Small Scale Biodiesel Production An Overview

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Introduction

Interest in renewable fuels has increased substantially in the past two years. Much of this interest is attributable to increases in the cost of traditional fuels, environmental concerns associated with fossil fuels, unease about America's increasing dependence on foreign energy, and government programs to support the development and production of renewable fuels.

Many Montana farm and ranch operations have been adversely affected by rising energy prices. In response, farmers and ranchers are evaluating renewable energy production alternatives that may mitigate the effects of increasing energy prices. This policy paper provides an overview of small scale biodiesel production processes and the major issues associated with their adoption.

Biodiesel Background

Biodiesel is a fuel derived from vegetable oils or animal fats that can be used either as a replacement for petroleum diesel or blended with petroleum diesel for use in a standard diesel engine. Diesel engines were originally designed to run on strait vegetable oil (SVO) but, during the 20th century, petroleum diesel fuel became more readily available and economical as a fuel source for diesel engines. Modern diesel engines are designed to operate on diesel fuel and not SVO.

Biodiesel is produced from a chemical reaction between a vegetable oil (or an animal fat), an alcohol, and a catalyst. Glycerin is also produced during this process. Animal fats and vegetable oils are comprised primarily of triglyceride molecules. The reaction of the triglyceride molecules with an alcohol (typically methanol) in the presence of a catalyst is called *transesterification*. The transesterification process transforms vegetable oil, alcohol and a catalyst into biodiesel and glycerin. Typical proportions required for this reaction are:

Inputs:	100 units of vegetable oil; 10 to 15 units of alcohol; 0.5 to 2 units of catalyst
Output:	100 units of biodiesel; 10 to 15 units of glycerol

The above proportions may be adjusted for differences in the chemical composition of the oils and fats to be processed, the type and purity of the alcohol used, and the technology employed to facilitate the reaction.

Biodiesel Production

Biodiesel may be produced in small quantities for individual use or in much larger quantities for commercial purposes. Biodiesel has been successfully produced with basic laboratory equipment in batches of one gallon (or less). It can also be produced with commercially available production equipment in batches of 15 to 400 gallons. Large scale commercial production of biodiesel may utilize continuous flow production equipment with annual capacities in excess of one million gallons. The technical feasibility of producing biodiesel in small quantities creates the potential for on-farm biodiesel production.

Small Scale Production Process

Small scale biodiesel production follows the same basic process, regardless of the quantity produced, although differences in inputs, equipment, and the desired quality attributes will determine the actual process used in any specific operation.[1] Biodiesel production is relatively simple; however, the simple nature of the process may tempt producers to overlook important process details.

[1] Some methods of producing biodiesel are not examined here. Those interested in a more detailed discussion of biodiesel production technology may want to read "Building a Successful Biodiesel Business" by Jon Van Gerpen, Rudy Pruszko, Davis Clements, Brent Shanks and Gerhard Knothe.

The production process begins with the pre-treatment of virgin (new) oil or recycled oil. Recycled oil may need to be filtered to remove particles and dried to reduce water content. Virgin oil needs to be degummed during the pretreatment process. Once the oil has been pretreated, a titration test is performed.[2] The results of the titration test are used to adjust the amount of catalyst required to successfully complete the transesterification process.

The next step in the process is to mix a catalyst into an alcohol. If sodium hydroxide and methanol are used, the resulting mixture is referred to as sodium methoxide. The catalyst, alcohol, and mixture are all hazardous materials that should be properly handled. The catalyst and alcohol mixture is combined with oil to facilitate transesterification. In some cases the catalyst, oil, and alcohol are heated prior to, or during, or both prior to and during transesterification. Adding heat shortens the time required for processing and may increase the overall reaction rate.

Once the transesterification process is completed, the glycerin and biodiesel must be separated. Glycerin is heavier than biodiesel and settles to the bottom of a reaction vessel, allowing it to be separated from biodiesel. Larger production units may use a centrifuge to separate the two liquids. At this point in the process, both the glycerin and biodiesel are contaminated with catalyst, alcohol, and oil that failed to react during the transesterification process. Soap generated during the process also contaminates the biodiesel and glycerin. Although glycerin tends to contain a higher percentage of contaminants, significant amounts of contaminates are also present in the biodiesel.

Removal of these contaminates is the final step in the production process. Excess alcohol is removed by heating biodiesel (or glycerin) to vaporize it. Often, the alcohol vapor is condensed back into liquid, which can be reused in the process. The fuel is then washed with water to remove other biodiesel contaminates.[3] Washing is accomplished by misting water over biodiesel or by bubbling water through it. The water droplets collect contaminates as they descend through the fuel. Finally, biodiesel is dried and filtered and the production process is complete.

Input Selection

Producers of biodiesel must decide what types of oil, catalyst, and alcohol they will use in their operation. The quality of oil used to produce biodiesel affects several aspects of the production process. If recycled oil is used, then several additional steps are needed to ensure successful biodiesel production. First, the oil must be filtered to remove any solid contaminants such as bone and other food particles. Second, the oil's free fatty acid level and water content should be measured.

High free fatty acid content causes soap to be produced during transesterification. Free fatty acid content in excess of 6 or 7 percent is likely to cause excessive soap production that may result in failed biodiesel production.[4] Water contained in the oil will also cause soap to be produced during processing. If water content is high, the oil may need to be dried before further processing. Virgin oils are unlikely to have high free fatty acid or water levels. However, virgin oils do need to be degummed before biodiesel production can occur. If virgin oils are purchased from a commercial processor, the oils have probably already been degummed. The consistency and low contamination levels of virgin oils make them ideal for biodiesel production, but typically they cost more than lower quality recycled oils.

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[2] A titration test measures several characteristics of the oil. Titration test results are used to adjust process parameters to ensure fuel of sufficiently high quality is produced.

[3] Washing and drying biodiesel improves fuel quality. However, some small scale producers choose to produce unwashed lower quality biodiesel for their personal use.

[4] William Kemp's "Biodiesel Basics and Beyond" provides additional information on oils with high free fatty acid content.

A successful biodiesel producer has to obtain a reliable source of oil, regardless whether the oil is virgin or recycled. Recycled oils are usually obtained from local restaurants and food processors, often at little or no cost.[5] Virgin oil can be produced by processing oilseeds (such as canola, safflower, camelina, flax, etc.) on the farm with small scale processing equipment or purchased from a commercial oilseed processing facility. Information on oilseed processing is provided in AMPC Briefing Papers numbers 86, 87, and 88.

Alcohol Selection

Price is the main factor in determining which alcohol to use in the production process. Ethanol and methanol are the two most common options. High quality methanol is cheaper than ethanol and, therefore, is used in nearly all biodiesel operations. Biodiesel producers interested in avoiding all fossil fuel use may choose to replace methanol (a fossil fuel) with ethanol. Methanol can be obtained in quantities of 5 gallons or more from many bulk fuel distributors and from distributors of racing fuel. The price of methanol can vary substantially depending on the quantity purchased. The cost of methanol represents a relatively large component of total cost of producing biodiesel.[6]

Catalyst Selection

A catalyst is required to facilitate the reaction between the oil and the alcohol. The most common catalysts used in small scale biodiesel production are sodium hydroxide (lye) and potassium hydroxide. Catalysts such as sodium methoxide and potassium methoxide are also used. Availability and compatibility with processing equipment are the two main determinants of catalyst selection, although price is also a contributing factor.[7]

Equipment Selection

Small scale biodiesel production equipment can be purchased on a "ready-to-use" basis from numerous manufactures. Price, capacity and functionality are the main attributes with respect to "ready-to-use" processors. Here is a list of items to consider when comparing processors:

- How many gallons can be processed per batch?
- How long does each batch take to process?
- Is the system capable of heating the oil and/or the alcohol-catalyst mixture?
- Does the system include methanol recovery equipment?
- Does the system have the capability to wash and dry the biodiesel?
- Does the system require any extra plumbing, fittings or pumps?
- Does the manufacture provide technical support?
- Does the system require that a specific catalyst be used?
- How much does the system cost?
- Does the quoted price of the system include shipping costs?

Equipment Suppliers

The internet is a useful tool for comparing available options for biodiesel production equipment. The following is a list of several biodiesel processing equipment retailers' web sites.

- EZ Biodiesel: www.ezbiodiesel.com
- Fuel Meister: www.fuelmeister.com
- Utah Biodiesel Supply: www.utahbiodieselsupply.com
- Biofuel Canada: www.biofuelcanada.ca

This list should not be considered a recommendation or endorsement of any company or product. The list is provided simply to provide an overview of the various types of commercially available biodiesel processing equipment.

[5] Permission should be obtained from the restaurant or food processor prior to collecting any used oil because they may already have an agreement in place for the disposal of their used oil.
[6] The production of biodiesel requires between 10 to 20 gallons of methanol for each 100 gallons of biodiesel produced. If methanol is purchased for $2.00 per gallon, each gallon of biodiesel produced will contain $0.20 to $0.40 of methanol.
[7] Many equipment manufacturers recommend catalysts appropriate for use with their specific equipment.

Final Products

The transesterification process produces two products, biodiesel and glycerin.

Biodiesel

Biodiesel quality depends on the inputs and processing techniques used in its production. The American Society for Testing and Materials (ASTM) has developed quality standards for biodiesel. Unfortunately for small scale producers, the cost of testing a batch biodiesel is likely to exceed the value of the fuel produced. Fuel that has not been tested for ASTM standards generally cannot be marketed on a commercial basis. Most small scale producers will be limited to producing biodiesel for personal use.

Lack of ASTM testing does not necessarily imply that fuel quality is poor, but small producers must focus on accurate processing procedures to ensure fuel quality. These steps may include proper filtering, accurate catalyst measurement and fuel washing procedures.

Glycerin

Glycerin produced during the biodiesel process is crude and unrefined. Numerous markets are available for refined glycerin, but these markets are not generally available to small producers because of the cost of glycerin refining. Crude glycerin produced in small scale biodiesel operations typically contains unreacted oil, catalyst, methanol (if not recovered during processing) and some biodiesel. Glycerin and biodiesel are generally considered as environmentally friendly, but the catalyst and methanol contained in crude glycerin are not. Thus, a producer's alternatives for disposing of crude glycerin may be limited. One option is to use the crude glycerin as fuel oil. Another is to compost it. Large volumes of liquid glycerin are produced in the biodiesel process (10% to 15% of biodiesel production) and adequate planning is required for successful composting. Some biodiesel producers also use glycerin as a dust suppressant or for soap making.

Regulatory and Policy Issues

Biodiesel production is affected by two forms of government policy. The first is regulatory policy. Local, state, and federal government agencies may require building and operating permits, licenses, and registration of different aspects of the biodiesel production process. More information about regulations, permits and licenses can be obtained from the Montana Department of Environment Quality (www.deq.mt.gov), the Montana Department of Transportation (www.mdt.mt.gov), your local county government, and other sources. Obtaining required permits and licenses is essential for successful biodiesel production. The second way in which government is involved is through tax and subsidy programs. State and federal agencies tax biodiesel but also offer incentives for biodiesel production. A detailed description of federal and Montana biodiesel related policies is presented in AMPC Policy Paper No. 16.[8]

Additional Information:

Montana farmers and ranchers will continue to explore opportunities to increase and stabilize their income. Small scale biodiesel production is one option that may help them to achieve this goal. This policy paper has presented an overview of biodiesel production processes and issues. Additional information on biodiesel related topics is located on the following Web sites.

National Biodiesel Board: www.biodiesel.org

American Society of for Testing and Materials: www.astm.org

University of Idaho's Bioenergy Website: http://www.uidaho.edu/bioenergy/

Montana Department of Environment Quality; Biomass Energy Program website: http://www.deq.mt.gov/Energy/bioenergy/index.asp

National Sustainable Agriculture Information Service: http://attra.ncat.org/farm_energy/biodiesel.html

[8] AMPC Policy Paper No. 16 "Oilseed, Biodiesel and Ethanol Subsidies & Renewable Energy Mandates: US Federal & Selected State Initiatives" is available at www.ampc.montana.edu.

References:

Kemp, W. H. (2006). Biodiesel Basics and Beyond.

Van_Gerpen, J., R. Pruszko, D. Clements, B. Shanks and G. Knothe (2006). Building a Successful Biodiesel Business.