Feasibility Report

Small Scale Biodiesel Production

WMRC
Waste Management and Research Center

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1.0 Introduction

Biodiesel is the name given to fuel for Diesel engines created by the chemical conversion of animal fats or vegetable oils. Pure vegetable oil works well as a fuel for Diesel engines itself, as Rudolf Diesel demonstrated in his engine at the 1900 world's fair with peanut oil as the fuel. However, vegetable oil is inherently viscous and cannot be burned efficiently at ambient temperatures in modern over-the-road vehicles. Conversion to Biodiesel fuel has the following advantages[5]:

- Readily mixes with petroleum diesel fuel in any ratio
- Restores lubricity of low-sulfur diesel fuel by mixing as little as 1% biodiesel
- Is made from renewable sources
- Reduction in viscosity over vegetable oil
- Can be burned in modern diesel with little or no modification
- Reduction in emissions of
    - Sulfur dioxide by 100%
    - Soot emissions by 40-60%
    - Carbon monoxide by 10-50%
    - Hydrocarbons by 10-50%
    - Nitrous oxide by 5-10%, depending on engine tuning and the age of the engine. Nitrous oxide emissions may increase in some instances.

This report is an overview of the Biodiesel production process on a small-scale basis.

2.0 The Biodiesel Reaction

For the reasons stated above, vegetable oil is transformed into biodiesel. The components that support combustion in the oil are the basis for biodiesel. These components, called fatty acids, have different properties that can be characterized by the number of hydrogen andcarbon atoms and the way these atoms are bonded together.

Table 1 shows the melting point, boiling point, and names of the most common fatty acids. It is important to note that vegetables oils are usually composed of several fatty acids. This means that the properties of an oil will be a mixture of the properties of the fatty acids it contains. It follows that the biodiesel made from the oil will also exhibit a mixture of these properties.

Table 1. **Structural Formula, Melting and Boiling Points for Fatty Acids** [3]

Fatty Acid	No. of Carbons and double bonds	Chemical structure	Melting point deg C	Boiling point deg C
Caprylic	C8	CH3(CH2)6COOH	16.5	239
Capric	C10	CH3(CH2)8COOH	31.3	269
Lauric	C12	CH3(CH2)10COOH	43.6	304
Myristic	C14	CH3(CH2)12COOH	58	332
Palmitic	C16:0	CH3(CH2)14COOH	62.9	349
Palmitoleic	C16:1	CH3(CH2)5CH=CH(CH2)7COOH	33	--
Stearic	C18:0	CH3(CH2)16COOH	69.9	371
Oleic	C18:1	CH3(CH2)7CH=CH(CH2)7COOH	16.3	--
Linoleic	C18:2	CH3(CH2)4CH=CHCH2CH=CH(CH2)7COOH	-5	--
Linolenic	C18:3	CH3(CH2)2CH=CHCH2CH=CHCH2CH=CH(CH2)7COOH	-11	--
Arachidic	C20:0	CH3(CH2)18COOH	75.2	--
Eicosenoic	C20:1	CH3(CH2)7CH=CH(CH2)9COOH	23	--
Behenic	C22:0	CH3(CH2)20COOH	80	--
Eurcic	C22:1	CH3(CH2)7CH=CH(CH2)11COOH	34	--

Common vegetable oils, along with the percentage of each type of fatty acid, are shown in Table 2. Also affected by the different molecule arrangements are ignition quality, low temperature viscosity, NOx emissions and the stability of the fuel. Fatty acids with one double bond (:1) are considered the best overall choice for biodiesel.[3]

The yellow grease listed at the top of Table 2 refers to most waste vegetable oil available at restaurants. The class “yellow” is an industry rating based on the quality of the grease. What is important to note in this table is that the fatty acid composition of yellow grease is estimated. The actual composition of yellow grease will reflect the source of the original oil.

Table 2. Percentage of fatty acid type for different oils.[3]

Fatty Acid Fat or oil	C8:0	C10:0	C12:0	C14:0	C16:0	C16:1	C18:0	C18:1	C18:2	C18:3	C20:0 C22:0	C20:1 C22:1	Other
Yellow Grease				1	23	1	10	50	15				
Tallow	--	--	0.2	2-3	25-30	2-3	21-26	39-42	2	--	0.4-1	0.3	0.5
Lard	--	--	--	1	25-30	2-5	12-16	41-51	4-22	--	,	2-3	0.2
Butter	1-2	2-3	1-4	8-13	25-32	2-5	25-32	22-29	3	--	0.4-2	.2-1.5	1-2
Coconut	5-9	4-10	44-51	13-18	7-10	--	1-4	5-8	1-3	--	--	--	--
Palm Kernal	2-4	3-7	45-52	14-19	6-9	0-1	1-3	10-18	1-2	--	1-2	--	--
Palm	--	--	--	1-6	32-47	--	1-6	40-52	2-11	--	--	--	--
Safflower	--	--	--	--	5.2	--	2.2	76.3	16.2	--	--	--	--
Peanut	--	--	--	0.5	6-11	1-2	3-6	39-66	17-38	--	5-10	--	--
Cottonseed	--	--	--	0-3	17-23	--	1-3	23-41	34-55	--	--	2-3	--
Corn	--	--	--	0-2	8-10	1-2	1-4	30-50	34-56	--	--	0-2	--
Sunflower	--	--	--	--	6	--	4.2	18.7	69.3	0.3	1.4	--	--
Soybean	--	--	--	0.3	7-11	0-1	3-6	22-34	50-60	2-10	5-10	--	--
Rapeseed	--	--	--	--	2-5	0.2	1-2	10-15	10-20	5-10	0.9	50-60	--
Linseed	--	--	--	0.2	5-9	--	0-1	9-29	8-29	45-67	--	--	--
Tung	--	--	--	--	--	--	--	4-13	8-15	72-88	--	--	--

The basic biodiesel reaction is shown in Figure 1. This reaction is known as transesterification (do-it-yourselfers often call it the one-step process). The triglyceride is vegetable oil. R_1, R_2 and R_3 represent any of the fatty acids listed in Table 1. Reacting one part Vegetable oil with three parts Methanol gives three parts Methyl Esters (Biodiesel) and one part Glycerol. In practical terms, the volume of Biodiesel will be equal to the input volume of vegetable oil.

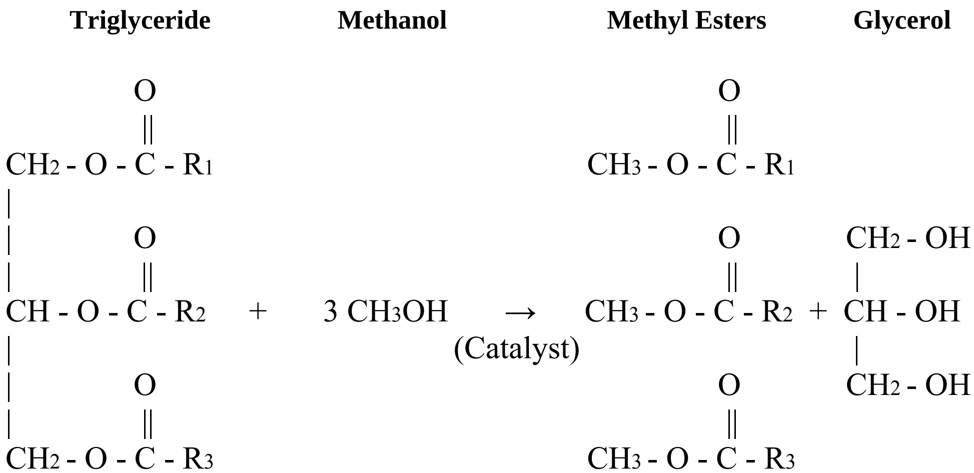

Figure 1. Transesterification Reaction. [1]

Notice in Figure 1 the addition of a catalyst. In theory, the catalyst is not consumed by the reaction and is removed in the glycerol and the wash water.

2.1 High Free Fatty Acid Grease

In the case of using waste vegetable oil (yellow grease) as a feedstock, free fatty acids (FFA's) may pose a problem. A free fatty acid is one that has already separated from the glycerol molecule. This is usually the result of the oil breaking down after many cycles of use. FFA's create 3 major problems.

- More catalyst will need to be used leading to higher cost
- Soap (fatty acid salt) is formed, making washing the finished product more difficult.
- Water is formed which will retard the main reaction
- The FFA's are not converted into fuel, reducing the yield

Figure 2 shows the reaction of FFA's and the catalyst NaOH.

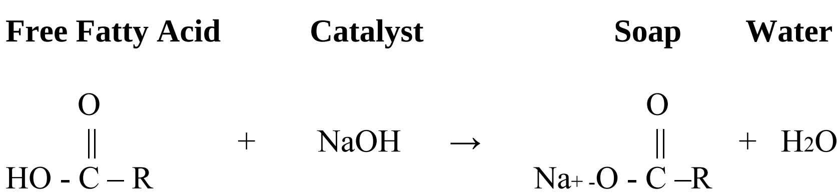

Figure 2. Formation of Soap. [1]

When the oil has less then 2.5% FFA, the problems listed previously are negligible by using the single step (transesterification) only. Others have reported good results up to 4% FFA.

2.2 Treating High FFA Waste Vegetable Oil

There are several methods to treat high FFA waste vegetable oils in small-scale systems. The easiest is to mix the high FFA oil with low FFA oil. This will work for an occasional high FFA batch. Other options require esterification (two-stage process) or intentionally make soap. These options are:

- Add catalyst and water to change FFA to soap, and remove the soap
- Add acid and a large percentage of Methanol to covert FFA to usable product
- Add acid, heat and a smaller percentage of Methanol to covert FFA to a usable product

Adding catalyst and water to high FFA oil is the easiest solution, but it also has some disadvantages. The percentage of feedstock that will be lost is higher then the percentage FFA. 100 gallons of waste vegetable oil will loose more than 10 gallons if it is 10% FFA. When this procedure is carried out in the reaction tank, the resulting water and soap created will collect above and below the oil. I found it time consuming to skim the soap off of the top of the oil.

Adding acid and large quantities of methanol to the oil is the most common method among small-scale producers. The disadvantage to this method besides time is the cost of the methanol. For 10% FFA, over seven gallons of methanol would be needed for the first stage to treat 40 gallons of oil. This is in addition to the eight gallons required for the second stage. A methanol recovery system could returnthree gallons from the first stage and 1 ½ gallon from the second, but this requires additional time and energy. This option requires an extra tank.[6]

Adding acid with high heat (90 degree C) and smaller quantities of Methanol is not widely used. WMRC is currently developing a bench scale process to test the feasibility.

3.0 Observations on obtaining waste vegetable oil

Waste vegetable oil (WVO) can be acquired from grease recyclers or directly from grease containers behind restaurants. Although it seems that free (from restaurant grease containers) as opposed to $1 per gallon (Dec, 2005 prices from grease recyclers) is a better deal, there are other facets to take into account.

When obtaining grease from containers, note that Solids and impurities will collect on the top and bottom of the oil. Better quality oil can be found in the middle. Generally the clearer the oil, the better the quality. Each time the center oil is removed, the concentration of contaminants increases. Eventually, there will be only low quality oil in the container. If this happens, it is best to wait until the grease recycler has dumped the container before collecting oil again. Using this method, WMRC has not had issues finding grease with FFA less then 2.5%. It is also important to note that manual grease collection is a challenge in the winter. The cold weather will solidify the grease.

Grease recyclers deal in large volumes of oil. Most will only sell truckloads (9,000 gallons) and not 55 gallons to individual customers. The advantage of processed WVO is that it is free of solids and water. It is also kept heated so that it is easy to transfer from one container to another. Processed WVO has a surprisingly high percentage FFA. Yellow grease from local recyclers (central Illinois) runs in the 8-15% range in the winter and 12-20% in the summer. The rise of percentage FFA in the peak summer months compared to the winter is attributed to constant heat from the summer weather. Because processed WVO has an FFA above 2.5%, it will require additional processing as discussed in the next section.

4.0 Biodiesel Processes

4.1 Process flow chart

Implementing the previously described processes results in the process flow shown in Figure 3.

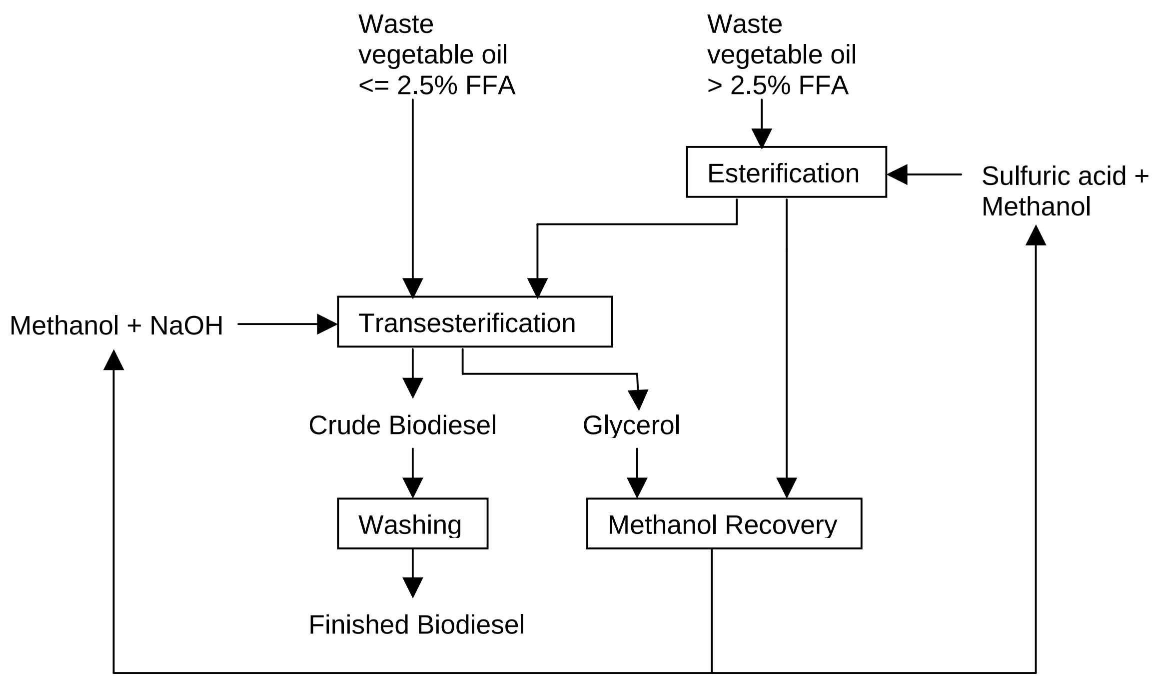

Figure 3. Process flow for Biodiesel process.

This process has two separate starting points. If vegetable oils can be obtained that are below 2.5% FFA, the esterification step is not necessary.

4.2 Process Details

The processes described here are used by WMRC in a controlled lab environment. We strongly recommend that you read and understand handling requirements of all chemicals used in this report. Take time to do additional research and obtain a thorough understanding of the processes involved before proceeding.

4.2.1 Heating of Oil

In order to speed up the reaction, the oil must be heated. The ideal temperature range is 120deg F to 140deg F. The reaction can take days at room temperature and will be inhibited above 140deg F. Heating with electric elements is usually the easiest way to bring the oil up to temperature. Equation 1 will give an estimate for the amount of time it takes to heat the oil.

$$Heating\,time(Hours) \cong \frac{\left[oil(gallons) * temperature\,increase(\deg F) * 2.3432 \frac{Wh}{gallon \bullet \deg F} \right]}{Heater\,power(Watts)}$$

Equation 1. Estimated heating time in hours

It is important to stir the oil as it is heated. This will result in a more even heating and reduce the temperature of oil exposed directly to the heating element.

4.2.2 Titration

In order to determine the percent of FFA in the oil, a process called titration is used. The vegetable oil is first mixed with methanol. Next, a mixture of Sodium Hydroxide (NaOH) and water is added until all of the FFA has been reacted. This is confirmed by checking the pH of the mixture. A pH of about 9 signifies all of the FFA has been reacted. Virgin vegetable oil from the same feed stock will usually titrate at approximately the same level, so checking every batch is not necessary. Waste Vegetable oil feed stocks will vary greatly. Every batch must be titrated.

The following items are needed to perform an accurate titration.

- Two 50mL flasks
- One 5mL graduated pipette
- A 1mL dropper
- A 10mL dropper
- A mixture of NaOH and water in 0.1% concentration
- pH solution and color chart

The NaOH water mixture can be prepared by adding 1 gram of NaOH to 1000ml distilled water. The mixture will be more accurate if it is first made as a 1% solution (10grams NaOH to 1000ml water). Next, add 100mL of the 1% solution to 900ml of distilled water. This will make a 0.1% NaOH solution.

The process for titration is as follows:

1) Place 10mL of Methanol in a 50ml flask
2) Add 1mL of vegetable oil (mix the oil thoroughly prior to drawing 1ml)
3) Mix the oil with the Methanol using the squirting action of the dropper
4) Add the ph indicator solution (usually 3 drops, check instructions)
5) Place 15ml 0.1% NaOH (know as titrant) solution in a 50ml flask
6) Draw exactly 5ml of the NaOH solution into the graduated pipette
7) Add the 0.1% NaOH to the methanol/oil mixture one drop at a time. Mix the solution using a swirling action between the drops. Using the eyedropper to mix the solution may help if the oil forms drops in the bottom of the flask.

8) Continue to add 0.1% NaOH until a pH of 9 (blue-green color) is reached. This may require more than 5ml. Refill the pipette and continue. Note the amount in ml that was required.
9) Look up the corresponding amount of NaOH required for the entire batch in Table 3. Multiply the amount by the number of gallons of oil to obtain the required amounts.

Table 3. Titration information

ml titration	%FFA	NaOH (grams) per gallon
0	0	13.25
0.5	0.3578222	15.15
1	0.7156445	17.025
1.5	1.0734667	18.925
2	1.431289	20.825
2.5	1.7891112	22.7
3	2.1469334	24.6
3.5	2.5047557	26.5
4	2.8625779	28.3875
4.5	3.2204002	30.28
5	3.5782224	32.1725

4.2.3 Mixing of Methanol and Catalyst

The purpose of mixing methanol and the catalyst (NaOH) is to react the two substances to form Methoxide. The amount of Methanol used should be 20% of the volume of the oil. Methanol and NaOH are dangerous chemicals by themselves, with Methoxide even more so. None of these substances should ever touch skin. Vapors should **NOT** be inhaled. Gloves, goggles and ventilation are required at **ALL TIMES** when working with these substances.

NaOH does not readily dissolve into Methanol. It is best to turn on the mixer to begin agitating the Methanol and slowly pour the NaOH in. When particles of NaOH cannot be seen, the Methoxide is ready to be added to the oil. This can usually be achieved in 20 – 30 minutes.

4.2.4 Draining of Glycerol

After the transesterification reaction, one must wait for the glycerol to settle to the bottom of the container. This happens because Glycerol is heavier then biodiesel. The settling will begin immediately, but the mixture should be left a minimum of eight hours (preferably 12) to make sure all of the Glycerol has settled out. The Glycerol volume should be approximately 20% of the original oil volume.

Figure 4 and Figure 5 show the difference in viscosity and color between the two liquids. The object is to remove only the Glycerol and stop when the biodiesel is reached. Glycerol looks very dark compared to the yellow biodiesel.   The viscosity difference is large enough between the two liquids that the difference in flow from the drain can be seen.

Figure 4. Draining Glycerol layer.

Figure 5. Draining biodiesel layer.

4.2.5 Washing of Fuel

The washing of raw biodiesel fuel is one of the most discussed subjects among do it yourselfers. The purpose is to wash out the remnants of the catalyst and other impurities. There are three main methods:

- Water wash only (a misting of water over the fuel, draining water off the bottom)
- Air bubble wash (slow bubbling of air through the fuel)
- Air/water bubble wash (with water in the bottom of the tank, bubbling air through water and then the fuel)

Which method works the best is dependent on the quality of the fuel. The method used at WMRC for all fuel is a combination of water washing and air bubble washing. Water is misted above the fuel at a rate of 5 gallons/hour. (The rate really depends on the diameter of the tank. The water should not break the surface of the biodiesel). The amount of wash water should equal the amount of oil, and can be drained throughout the washing process.

After the water is drained, the air washing process can start. At this point, the biodiesel is usually a pale yellow color. Air should be bubbled through the biodiesel mixture for approximately 8 hours. The bubbling should be just enough to agitate the biodiesel surface. A final drain of accumulated contaminants is done immediately after the air bubble wash is finished. The fuel is now ready for use.

4.3 Transesterification (biodiesel reaction for oils < 2.5%FFA)

The transesterification process can be summarized in the following steps:

1) Heat oil to 130deg F
2) Titrate the oil (determine how much sodium hydroxide to add)
3) Mix the sodium hydroxide and methanol to make methoxide
4) Mix the methoxide with the oil
5) Drain glycerol
6) Wash biodiesel

A detailed process and timeline are shown in figure 6.

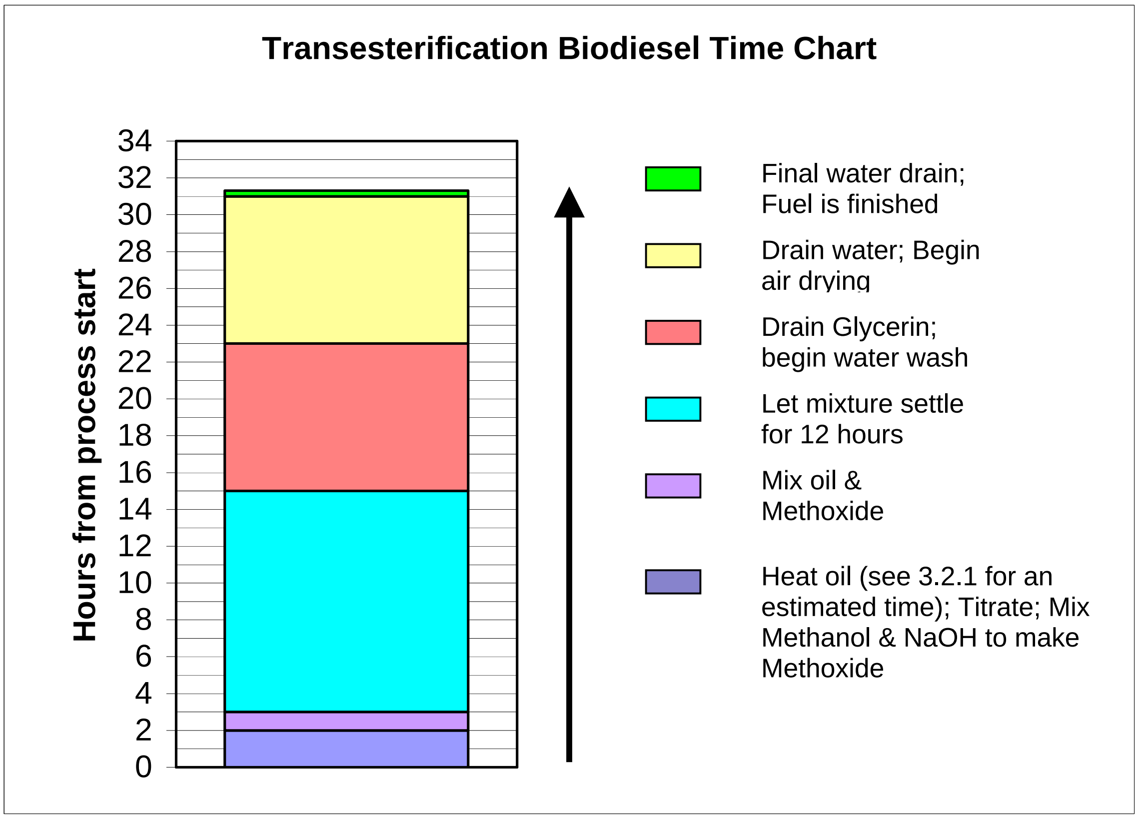

Figure 6. Biodiesel transesterification process and timeline.

4.4 Esterification of (pretreatment where FFA > 2.5%)

Esterification is done as a pretreatment step to the transesterification procedure when the FFA content is higher then 2.5%. In practice, it is a bit more complicated to implement then transesterification. A byproduct of the process is water, which impedes the reaction. As there is more FFA in the oil, more methanol percentage wise must be added to compensate for the water. To overcome this, industrial producers use counter current reactors that enable a continuous flow of high FFA oil in and water out.

Esterification is not covered in this document because it has not been thoroughly tested by WMRC.

5.0 Materials and Costs

5.1 Vegetable Oil Feedstocks

Virgin vegetable oils are the main feedstock for most biodiesel plants in the U.S. Virgin oil varies little in FFA from batch to batch, so the process can be repeated without change. Table 4 shows the amount of oil that can be expected from different types of oilseed plants along with estimated costs[4]. This is not an inclusive list, but contains the main oilseed crops that can be grown in the Midwest U.S. region. For reference, processed waste vegetable oil sells for $1 per gallon.

Table 4. Oil content and estimated cost of selected Midwest crops assuming no byproduct income.

Seed [1]	Oil content % [2]	Cold press oil removed % [2]	Oil Gallons/acre [3]	Oil Gallons/acre cold press	Grain lbs/acre	Grain bu/acre	Grain lbs/bushel [4]	$/bushel May 2005 [5]	$/cwt (100 lbs) May 2005	$/gallon cold press	$/gallon hexane extraction
Sunflower	42	69	102	70	1846	18.5	100	$14.00	$14.00	$3.67	$2.53
Soybean	19	42	48	20	1920	32	60	$5.80	$9.67	$9.21	$3.87
Safflower	35	66	83	55	1802	47.5	38	$5.32	$14.00	$4.61	$3.04
Canola	42	64	127	81	2298	46	50	$5.10	$10.20	$2.88	$1.85
Mustard Seed	35	63	61	38	1325	26.5	50	$6.35	$12.70	$4.38	$2.76
Linseed	38	66	51	34	1020	18	56	$13.00	$23.21	$7.03	$4.64
Hemp [6]	34	62	39	24	872	19	44	$22.00	$50.00	$18.03	$11.18

Note: Price per gallon does not include the cost of oil extraction; Price per gallon does not include revenue from sale of meal.

1 Note: Crops listed can be expected to grow in the Midwest region of the U.S.

2 Note: Adapted from table provided by Egon Keller GMBH & Co, a manufacturer of oilseed presses

3 Note: www.journeytoforever.org vegetable oil yields

4 Note: Canada Grains Council 1999 Statistical Handbook

5 Note: Estimated prices in Fall 2005, based on Canadian market prices and local Illinois elevator prices.

6 Note: Hemp pricing information and lbs/bu obtained from Canadian Hemp Trade Alliance

It is important to note that the last two columns of Table 4 show different costs per gallon depending on the type of extraction used. Columns 3 and 11 represent cold pressing, which is the normal process used in small-scale operations. It is essentially a manual process where the oilseed is crushed, separating the oil and expelling the solid as a press cake. Column 3 shows that this method removes approximately 60% in most instances. The amount of oil removed is dependent on the shell on the seed.

Hexane extraction is the method used by large-scale operations[1]. Hexane is a hazardous air pollutant and also very flammable. It can be found in gasoline. The facilities that use it for oil extraction have recovery methods that keep it from escaping into the atmosphere. This method is not considered to be adaptable to home use.

Comparison of prices in columns 11 and 12 to current gas prices would indicate that biodiesel from local oilseed crops is not feasible. However, these prices do not take into account the sale of the meal. Soybean meal does have a market in Illinois, and when this is subtracted from the cost of soybeans the price per gallon is a more reasonable $1.61. Table 5 shows the cost breakdown for soybeans, based on 7.6 lbs of oil per gallon.

Table 5. December 2005 Central Illinois truck prices.

Soybean	Soybean Oil, Crude			Soybean Meal	
$/bushel	$/lb	$/gallon	$/bushel	$/ton	$/bushel
$6.14	0.2115	$1.61	$2.43	$209.60	$4.62

Source: USDA-Illinois Dept of Ag Market News Springfield, IL

Other meals are valuable as livestock feed. This is particularly true with cold pressed meals. The remaining oil contains nutrients and also reduces the dust during handling.

5.2 Cost of Reactants

The costs of Sodium Hydroxide and Methanol vary greatly according to purchase quantities and location of purchase. For this reason, Tables 6 and 7 have been created to quickly determine the cost of a batch of biodiesel. All values are based on one gallon of oil.

Example

100 gallons yellow grease $1/gallon =>	$100
Titration 2mL, NaOH $4/lb = 0.18 * 100 =>	$18
Methanol $3.50/gal = 0.70 * 100 =>	$70
Total =>	$188 or $1.88 per gallon

Table 6. Cost per gallon of vegetable oil based on Sodium Hydroxide price and Titration.

		0 ml Titr	0.5 ml Titr	1.5 ml Titr	2 ml Titr	3 ml Titr	4 ml Titr	5 ml Titr
NaOH $/lb	NaOH $/gram	$/gal oil	$/gal oil	$/gal oil	$/gal oil	$/gal oil	$/gal oil	$/gal oil
0.05	0.00011	0.0015	0.0017	0.0021	0.0023	0.0027	0.0031	0.0035
0.10	0.00022	0.0029	0.0033	0.0042	0.0046	0.0054	0.0063	0.0071
0.20	0.00044	0.006	0.007	0.008	0.009	0.011	0.013	0.014
0.30	0.00066	0.009	0.010	0.013	0.014	0.016	0.019	0.021
0.40	0.00088	0.012	0.013	0.017	0.018	0.022	0.025	0.028
0.50	0.00110	0.015	0.017	0.021	0.023	0.027	0.031	0.035
0.80	0.00176	0.02	0.03	0.03	0.04	0.04	0.05	0.06
1.00	0.00220	0.03	0.03	0.04	0.05	0.05	0.06	0.07
2.00	0.00441	0.06	0.07	0.08	0.09	0.11	0.13	0.14
3.00	0.00661	0.09	0.10	0.13	0.14	0.16	0.19	0.21
4.00	0.00881	0.12	0.13	0.17	0.18	0.22	0.25	0.28
5.00	0.01101	0.15	0.17	0.21	0.23	0.27	0.31	0.35

Table 7. Cost per gallon of vegetable oil based on Methanol cost.

Methanol $/gallon	$/gal of oil
$0.50	$0.10
$0.75	$0.15
$1.00	$0.20
$1.25	$0.25
$1.50	$0.30
$1.75	$0.35
$2.00	$0.40
$2.25	$0.45
$2.50	$0.50
$2.75	$0.55
$3.00	$0.60
$3.25	$0.65
$3.50	$0.70
$3.75	$0.75

5.3 Glycerol

Glycerol is a byproduct of the biodiesel reaction. Although it is well known that glycerol is used in soap, medicines and cosmetics, the glycerol we are dealing with is not of the proper purity. Up to 20% is methanol and it will contain other impurities such as lye[2]. The best way to dispose of the glycerol is through a wastewater treatment plant. Any hauler with a dumping permit (septic tank cleaners) should be able to take the glycerol.

Fees are very reasonable for this service, but will vary over a wide range due to distance and ease of loading at the customer site.

5.4 Biodiesel Processor Layout

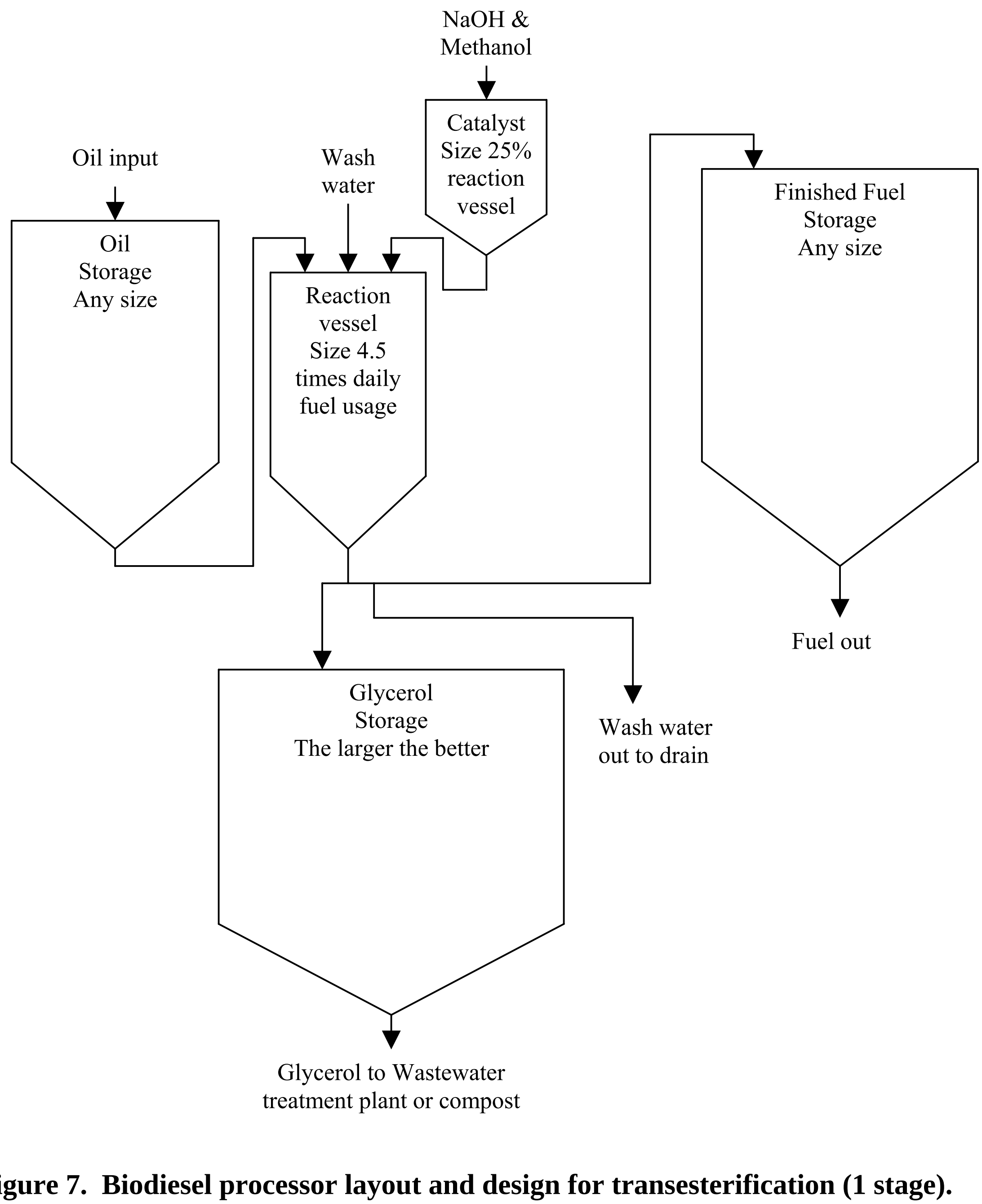

Figure 7. Biodiesel processor layout and design for transesterification (1 stage).

A complete transesterification biodiesel system is shown in Figure 7. All tanks in this system can be constructed from polyethylene or stainless steel. Steel is also an option for all except the catalyst reaction tank. Usually polyethylene is used because of the low cost and availability.

Starting from the left, the first tank is the oil storage tank. The sizing of this tank is dependent on the amount of oil that will be received at one time. If oil is purchased by the truckload, sizes up to 10,000 gallons may be required. Another option when dealing with small quantities is to store the oil in 55-gallon drums as needed instead of using a permanent tank.

The second tank from the left is the reaction tank. This is most important part of the system. The reaction tank requires either a mixer or pump to agitate the mixture when a reaction is taking place. It also may require heating, depending on if heating is done in the oil storage tank. Polyethylene will stand the maximum 140 degrees F temperature, however extreme care must be taken when using a heating element. Steel or Stainless is preferred for this component.

The sizing of the reaction tank is estimated at 4.5 times the daily fuel usage. This comes from two 8 hours days to make the fuel plus one day buffer. The extra 1.5 times is to leave extra room for the mixing and the wash water. Not allowing enough room for the wash water would require the water to be drained often.

The catalyst reaction vessel is the smallest in the system. It is also shown elevated above the top of the biodiesel reaction tank. It is important to locate the catalyst tank higher to avoid the contents of the main reaction tank from contaminating it. Some systems mount the catalyst tank lower and use a check valve. This works to a point, but many times the valve will stick due to catalyst residue. It is also harder to control the flow with the check valve setup.

Sizing of the catalyst-mixing tank is 25% of the main reaction tank or 40% of the amount of oil used. The catalyst tank is filled to 20% of the volume oil used, but because the mixture is hazardous it is best to double the size to avoid spillage or splashing. A mixer must be used in this tank.

The fuel storage tank can be any size. It is best to locate it away from the other equipment so that is will not be accidentally damaged.

The glycerol storage tank is not required, but is the best solution when the glycerol is to be picked up by a waste hauler. The tank should be sized according to what the waste hauler can move in a load. The charges are generally the same regardless of how full the truck is. Location should be determined by ease of access as haulers charge by the amount of time to load the truck.

6.0 Safety and Environment

Biodiesel producers are regulated by two entities: OSHA and the environmental protection agency. OSHA's concern is with the environment for the workers. It considers biodiesel production facilities to be chemical plants. The handling/storage of class A flammable liquids (methanol) can be found under section 29.1910.106. Some of the rules that may apply are:

- Methanol storage containers must be metal, grounded, use masonry supports and must not spill contents if connectors burn through
- Space required around tanks for fire fighting access
- Explosion proof electrical wiring
- No other operations in the room with the equipment

The environmental protection agency (EPA) deals only with the protection of the environment. In the case of biodiesel, most of the concern is about containment from spills of the various fluids.

References

1. J. Van Gerpen, B. Shanks, and R. Pruszko, D. Clements, and G. Knothe, “Biodiesel Production Technology”, Report from Iowa State University for the National Renewable Energy Laboratory, NREL/SR-510-36244, July 2004.

2. Jon Van Gerpen, “Business Management for Biodiesel Producers”, Report from Iowa State University for the National Renewable Energy Laboratory, NREL/SR-510-36242, July 2004.

3. K. Shaine Tyson, Joseph Bozell, Robert Wallace, Eugene Petersen, Luc Moens, “Biomass Oil Analysis: Research Needs and Recommendations”, National Renewable Energy Laboratory, NREL/TP-510-34796, June 2004.

4. Steven Hobbs, “Bio-diesel, farming for the future”, Presentation to the 11th Australian Agronomy Conference, 2003.

5. Tickell, Joshua, 2003. “From the Fryer to the Fuel Tank”, Bookmasters: Ashland, OH.

6. St. Louis biodiesel club discussion forum