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Bioenergy

Maximizing the Biodiesel Process

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Vegetable oils, whether from used cooking oil or oilseeds, are transformed into biodiesel with the help of a chemical reaction called transesterification. The main reason we use the transesterification process is to thin these oils so that they are more suitable for use in diesel engines. To do this, the oil molecules, made up primarily of triglycerides (Fig. 1) are broken apart into glycerol (Fig. 2) and fatty acid esters (Fig. 3).

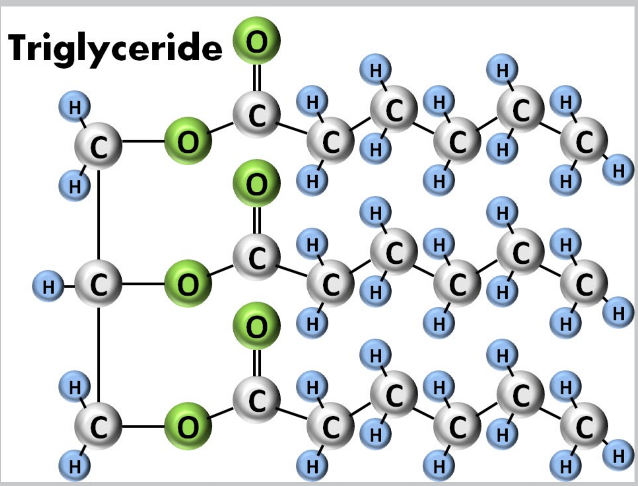

Fig. 1. The chemical structure of a triglyceride molecule.

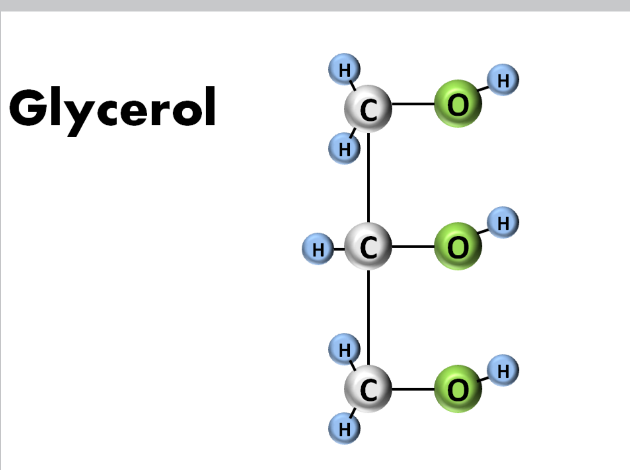

Fig. 2. The chemical structure of a glycerol molecule.

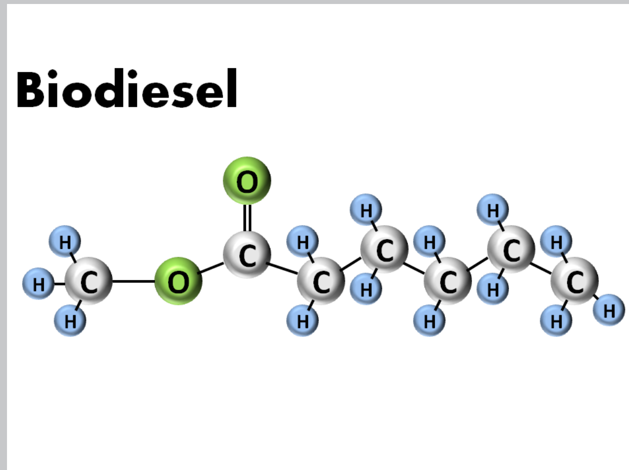

Fig. 3. The chemical structure of a fatty acid methyl ester (biodiesel).

The fatty acid esters are the biodiesel and can be easily separated from the glycerol that is also formed because the biodiesel is less dense and floats on top (similar to oil and vinegar). Breaking the triglyceride molecules apart requires an alcohol (usually methanol) and a catalyst (usually sodium or potassium hydroxide, similar to lye). The catalyst is used to help speed up the reaction. In addition to the catalyst, a number of other factors that affect the reaction process are *time, heat, type of catalyst, feedstock, alcohol*, and *mixing*.

Time

The time allowed for transesterification is important in producing a high quality biodiesel with good yields. Using basic catalysts (i.e. sodium or potassium hydroxide), the reaction generally proceeds very rapidly in the beginning and then slows as more biodiesel is produced and there are fewer materials to react. A study by Freedman et al. (1984) identified yields of around 55% for peanut and cottonseed oil and 80% for sunflower and soybean oil after only one minute of reaction time. Since the reaction slows down after this, it is usually advised to allow the reaction to take place for 1.5 to 2 hours to maximize yield and quality.

Heat

The addition of heat is always useful for making reactions go faster. In biodiesel production, increasing temperature will increase how quickly biodiesel is produced. A study by Freedman et al. (1984) with soybean oil found that a temperature of 140°F could produce 94% of the total biodiesel yield in about 6 minutes versus a yield of 64% at 90°F (Fig. 4).

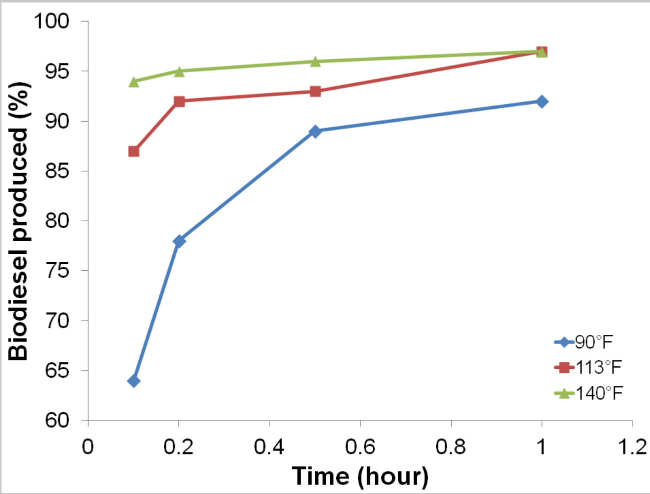

Fig. 4. The effect of temperature on biodiesel production (adapted from Freedman et al., 1984).

Type of catalyst

Basic catalysts, like sodium or potassium hydroxide, are good at increasing the rate of the reaction for producing biodiesel. Another option is a sodium methylate (also known as sodium methoxide) solution already dissolved in methanol. This solution can produce higher yields, require less catalyst and improve safety (due to lower exposure to corrosive dust).

Feedstock

The type of oil feedstock you use may depend on the level of free fatty acids (FFAs) it contains. Free fatty acids are large molecules containing many carbon atoms with an acid group at one end. These FFAs can interact with the basic catalyst to form soap which will cause problems separating the two end products; biodiesel and glycerol. In general, a FFA level greater than 5% will cause this. If this occurs, an extra processing step will be necessary which will involve using an acidic catalyst to convert the FFAs to biodiesel before the transesterification process can take place.

Alcohol

The transesterification reaction requires 1-1.5 gallons methanol for every 10 gallons of oil used to make biodiesel (oil-to-methanol ratio of 8:1). For maximum yield, however, more alcohol is usually used. Generally, about 2.5 gallons of methanol for every 10 gallons of oil (or an oil-to-methanol ratio of 4:1) is used since it gives the best yields (Fig. 5).

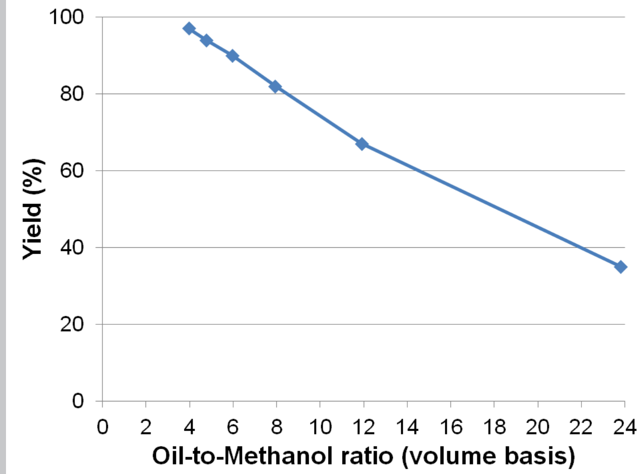

Fig. 5. Effect of oil-to-methanol ratio, based on volume, on biodiesel production (adapted from Freedman et al., 1984).

If there is too much alcohol, however, there can be difficulty in separating the biodiesel from the glycerol because the glycerol becomes more soluble in the biodiesel.

The type of alcohol used can also have an effect on the overall effectiveness of biodiesel production. Typically, methanol is used because it is cheaper but also because an alcohol like ethanol can prevent the separation of the biodiesel and glycerol products.

Mixing

In the reaction mixture, the catalyst will dissolve in the alcohol but the oil and alcohol are not soluble in one another. Therefore, mixing is important for initiating the reaction. Also, a slower rate of mixing can reduce the overall reaction rate.

Additional Resources

Freedman, B., E.H. Pryde, and T.L. Mounts. 1984. Variables affecting the yields of fatty esters from transesterified vegetable oils. Journal of the American Oil Chemists' Society 61(10):1638-1643.

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Meher, L.C., D. Vidya Sagar, S.N. Naik. 2006. Technical aspects of biodiesel production by transesterification – a review. Renewable and Sustainable Energy Reviews 10:248-268.

Stamenković, O.S., M.L. Lazić, Z.B. Todorović, V.B. Veljković, and D.U. Skala. 2007. The effect of agitation intensity on alkali-catalyzed methanolysis of sunflower oil. Bioresource Tech. 98:2688-2699.

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