1999 Project Abstract
For the Period Ending June 30, 2001

FINAL REPORT

TITLE: Evaluate Biodiesel Made From Waste Fats and Oils.

PROJECT MANAGER: Mike Youngerberg
ORGANIZATION: Minnesota Soybean Growers Association
ADDRESS: 360 Pierce Ave., Suite 110
North Mankato, MN 56003
WEB SITE ADDRESS: www.mnsoybean.org
FUND:
LEGAL CITATION: Carryforward Language: ML 2001, 1st Special Session, Ch. 2, Sec. 14, Subd. 18, paragraph (a): The availability of the appropriation for the following project is extended to June 30, 2002: ML 99, Ch. 231, Sec. 16, Subd. 009c
(c) Evaluate Biodiesel Made From Waste Fats and Oils.
$63,000 the first year and $62,000 the second year are from the trust fund to the commissioner of agriculture in cooperation with the Minnesota Soybean Growers Association to produce a diesel fuel from soybeans and waste cooking oils and greases, for laboratory evaluation of the fuel for particulates and engine power, and for trial in light-duty vehicles. The appropriation must be matched by at least $50,000 of nonstate money.

APPROPRIATION AMOUNT: $125,000 TF/Match

Overall Project Outcome and Results

A new biodiesel fuel formulation was developed, evaluated, and its efficiencies were demonstrated via engine testing. Through analysis, equal amounts of waste grease methyl esters (WGME) and soy methyl esters (SME) were determined to be the best-blended formula that met the objectives of the project. The objectives included developing a biodiesel fuel with low cost considerations and acceptable cold weather performance. This blended fuel consisted of 10% WGME, 10% SME, and 80% petroleum diesel fuel.

The observed findings in the emissions evaluation on this B20 fuel showed a reduction in particulate matter, carbon monoxide, and gaseous hydrocarbons by 16-18%. Nitrous oxides also were reduced by approximately 5%. Furthermore, no difficulties were encountered in the over-the-road demonstration. Lube oil analyses revealed no unusual engine wear; fuel dilution or negative effects on the truck's fuel system, and the truck operators could not discern any change in vehicle performance.

Concurrent project objectives included developing an estimate of the total yellow grease resources available in the Mpls/St. Paul metro area. The findings indicated that 24 million pounds of yellow grease are produced in the metropolitan area yearly. If processed, this was equivalent to 3 million gallons of biodiesel. An economic impact study suggested that a 50% and a 100% increase in yellow grease production, over and above the estimates for the metro area, could result in an annual 4.5 to 6.0 million gallons of WGME biodiesel production, respectively. The increase would allow for consideration of statewide yellow grease production as well as the prospect for collecting grease that is now discarded. Given the assumptions made in the above analysis, Minnesota could potentially generate 3 to 6 million gallons of biodiesel from yellow grease annually. MDA included a report, "Factors to Consider Regarding: The Feasibility of Biodiesel from Waste/Recycled Greases and Animal Fats."

Project Results Use and Dissemination

The results of the project will be useful to the State's energy users, regulators, policymakers and citizens as they look at Minnesota's long-term energy and environmental needs. Copies of the reports are available on the Minnesota Department of Agricultures website (www.mda.state.mn.us) or may be obtained by contacting the project manager.

October 15, 2002

LCMR Final Work Program Report

I. PROJECT TITLE: **EVALUATE BIODIESEL MADE FROM WASTE FATS AND OILS**

Project Manager:	Mike Youngerberg
Affiliation:	Minnesota Soybean Growers Association
Mailing Address:	360 Pierce Ave., Suite 110 N. Mankato, MN 56003
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Total Biennial Project Budget:

LCMR:	**$125,000.00**	**$ Match: ~~$50,000~~**	**$51,317.92**
LCMR Amount Spent:	**$ 103,972.22**	**-$ Match Amount Spent:**	**$51,317.92**
= LCMR Balance: (cancelled)	**$ 20,474.78**	**=Match Balance**	**$0**

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B. Status of Match Requirement:
The Minnesota Soybean Growers Association (MSGA) has agreed to provide $50,000 for this project.

II. FINAL PROJECT SUMMARY:

A new biodiesel fuel formulation was developed, evaluated, and its efficiencies were demonstrated via engine testing. Through analysis, equal amounts of waste grease methyl esters (WGME) and soy methyl esters (SME) were determined to be the best-blended formula that met the objectives of the project. The objectives included developing a biodiesel fuel with low cost considerations and acceptable cold weather performance. This blended fuel consisted of 10% WGME, 10% SME, and 80% petroleum diesel fuel.

The observed findings in the emissions evaluation on this B20 fuel showed a reduction in particulate matter, carbon monoxide, and gaseous hydrocarbons by 16-18%. Nitrous oxides also were reduced by approximately 5%. Furthermore, no difficulties were

encountered in the over-the-road demonstration. Lube oil analyses revealed no unusual engine wear; fuel dilution or negative effects on the truck's fuel system, and the truck operators could not discern any change in vehicle performance.

Concurrent project objectives included developing an estimate of the total yellow grease resources available in the Mpls/St. Paul metro area. The findings indicated that 24 million pounds of yellow grease was produced in the metropolitan area yearly. If processed, this was equivalent to 3 million gallons of biodiesel. An economic impact study suggested that a 50% and a 100% increase in yellow grease production, over and above the estimates for the metro area, could result in an annual 4.5 to 6.0 million gallons of WGME biodiesel production, respectively. The increase would allow for consideration of statewide yellow grease production as well as the prospect for collecting grease that is now discarded. Given the assumptions made in the above analysis, Minnesota could potentially generate 3 to 6 million gallons of biodiesel from yellow grease annually. MDA included a report, "Overview of: The Feasibility of Biodiesel from Waste/Recycled Greases and Animal Fats."

IV. OUTLINE OF PROJECT RESULTS:

- *Result 1 - Fuel Development and Analysis*: The Agricultural Utilization Research Institute (AURI) will produce a diesel fuel made from a blend of waste grease/cooking oils and soybean oil that is suited to the Minnesota climate. Waste greases/oils gel at moderate temperatures and must be blended with soy-based diesel fuel for all weather use. The blend development will focus on the process for making the fuel, and fuel characteristics such as viscosity, pour point and gel point. The most cost-effective method of producing the fuel will be identified. One blend will be developed for evaluation in an engine test lab (for more information on this portion of the project, see Part X. Research Projects).

  LCMR Budget: $ 25,000
  LCMR Balance: $ 0
  Completion date: Dec. 1999

RESULT 1 - FINAL REPORT:

The first phase of this project included investigating and converting a variety of neat and spent animal fat and vegetable oil feedstocks to their respective fatty acid esters. The feedstocks were subjected to three esterification processes, which included base catalyses, high temperature/high pressure, and acid-base catalyzed reactions. The alcohol that was used in each procedure was methanol. Methyl ester recoveries of the reactions varied within each feedstock and within each reaction. The successful products were evaluated for kinematic viscosity, free fatty acid content, specific gravity and cloud/pour points. Further fuel qualification testing on the acid-base catalyzed methyl esters included cold filter plugging point, water and sediment, glycerin and sulfur content. With the exception of the acidulated soybean soapstock esters, these renewable fuels fell within the ASTM biodiesel fuel specifications.

The second phase of this project moved toward purchasing soybean methyl esters (SME) and waste grease methyl esters (WGME). These biodiesel fuels were blended at ten percent and twenty-five percent increments. Thorough testing was completed on the

blended samples with special emphasis placed on their cold temperature properties, sulfur content, and economics. From theses results the best SME/WGME combination would undergo engine testing in a B20 blend at the University of Minnesota Center for Diesel Research.

- *Result 2 - Laboratory Evaluation*: The fuel developed during the first portion of the project will blended with petroleum diesel in make B20 and tested at the University of Minnesota's Center for Diesel Research (CDR). The B20 will be burned in an engine to determine its effect on engine power and on gaseous and particulate emissions. (For more information on this portion of the project, see Part X. Research Projects).

  LCMR Budget: $ 45,000
  LCMR Balance: $ 2,435.67
  Completion date: Apr, 2000

RESULT 2: FINAL REPORT

The objective of this project was to evaluate and demonstrate a new biodiesel fuel made from soybean oil and waste cooking oils and greases, while considering low cost and acceptable cold weather performance. Most biodiesel made in the U.S. is made from soybean oil, and is called soy methyl ester. A less expensive biodiesel can also be made from waste greases and oils, but waste grease methyl esters have higher cloud, pour and cold filter plugging points than soy methyl esters.

After an extensive analysis of two commercially available soy methyl esters and one waste grease methyl ester, a biodiesel that consisted of a 50% of each of those fuels was selected as a blend stock for making B20. The B20 produced from that fuel was 80% petrodiesel, 10 % soy methyl ester, and 10 % waste grease methyl ester. That fuel was a compromise; it was selected to reduce cost while maintaining cold weather performance.

An emissions evaluation of the B20 was conducted at the University of Minnesota's Center for Diesel Research. An 8-mode steady state test was conducted in a Caterpillar 3116 engine equipped with a catalytic converter. The use of the B20 reduced particulate matter, carbon monoxide, and gaseous hydrocarbons by 16-18%. The use of methyl ester fuels will cause a small increase in the emissions of oxides of nitrogen from most engines, but a reduction of about 5% was observed in this study.

- *Result 3 - Vehicle Demonstration*:

The B20 fuel will be used in 4 vehicles used for road maintenance in Hennepin County. This will be a continuation of an existing study where B20 made exclusively from soybean oils is being evaluated. By continuing this demonstration project with the new fuel, over $65,000 can be saved in the cost for a new heated fuel tank and vehicle fuel heating systems.

LCMR Budget:	$ 55,000	Match:	~~$ 20,000~~ 27,693.36
LCMR Balance:	$ 18,592.11	Match Balance:	$ 0.0
Completion date:	~~May 2001~~ May 2002		

RESULT 3: FINAL REPORT

The B20 was also used in four road maintenance trucks at the Hennepin County Department of Public Works during the winter of 2001-2002. There were no problems in storing or transferring the biodiesel during the demonstration. The trucks using the B20 had the same average fuel consumption rate (on a miles per gallon basis) as trucks using straight diesel fuel. Lube oil analyses revealed that no unusual engine wear or fuel dilution was occurring. There were no observable effects on the truck's fuel system, and the truck operators could not discern any change in vehicle performance.

- *Result 4 - Market Analysis of the Use of the new Fuel*:

An economic and environmental study of the use of the fuel will be conducted by MNDOA in cooperation with AURI and CDR. The study will include a review of the supply of the fuel feedstocks, and existing collection technology for waste grease and oils. The study will determine the viability of using waste grease as a feedstock for producing fuel, and the economic and environmental impact on the state of Minnesota.

LCMR Budget:	$0	Match:	$ **~~$30,000~~ $23,624.56**
LCMR Balance:	$ 0	Match Balance:	$ 0.0
Completion date:	~~June 2001~~ May 2002		

RESULT 4: FINAL REPORT

The University of Minnesota also made an estimate of the total yellow grease resources available in the Minneapolis-St. Paul metro area. Yellow grease is primarily refined used cooking grease recycled from restaurants, and can be used as a low-cost feedstock for producing biodiesel. The total yellow grease production available in the Minneapolis-St. Paul area was estimated to be 24,000,000-31,000,000 million pounds/year. An estimated 1,000,000-7,000,000 pounds/year is not currently being recycled.

From the information gathered by the UofM, the Minnesota Department of Agriculture conducted an economic impact study estimates the impact of the processing and sale of spent cooking oil into yellow grease based on the survey result for the Twin Cities metropolitan area. The UofM report indicates that 24 million pounds represents a conservative estimate of the yellow grease produced in the metropolitan area, the equivalent of 3 million gallons of biodiesel

The MDA study contemplated the potential statewide impact of a 50 percent and a 100 percent increase in yellow grease production increments over and above the 24 million pound UofM estimate for the metro area. These percentage increases would result in yellow grease production of 36 million and 48 million pounds or 4.5 to 6.0 million gallons of biodiesel production, respectively. The increase would allow for consideration of state-wide production, the uncertainty in data sources as well as the prospect for collecting grease that is now discarded.

If the process is effective and economical, it doesn't appear that any fat or oil product would be excluded as a candidate for use as a raw material for biodiesel. The potential for a wide variety and multiple origins of virgin and recycled fat products will allow the biodiesel industry to maintain a wide range of raw material options. These options can help stabilize biodiesel prices.

Depending on the accuracy of reports obtained in conjunction with this study there is also the potential for 190 million gallons from trap grease and 100 million gallons from choice white grease. Thus, given the assumptions made in the above analysis, Minnesota could generate 3 to 6 million gallons of biodiesel from yellow grease annually.

V. DISSEMINATION: During the project, data and information will be shared amongst AURI, CDR, MNDOA, and MSGA. Updates will be published in AURI's Ag Innovation News. Information will be included in the MSGA's web site and other appropriate web sites to be identified as the project progresses.

VI. CONTEXT:

A. Significance: Biodiesel is the name for a variety of ester-based oxygenated fuels from renewable biological sources. It can be used in compression ignition (diesel) engines without any modifications. Pure biodiesel is biodegradable, nontoxic and essentially free of sulfur and aromatics.

Biodiesel has been used in Europe and other countries for years. In the U.S., the use of biodiesel is just emerging. The biodiesel industry has been working with government agencies to meet all regulatory requirements. Over $10 million has been spent on a variety of engine testing and vehicle demonstration programs over the last 5 years. Almost all of this work has been conducted using biodiesel developed from vegetable oils. Only a small amount of effort has been directed towards evaluating biodiesel produced from waste greases and oils. The CDR conducted one study of fuel derived from recycled yellow grease. The B50 (50% biodiesel, 50% petroleum diesel) was evaluated in a light-duty engine operated over a transient duty cycle. The use of the fuel resulted in a reduction in carbon monoxide emissions of 40 %, gaseous hydrocarbons of 50%, and particulate matter was reduced by 23%. Engine power was reduced by 7 %.

As stated previously, biodiesel produced from vegetable oils is expensive compared to diesel fuel. This project will produce and demonstrate a biodiesel fuel that is less expensive than biodiesel produced solely from vegetable oils, and help alleviate the problems associated with waste grease and oils. This fuel will be developed using the lowest cost blend of soybean oil and waste grease feedstock that will produce a fuel that can be used in the cold climate of Minnesota.

This project could benefit the state of Minnesota by developing a fuel that helps improve air quality, provides a market for soybeans, and burns waste grease and oils that are now land filled or dumped into sanitary sewers. It could reduce the state's cost for imported petroleum, and help the state comply with the US DOE EPACT fleet program requirements. (New vehicle purchases by states must include 75% alternate fuel vehicles (AFV) by 2001. Federal fleets must purchase 75% AFV's by 1999).

B. Time: The project should be completed in two years.

C. Budget Context: Project participants are seeking additional funds to increase the scope of the program. This budget presentation will include only LCMR funds.

1. Budget:

	Total	CDR	AURI
Personnel	$89,000	58,000	31,000
Equipment & Supplies	$ 6,500	3,500	3,000
This includes miscellaneous laboratory and office supplies			
Other:			
Fuel	$20,000	17,500	2,500
Maintenance and utilities	$ 2,500	2,500	
Catalytic converter	$ 2,000	2,000	
Contract for sample analysis	$ 1,500	1,500	
Travel	$ 3,500	1,500	2,000
Total $	**$125,000**	**$86,500**	**$38,500**

The following individuals will be involved in the project, and will be paid from LCMR funds:

1. Robert Waytulonis, Associate Director, University of Minnesota, Center for Diesel Research (CDR). ($1,000 LCMR dollars, 1 % of time on project.)
1. Kelly Strebig, Research Engineer, University of Minnesota, Center for Diesel Research (CDR). ($9,000 LCMR dollars, 10 % of time on project.)
2. Kenneth Bickel, Research Fellow, University of Minnesota, Center for Diesel Research (CDR) staff ($34,000 LCMR dollars, 35 % of time on project).
3. Max Norris, Senior Scientist Commercial Development, Agricultural Utilization Research Institute (AURI). ($6,000 LCMR dollars, 5% of time on project)
4. Jerry Crawford, Analytical Chemist, Agricultural Utilization Research Institute (AURI). ($9,500 LCMR dollars, 11 % of time on project).
5. Rose Patzer, Chemical Specialist, Agricultural Utilization Research Institute (AURI). (15,5000 LCMR dollars, 37 % of time on project.
6. A contract employee will be hired to provide release time for AURI staff identified in items 3, 4 & 5 using AURI funds. This action allows AURI to provide support to the Waste Fats and Oils Project and to meet our obligations to other AURI clients.

Note: For the personnel listed, the percentages of time are given for the period the individual will spend on the project, not the percentage of time over the entire two years of the project.

2. Attachment gives more budget detail, including how matching funds will be spent.

VII. COOPERATION:

The project will involve personnel and technical resources of the Minnesota Department of Agriculture (MDOA), the Agricultural Utilization Research Institute (AURI), the University of Minnesota Center for Diesel Research (CDR), the Minnesota Soybean Growers Association (MSGA). Hennepin County will provide vehicles and data during the field study.

VIII. LOCATION: The administrative, research and some program activities will take place at the locations of the CDR in Minneapolis, the MDA in St. Paul, at the AURI office in Marshall, Minnesota. Field-testing and data collection during the field study will occur in Hennepin County.

IX. REPORTING REQUIREMENTS:

Periodic workprogram updates will be submitted not later than March 2000 and December 2000. A final workprogram report and associated products will be submitted by June 30, 2002, or by the completion date as set in the appropriation.

6/soydiesel/LCMR9WPfinal

Attachment A

Attachment A: Deliverable Items and Related Budget										
LCMR Project Bienniel Budget										
5/29/01	Result 1		Result 2		Result 3		Result 4			
Budget Item	Development of fuel		Laboratory evaluation		Field study		Market analysis		**Total**	
	LCMR $	Match $	LCMR $	Match $	LCMR $	Match $	LCMR $	Match $	LCMR $	Match $
~~Wages, salaries & benefits~~	~~20,000~~		~~,38500~~		~~,31000~~	~~,20000~~		~~22,500~~	~~,89,500~~	~~,42500~~
Wages, salaries & benefits	**14,850.00**		**42,000**		31,000	20,000		**30,000**	**87,850**	50,000
Space rental, maintenance and utilities			500		1,000				1,500	0
Printing and Advertising									0	0
Communications, Telephone, mail, etc.	100		100		500			~~1,000~~	700	~~,1000~~
Contracts									0	0
Professional/technical	**7,968.61**							~~16,500~~	7,968.61	~~,16500~~
Other Contracts			~~,1500~~						~~,1,500~~	0
Local auto mileage paid					1,500				1,500	0
~~Other travel expenses in Minnesota~~	~~2,000~~								~~,2000~~	
Other travel expenses in Minnesota	**498.62**								**498.62**	
Travel outside Minnesota								~~2,000~~	0	~~0~~
Office Supplies	100		100		200			~~1,000~~	400	~~,1000~~
~~Other Supplies~~	~~2,500~~		1,800		20,000				21,800	
Other Supplies	**1,482.77**								1,482.77	
~~Tools and Equipment~~	~~300~~		500		300				800	
Tools and Equipment	**0**									
Office equipment and computers					500			~~1,000~~	500	~~,1000~~
Other capital equipment			~~,2000~~						~~,2,000~~	0
Other direct operating costs								~~6,000~~	0	~~,6000~~
Land acquisition									0	0
Land Rights Acquisition									0	0
Buildings and other improvements									0	0
Legal fees									0	0
TOTAL	$25,000	$0	$45,000	$0	$55,000	$20,000	$0	$30,000	$125,000	$50,000