CROP INSIGHTS

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# Biodiesel Production in the US

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## Summary

- Biodiesel is a domestic, renewable fuel for diesel engines derived from natural oils and fats. Biodiesel offers economic, environmental, fuel quality and energy security benefits vs. petroleum-based diesel.
- Soybean oil is by far the leading feedstock for biodiesel production in the US. Other sources include canola oil, corn oil, and used cooking oils and fats.
- Natural oils are converted to biodiesel by a relatively simple refining process called transesterification.
- Pioneer is working with biodiesel processors to explore the opportunities for soybean products that may provide higher oil levels. Pioneer has designated its highest oil varieties as Pioneer IndustrySelect® High Oil varieties.
- Soybeans also require high yield potential to maximize oil yield per acre. Defensive traits are equally important to protect against yield-robbing pests and diseases.
- This Crop Insights will describe biodiesel production in the US, including crops used, production methods, and Pioneer's efforts to support this growing industry.

## Introduction

Biodiesel is a domestic, renewable fuel for diesel engines derived from vegetable oils and animal fats, including used oils and fats. Soybean oil is the leading vegetable oil produced in the US and the leading feedstock for biodiesel production. Biodiesel is not the same thing as raw vegetable oil; rather, it is produced by a chemical process which removes the glycerin and converts the oil into methyl esters.

Biodiesel can be used in any concentration with petroleum-based diesel fuel with little or no modification to existing diesel engines. These blended fuels are referred to as "biodiesel blends", and include the percentage of biodiesel in the blend, such as B2 (2%), B5 (5%) or B20 (20%).

The biodiesel industry is growing rapidly in the US (Figure 1) , and continued rapid growth is expected over the next decade. Current biodiesel production capacity of about 350 million gallons per year is expected to double within the next 18 months. In fact, there are more plants under construction or pre-construction than currently in operation (Figures 2 and 3). If capacity eventually reaches 1 billion gallons, this would represent almost 2% of the total diesel consumption in the US, which is near 55 billion gallons. In other words, continued growth of the biodiesel industry could soon generate enough production capacity to blend all diesel currently used in the US at the B2 level.

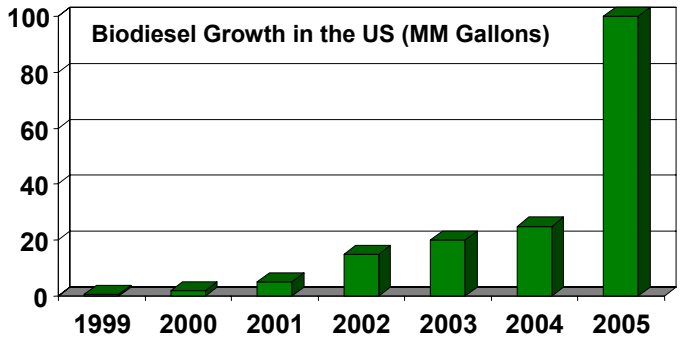


**Figure 1.** Biodiesel production in the US (millions of gal.)[1]

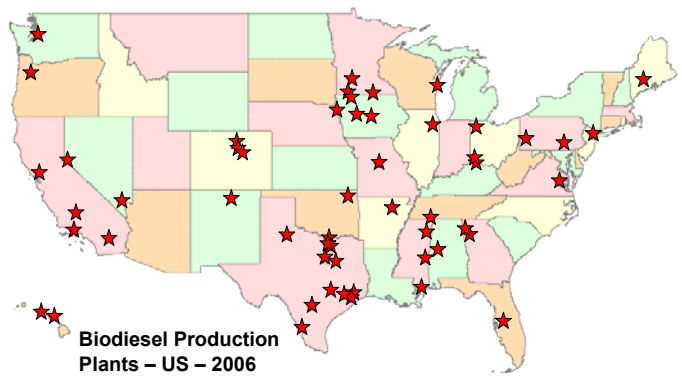


**Figure 2.** Biodiesel production plants in the US, 2006. [1]

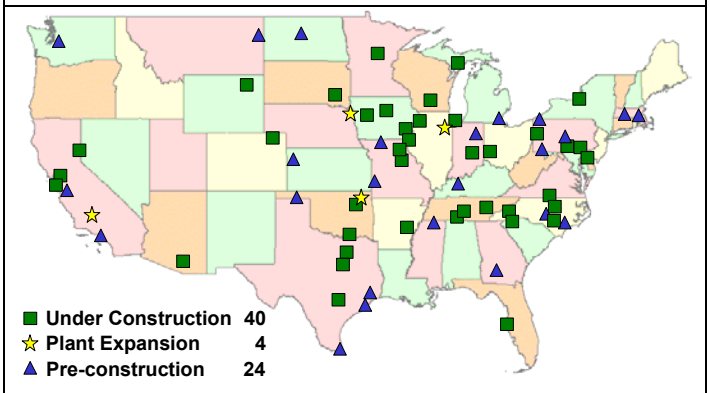


**Figure 3.** Biodiesel production plants under construction or in planning stages in the US in 2006. [1]

## Benefits of Biodiesel

Biodiesel offers economic, energy security, fuel quality, and environmental benefits vs. petroleum-based diesel:

**Economic Benefits –** According to proponents, increased utilization of renewable biofuels results in significant micro-economic benefits to both the urban and rural sectors, and the balance of trade. Increased demand for soybeans should help stabilize soybean prices received by producers (one bushel of soybeans produces about 1.5 gallons of biodiesel.)

**Energy Security Benefits –** Biodiesel is a domestically produced, renewable fuel source. It can be manufactured with existing technology and used in conventional diesel engines. For these reasons, it provides an immediate opportunity to began reducing our dependence on foreign oil.

Moreover, biodiesel has a positive net energy balance. For every unit of energy needed to produce a gallon of biodiesel, 3.24 units of energy are gained.

**Fuel Quality Benefits -** Biodiesel has positive performance attributes such as an increased cetane rating, high fuel lubricity, and high oxygen content. Its lubricating properties have proven to increase the longevity and cleanliness of diesel engines.

The cold weather properties of 2% or 5% biodiesel blends (B2 or B5) are virtually indistinguishable from those of no. 2 diesel. However, like no. 2 diesel, biodiesel blends can experience cold flow problems at low temperatures, especially with blends over 20%. The same additives used to lower the pour point of no. 2 diesel can be used with biodiesel blends in cold weather, or no. 1 diesel can be added with the same effect.

**Environmental Benefits -** Biodiesel is a cleaner-burning fuel than petroleum diesel. Biodiesel contains no sulfur or aromatics, and use of biodiesel in a conventional diesel engine results in substantial reduction of unburned hydrocarbons, carbon monoxide and particulate matter. A US Department of Energy study showed that the production and use of biodiesel resulted in a 78.5% reduction in carbon dioxide emissions compared to petroleum diesel. This reduction in "greenhouse gases" may help prevent undesired warming of the earth and its environmental consequences.

In it's pure form (B100), biodiesel is biodegradable and nontoxic. When replacing petroleum diesel as a marine engine fuel, this could help prevent damage to marine environments such as wetlands, marshes, rivers and oceans.

## Biodiesel Production Process

Biodiesel is made through a relatively simple refining process called transesterification. Of three well-known methods of transesterification of oils, the base-catalyzed reaction is the most economical and most widely used today. It's advantages include:

- Low temperature (~100 F) and low pressure (20 psi) processing.
- Direct conversion to methyl ester.
- Nearly complete conversion (98%) of oil to biodiesel with minimal reaction time and side reactions.
- Simple plant construction using conventional equipment.

The general biodiesel production process is depicted in Figure 4. A fat or oil is degummed, then reacted with an alcohol such as methanol in the presence of a catalyst to produce glycerin and methyl esters (biodiesel). The methanol is supplied in excess to assist in quick conversion and the unused portion is recovered and reused. The catalyst is most often sodium or potassium hydroxide which has already been mixed with the methanol. Technical know-ledge is increasing with the growth of the industry. Many producers are tweaking the process to improve efficiency, including a pre-processing step in addition to degumming.

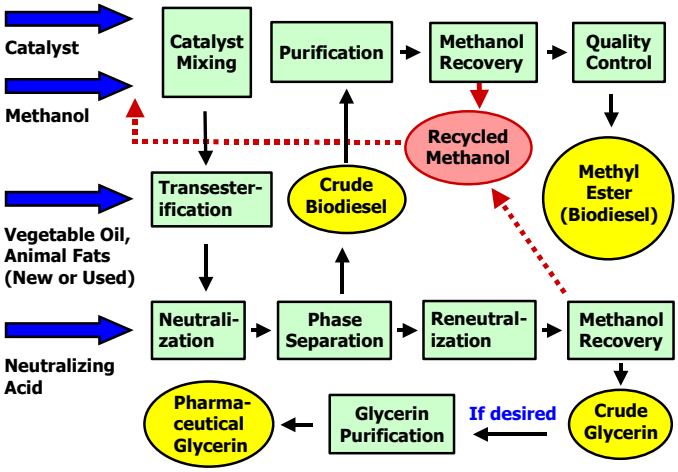


**Figure 4.** General diagram of the base-catalyzed esterification process to produce methyl esters (biodiesel) from natural oils.

### Biodiesel Feedstocks

Feedstocks for biodiesel production include vegetable oil from soybean, canola (rapeseed), palm, corn, sunflower and cottonseed. Other fats and oils, including tallow, pork fat, chicken fat, yellow grease and recycled cooking oil are also used as feedstocks, but are not expected to grow at the same rate as vegetable oils.

High quality feedstocks require a minimum content of free fatty acid, phosphorus and moisture in the oil. For this reason, animal fats and recycled cooking oil with high free

fatty acids need to be degummed and purified before they can go to reaction.

## Crops for Biodiesel Production

Soybeans are by far the main source of vegetable oil production in the US and likewise, biodiesel production. In fact, almost 90% of biodiesel produced in the US is made from soybean oil. Some experts estimate that if the biodiesel industry keeps its current momentum, over 10% of US soy-bean oil could be used for biodiesel production in the next few years. Canola is another popular oilseed crop used for vegetable oil and biodiesel production in the northern US.

Although corn grain is relatively low in oil content (less than 5%), the tremendous volume of corn processed for ethanol make corn a significant potential source for oil for biodiesel. New production techniques can extract the corn oil from dry distiller's grain (DDG), a by-product of ethanol manufacture. This oil is usually not suitable as a food product, but is acceptable for biodiesel production.

As the biodiesel industry grows, use of vegetable oils for fuel will compete directly with their higher value use for food. This will raise the price of vegetable oils and could affect acreages devoted to oilseed crops. While canola acreage is expected to increase, soybean demand has traditionally been driven by the meal market rather than the oil market, which makes acreage changes less certain.

**Table 1.** Oil and biodiesel yield of soybeans and canola.

| | Soybeans | Canola |
|---|---|---|
| **Yield per acre** | 45 bu | 1600 lbs |
| **Oil Content** | ~18% | ~44% |
| **Lbs oil / acre** | ~500 | ~700 |
| **Gallons biodiesel per acre** | 66 | 92 |
| **Acres per million gallons biodiesel** | ~20,000 | ~14,000 |
| 7.6 lbs of oil are required to produce 1 gallon of biodiesel. | | |

## Pioneer Hi-Bred Efforts in Biodiesel

Pioneer is a strong supporter of bio-based fuels to enhance grower income and to reduce reliance on imported energy sources. Pioneer is working diligently to develop seed products that enhance the growth potential of this emerging market for grains and oilseeds. For biodiesel, this effort is targeted primarily around oil content of oilseeds, which is the primary value driver for biodiesel production. For this reason, Pioneer has characterized the oil content for all soybean and canola seed products in their lineup. This can aid in selection of seed products for growers who have opportunity to market to a biodiesel processor.

**Image 4.** Soybeans and canola lead all crops in North America for vegetable oil and biodiesel production.

## Soybeans

Soybean meal as a high-protein supplement to livestock feed rations has been the traditional driver of soybean production rather than oil content. However, the increased demand for soybean oil may increase its price and importance vs. meal. Regionally, if biodiesel producers could structure premiums for soybeans based on oil content, high-oil soybeans would likely be demanded by growers with the opportunity to market to a biodiesel plant.

### Pioneer Soybean Research and Development

Pioneer characterizes its soybean varieties for oil content. Genetic differences for this trait, though currently small, make selection of higher oil soybeans possible. A small increase in oil content could mean significant savings for plants producing millions of gallons of biodiesel, as vegetable oil feedstocks comprise about 80% of the cost of biodiesel production. Pioneer is working with biodiesel processors to explore the opportunities for soybean products that may provide higher oil levels.

In addition to high oil content, soybeans require high yield potential to maximize oil yield per acre. Defensive traits are equally important to protect against yield-robbing pests and diseases. Seed companies and growers must consider yield potential and disease resistance traits just as carefully as oil content when selecting soybean varieties destined for biodiesel production.

### Pioneer IndustrySelect® High Oil and/or High Protein Soybean Varieties

Pioneer soybean varieties with characterization data[2] that indicate oil levels of 19% or more (at 13% grain moisture) and/or protein levels of 35% or more (at 13% grain moisture) have been designated as Pioneer IndustrySelect® High Oil and/or High Protein Soybean Varieties. These varieties can be identified on Pioneer's website at the following link:

http://www.pioneer.com/media/industryselect/about_industryselect/high_oil_soybeans.pdf

It's important to note that weather and environmental conditions can impact protein and oil levels from location to location and year to year. Future percent oil and protein data figures may vary because of these factors.

## Canola

Canola offers unique characteristics that produce high quality biodiesel:

- High oil content
- Low levels of saturated fat
- Low iodine values = a stable oil

Since the early 1990s, the average oil content of canola has increased substantially. The 2005 crop exceeded 44%, and some canola varieties produced 50% oil content in some environments. Higher oil means more oil per acre, which leads to more of the feedstock available for biodiesel production and less by-product relative to other oilseeds. Biodiesel producers realize greater efficiencies from canola.

**Pioneer Canola Research and Development**

Canola researchers at Pioneer are focusing their efforts on developing stable, high performing products for the market. An important selection criterion is oil quantity and quality.

Pioneer characterizes all canola products for oil content and quality and advances those products that deliver not only the highest harvestable yield potential but also higher oil content. A number of Pioneer canola products deliver oil content that surpasses the industry checks in the Canadian registration trials.

[1] Graph and maps courtesy of the National Biodiesel Board Website: http://www.biodiesel.org/

[2]Pioneer® brand soybean varieties are characterized for their protein and oil content using near-infrared instruments (NIR), with industry standard calibrations from the Federal Grain Inspection Service (FGIS).

## Websites for Biodiesel Information

National Biodiesel Board. http://www.biodiesel.org/

Canadian Renewable Fuels Association – Biodiesel
http://www.greenfuels.org/biodiesel/index.htm

Biodiesel Use in Engines. North Dakota State University.
http://www.ext.nodak.edu/extpubs/ageng/machine/ae1305w.htm

Soy Biodiesel. Iowa State University
http://extension.agron.iastate.edu/soybean/uses_biodiesel.html