Biodiesel Fuel Production Processes: A Short Review

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Abstract-
This review considered the recent efforts made in the biodiesel fuel production processes. The review on some of these production techniques centered on their cutting edge as well as their limitations. The review shows the possibility of having simple production techniques with a set of favourable processing conditions that will result into quality biodiesel production at the possible minimum costs.

Key words: Biodiesel, production process, transesterification

1. Introduction

The sky-rocketing of the world energy demand is traceable to the escalated growth in world population, industrialization and technology. Edirin and Nosa (2012) reported that global energy demand is expected to grow by 50% in the year 2025. Currently, the globe dependent heavily on coal, petroleum and natural gas as sources of energy. These sources, also known as fossil or nonrenewable resources, release life threaten emissions into the environment as a result of their usage. Hence, gargantuan and concerted efforts must ceaselessly be made to ensure that there is steady exponential growth in the production rate of renewable and sustainable forms of energy at the global level [2].

Part of the required efforts in meeting the global energy demand is the evaluation of the existing energy production techniques, so as point out areas where there is need for improvement or total overhauling. And one of the promising renewable energy sources is biodiesel fuel. Biodiesel, as a fuel, has high inherent energy level, high level of energy security, and satisfactory environmental (as well as social) impacts [3]. Biodiesel is simply defined as mono-alkyl ester of fatty acids which can be derived from lipids (animal fats, plant oils, microbial oils) or agricultural wastes (biomass). It is adjudged a very promising fuel in transportation sector due to the fact that it exhibits similar properties with petroleum diesel. And this makes it possible to blend biodiesel with petroleum diesel at any required ratio or use directly alone (B100) in petroleum diesel engines with little or no engine modification [4].

Keeping abreast of the trends in biodiesel production technologies is highly essential. By so doing, there would be access to new or enhanced production techniques that are cost effective with the production of high yield and high quality biodiesel. Therefore, the aim of this review is to briefly discuss the trend in biodiesel production processes, with emphases on the latest modifications in transesterification process.

2. Methods of biodiesel production

Biodiesel can be produced using different production processes. The production process to adopt depends on the availability of the raw materials (feedstocks) and ease of the application of the available production technology. The biodiesel production methods examined in this review are discussed below.
2.1 Pyrolysis process

The word “pyrolysis” is derived from pyro (which can be interpreted as "fire") and lysis (which is being interpreted as "separating"). Hence, pyrolysis can be simply defined as the decomposition or disintegration of organic compounds at very high temperatures, aided either by the presence of a suitable catalyst or absence of air [5]. It is an irreversible reaction involving the simultaneous change in both the physical and chemical and physical behaviours of the materials used to produce other useful material(s) due to the application of heat [5].

The organic materials that can be pyrolysed include animal fats, vegetable oils, natural triglycerides. [6]. The liquid components of the pyrolysed fats and triglycerides include biodiesel which function in the same manner as petroleum diesel in diesel engine. These liquid products have cetane number, flashpoint, pour point, heating values and viscosity properties that are similar to that of petroleum diesel [7].

The pyrolysis of any material is generally considered not to be environmentally friendly due to the release of high carbon residue, green gases and ash content that exceed the quantities obtained from the fossil fuels [5]. Also, the technology involved is an expensive one. These hinder its wide acceptance as a major process of biofuel production.

2.2 Trans-esterification process

To increase the engine fuel volatility and reduce its viscosity, lipids (vegetable oils or animal fats) are subjected to a process called trans-esterification. It is one of the commonly used method of biodiesel production due to its ease of operation. It involves reversible reaction between the triglyceride of lipids and short chained alcohol (methanol, ethanol or propanol), in the presence of a suitable catalyst to yield fatty acid alkyl ester (biodiesel) and glycerol [8]. The chemical reaction involved is as represented in Figure 1.

![Figure 1: Trans-esterification reaction for biodiesel production](image1)

The process is also known as alcoholysis (methanolysis, if methanol is used and ethanollysis, if ethanol is used). Based on the catalyst used, it can be referred to as enzyme-catalysed trans-esterification, acid-catalysed trans-esterification or base-catalysed trans-esterification process. It can also be seen as homogenous reaction process if the catalyst used is in liquid form as the reagents involved. And it is referred to as heterogenous reaction process if a solid catalyst is used [9]. Examples of the catalysts used in homogenous reaction process are KOH, NaOH, CH3ONa and H2SO4 while examples of the catalysts required for heterogenous reactions are CaO, and MgO.
The commonly reported experimental conditions for biodiesel production in homogenous process are methanol/oil mole ratio of 6, catalyst concentration of 0.5 wt./wt.%, reaction time of 60 minutes and reaction temperature of 60 °C. While optimum conditions for heterogenous reaction are methanol/oil mole ratio of 12, catalyst concentration of (2 – 5) wt./wt.%, reaction time of 120 minutes and reaction temperature of 60 °C [8]. That is homogenous process requires short reaction time, small catalyst concentration and small quantity of methanol to achieve same biodiesel yield compare with heterogenous process. But the advantages of the heterogenous process over homogenous process include high purity level of biodiesel, catalyst reusability and absence of washing water [9].

2.3 Microalgae biodiesel production process

This approach of biodiesel production, chemical or mechanical process is engaged in the extraction of oil or lipid from the microalgae biomass. The main challenge associated with this technique is the low yield of the extracted algal oil or lipids from microalgae cells, and this ultimately resulted into low yield of biodiesel economical. The extraction of lipid can be carried out through various methods such as mechanical press, solvent extraction, and supercritical fluid extraction. The extracted lipid can then be further processed into biodiesel production via different techniques such as transesterification. The low yield of the extracted oil and the high cost of auto bioreactor equipment required for biodiesel production make this technique not to be embraced as a common practiced [9].

3. The challenge of impurities in biodiesel on engine

It is highly essential that the production process engaged during production process produces high quality biodiesel. The effects of the presence of impurities in biodiesel on engine could be mild or severe, depending on the quantity and chemical nature of the impurities. The impurities include water, methanol, free fatty acid, soap, glycerol, catalyst, metals etc. Table 1 shows some of the effects of these impurities on engine.

Table 1: The effects of Impurities in Biodiesel on Engines

| Impurity                    | Effect on Engine                                      |
|-----------------------------|-------------------------------------------------------|
| Metals, Soap, Catalyst     | Carbon residue deposits in the injectors               |
|                             | Blockage of the engine oil filter                      |
|                             | Black smoke due to incomplete combustion               |
| Free Fatty Acids (FFA)      | Corrosion of the metallic parts                        |
|                             | Poor oxidation stability resulting in incomplete combustion |
| Water                       | Corrosion                                              |
|                             | Hydrolysis formation                                  |
|                             | Bacteriological growth                                 |
|                             | Blockage of the engine oil filter                      |
| Methanol                    | Corrosion of engine components                         |
| Glycerol                    | Carbon residue deposits in the injectors               |
|                             | Increase aldehydes emissions                          |

Source: [10].
4. New trend in biodiesel production processes

4.1 Use of Fresnel Lens Solar Concentrator (FSC)
Research has recently shown that the heat required for the production of biodiesel, at commercial level, can be easily generated through the application of a fast emerging heat production technique known as Fresnel Lens Solar Concentrator System (FSC). It is an improved solar energy generating system and it consists of Fresnel lens, heat receiver tracking system and heat removing device. Udawant et al, (2016). The application of FSC during transesterification process allow sufficient heat energy to be generated within very short reaction time, as well as increased biodiesel yield.

Widayat et al, (2019) revealed that the transesterification of waste cooking oil using FSC technology gave biodiesel yield of 99.18% in a reaction time of 5 minutes, reaction temperature of 60 °C, and catalyst concentration of 2.5wt./wt.%. But biodiesel yield of 21.3% was obtained under the same experimental conditions when the conventional heating approach was engaged. Also, their results showed that 98% yield of biodiesel produced using the conventional method required 70 minutes of reaction time and 60 °C reaction temperature. FSC has higher thermal efficiency compare to the conventional heating method and it saves time.

4.2 Reactive distillation
Another emerging trend in biodiesel production involves the introduction of reactive distillation. That is, the application of a single device that carries out reaction operation of the reagents and the separation of the products simultaneously. This technique allows a few devices to be used in the production of biodiesel, hence the technology is cost effective. The optimum conditions for the production of 95% biodiesel yield (from waste vegetable oil, methanol and KOH catalyst), using reactive distillation, are reaction temperature of (50–60) °C, reaction time of 60 minutes and (0.5–1.5 wt./wt.%) catalyst concentration [13].

Another benefit associated with the use of reactive distillation is the total recovery of the excess methanol at the upper portion of the reactive distillation system. This system has been successfully used for acid catalyzed operations.

4.3 Addition of acetone to homogenous transesterification reaction
The addition of acetone in a homogenous transesterification reaction involving vegetable oil and methanol (using alkaline catalyst) has been proved to promote short reaction time and also enhance minimum emission during fuel usage. It was reported by Yasuaki et. al. (2011) that acetone addition aids the forward reaction of transesterification process by enhancing the reactive nature of the methanol thereby promote high yield of biodiesel within short period of reaction.

4.4 Non-catalysed supercritical process
The non-catalysed supercritical process involves biodiesel production at high temperature (300 – 450 °C) and high pressure (>90 atm) from the superheated vegetable oil and methanol in the absence of catalyst. The superheated state of both the oil and methanol accounts for the elimination of the catalyst. High yield and high purity level of biodiesel is achieved within short reaction time of say 4 minutes [6].

Efforts need to be intensified on how to reduce the various costs involved during the operation. This is because, the challenges associated with this technology include high capital cost, high operating cost and high energy consumption. Also, failure to quickly convert the
biodiesel obtained in vapour state to liquid form will result into its decomposition by forming short chained organic compounds [6].

4.5 **In situ transesterification process of microalgae**

This is a process that combine both the oil extraction from microalgae and the transesterification reaction to form biodiesel. It is cost effective in the sense that few equipment would be required. Ehinem et al. (2012) reported that 99.9% biodiesel yield (with high purity level) was obtained from the in situ transesterification process of dry microalgae *Chlorella* when subjected to oil extraction (using pentane solvent) and transesterification conditions of 0.04 mole H$_2$SO$_4$ catalyst, methanol to oil mole ratio of 52, reaction time of 2 hours and reaction temperature of 60 °C.

4.6 **Impregnation of CO$_3^-$ of K or Na salt on CaO catalyst**

CaO is an excellent heterogenous catalyst for high yield of biodiesel during transesterification process. Research has recently shown that the stable and efficient catalytic behavior of CaO can further be enhanced through the impregnation of nano-sized CO$_3^-$ of K or Na salt. Wet or dry impregnation can be adopted. Biodiesel production involving process variables of methanol/oil mole ratio of 9 and catalyst concentration of 2wt./wt.% gave a yield of 92.4% with unimpregnated CaO catalyst, but biodiesel yield of 96.4% was obtained, when same process variables and CaO catalyst impregnated with K$_2$CO$_3$ were used [16]. The higher yield of biodiesel obtained from the CaO impregnated process could be explained in term of the reactive nature of both K and Na. That is, K or Na acts as catalyst enhancer thereby boost the catalytic performance of CaO to ensure the catalyst drives the reaction into completion during the transesterification process [9,16]. One limitation in the adoption of this technique during biodiesel production is the increase in the production cost.

**Conclusion**

This short review reveals the dynamic nature of the biodiesel production processes, as well as the efforts being made to achieve simple technique(s) under a set of favourable processing conditions that will give high quality level of biodiesel at the possible minimum costs.

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