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Review Article

Factors Affecting Biodiesel Production

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Biodiesel is a renewable alternate fuel to diesel engines that could be partially or fully replace or reduce the use of petroleum diesel fuel. Biodiesel can be produced from plant and animal fats through transesterification reaction. The transesterification reaction is affected by molar ratio of alcohol, presence of water and Free Fatty Acid content, reaction temperature, catalyst concentration and agitation speed. This review paper discuss about the factors involved in transesterification reaction.

Importance of biodiesel is always increasing due to increase in environment pollution caused by fossil fuel, depletion of world petroleum reserves (petrol and diesel) and ever increasing of fossil fuel prices. Vegetable oils are an alternative form of renewable fuel to diesel engines. But direct application of vegetable oil as fuel to diesel engines is not possible due to its higher viscosity. Hence reduction of vegetable oil viscosity is an urgent need. The viscosity of vegetable oils can be reduced by using different methods namely blending, pyrolysis, microemulsification and transesterification (Peterson *et al.,* 1991; Williamson and Badr, 1998; Ma and Hanna, 1999; Muniyappa *et al.,* 1996). However, transesterification methods have been widely used to reduce the viscosity and improve the fuel property of vegetable oils. But the transesterification reaction is strongly influenced by several factors including molar ratio of alcohol, catalyst, presence of water, free fatty acid in oil samples, reaction temperature, reaction time and agitation speed. Therefore the present review exposes the factors that will affect the transesterification reaction.

Effect of molar ratio of alcohol

Molar ratio of alcohol plays a vital role in biodiesel yield (Leung and Guo, 2006; Zhang *et al.,* 2003: Ma and Hanna, 1999; Freedman *et al.,* 1986). Normally the transesterification reaction requires 3 mol of alcohol for one mol of triglycerides to three mol of fatty acid ester and one mol of glycerol. Excess amount of alcohol increases conversion of fats into esters within a short time. So the yield of biodiesel increases with increase in the concentration of alcohol up to certain concentration. However further increase of alcohol content does not increase the yield of biodiesel but it also increase the cost of

alcohol recovery (Leung and Guo, 2006). In addition to this the ratio of alcohol content may vary with catalyst used , i.e. when we use alkali catalyst the reaction requires 6:1 ratio of alcohol to catalyze the transesterification of oils or fats (Zhang *et al.,* 2003; Freedman *et al.,* 1986). In case the oil samples contain high free fatty acid (FFA) such reaction does not respond to alkali catalyst. In that situation acid catalyst will be effective to catalyze the reaction and the reaction requires higher amount of alcohol than alkali catalyst. This is due to the fact that acid catalyst tolerates the FFA content and water content present in the oil samples. For example waste cooking oil requires higher ratio of alcohol i.e. 15:1 when subjected to acid catalyst reaction (Leung and Guo, 2006; Ali *et al.,* 1995: Sprules and Price, 1950; Zhang, 1994).

Effect of water and FFA contents

The water and Free Fatty Acid (FFA) contents are critical factors for transesterification reaction. Base-catalyzed transesterification reaction requires water free and low acid value (< 1) raw materials (Demirbas, 2009) for biodiesel production. If the oil samples have high FFA content (more than 1%) then the reaction requires more alkali catalyst to neutralize the FFA. Presence of water gives greater negative effect than that of FFAs because Water can cause soap formation and frothing which can cause increase in viscosity. In addition formation of gels and foams hinders the separation of glycerol from biodiesel (Demirbas, 2009 and 2005). Free fatty acid and water always produce negative result during transesterification and causes soap formation and consumes the catalyst which leads to reduction of catalyst effect. Water and FFA also leads to the reduction of methyl ester. To overcome this problem, supercritical methanol method (623 K, 43 MPa, 4 min of treatment with a methanol to oil molar ratio of 42:1) was proposed by Kusdiana and Saka (2004) which was compared to alkaline and acid-catalyzed method. It may be noted that water has less influence in supercritical methanol method.

Reaction time

Freedman et al (1986) observed the increase in fatty acid esters conversion when there is an increase in reaction time. The reaction is slow at the beginning due to mixing and dispersion of alcohol and oil. After that the reaction proceeds very fast. However the maximum ester conversion was achieved within < 90 min. Further increase in reaction time does not increase the yield product i.e. biodiesel/mono alkyl ester (Leung and Guo, 2006; Alamu *et al.,* 2007). Besides, longer reaction time leads to the reduction of end product (biodiesel) due to the reversible reaction of transesterification resulting in loss of esters as well as soap formation (Eevera *et al.,* 2009; Ma *et al.,* 1998).

Reaction temperature

Reaction temperature is another important factor that will affect the yield of biodiesel. For example higher reaction temperature increases the reaction rate and shortened the reaction time due to the reduction in viscosity of oils. However, Leung and Guo (2006) and Eevera *et al.,* (2009) found that

increase in reaction temperature beyond the optimal level leads to decrease of biodiesel yield, because higher reaction temperature accelerates the saponification of triglycerides. Usually the transesterification reaction temperature should be below the boiling point of alcohol in order to prevent the alcohol evaporation. The range of optimal reaction temperature may vary from 50°c to 60°c depends upon the oils or fats used (Leung and Guo, 2006; Ma and Hanna, 1999; Freedman *et al.,* 1984).

Catalyst concentration

Biodiesel formation is also affected by the concentration of catalyst. Most commonly used catalyst for biodiesel production is sodium hydroxide (NaOH) or Potassium hydroxide (KOH). However, Freedman et al (1984) found that the sodium methoxide would be more effective because mixing of sodium hydroxide with methanol produce little amount of water which inhibit the formation of end product (Biodiesel) due to the hydrolysis reaction (Guo, 2005). This is one of the reason for mixing of catalyst with methanol first and then added to the oil or fats. In addition to this when the concentration of catalyst is increases with oil samples, the conversion of triglycerides into biodiesel is also increases. On the other hand insufficient amount of catalyst leads to the incomplete conversion of triglycerides into fatty acid esters (Leung and Guo, 2006; Guo, 2005). However, optimal product yield (biodiesel) was achieved when the concentration of NaOH reaches 1.5 wt.% at the same time further increase of catalyst concentration proved to have negative impact on end product yield. Because addition of excess amount of alkali catalyst react with triglycerides to form more soap (Leung and Guo, 2006; Gabelman and Hwang, 1999).

Agitation speed

Agitation speed plays an important role in the formation of end product (mono alkyl ester or biodiesel), because agitation of oil and catalyst mixture enhances the reaction. For example the mixing intensities chosen were 200 rpm, 400 rpm, 600 rpm and 800 rpm for 60 min while other parameters were kept constant. At 400 rpm higher conversion of end product were obtained. Because, lower stirring speed shows lower product formation. On the other hand higher stirring speed favors formation of soap. This is due to the reverse behavior of transesterification reaction (Knothe *et al*., 2005; Demirbas, 2008; Eevera *et al*., 2009; Rashid and Anwar, 2008).

Conclusion

In recent years, biodiesel has become more attractive alternative fuel to diesel engines because of its eco-friendly benefit and from renewable nature i.e. plant and animal fats. Transesterification is a commonly employed method to reduce the viscosity during the production of biodiesel. The purpose of this method is to reduce the viscosity of oil or fat using acid or base catalyst in the presence of methanol or ethanol. However, trans-esterification reaction strongly affect by

molar ratio of alcohol, reaction temperature, reaction time and catalyst concentration. Hence this paper briefly discusses the factors that will affect the biodiesel production reaction.

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