Chemistry of the BioPro 190

The primary biodiesel reaction is called a transesterification reaction. In this reaction, a typical oil molecule called a triglyceride is chemically changed into three molecules called methyl esters. This reaction consumes three methanol molecules and releases one glycerin molecule. These three methyl esters (also called fatty acid methyl esters) are what we call biodiesel. (Please see attached page) Having three smaller molecules instead of one great big one has a number of advantages.

- It is less viscous so it is able to flow properly through the fuel system.
- It has a higher cetane rating.
- It is far less prone to polymerizing (when lots of molecules stick together to form a plastic).
- It has a lower freezing or gel point. (As a very general rule of thumb, biodiesel has about a 30 degree lower gel point than the original feedstock from which it is made.)

In order for the above reaction to happen, there must be an adequate amount of lye present to catalyze the reaction. There must be a bare minimum of about 3.5 grams of Sodium Hydroxide per liter of oil in order for the reaction to produce usable fuel (although it is preferable to have closer to 5.5 grams per liter.) The problem that most people run into is that there is often the presence of molecules called free fatty acids. These free fatty acids look just like a biodiesel molecule except that there is not a methanol attached to them. This is what makes them "free". (Note that fatty acid methyl esters are not actually acidic. They get their name because they are formed by the reaction of a free fatty acid and an alcohol molecule. The free fatty acids *are* acidic; they smell and taste sour. The real problem is that these free fatty acids stick to the lye being used in the reaction and neutralize it. The product of this reaction is one molecule of soap and one molecule of water. (Lye is a base and acids and bases are opposites so they neutralize each other.) When the free fatty acids neutralize the lye, the reaction will not proceed. The result will just be methanol and oil mixed together.

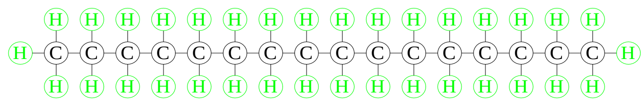
People often deal with this problem by titrating their feedstock. This is a method used to find out how much lye the free fatty acids will neutralize before they are all turned into soap. Then, more lye is added to compensate. For many, this process is quite effective. However, with just a few percent free fatty acids in the feedstock, the amount of soap produced in the neutalization makes it difficult or impossible to wash the fuel, and can lower the yields significantly.

That is why the BioPro 190 runs in two major stages. During the first stage (reaction 1), a process called an esterification occurs. The role of the esterification is to turn the free fatty acids in the oil into methyl esters by attaching a molecule of methanol to each one. This effectively turns most of the free fatty acids into biodiesel. Sulfuric acid is the catalyst that allows this reaction to happen. With the bulk of the free fatty acids gone, the lye is no longer at risk of being neutralized by the free fatty acids because most of the free fatty acids have been turned into biodiesel. This allows the user of the machine to regularly add a predetermined amount of lye instead of having to titrate each time.

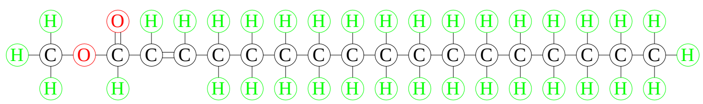
Interestingly, though, the esterification reaction never consumes all of the free fatty acids. It is an equilibrium controlled reaction, meaning that it can run backwards and forwards depending on the concentrations of the reactants and products. Because of this there will always be some reactants (free fatty acids) present as well as some products. Due to the large amount of methanol added at the beginning, the reaction is driven to produce mostly products (biodiesel and water.) Unfortunately, if the feedstock has a large amount of water in it to begin with, the esterification reaction will not proceed forward very well. Also, even with this reaction, there is a limit to the amount of free fatty acids that can be present in the oil. The chart accompanying the section *Feedstock* shows the limits of free fatty acids and water allowable in the feedstock.

As a quick calculation shows that, a user of the BioPro 190 is instructed to add the equivalent of 8 grams of lye per liter of oil. 1.5 grams of this is immediately neutralized by the Sulfuric Acid. This leaves 6.5 grams per liter to catalyze the reaction. If there are no free fatty acids present, at the start of reaction 2 we have found that the small amount of extra lye is not detrimental to the fuel making process. However, unless the user is processing oil that is very low in free fatty acids, the extra lye is often consumed by the free fatty acids that still remain after the esterification reaction.

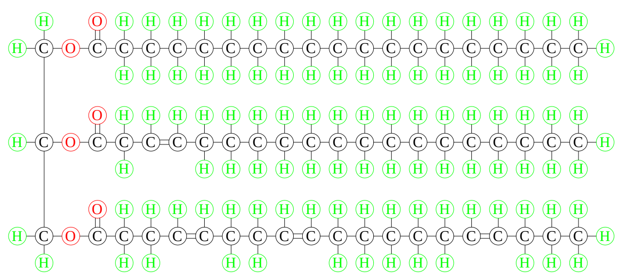
Diesel Fuel #2



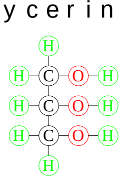
Biodiesel



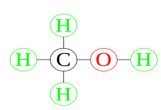
Natural Oil (Triglyceride)



Glycerin



Methanol



As can be clearly seen, a molecule of biodiesel looks just like one third of a natural oil molecule. A free fatty acid looks just like the biodiesel molecule, except that the carbon and three hydrogens over on the left side of the molecule are replaced with one single hydrogen attached to the oxygen.

H=Hydrogen
C=Carbon
O=Oxygen