluate the effectiveness of the biodiesel fuels and control devices for potential use in the underground mine environment.

Status: December 30, 1995

Accomplishments:

- The amount of solid, carbonaceous component of the DPM appeared to be lower with biodiesel fuel as compared to the diesel fuel. Use of the blend fuel typically resulted in emissions reductions less than found with the diesel fuel.
- Major differences between diesel and biodiesel fuels were probably due to the presence of unburned methyl esters in the extracts of exhaust samples obtained when biodiesel fuel was used. Use of the OCC for the 90/10 cycle decreased the magnitude of the unburned fuel peaks.
- Whether or not the OCC was used, lower particle-associated and vapor phase mutagenic activity was typically found when using the biodiesel fuel than with the diesel fuel.

Participants: Michigan Technological University

Sponsoring Organization(s): Michigan Technological University, U.S. Bureau of Mines Twin Cities Research Center

Point of Contact: Susan T. Bagley, Michigan Technological University, 1400 Townsend Drive, Houghton, MI 49931-1295, phone 906.487.2385.

Paper(s):

Bagley, S.T.; Gratz, L.D.; Johnson, J.H. (1995). *Chemical and Biological Characterization of Emissions from a Biodiesel-Fueled Underground Mining Diesel Engine with and without an Oxidation Catalytic Converter.* Houghton, MI: Michigan Technological University. Available from the National Biodiesel Board, Jefferson City, MO 65110.

Project Title:

Comprehensive Emissions and Chemical Characterization of Rapeseed Oil-Derived Biodiesel

Background: The Montana Department of Environmental Quality in cooperation with RBEP and Chrysler were interested in developing data needed by potential markets and producers of rapeseed-based ethyl or methyl esters. This interest was the genesis for this project.

Objectives:

- Gain commercial acceptance and development of REE and RME.
- Provide emissions and performance data from tests conducted by an industry-accepted laboratory (of special interest are the results from toxic air emissions).
- Target heavy-duty diesel applications, especially environmentally sensitive applications such as the tourism industry's buses and trucks.

Status: FY 1995-FY 1996

Accomplishments:

- The complete biodiesel testing using a Cummins B diesel engine was completed by March 1996.
- Completion and publication of final testing report was concluded September 1996.

Participants: The University of Idaho; Montana Department of Environmental Quality; Dodge Truck Division of the Chrysler Corporation; Cummins Engine Company; J.R. Simplot; Koch Agricultural Services Company; and, the University of California-Davis.

Sponsoring Organization(s): Pacific Northwest and Alaska Regional Biomass Energy Program

Point of Contact: Howard Haines, Department of Environmental Quality, P.O. Box 200901, Helena, MT 59620-0901, phone 406.444.6773, fax 406.444.1804, e-mail hhaines@mt.gov.

Papers:

Sharpe, C. A. (1996). *Emissions and Lubricity Evaluation of Rapeseed Derived Biodiesel Fuels.*

Project Title:

DDC 6V-71N Emission Testing on Diesel & Biodiesel Blend

Background: The EPA has issued rules that require transit properties to reduce emissions on their engines after January 1, 1995, when rebuilding or replacing them. The test is intended to demonstrate reduction in emissions on older coach engines. If successful, a methyl soyate/ diesel blend could then be introduced into the marketplace as a means or option to comply, in part, with the EPA rulemaking.

Objectives:

- Demonstrate and determine whether a methyl soyate (biodiesel) blend could reduce emissions from older engines.
- Set up a test engine in its received condition in the EPA transient test cell and verifies engine performance.
- Conduct regulated gaseous and particulate EPA emissions tests on No. 2 EPA diesel fuel and on a 20%/80% methyl soyate/No. 2 EPA diesel blend.
- Compile, document, and summarize the results for NBB.

Status: July 12, 1994

Accomplishments:

- The results of the testing indicate that the use of a 20%/80 % blend, even in a well-used engine, significantly reduced emission of THC and CO.
- Extremely high particulate values with petrodiesel, particularly the soluble organic fraction of the particulate, indicated the need for a rebuild of the engine, which was accomplished.
- Biodiesel increases the SOF portion of the particulates and biodiesel's measured particulate reduction using engines with high SOF is diminished although visible reduction (opacity reduction) is still similar.
- After the rebuild a B20 blend, exhaust catalyst, and 4º engine retard produced reductions in all regulated emissions compared to the baseline diesel.

Participants: Fosseen Manufacturing & Development and ORTECH International

Sponsoring Organization(s): National Biodiesel Board

Point of Contact: Ms. Bev Thessen, National Biodiesel Board, P.O. Box 104898, Jefferson City, MO, 65110-4898, phone 573.635.3893, fax 573.635.7913, e-mail biodiesel@sockets.net.

Paper:

Fosseen Manufacturing and Development. (July 1994). *DDC6V-71N Emission Testing on Diesel and Biodiesel Blend.* NSDB 219-1. Jefferson City, MO: National SoyDiesel Board. Work performed by Fosseen Manufacturing & Development, Radcliffe, IA.

Project Title:

DDC 6V-92TA MUI Coach Upgrade Emission Optimization on 20%/80% Soy/Diesel Blends

Background: Increasingly stringent legislation on engine exhaust emission levels has resulted in research to use alternative fuels and blends to reduce emissions, especially NO_x and particulates.

Objectives:

- Document emissions on the test engines with EPA-base diesel, 20%/80% ME blend, a 30%/70% ME blend and a 20%/80% blend with the use of a catalyst.
- Optimize timing with the 20%/80% blend toward NO_x.
- Carry out EPA testing with and without a catalyst on the 20%/80% blend.

Status: November 30, 1993-September 30, 1994 Complete.

Accomplishments:

- Increasing emissions reductions are found on the 20% and 30% blends for CO and HC.
- NO_x is marginally increased and PM is marginally decreased with the optimized engine.
- The PM composition is changed with ME blends and carbon or insoluble fraction is observed.
- The OCC achieves a significant reduction in particulates.

Participants: Fosseen Manufacturing & Development, Ltd.

Sponsoring Organization(s): National Biodiesel Board

Point of Contact: Ms. Bev Thessen, National Biodiesel Board, P.O. Box 104898, Jefferson City, MO, 65110-4898, phone 573.635.3893; fax 573.635.7913; e-mail biodiesel@sockets.net.

Paper:

Fosseen Manufacturing and Development. (September 1994). *DDC 6V-92TA MUI Coach Upgrade Emission Optimization on 20%/80% Soy/Diesel Blend.* NBB 260-2 and 231-1. Jefferson City, MO: National Biodiesel Board. Work performed by Fosseen Manufacturing & Development, Radcliffe, IA.

Project Title:

Development of Biodiesel for Use in High-Speed Diesel Engines

Background: Alternative fuels, which will improve the environment, reduce the use of petroleum reserves, reduce foreign imports, and increase use of renewable fuels, are a U.S. priority. Locally produced rapeseed may be a solution to both petroleum depletion and environmental pollution.

Objectives:
- Find acceptable recipes for RME and REE.
- Determine whether RME and REE are acceptable substitutes for diesel fuel.

Status: Completed

Accomplishments:
- Biodiesel (both REE and RME) have been found to be acceptable substitutes for diesel fuel, performing normally in unmodified diesel engines.
- Recipes for producing both RME and REE have been developed and used to produce demonstration quantities of fuel.
- Biodiesel is safer because the flashpoint is more than 100ºF higher than that of diesel.
- Biodegradability of rape esters was higher than the biodegradability of reference dextrose and much higher than diesel fuel.
- Toxicity of biodiesel was at least 15 times less than diesel and probably much lower.
- Emissions tests have shown a reduction in HC, CO, and NO_x and an increase in CO_2 and PM. The results for PM are not significantly different from diesel, but the others were.

Participants: University of Idaho

Sponsoring Organization(s): Pacific Northwest and Alaska Regional Biomass Energy Program, Idaho Department of Water Resources, Energy Division, U.S. Department of Agriculture-Agricultural Research Service Cooperative Agreement

Point of Contact: Dr. Charles Peterson, Department of Agricultural Engineering, University of Idaho, Moscow, Idaho 83844, phone 208.885.7906, fax 208.885.8923, e-mail peterson@novell.uidaho.edu.

Paper(s):

Peterson, C.; Reece, D.; Thompson, J.; Beck, S.; Chase, C. (1994). "Development of Biodiesel for Use in High-Speed Diesel Engines." *Proceedings of the 6th National Bioenergy Conference, vol. I, Bioenergy '94,* Reno-Sparks, NV. Western Regional Biomass Energy Program, pp 97-104.

Project Title:

Effects of an Oxidation Catalytic Converter and a Biodiesel Fuel on the Chemical, Biological and Particle Size Characteristics of Emissions from an IDI Diesel Engine

Background: This study was conducted to obtain additional information on exhaust emissions and potential health effects from an indirect injection diesel engine, typical of those used in underground mines. This study will test the effects of using soy-derived, fatty acid mono-ester (or biodiesel) fuel and an OCC.

Objectives:

- Obtain samples of particulate and vapor phase organic material from a typical mine diesel engine operating on No. 2 diesel fuel and biodiesel fuel with and without an OCC control device.
- Determine the effects of fuels and OCC on the size and distribution of the diesel PM.
- Analyze all data obtained as part of this project in order to evaluate the effectiveness of the biodiesel fuels and control devices for potential use in the underground mine environment as a method for controlling TPM emissions.

Status: January 1997

Accomplishments:

- The project found the combination of reduced particles with deep-lung penetration would support the use of this biodiesel fuel for TPM-control with diesel engines in confined spaces.
- In order to achieve the maximum particulate reduction, an OCC is recommended when using biodiesel fuel for these applications.
- The use of biodiesel fuel should not increase any of the potentially toxic, health-related emissions that were monitored as part of the study.
- Further testing of this fuel in the field with an appropriate OCC is warranted to determine the effects of the fuel and the OCC on diesel PM in the ambient air.

Participants: Michigan Technology University, University of Minnesota

Sponsoring Organization(s): National Biodiesel Board

Points of Contact: Ms. Bev Thessen, National Biodiesel Board, P.O. Box 104898, Jefferson City, MO, 65110-4898, phone 573.635.3893, fax 573.635.7913, e-mail biodiesel@sockets.net. Susan T. Bagley, Department of Biological Sciences, Department of Mechanical Engineering, Michigan Technological University, 1400 Townsend Drive, Houghton, MI 49931-1295, phone 906.487.2385. Joseph F. McDonald, Center for Diesel Research, Department of Mechanical Engineering, University of Minnesota, 111 Church Street, SE, Minneapolis, MN 55455-0111, phone 612.725.4750.

Paper:

Bagley, S.T.; Gratz, L.D.; Johnson, J.H.; McDonald, J.F. (1997). *Effects of an Oxidation Catalytic Converter and a Biodiesel Fuel on the Chemical, Biological, and Particle Size Characteristics of Emissions from and IDI Diesel Engine.* Houghton, MI: Michigan Technological University. Available from the National Biodiesel Board, Jefferson City, MO 65110.

Project Title:

Effects of Methyl Esters of Tallow and Grease on Exhaust Emissions and Performance of a Cummins L10 Engine

Background: With the passage of the CAAA-90 came a renewed interest in clean-burning fuels. This research project was one of many that tested the emissions performance of biodiesel to understand its emissions-reducing potential.

Objectives: To determine the effect of TME and GME on the exhaust emissions from a Cummins L10-280E diesel engine

Status: September 16, 1993

Accomplishments:

- Exhaust emissions and performance tests with TME and GME fuels showed significant reduction in HC, CO, and particulates compared to low -sulfur base diesel fuel.
- NO_x emissions and fuel consumption increased.
- The fuel consumption and emissions responses to the TME and GME fuels were essentially the same as those to SME fuels.

Participants: IIT Research Institute, National Institute for Petroleum and Energy Research

Sponsoring Organization(s): Fats and Proteins Research Foundation, Inc.

Point of Contact: William Marshall, IIT Research Institute, National Institute for Petroleum and Energy Research, 220 North Virginia Ave., Bartlesville, OK 74005, phone 918.336.2400, fax 918.337.4365.

Paper(s):

Marshall, .W. (September 1993). *Effects of Methyl Esters of Tallow and Grease on Exhaust Emissions and Performance of a Cummins L10 Engine.* #B08861. Ft. Myers Beach, FL: Fats and Proteins Research Foundation, Inc. Work performed by National Institute for Petroleum and Energy Research, Bartlesville, OK.

Project Title:

Emission Characteristics of Methyl Soyate in Underground Mining Engines

Background: Underground mining is a particularly sensitive application for any engine because of the effects of emissions on air quality and the direct impacts on groundwater. This program focuses on the use of biodiesel fuel in the large, low-speed diesel engines characteristic of underground mining applications.

Objectives:

- Establish engine settings and conduct emission tests of test fuel on mine type diesel engines.
- Conduct chemical and biological assays to evaluate diesel exhaust for potential health effects.
- Test quantities of SME for engine emission evaluation from the AURI test pilot plant.
- Compare emissions from methyl ester fuels, specifically TME and distilled methyl esters of waste yellow grease, with results from previous SME testing to determine whether exhaust emissions are essentially similar.

Status: Project completed.

Accomplishments: Will be detailed in final project report.

Participants: Max E. Norris, Agricultural Utilization Research Institute c/o Southwest State University, Marshall, MN 56258

Sponsoring Organization(s): U.S. Department of Agriculture-Cooperative State Research, Education, and Extension Services

Point of Contact: Max E. Norris, Agricultural Utilization Research Institute c/o Southwest State University, Room ST107, 1501 State Street, Marshall, MN 56258, phone 507.537.7440

Papers: None available at this time.

Project Title:

Emission Performance of Biodiesel Fuels in Heavy-Duty Pickup Truck

Background: There has been some work done on the use of biodiesel and biodiesel blends in heavy-duty pickup trucks, specifically at the University of Idaho with a Dodge pickup powered by the Cummins 5.9 L B-series engine. In this work, regulated emissions were measured over the FTP 75 cycle. The goal of this work is to gather much more detail of the emissions performance of a representative domestic pickup truck powered by a diesel engine. These data can then serve as a guide for emissions reduction methodologies to be developed in DOE's Office of Heavy Vehicle Technologies. In addition, efforts will be made to measure off-cycle emissions, including PM, in order to quantify the effect of biodiesel and biodiesel blends on these emissions.

Objective:

- Produce comprehensive emission and performance data on biodiesel and diesel-biodiesel-blends in the Navistar-powered Ford F-250. The fuel matrix will contain regular diesel fuel B-20 and B-100 fuels with SME, as well as Fischer-Tropsch diesel.
- Pay special attention to the measurement of unregulated emissions and modal analysis of particulate mass.

Status: FY 1997-FY 1998 (F-T diesel)

Accomplishments:

- The project will show the influence of biodiesel and biodiesel blends and Fischer Tropsch diesel on emissions in comparison with conventional diesel fuel in a commercially available heavy-duty pickup.
- A lookup table with information on emissions as a function of vehicle speed and acceleration will be constructed for most of the vehicle's operating range.
- Additional work will include bag speciation of HCs and determination of aldehydes over the FTP and other cycles.

Participant: Oak Ridge National Laboratory

Sponsoring Organizations: U.S. Department of Energy Office of Heavy Vehicle Technologies.

Point of Contact: Brian West, Oak Ridge National Laboratory, P.O. Box 2009, MS-8087, Oak Ridge, TN 37831-8087, phone 423.574.0248, fax 423.574.2102.

Papers: None available at this time.

Project Title:

Emission Performance of Selected Biodiesel Fuels as a Platform for Future Diesel Alternative Evaluations

Background: There is a great interest in biodiesel in many areas, both in Europe and in North America. Internationally, a lot of information on biodiesel has been published. However, the engines used in many cases have been old, high-emitting farm tractor diesel engines. One can expect that different engine concepts react differently. This is especially true when exhaust gas aftertreatment is used for emission reduction. There are no extensive analysis data for various engine alternatives and for the unregulated emissions. This project is being done jointly with VTT Energy of Finland.

Objectives:

- To produce emission and performance data on biodiesel and diesel-biodiesel-blends in different diesel engines. Advanced diesel engines of different sizes and for different applications will be used. Some of the test engines will have exhaust gas aftertreatment. The fuel matrix will contain regular and reformulated diesel fuel as reference.
- Pay special attention to the measurement of unregulated emissions and analysis of particulate composition.

Status: January 1997-June 1999

Accomplishments:

- The project will show the influence of biodiesel and biodiesel blends on emissions in comparison with conventional and improved diesel fuel qualities in modern diesel engines.
- It will also show the fuel effect on diesel exhaust aftertreatment devices.
- A final report containing detailed information on exhaust gas composition and exhaust particulate biological effects will be produced. The emission performance of different biodiesels and biodiesel blends in comparison with both conventional and reformulated diesel will be discussed in detail.
- Conclusions on the optimum usage of different biodiesel qualities will be drawn.

Participants: Oak Ridge National Laboratory; VTT Energy, Finland.

Sponsoring Organization(s): International Energy Agency Alternative Motor Fuels Committee; DOE Office of Heavy Vehicle Technologies; Technology Development Centre of Finland (TEKES).

Point of Contact: John Storey, OM, P.O. Box 2009, MS-8087, Oak Ridge, TN 37831-8087, phone 423.574.0574, fax 423.574.2102.

Paper: None available at this time.

Project Title:

Emissions and Engine Performance from Blends of Soya and Canola Methyl Esters with ARB #2 Diesel in a DCC 6V92TA MUI Engine

Background: Research conducted using raw, degummed vegetable oils during the early 1980s demonstrated that diesel engines can operate with vegetable oils. Additional research demonstrated that methyl esters derived from vegetable oils create fewer difficulties that the use of vegetable oil in heavy-duty diesel engines.

Objectives:

- A DDC 6V92TZ MUI engine was operated on several blends of EPA No. 2 diesel, CARB No. 2 diesel, SME, and CME.
- Various fuels and fuel blend characteristics were determined and engine emissions from these fuels and blends were compared.

Status: October 1995

Accomplishments:

- The research found that SME and CME/No. 2 diesel blends, in conjunction with technologies that reduce the soluble fraction of particulate emissions, merit further exploration as emissions reducing fuel options for North American mass transits.
- However, SME/No. 2 diesel fuel blends are not deemed a viable mass transit "transition fuel" for Los Angeles basin and California conditions.

Participants: The ADEPT Group, Inc.

Sponsoring Organization(s): , U.S. Department of Agriculture, California Department of Food and Agriculture, Division of Measurements Standards, Iowa State University, Department of Mechanical Engineering.

Point of Contact: Alex Spataru and Claude Romig, The ADEPT Group, Inc.; 10920 Wilshire Blvd., #1203, Los Angeles, CA 90024, phone 310.208.8074, fax 310.208.0129

Paper:

Spataru, A.; Romig, C. (1995). "Emissions and Engine Performance from Blends of Soya and Canola Methyl Esters with ARB #2 Diesel in a DCC 6V92TA MUI Engine." *Emissions Processes and Control Technologies in Diesel Engines; October 16-19, 1995, Toronto, Ontario.* SAE 952388. Warrendale, PA: Society of Automotive Engineers, Inc., pp. 179-188.

Project Title:

Emissions and Performance Characteristics of a 4-Stroke, Direct Injected Diesel Engine Fueled with Blends of Biodiesel and Low Sulfur Diesel Fuel

Background: More stringent emissions legislation and the availability vegetable oils have increased the evaluation of SMEs as diesel fuel substitutes. The purpose of this study is to evaluate the potential for using SME as a blending agent with low-sulfur diesel fuel and to optimize the performance and emissions characteristics of a direct-injected, four-stroke engine.

Status: February 27-March 2, 1995

Objectives:

- Conduct testing on 100% low-sulfur diesel to a baseline for emissions, fuel consumption, and performance.
- Characterize emissions and performance for blends at standard diesel calibration.
- Conduct injection timing swings and evaluate for each blend.
- Identify the blends, vary injection pressure and timing at discrete points in the engine map, and determine an optimum strategy.
- Select the best blend and evaluate the potential benefits of an oxidation catalyst
- Evaluate the level at which EGR helps reduce NO_x
- Compare the results against the baseline test results.

Accomplishments:

- In comparison with the baseline, biodiesel blends generally result in lower black smoke emissions and substantially lower particulate emissions.
- Higher NO_x, volatile particles, and fuel consumption were observed as SME use is increased in the unmodified engine.
- The use of 20% and 50% blends saw a decrease in NO_x, particulates. and fuel consumption but the three were not achieved simultaneously.
- Optimizing the engine calibration with a 20% blend caused a decrease in NO_x, particulates and fuel consumption simultaneously.
- EGR can provide a decrease in NO_x but with a substantial penalty in fuel economy and some other emissions.

Participants: FEV of America, Navistar International. and Society of American Engineers

Sponsoring Organization(s): National Biodiesel Board

Point of Contact: Ms. Bev Thessen, National Biodiesel Board, P.O. Box 104898, Jefferson City, MO, 65110-4898, phone 573.635.3893, fax 573.635.7913, e-mail biodiesel@sockets.net. Robert Last, FEV of America,25899 West Twelve Mile Road, Suite 130, Southfield, MI 48034-1800, phone 810.352.1400, fax 810.352.1404.

Paper:

Last, R.J.; Kruger, M.; Dumholz, M. (1995). "Emissions and Performance Characteristics of a 4-Stroke, Direct Injected Diesel Engine Fueled with Blends of Biodiesel and Low Sulfur Diesel Fuel." *International Congress and Exposition,* February 27- March 2, Detroit, MI. SAE 950054. Warrendale, PA: Society of Automotive Engineers, Inc., pp 1-13.

Project Title:

Emissions Characteristics of Ethyl and Methyl Ester of Rapeseed Oil Compared with Low Sulfur Diesel Control Fuel in a Chassis Dynamometer Test of a Pickup Truck

Background: The CAA forms the legislative base for fuel, engine, and emissions standards.

Objectives:

- Compare regulated emissions data included THC, CO, CO_2, NO_x, and PM, for REE, RME, and diesel control fuel.
- Obtain emissions data for blends of REE and RME with diesel control fuel at the 20% and 50% levels.

Status: April 1995

Accomplishments:

- HC and CO were reduced by around 50% when 100% vegetable oil fuel was compared to low-sulfur diesel control fuel.
- PM increased when 100% vegetable oil fuel was compared to low-sulfur diesel control fuel.

Participants: University of Idaho, Los Angeles Metropolitan Transit Authority, and Pacific Northwest and Alaska Regional Biomass Energy Program

Sponsoring Organization(s): Pacific Northwest and Alaska Regional Biomass Energy Program, The Idaho Department of Water Resources, Energy Division

Point of Contact: Dr. Charles Peterson, Department of Agricultural Engineering, University of Idaho, Moscow, ID 83844, phone 208.885.7906, fax 208.885.8923, e-mail peterson@novell.uidaho.edu.

Paper(s):

Peterson, C.L.; Reece, D. (1995) Emissions Characteristics of Ethyl and Methyl Ester of Rapeseed Oil Compared with Low Sulfur Diesel Control Fuel in a Chassis Dynamometer Test of a Pickup Truck. ASAE Paper No. 94-6532. Moscow, ID: University of Idaho. Available from the American Society of Automotive Engineers, St. Joseph, MI 49085.

Project Title:

Emissions Characteristics of Soy Methyl Ester Fuels in an IDI Compression Ignition Engine

Background: As part of the ongoing program to control the emissions of diesel-powered equipment used in underground mines, the U.S. Bureau of Mines evaluated exhaust emissions from a compression ignition engines using oxygenated diesel fuels and a diesel oxidation catalyst.

Objectives:

- Compare and characterize gaseous and particulate emissions from a heavy-duty diesel engine using a typical low-sulfur, No. 2 petroleum diesel fuel, an SME blend with petroleum diesel fuel, and a 100% SME fuel.
- Characterize basic combustion phenomena to help explain emissions and performance results.

Status: March 1995

Accomplishments: Not available.

Participants: University of Minnesota

Sponsoring Organization(s): U.S. Bureau of Mines

Point of Contact: Joseph F. McDonald, Center for Diesel Research, Department of Mechanical Engineering, University of Minnesota, 111 Church Street, SE, Minneapolis, MN 55455-0111, phone 612.725.4750.

Paper(s):

McDonald, J.F.; Purcell, D.L.; McClure, B.T.; Kittleson, D.B. (1995). "Emissions Characteristics of Soy Methyl Ester Fuels in an IDI Compression Ignition Engine." *International Congress and Exposition,* February 27- March 2, Detroit, MI. SAE 950400. Warrendale, PA: Society of Automotive Engineers, Inc., pp. 1-17.