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REVIEW

The effects of alcohol to oil molar ratios and the type of alcohol on biodiesel production using transesterification process

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Abstract The nature of alcohol and alcohol to oil molar ratio plays an important role on the method of biodiesel production. As a result, this paper examined different alcohols commonly used for the production of biodiesel fuel with more emphasis on methanol and ethanol. Further the different alcohol to oil molar ratios used for the production of biodiesel have been extensively discussed and reported. Also the effects of alcohol to molar ratios on biodiesel refining process and its physicochemical properties were investigated.

1. Introduction

Presently, global warming effect, fossil fuel diminishing reserves, and higher petroleum prices are the main issues driving worldwide interest on the development of alternative renewable, biodegradable and sustainable biofuels [10]. Fossil fuel combustion leads to about 98% of carbon emissions [31]. As such, renewable resources such as biofuels, wind, water, and hydrothermal energy are being widely considered as potential alternative sources of energy [74]. Biofuels such as biodiesel are considered to be a potential candidate to replace petro-diesel fuel [15]. In addition it is ranked among the fastest developing alternative to petro-diesel fuel in many developed and developing countries worldwide [74]. This is because the net level of carbon dioxide in the atmosphere is not increased by burning biofuel, and this minimizes the intensity of greenhouse effect [62]. Besides, its decreases particulate emissions, unburned hydrocarbons, and sulfur dioxide generated through its combustion process [56]. A life cycle analysis of biodiesel fuel demonstrated that overall CO_2 emission is reduced by 78% compared to petro-diesel fuel, hence eco-friendly [85]. Thus, biodiesel has the potential of lowering the net gas emissions from the transportation sector; that causes global warming and it could significantly decrease the mass and carcinogenicity of particulate matter emissions. Recently the interest in biodiesel fuel production

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has increased due to its environmental benignity [49]. For countries in which petroleum is imported, biodiesel technology is a big advantage [54].

The technologies usually employed to produce biodiesel fuel are classified into direct/blends, microemulsion, pyrolysis and transesterification reaction [26,29,32]. However, transesterification reaction is the most commercially used technology for the production of biodiesel [6,5]. Transesterification is the reaction through which triglycerides react with an alcohol in the presence of catalyst to produce biodiesel and by-product, glycerol [27,28,30,33]. This reaction is mostly affected by numerous factors among others which include: alcohol to oil molar ratio, reaction time, nature and amount of catalyst, reaction temperature, and the nature of feedstocks composition [26]. Nonetheless, alcohol to oil molar ratio is believed to be the most critical in the dynamics of biodiesel production [48].

Conventionally, biodiesel is transesterified using refined vegetable oils, catalyzed by an alkali [51]. Fig. 1 presents a schematic diagram of alkali-catalyzed transesterification for the production of biodiesel. However, edible vegetable oils contribute over 95% of global biodiesel production [48]. This process usually provides high-quality biodiesel fuel with less refining procedure. But, the prices of refined virgin oils are usually very high, hence rendering commercial biodiesel fuel production impracticable [16]. Recently, alternative feedstocks such as natural plant oils, animal fats, waste/used cooking oils, and non-edible feedstocks such as jatropha curcas, pongamia, castor and microalgal oils are used to produce biodiesel fuels, to circumvent the high prices of biodiesel fuel and improve its development [59]. Other low quality feedstocks being explored include: chicken fats, pork lard, beef tallow, and yellow grease [23]. Currently, microalgae are considered the most promising source of renewable energy. Although, these feedstocks are of low prices, the production and the refining processes of biodiesel products through such low quality feedstocks are difficult [48,24]. However several investigations have revealed the potential of biodiesel production through low-quality feedstocks. Fig. 2 shows percentage share of each renewable energy source [25]. Also, several researches have investigated the effects of alcohol to molar ratios on the production of biodiesel [63]. Therefore, this paper critically analyzed the effects of alcohols and oil to alcohol molar ratios as main variables in the production and refining of crude biodiesel products.

2. Alcohols for biodiesel production

Alcohol is one of the most important raw materials for the production of biodiesel. Alcohols are primary and secondary monohydric aliphatic alcohols comprising 1–8 carbon atoms [57]. A number of alcohols have been explored for biodiesel production, the most widely used acyl acceptors are methanol and to a slight extent, ethanol. Other alcohols utilized in producing biodiesel are the short-chain alcohols such as propanol, butanol, isopropanol, tert-butanol, branched alcohols and octanol, however these alcohols are costly [93].

Methanol and ethanol are the most often used alcohols in biodiesel production. Methanol is particularly preferred because of its physical and chemical advantages. Beside its reaction with triglycerides is quick and it can be easily dissolved in NaOH [57]. Demirbas [27] remarked that methanol, also known as "wood alcohol", is usually simpler to find compared to ethanol. Additionally triglycerides can react with varieties of alcohols. But the short-chain alcohols provide better conversions under the same reaction time [89]. Table 1 presents main production facilities of methanol and bio-methanol [27].

2.1. Methanol

As earlier mentioned, for biodiesel production via transesterification reaction, methanol is the most common alcohol used. However, the level of water in an alcohol is crucial for its successful application in the production of biodiesel. This is because the presence of water during transesterification reaction causes hydrolysis of triglycerides to free fatty acids which leads to soap formation, and poor yield. Unfortunately, the entire short-chain alcohols are hygroscopic and could easily absorb water from the atmosphere [84,92]. On the other hand, long-chain alcohols are mostly sensitive to contamination by water [85]. Van Gerpen et al. [84] remarked that biodiesel is produced from various alcohols, and the nature of alcohol used in the production process does not make any chemical

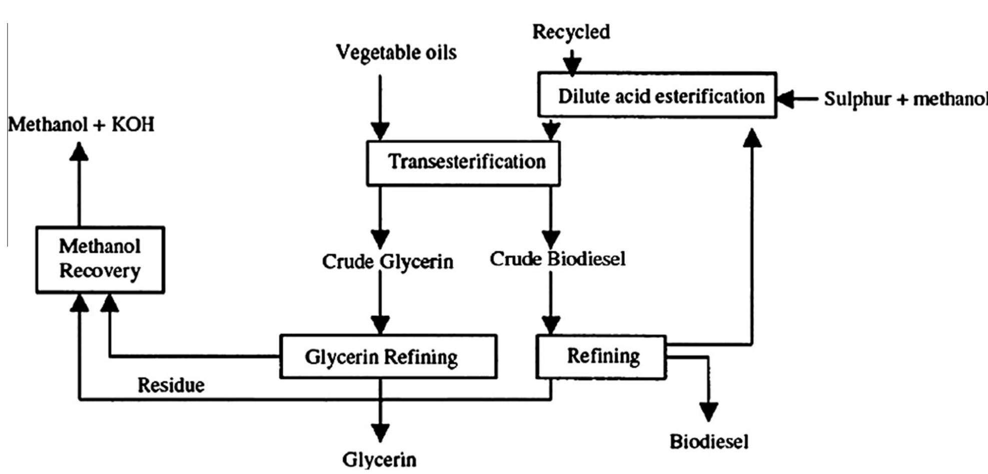

Figure 1 Schematic diagram of alkali-catalyzed transesterification for the production of biodiesel [48].