# BIOdiesel TechNOTES

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Biodiesel Education Program, University of Idaho
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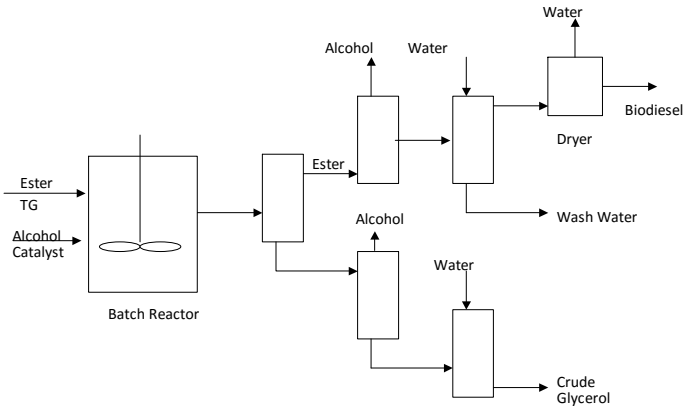
## Biodiesel Production Methods

Biodiesel production methods have evolved over the past 30 years from batch types to semi-continuous flow arrangements to true continuous flow schemes. All systems require a feedstock of some kind, an alcohol and usually a catalyst to initiate the reaction along with separation and purification steps. Separation is typically done by gravity or centrifugation. Water washing or a dry wash method using absorbents, ion exchange resins, filtration or a combination of these generally removes contaminants. Methanol removal is either done before or after the wash depending on the type of purification used. This TechNote describes some of the various production methods in use today as well as some experimental models still in the design and testing phase.

Batch type methods continue to be used and are still very active, especially among smaller plants, home brewers, and in economically or technologically depressed areas around the world. They require reaction tanks, storage tanks, a way to transfer, mix, separate then wash and dry the final product. Typically, more person-hours are needed per gallon than those for continuous flow. Batch systems, however, are low cost, flexible, and easy to start-up and shutdown.



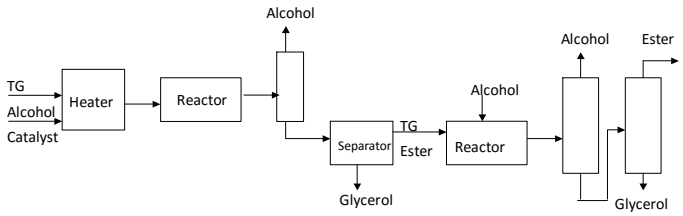

**Batch Reaction Process**

One modification of the batch plant incorporates two reactors with one or two larger settling tanks. This could be described as semi-continuous flow. While one batch is reacting the second batch is being prepared. When the first one is fully reacted, the contents are pumped into the settling tank, then the next one, alternating between the two until the settling tank is full. Subsequent batches can be placed in a second settling tank. Separation and purification are accomplished during other work cycles. Alternatively, separation can be done through centrifugation greatly shortening the downstream processing times.

There are a great number of continuous flow configurations in use today. They typically require a sophisticated method of monitoring and metering out the reactants in the proper proportions and feeding them into the reaction system as well as to control and direct flows for separation and purification of products and by-products.

A continuous flow system adapted from the batch process utilizes two continuously stirred tank reactors (CSTR) in series where the reactants are fed in at such a rate that the mixture is homogeneous. As reactants exit the first CSTR they have time to settle while the glycerol is drained off and the upper phase is fed into the second CSTR along with fresh reactants so that reaction is complete by the time the product exits the second reaction step.

Plug flow systems are set up to feed reactants at optimal rates and to push the mixture through pipes containing a series of static mixers. The length and feed rates are set so the reaction is complete at the exit. Continuous settling tanks or centrifugation accomplishes separation.




**Plug Flow Reaction System**

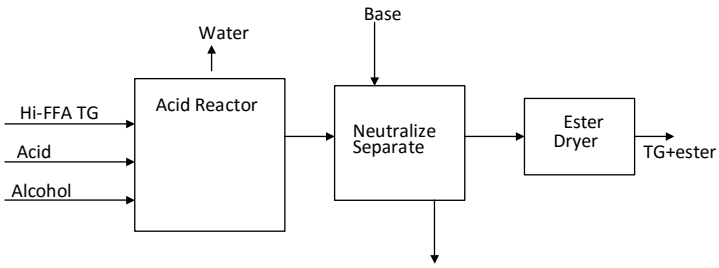
Some schemes make use of dynamic ultra-high sheer mixers to speed up the reaction by mashing the reactants together by sheer force and the action of cavitation. This type of mixer can be used in many different configurations but are usually set up to recirculate a portion of the flow and direct the remainder through static mixers to ensure complete reaction.

Ultrasonic units have a similar effect to high sheer mixers but have no moving parts and are credited with super-fast reaction times at high flow rates. They are often used in tandem as well as in series. Reactants are pumped through the ultrasonic zones where they are subjected to intense energy exposure that reduces the particle size to microscopic levels, which readily react.

The supercritical method relies on very high temperatures and pressures in the range of 350°C and 1200 psi. Under these conditions, reactions happen quickly without the aid of a catalyst. This method is energy intensive with high start-up costs, but low-cost feedstock can be used.

Glycolysis is a method for dealing with high FFA feedstocks. The procedure involves combining the feedstock with glycerol and methanol at high temperatures to convert the FFA's into mono- and di-glycerides. This reaction, which yields pure, water-free glycerides, is followed by a conventional base catalyzed transesterification step. After separation, the glycerol is purified to be reused in glycolysis while the esters are typically distilled to produce a high-quality biodiesel.

Another method for utilizing high FFA material is to convert the FFA's to esters using an acid catalyst. This esterification step can be used with feedstocks with FFA content ranging from 2 to 100% but is typically applied to oils and fats at the higher side of that range. This process can be followed by transesterification to complete the reaction.




**Acid Catalyzed Direct Esterification Process**

At optimum conditions, microalgae can contain up to 70% oil and yield as much as 5,000 gallons per acre per year. Harvesting, extracting and drying are time consuming and expensive. However, researchers at the UI have been looking at in-situ transesterification of lipids in microalgae in sub-/super-critical methanol. In this high temperature, high pressure process, the FFA's and triglycerides are converted to biodiesel as they are being extracted from the biomass. This can be accomplished wet or dry and with or without the use of a catalyst depending on process parameters. For more information on this work, please refer to TechNote #20.

Another experimental method being explored at the UI is the non-thermal liquid plasma (NTLP) technology. With a high voltage of 2-10kV from a low-cost AC power source, the energy associated with electric discharge in the feedstock mixture is strong enough to break down the chemical bonds of oil and alcohol so that the liquid plasma can induce the transesterification process and provide the energy needed for completion of the reaction. The process completes in milliseconds by ionizing the feedstock, resulting in higher conversion rates (>98%) than conventional methods. Other advantages include small reactor size, wide ranging scalability, feedstock flexibility, low cost low temperature operation, accelerated glycerol separation and insensitivity to contaminants and environmental disturbances.