The Feasibility of On-farm Biodiesel Production

By Erin Sawyer

The Department of Agricultural Economics Project on Organic Agriculture

University of Saskatchewan

2007

1.0 Introduction

Organic farming is challenged with promoting and enhancing ecosystem health by using a balanced choice of crops and implementing diversified crop rotation systems (Food and Agriculture Organization 2003). In addition, there is an emphasis placed on using renewable raw materials, including renewable energy sources, to maintain the sustainability of the production system (Fredriksson *et al.* 2006). It has been suggested that organic farming uses more fossil fuels on a per acre basis than conventional farming because of the need to cultivate more often to control weeds (Weseen, 2007). Because of this, there is an interest within the organic community to determine the feasibility of replacing fossil fuels with biofuels in their production systems. Biofuels are fuels produced from agricultural crops, the most common being ethanol and biodiesel. Ethanol can be made from sugar cane, wheat, corn and other agricultural crops, while biodiesel is made primarily from oilseed crops. In this paper, the feasibility of producing on-farm biodiesel is examined. First, the production of biodiesel is explained, followed by a discussion of the advantages and disadvantages of its use. This is followed by a brief review of recent literature on the economic feasibility of producing biodiesel on-farm. This is followed by conclusions.

2.0 What is Biodiesel?

Biodiesel is a fuel alternative made from a combination of vegetable oil or animal fat, alcohol (generally methanol or ethanol) and a catalyst, usually lye. It is a biodegradable transportation fuel for use in diesel engines and can be used alone or as an additive to diesel fuel. Due to its biodegradable composition and its use of renewable bioresources, biodiesel has been gaining popularity in the fuel industry. This is because it potentially represents a sustainable alternative to non-renewable fossil fuels.

Chemically, biodiesel is comprised of methyl esters of long-chain fatty acids and is derived from animal fat or vegetable oil by removing the glycerin in a reactive refinery process (Burtis 2006) (see figure 1 for a graphic explanation of the process). The alcohol and the base compound (lye) are used to split vegetable oil into components. The ester component is what is known as biodiesel, while the separated by-product is glycerin (Alberta Agriculture 2006). Glycerin has value as a co-product and can be used in soaps, lotions, and as a lubricant. Protein meal is a second co-product and is used as animal feed.

Biodiesel can be made from a variety of sources including new or waste food-grade cooking oil, animal renderings, or oilseeds. Oil can be extracted from seeds using an oil press, an expeller, or even more primitively with a mortar and pestle (Bachmann 2004). The vegetable oil must be filtered and heated to at least 140°F prior to use in a diesel engine (Ryan 2004). In terms of biodiesel production, canola rates as the highest yielding oilseed in the U.S. (and presumably in Canada) at 1,372 litres per hectare.

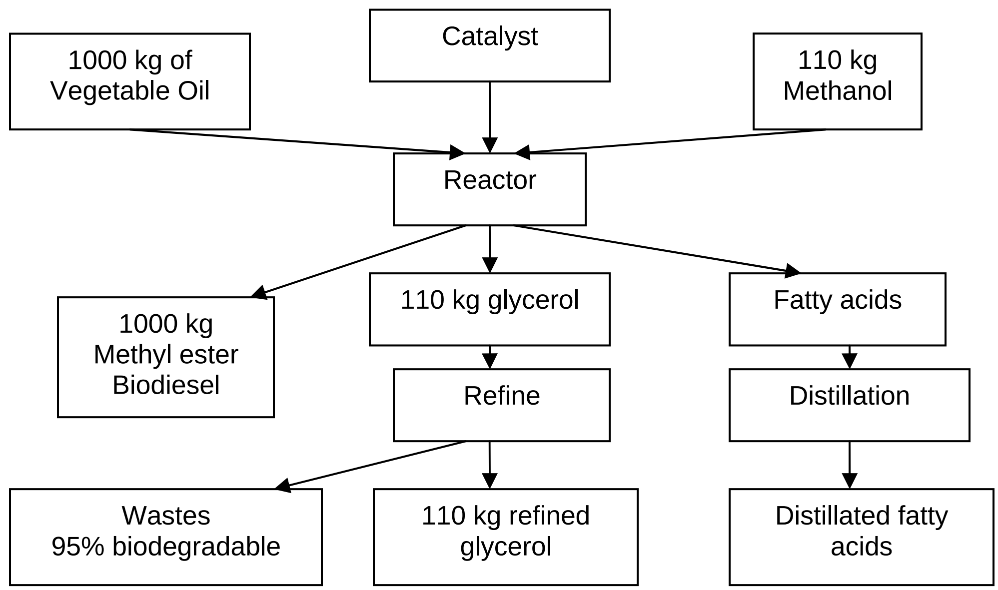

Figure 1: Overview of the production of biodiesel and by-products
Source: Kingwell and Plunkett (2006)

3.0 Biodiesel: a fuel of the future and the past

The use of biodiesel is not a new idea, as both vegetable oils and alcohols were used as fuels when transportation became motorized (Bernesson 2004). Original diesel engines were powered by straight vegetable oil, as their engines were built for heavy oil fuels (Bernesson 2004). In the1920s, both Henry Ford and Charles F. Kettering (head of research at General Motors) believed alcohol would be the fuel of the future (Bernesson 2004). Instead, inexpensive fossil fuels took over as the fuel of choice for motorized transportation and it has remained this way ever since.

Fossil fuels consist of crude oil, coal, natural gas or heavy oils that are formed from decaying plants and animals that have been exposed to heat and pressure by the earth's crust during the past hundreds of millions of years. Fossil fuels are a finite resource and due to decreasing oil reserves and the increased cost of extracting crude oil, fuel prices have been increasing. In the past few years the price of fossil fuels has increased substantially from $45 per barrel in 2000 to $76 per barrel in 2006 (Petro-Canada 2006). These increasing prices and environmental concerns are causing society to reexamine biofuels as a fossil fuel alternative. The next sections of the paper examine the advantages and disadvantages of biodiesel in terms of its functionality as a fuel, its impact on the environment and the rural economy, and its economic feasibility.

3.1 Advantages

In terms of its functionality as a fuel, biodiesel is beneficial to the operation of many farm vehicles and machinery. Biodiesel can provide significant benefits as a lubricity additive in diesel fuel (Alberta Ag. 2006), which can decrease the wear and tear on an engine. Because of this, John Deere, Case-International Harvester and Ford have all issued warranties supporting the use of biodiesel (Kingwell and Plunkett 2006) provided the B100 blend stock meets American Standard for Testing Material ASTM D6751 specifications and is in a blend no higher than B5 (Nagy and Furtan 2006). The European Union and Canada also have standards in place: EN 14214 and the Canada General Standards Board specification CAN/CGSB-3.520 Automotive Low-Sulphur Diesel Fuel Containing Low Levels of Biodiesel Esters (B1 to B5), respectively.

Biodiesel has several environmental advantages over fossil fuels. First, it is non-toxic and degrades quickly. Within 28 days, pure biodiesel degrades 85-88% in water (Kingwell and Plunkett 2006). Second, it produces fewer emissions than petroleum diesel. A 20% blend of biodiesel (B20) produces approximately 12-20% fewer emissions than petroleum diesel alone. Table 1 illustrates the environmental advantage of biodiesel through reduced emissions and particulates from vehicle exhaust.

Table 1: Average biodiesel emissions compared to conventional diesel

Emission	**B100**	**B20**
Total Unburned Hydrocarbons	-67%	-20%
Carbon Monoxide	-48%	-12%
Particulate Matter	-47%	-12%
Nitrogen oxides	+10%	+2% to -2%

Source: National Biodiesel Board (2006)

Carbon dioxide, total particulate matter and carbon monoxide emissions are all reduced through the use of biodiesel. Nitrogen oxide emissions seem to increase but can be brought to a base level with engine timing adjustments (Alberta Ag. 2006). In addition to its low emissions levels, biodiesel also has a net energy ration of 2.5-3.2:1 (depending on the oilseed used). This means that for every unit of energy consumed in the production of biodiesel, 2.5-3.2 units of energy are produced (Kurki *et al.* 2006). Kurki *et al.* (2006, p.6) states that “the energy ratio is a comparison of the energy stored in the fuel to the energy required to grow, process and distribute that fuel”. As a comparison, ethanol only has an energy ratio of 1.2:1, giving biodiesel a clear advantage as an energy source (Burtis 2006).

Like ethanol, biodiesel has been viewed as a potential key for revitalizing rural communities. Canadian farmers are consistently increasing efficiency, but face stiff competition from international producers who may have better agro-climatic conditions, cheaper labour, and more subsidies. This, combined with lower commodity prices has contributed to a decline in rural populations in Canada. Although, there has been much talk about revitalizing rural communities, there has been little success in reversing the trend. Proponents of biofuels suggest that as the price of fossil fuels increase, it may become cost-effective to utilize biofuels over fossil fuels. If this occurs, there will be a increased demand for oilseed crops that are used to produce biodiesel. An increase in the demand for these crops (as the food industry is anticipated to require similar if not greater amounts of oilseeds) should increase the price producers receives for their crop, thus increasing the profitability of farming and slowing the decline of rural communities. To some extent, increased commodity prices caused by biofuels production are already occurring.

The potential to offset rising fossil fuel costs could also be a benefit to producers who are able to utilize biofuels as a substitute. Increasing fuel prices have increased the cost of major on-farm activities, such as seeding, harvesting, and the transportation of agricultural products. In addition, rising fuel costs impact the price of key agricultural inputs such as chemicals and fertilizers (Kingwell and Plunkett 2006). Because biodiesel can be used as a fuel for farm machinery and can be used as a home heating fuel with very few modifications (Burtis 2006), its potential to be used as a substitute for fossil fuels is large. The extent to which this will occur, of course, depends on the price of fossil fuels as well as the costs associated with biodiesel production. This is discussed in more detail in Section 4 of this paper.

It is evident from the discussion here that there are several potential benefits to converting from fossil fuels to biofuels. The next section discusses so of the potential disadvantages.

3.2 Disadvantages

One limitation to the use of biodiesel is the fact that it tends to gel at low temperatures. Gelling can be reduced by adding a winterizing agent formulated for diesel fuels (Kurki *et al.* 2006). This could be a problem for producers in the colder regions of Canada, however, biodiesel has been used in several case studies including Toronto Hydro vehicles, on Montreal city buses and in tractors at the University of Guelph without issues (Clark *et al.* 2006).

While machinery manufacturers have maintained warranties for equipment run on B5 blends that meet the ASTM standards, they will not guarantee their products for any blend higher than 5%. This is a severe limitation to the conversion from petroleum diesel to biodiesel in an agricultural business.

As will be illustrated in the next section, there may also be some limitations regarding the economics of biodiesel production. While the economic analysis does not include the potential social benefits provided through reduced emissions (due to the difficulty in quantifying these values), it does illustrate the costs of the physical production of biodiesel on farm, which are not favourable when compared to the current costs of fossil fuels.

4.0 The Economics of Biodiesel

Numerous studies on the production of biodiesel have been conducted. These studies range from analyses of farm-scale production to large-scale biodiesel production facilities. This section will provide a brief overview of some of these studies and present their findings as they relate to the feasibility of on-farm production of biodiesel.

The majority of the studies of on farm-scale biodiesel did not find economic benefits to its use. In his study on the economics of biodiesel using canola, Carter (2006) states that “growing canola for use as biodiesel is currently uneconomic” and that producing canola for biodiesel did not create any additional financial benefits over producing canola for human consumption. In a review of twelve feasibility studies of community-scale farmer cooperatives for biodiesel, Bender (1999) found that the production costs of biodiesel were greater than the pre-tax diesel prices in the U.S. and various European countries. Nagy and Furtan (2006) found that the production of on-farm biodiesel would not cover the fixed costs of investing in production in all market scenarios. In their study on the potential of biodiesel for the Arkansas economy, Manning *et al.* (2006) found that all but the most efficient producers will likely be dependent on subsidies to be profitable. Spurred by the increase in fuel prices, Kingwell and Plunkett (2006) examined the technical and economic feasibility of on-farm biofuel production and concluded that diesel prices are not yet high enough to justify producers investing in their own on-farm production of biodiesel from canola.

Nagy and Furtan (2006) utilized a linear programming model in their assessment of biodiesel production in Saskatchewan. They analyzed both a large scale production facility and an on-farm scenario. Based on their analysis they determined that a 2024ha farm using a B100 blend would face operating costs of $0.2559/litre and fixed costs of $0.1946/litre for both oilseed crushing and biodiesel manufacturing to produce 60,000 litres (see tables 2 & 3)[1]. They speculate that depending on the soil zone and tillage system used, enough canola for a B100 blend could be produced on between 3% and 7% of the cultivated area (table 4). They modeled five different scenarios: 1) a base scenario (95% extraction rate, price of crude oil is $50); 2) an increased cost of seed by $100 per tonne over the base case; 2) a decreased oil extraction rate (by 3%) from the base case; 4) an increased oil extraction rate (by 3%) over the base rate, and 5) setting the price of crude oil at $40, $10 below the base scenario. They found losses in each of these scenarios as the production of biodiesel was unable to cover the fixed costs of producing the fuel. Table 2 shows the estimated costs associated with crushing for biodiesel production, while Table 3 shows the estimated costs of on-farm manufacturing of biodiesel. Table 4 presents acreage and yield requirements for different levels of biodiesel production in each of the soil zones.

[1] For a complete list of all assumptions please see Nagy and Furtan 2006.

Table 2: Estimated Cost of On Farm Oilseed Crushing ($/Litre of Biodiesel)

Operating Expense	$/litre Biodiesel	%
Natural Gas[a]	0.0115	23.8
Electricity[b]	0.0030	6.3
Direct labour[c]	0.0178	36.6
Direct labour benefits[c]	0.0023	4.7
Maintenance[d]	0.0079	16.3
Insurance[e]	0.0050	10.3
Processing Supplies	0.0010	2.0
Total Operating Expenses	**0.0485**	**100.0**
Fixed Expenses	**$/litre Biodiesel**	
Depreciation[f]	0.079	
Interest on LTD[g]	0.042	
Total Fixed	**0.121**	

Source: Nagy and Furtan 2006
a. Natural Gas is priced at the farm rate from Sask Energy.
b. Electricity is priced at the farm rate from Sask Power.
c. Direct labour and benefits allocates 20% of a hired employee for two months.
d. Maintenance – 1% of plant capital cost from (S&T)[2] and MNP 2004.
e. Building Insurance.
f. Deprectiaon at 10% of the fixed cost of $47,400.
g. Interest of 8% on a loan for 2/3 of the fixed cost of $47,400.

Table 3: Estimated Cost of On-Farm Biodiesel Manufacturing ($/litre of biodiesel)

Operating Expenses	$/litre of biodiesel	%
Natural Gas[a]	0.0051	2.5
Electricity[b]	0.0017	0.8
Methanol[c]	0.0420	20.2
Direct labour[d]	0.0667	32.1
Direct labour benefits[d]	0.0086	4.1
Maintenance[e]	0.0048	2.3
Quality control[f]	0.0467	22.5
Processing supplies	0.0319	15.4
Total Operating Expenses	**0.2074**	**100.0**
Fixed Costs	**$/litre of biodiesel**	
Deprectiation[g]	0.048	
Interest on LTD[h]	0.026	
Total Fixed	**0.0736**	

Source: Nagy and Furtan 2006
a. Natural Gas is priced at the farm rate used as building heat source. Source Sask Energy.
b. Electricity is priced at the farm rate from Sask Power.
c. Methanol use is 30% higher than a commercial plant plus no volume discounts.
d. Direct labour and benefits allocateds 30% of a hired employee for two months.
e. Maintenance – 1% of plant capital cost (S&T)[2] and MNP 2004.
f. Quality Control- the cost of two laboratory analysis of the biodiesel at $1400 per test
g. Depreciation at 10% of the fixed cost of $28,800.
h. Interest of 8% on a loan for 2/3 of the fixed cost of $28,800.

Table 4: Litres of Biodiesel, Tonnes of Canola & Harvested Area (2024 ha Conventional Farm)

	Brown	Dark Brown	Black	Canola Seed			Harvested Area		
Tillage System	**Biodiesel B100 (Litres)**			**Tonnes**	**Tonnes**	**Tonnes**	**Ha**	**Ha**	**Ha**
Conventional	57793	65408	79006	140	159	192	139	113	98
Minimum	47595	53091	67799	115	129	164	114	92	84
Zero Tillage	38912	45895	49550	94	111	120	94	79	61
	Biodiesel B20 (Litres)			**Tonnes**	**Tonnes**	**Tonnes**	**Ha**	**Ha**	**Ha**
Conventional	11559	13082	15801	28	32	38	28	23	20
Minimum	9519	10618	13560	23	26	33	23	18	17
Zero Tillage	7782	9179	9910	19	22	24	19	16	12
	Biodiesel B5 (Litres)			**Tonnes**	**Tonnes**	**Tonnes**	**Ha**	**Ha**	**Ha**
Conventional	2890	3270	3950	7	8	10	7	6	5
Minimum	2380	2655	3390	6	6	8	6	5	4
Zero Tillage	1946	2295	2477	5	6	6	5	4	3

Source: Nagy and Furtan 2006

In Sweden, organic farms are estimated to consume approximately 36,000,000 litres of diesel oil each year (Baky *et al.* 2002 in Fredriksson *et al.* 2006). Fredriksson *et al*. 2006) further estimated that 9.3% or 93ha would have to be used to fulfill the farm's fuel demand, assuming that canola yields exceed 1240 kg/ha. Organic farms in Sweden are smaller than the conventional farm examined by Nagy and Furtan (2006), however, 1000ha farms may be a better proxy for organic farms in Canada. Bernesson (2004) and Bernesson *et al.* (2004) have determined the cost of farm scale production of biodiesel to be 850 Euros/m^3 ($1.30CAD/litre). These calculations were based on the use of conventional raw materials, whereas organic raw materials would cost approximately 30% more leading to a cost of 1050 Euros/m^3 ($1.60CAD/litres). Given that the current price of diesel in Europe is 650 Euros/m^3 ($1.00CAD/litre), it is evident that organic producers wanting to utilize biodiesel would face a substantial increase in production costs (Fredriksson *et al.* 2006).

Many researchers suggest that there may be economies of scale in biodiesel production. Economies of scale occur when the unit cost of producing a good decreases as you produce more of the good. This has led some to suggest that producer based cooperatives may be more efficient than farm-scale production involving a single farm. In addition to the potential for capturing economies of scale, these community-level production facilities could ensure compliance with standards that satisfactory to engine manufacturers, thus permitting for the sale of biodiesel outside the farming community (Kurki *et al.* 2006). It has also been suggested that farmer biodiesel cooperatives would be most advantageous for mixed farmers because it would allow them to take advantage of the protein byproduct in their livestock operations (Bender 1999). On the other hand, Bernesson (2004) found that any economies of scale from efficient use of machinery and buildings and oil extraction efficiency in the production of biodiesel were, to a certain extent, overweighed by the longer transport distances involved.

At this point of time, the production of on-farm biodiesel does not appear to be beneficial to the profitability of the organic farmer. Rising fuel prices and greater environmental concerns by global citizens could increase the demand for bio-based fuels but until this happens it may be more beneficial for groups of organic farmers to join together and develop biodiesel cooperatives in order to meet their sustainability objectives, although the economics of doing this would need to be verified.

5.0 Conclusion

Biodiesel is an alternative fuel source produced from bioresources, mainly oilseed crops. The debate surrounding biofuels has been reinvigorated because of increasing fossil fuel prices, the desire to revitalize the rural economy, and consumer concerns surrounding the environment. Organic production seeks to minimize ecological damage to the land resulting from unsustainable farm practices. Currently, most organic farmers use non-renewable fuel sources to power their machinery. It is possible for biodiesel to be produced on a small scale, thus allowing organic farmers to rely to a greater extent on renewable fuel sources. There are some environmental advantages to the use of biodiesel, most notably reduced greenhouse gas emissions. Other potential advantages are that biodiesel can increase engine lubricity thus extending an engines lifespan, and that its production results in a variety of co-products that have other uses. Disadvantages include a low gel temperature and difficulties maintaining a manufacturer’s warranty on farm equipment when biodiesel is blended with conventional diesel at a blend higher than B5. But the largest challenge to a conversion to biodiesel is the cost. At this time, it is not economically feasible to switch to biodiesel from conventional diesel because the current price of conventional diesel is lower than the cost of producing biodiesel. There are potential economies of scale resulting from community-scale biodiesel production facility but whether the cost savings are enough to warrant investing in such a plant has not been established. Economics aside, society may choose to proceed with the production of biodiesel to encourage a reduction of greenhouse gas emissions and to prolong our existing supplies of fossil fuels. To some extent this is already occurring.

References

Alberta Agriculture, Food and Rural Development. 2006. Vegetable Oil Fuels. Available at http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/eng4435

Bachmann, J. 2004. Oilseed Processing for Small-Scale Producers: Value Added and Processing Guide. ATTRA – National Sustainable Agriculture Information Service. Available at www.attra.ncat.org

Bernesson, S. 2004. Farm-scale production of RME and ethanol for heavy diesel engines – with emphasis on environmental assessment. Doctoral Thesis. Swedish University of Agricultural Sciences. Available at http://diss-epsilon.slu.se/archive/00000698/

Bernesson, S., D. Nilsson and P.-A. Hansson. 2004. A limited LCA comparing large- and small-scale production of rape methyl ester (RME) under Swedish conditions. *Biomass and Bioenergy*. 26(6):545-559.

Burtis, B. 2006. Biofuels and Energy Production Options for the Farm. Climate Change and Northeast Agriculture. Available at http://www.agric.wa.gov.au/pls/portal30/docs/FOLDER/IKMP/SUST/BIOFUEL/EconomicsBiofuelProdn.pdf

Carter, C. 2006. Economics of Biodiesel Using Canola. Available at http://www.agric.wa.gov.au/pls/portal30/docs/FOLDER/IKMP/SUST/BIOFUEL/200507_BDCanolaEcon.pdf

Clark, S., J. DeBruyn and T. Tondevold. 2006. Biodiesel Use On-farm? Ontario Ministry of Agriculture, Food and Rural Affairs. Available at www.omafra.gov.on.ca

Food and Agriculture Organization. 2003. World agriculture towards 2015/2030: An FAO perspective. www.fao.org.

Fredriksson, H., A. Baky, S. Bernesson, Å. Nordberg, O. Norén, P.-A. Hansson. 2006. Use of on-farm produced biofuels on organic farms – Evaluation of energy balances and environmental loads for three possible fuels. *Agricultural Systems*. 89: 184-203.

Kingwell, R., and B. Plunkett. 2006. Economics of On-Farm Biofuel Production. Invited Paper at Bioenergy and Biofuels, Feb. 10, 2006. Perth. Available at http://www.agric.wa.gov.au/pls/portal30/docs/FOLDER/IKMP/SUST/BIOFUEL/EconomicsBiofuelProdn.pdf

Kurki, A., A. Hill, and M. Morris. 2006. Biodiesel: The Sustainability Dimensions. ATTRA – National Sustainable Agriculture Information Service. Available at www.attra.ncat.org

Manning, P., M. Popp and M. Cochran. 2006. Biodiesel: Potential and Possibilities for the Arkansas Economy. Presentation. Available at www.1-800-**arkansas**.com/energy/files/**biodiesel**/MARK%20COCHRAN.ppt

Nagy, C. and H. Furtan. 2006. Economic Assessment of Biodiesel in Saskatchewan. Unpublished.

National Biodiesel Board. 2006. Biodiesel Emissions. Available at http://www.biodiesel.org/pdf_files/fuelfactsheets/emissions.pdf

Petro-Canada. 2006. Monthly Crude Oil Prices. Available at http://www.petro-canada.ca/eng/investor/9274.htm

Ryan, D. 2004. Biodiesel – A Primer. ATTRA – National Sustainable Agriculture Information Service. Available at www.attra.ncat.org.

Weseen, A.S. 2006. Personal Communication on Dec. 11, 2006.