Biodiesel

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Recently, considerable attention has been drawn to the production of alternative fuels from domestic, renewable resources. The two most often referenced fuels are ethanol and biodiesel. Biodiesel is a substitute diesel fuel that has been shown to be non-toxic, biodegradable, and has demonstrated significant reductions in all exhaust emissions over petroleum diesel. Biodiesel is produced from the chemical bonding of an alcohol with oils, fats, or greases. Biodiesel is simple to use and can be blended at any level with petroleum diesel to create a biodiesel blend. It can be used in compression-ignition (diesel) engines without modifications.

Table 1. Biodiesel Feedstock Pricing and Impact on Production Costs

Feedstock	Price per Pound in Cents	Estimated Pounds of Feedstock per Gallon of Biodiesel	Feedstock Cost per Gallon of Biodiesel Produced
Crude Soybean Oil	$.25	7.5	$1.88
Tallow, Inedible	$.18	7.5	$1.35
Yellow Grease (<10% FFA)	$.12	8.0	$0.96
Brown Grease (>20% FFA)	$.05	8.0	$0.40

Biodiesel is increasingly being used in federal, state, and transit fleets, private truck companies, ferries, tourist boats and launches, locomotives, power generators, home heating furnaces, and other equipment. There is a growing interest in using biodiesel where workers and school children are exposed to diesel exhaust and to control local pollution sources that face restricted use unless emissions can be reduced.

Biodiesel production costs are highly dependent upon feedstock costs. The cost of the fats or oils used to make biodiesel is 60 to 75 percent of the finished product cost; therefore, less expensive raw materials are better (see Table 1). To economically produce biodiesel, a production facility must have access to low-value feedstock, develop quality, high-value co-products, and enjoy a cost-effective and high-yielding process. These traits are all tantamount to the long standing rendering industry where yield, quality, and cost have been the drivers for highly successful operations.

The rendering industry is uniquely positioned to become a leader in biodiesel production due to its access and control of volumes of low-value feedstock such as yellow and brown grease. This opens a golden opportunity for the use of animal wastes, fats, and rendered products as biodiesel production feedstock. Throughout the world, there is an enormous amount of recycled fats, oils, and greases generated from slaughterhouses, renderers, restaurants, food processing industries, and fast food shops everyday. Current practice for utilizing these products is to employ them as concentrated sources of energy in animal feeds, building blocks for chemical processes and products, and to blend with other feedstocks. However, these are becoming limited markets and biodiesel has the potential to become the most significant market of animal fat.

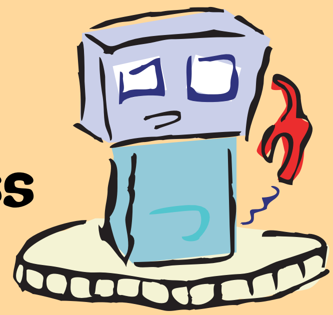
The United States produces approximately 23.7 billion pounds of plant oils and 11.6 billion pounds of animal fats and recycled cooking oils annually (see Chart 1). The animal fats supply can potentially be converted to over 1.375 billion gallons of biodiesel, or approximately one third of the total U.S. production capacity. Because of the availability of this low-cost renewable fuel source, biodiesel production has the potential to become an integral and complimentary business line for existing rendering facilities.

Biodiesel Production Technology

As stated previously, feedstock costs play a major role in the overall cost of biodiesel production. To address this, a successful biodiesel producer must employ a technology that efficiently synthesizes the lower cost, lower quality feedstocks such as animal fats and rendered products and recovers a high quality, valuable co-product – glycerol. The glycerol will provide added value to the process and offset the production costs of biodiesel thereby effectively producing a biodiesel fuel that can be marketed at values competitive with petroleum diesel.

Currently, most biodiesel is produced from vegetable oils by a two-step process of acid catalyzed esterification followed by a base catalyzed transesterification. The vegetable oil is treated with an acid and methanol mix to convert the free fatty acid portion to fatty acid methyl esters. The acid is generally sulfuric acid, which serves as a catalyst. In the transesterification step, the glyceride portion of the oil is mixed with more methanol and a catalyst (usually sodium or potassium hydroxide) to form esters and glycerol. The two phases are then separated from each other and the methyl ester product is purified using a water wash process. The higher the free fatty acid content

A compelling business for the rendering industry.



in the feedstock, the more complex the process becomes requiring additional acid consumption, reduced yield, and multiple acid esterification steps. If the free fatty acid conversion is not complete, soap is generated during the subsequent transesterification step, making separation of the glycerol and water wash purification difficult. The sulfuric acid must be neutralized prior to conducting the base catalyzed transesterification, further adding to the salt burden of the process. In traditional processes, this salt product will report to the glycerol phase making glycerol co-product recovery difficult and expensive.

As renderers enter the biodiesel production marketplace, they will require biodiesel production technologies and processes that recognize the complexity and range of the available feedstocks and the corresponding value of a high quality glycerol co-product. Additionally, yield of feedstock to produce biodiesel is very important. A one-cent per pound change in feedstock prices will result in a seven- to eight-cent per gallon change in the finished biodiesel production costs. Cost-effective multi-feedstock capability, product yield, and co-product quality are the most important factors when considering a biodiesel production technology. Other factors include operational costs such as labor, energy, chemicals and consumables, processing time, waste treatment or disposal, and capital depreciation.

Several technologies have recently been developed that have replaced the traditional acid esterification and water wash purification processes with other product separation, purification, and recovery technologies. Technology developments have also resulted in continuous operations as opposed to the traditional batch operations thereby greatly reducing the required process cycle time from days to hours. Glycerol recovery technologies are also being implemented, resulting in recovered glycerol quality in excess of 95 percent pure. Renderers need to be aware, however, that final glycerol product classification as either kosher, pharma, or United States Pharmacopeia-grade glycerol may be dependent upon certification of the feedstock source.

Product yield is a business concept quite familiar to renderers. Yield of biodiesel is often times reported on a percentage basis. The genesis for this value must be well characterized and understood for it to be meaningful. While most feedstocks nominally weigh 7.4 pounds per gallon and the unit weight of biodiesel is generally reported to be 7.34 pounds per gallon, it can easily be seen how yields nearing 100 percent are reported. Moreover, through the process, the separation and removal of the glycerol is typically offset by the addition of methanol, further supporting the reported absolute yields. The conversion of fatty acids or glycerides to biodiesel is easily accomplished;

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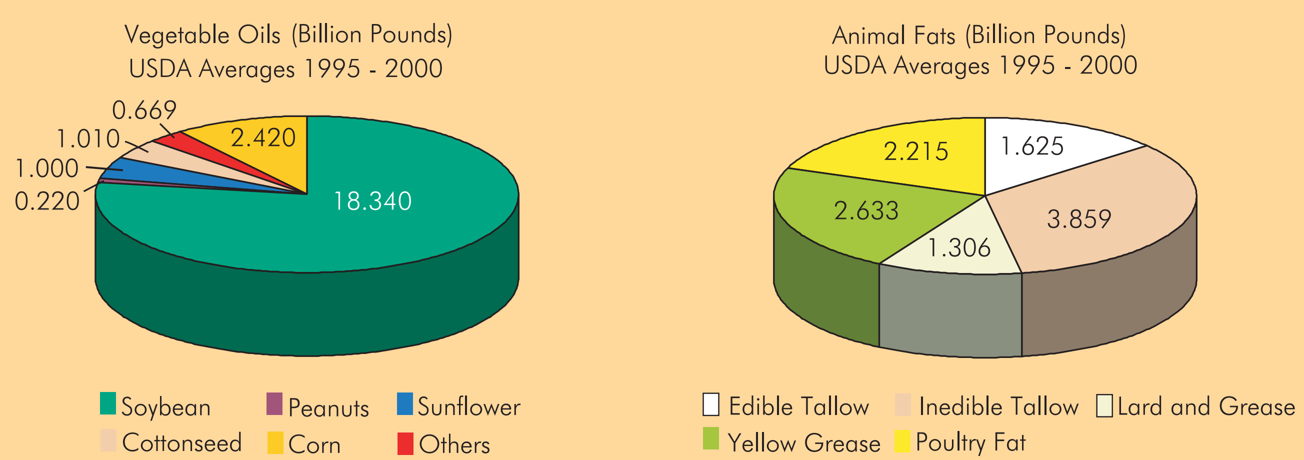
Chart 1. U.S. Production of Plant Oils and Animal Fats/Recycled Cooking Oil



Biodiesel *Continued from page 17*

however, the reality of achieving perfect process efficiency both in terms of conversion and product recovery is difficult. One must also be aware that not all feedstocks are similar in terms of fatty acid value, glyceride assay and moisture, insoluble impurities, and unsaponifiables. These differences, along with process conversion and product recovery efficiencies, can affect yield significantly. As a result, consistency in how yield is calculated and reported is often missing and biodiesel producers need to be cognizant of the basis for yield projections.

Prior to use as a commercial fuel, the finished biodiesel must be analyzed to ensure it meets certain fuel quality standards. In the United States, the standard is the American Society of Testing and Materials D-6751, which identifies the parameters pure biodiesel (B100) must meet before being used as a pure fuel or being blended with petroleum diesel. Other standards have been developed and adopted, particularly in Europe. See Table 2 below for a comparison of the various standards.

The production of biodiesel is not a panacea. The competition, petroleum diesel, is a formidable force and currently enjoys a price advantage, customer acceptance, and widespread availability. However, this dominant fuel supply is under increasing pressure from environmentalists and health experts and is subject to global issues beyond domestic control.

Total U.S. demand for distillate fuel oil for the year 2000 was 3.72 million barrels per day, or 60 billion gallons annually, the highest ever, of which 52.9 percent was from net imports (imports minus exports). Distillate fuel oil consists of diesel fuels and fuel oils.

The current biodiesel market is estimated at 1.2 billion gallons per year as a two percent blend (B2) with petroleum diesel. A challenge for the rendering industry is to help develop this market. The good news is that there are significant social, economic, and political (national and international) pressures to improve this market and the rendering industry must continue to play a role in

Table 2. Comparison of Various Biodiesel Standards

		Austria	Czech Republic	France	Germany	Italy	Sweden	United States
Standard/ Specification		ON C1191	CSN 65 6507	Journal Officiel	DIN E 51606	UNI 10635	SS 155436	ASTM D-6751-02
Date		July 1, 1997	Sept. 1998	Sept. 14, 1997	Sept. 1997	Apr. 21, 1997	Nov 27, 1996	Jan. 2002
Application	**Units**	FAME*	RME*	VOME*	FAME*	VOME*	VOME*	FAME*
Density 15°C	g/cm3	0.85-0.89	0.87-0.89	0.87-0.90	0.875-0.90	0.86-0.90	0.87-0.90	–
Viscosity 40°C	mm2/s	3.5-5.0	3.5-5.0	3.5-5.0	3.5-5.0	3.5-5.0	3.5-5.0	1.9-6.0
Distillation 95%	°C	–	–	<360	–	<360	–	360 max
Flashpoint	°C	>100	>110	>100	>110	>100	>100	130
CFPP	°C	0/-15	-5	–	0/-10/-20	–	-5	
Pourpoint	°C	–	–	<-10	–	<0/<-15	–	
Sulfur	% mass	<0.02	<0.02	–	<0.01	<0.01	<0.001	0.05 max
CCR 100%	% mass	<0.05	<0.05		<0.05			0.050 max
10% Dist.Resid.	% mass			<0.3		<0.5	–	
Sulfated Ash	% mass	<0.02	<0.02	–	<0.03	–	–	0.020 max
(Oxid) Ash	% mass	–	–	–	–	<0.01	<0.01	
Water	mg/kg	–	<500	<200	<300	<700	<300	500 max
Total Contam.	mg/kg	–	<24	–	<20	–	<20	
Copper Corrosion 3h/50°C		–	1	–	1	–	–	No. 3 max
Cetane No.	–	>49	>48	>49	>49	–	>48	47 min
Neutral. No.	mgKOH/g	<0.8	<0.5	<0.5	<0.5	<0.5	<0.6	0.80 max
Methanol	% mass	<0.20	–	<0.1	<0.3	<0.2	<0.2	
Ester Content	% mass	–	–	>96.5	–	>98	>98	
Monoglycerides	% mass	–	–	<0.8	<0.8	<0.8	<0.8	
Diglyceride	% mass	–	–	<0.2	<0.4	<0.2	<0.1	
Triglyceride	% mass	–	–	<0.2	<0.4	<0.1	<0.1	
Free Glycerol	% mass	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	0.02 max
Total Glycerol	% mass	<0.24	<0.24	<0.25	<0.25	–	–	0.24 max
Iodine No.		<120	–	<115	<115	–	<125	
C18:3 and High. Unsat. Acids	% mass	<15	–	–	–	–	–	
Phosphorous	mg/kg	<20	<20	<10	<10	<10	<10	<10
Alkaline Metals (Na, K)	mg/kg	–	<10	<5	<5	–	<10	
Cloud Point	°C							Report

* FAME - Fatty Acid Methyl Esters; RME - Rapeseed Methyl Esters; VOME - Vegetable Oil Methyl Esters

establishing market pull for this product.

Renderers have long been referred to as "the original recyclers" and without a doubt, the rendering process provides the most logical and environmentally sensible approach for recycling animal by-products and used greases into usable commodities. Now this industry is poised to once again lead in the development of a new frontier – biodiesel production. This new industry will create new production jobs, reduce the United States' dependency on foreign oil, provide a distinct environmental improvement, and most importantly, provide a renewable energy source.

Many felt that to spur on the progress of biodiesel production, particularly in the United States, legislation mandating usage, government subsidies, or liberation of excise duties is needed.

In 2000, biodiesel became the only alternative fuel in the United States to have completed the Environmental Protection Agency-required Tier I and II Health Effects testing under the Clean Air Act. These independent tests conclusively demonstrated biodiesel's significant reduction of virtually all regulated emissions, and showed that biodiesel does not pose a threat to human health. Biodiesel production is a compelling business opportunity for all members of the rendering industry.

Technology Providers

In preparation for this article, biodiesel technology providers were given the opportunity to describe their technology, provide information regarding their technology's performance and suitability to the rendering industry's feedstocks, and to comment on the biodiesel industry in general. These companies are thanked for their participation in this industry-wide summary. In addition, each technology provider was asked to comment on three questions.

1. Where do you see the biodiesel industry in two, five, and 10 years?

2. What are the hurdles and/or roadblocks for the biodiesel industry to overcome?

3. What does the biodiesel industry need in terms of markets, resources, technologies, legislation, customer acceptance, industrial standards, etc., to enable it to gain a substantial share of the world energy market?

Responses consistently stated that biodiesel had the potential to provide up to five percent of the world's total diesel consumption within the next five to 10 years. Many felt that to spur on the progress of biodiesel production, particularly in the United States, legislation mandating usage, government subsidies, or liberation of excise duties is needed. Many suggested that public awareness campaigns led by the National Biodiesel Board and engine manufacturers would be of great benefit in developing a market demand for the product and that these entities should take the lead in developing relationships with the petroleum fuels industry as a partner and not as competition.

Biodiesel Production Capacity in Million Gallons Per Year

Country	1997	2000	2003
France	21.0	76.4	98.3
Germany	21.6	61.4	73.7
United States	1.0	7.0	25.0
Italy	0.4	10.5	23.4
Austria	5.1	6.0	8.3
Belgium	4.5	5.1	6.0
Total	**53.6**	**166.4**	**234.7**

Sentiments from all providers echoed the need for quality standards in biodiesel production and to maintain consistency of quality and wide availability. The major hurdles mentioned for the biodiesel industry include cost and technical acceptance by engine manufacturers and state regulatory agencies. Many technology providers felt that a bright future awaits if biodiesel can become a preferred additive in concentrations of less than five percent, to serve as a renewable environmentally friendly cetane booster, lubricity enhancer, and oxygenate. Table 3 on pages 20 and 21 summarizes the responses from these biodiesel technology providers.

In addition to the technology providers listed in Table 3, considerable research and development of biodiesel production technologies, biodiesel testing, and potential feedstock sources is conducted at both Iowa State University (www.iastate.edu/Inside/2003/0613/biofuels.shtml) under the direction of Dr. Jon Van Gerpen (e-mail jvg@iastate.edu), and at the University of Idaho (www.uro.uidaho.edu/home/) under the direction of Dr. Charles Peterson (e-mail peterson@uidaho.edu). The Fats and Proteins Research Foundation, Inc. (www.fprf.org), under the direction of Dr. Gary G. Pearl (e-mail gpearl@fprf.org), is also leading the way for biodiesel production from animal fats and fully supports and contributes resources to the rendering industry's research needs and initiatives.

As can be seen, the majority of biodiesel processes employ a continuous process and are ready for commercial deployment utilizing a variety of feedstocks. Approximately half of the technologies surveyed claim capabilities to efficiently handle feedstocks with high (greater than 20 percent) free fatty acid contents while nearly all technologies recover the glycerol co-product with at least 80 percent purity. A potential biodiesel producer has a vast array of technologies to review in selecting the right technology for their operation and is encouraged to contact each of the respective technology providers for more specific process details, business arrangements, and economic proformas. The final selection of the most appropriate technology must be able to satisfy both the technical and commercial criteria for a successful and enduring operation. ❖