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Energy and cost analyses of biodiesel production from waste cooking oil

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ABSTRACT

Waste cooking oil is one of the energy sources for its unique composition which contains glycerol, It can be a good base for producing biodiesel. The objective of this study is to perform the energy and economic analyses of biodiesel production from Waste Cooking Oil (WCO) by the conventional transesterification method at the Tarbiat Modares University, Tehran, Iran. Data is acceded by performed biodiesel machine, with three replications during spring season (2012) in the same condition. The volume of biodiesel machine is 2000 L and the area of this lab is 100 m^2. The total energy input and energy output were calculated as 30.05 and 44.91 MJ L^{-1}, respectively. The energy output/input ratio was 1.49 in biodiesel production. The shares of renewable and non-renewable energy were 77.31% and 22.69%, respectively from total energy input. The benefit to cost ratio was found to be 2.081 according to the result of economical analysis of biodiesel production. The mean net return and productivity from biodiesel production were found to be 1.298 \$ L^{-1} and 0.946 kg \$$^{-1}$, respectively. The results showed that by applying ultrasonic and microwave instead of transesterfication and great managing, more benefit can be resulted.

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1. Introduction

Biomass can be re-grown from seeds or plant parts as long as solar energy, soil nutrients and a source of water exist. For this reason, biomass is recognized as a renewable source of energy. In recent years global interest in renewable energy production has significantly increased due to being eco-friendly and is seen as a means of helping to reduce global warming by displacing the use of fossil fuels. However, to be considered as a sustainable source, the input of energy required for biomass production must not exceed the output or amount of energy that can be extracted from the biomass. Due to its renewable, biodegradable, nontoxic and environmentally beneficial characteristics, biofuel is considered as an ideal alternative for fossil fuels. The production and use of biofuel has the potential of reducing dependence on petroleum, improving environmental quality, lowering the amount of emissions produced by human activities such as greenhouse gases (GHG), promoting rural development, and providing job opportunities [1,2]. Like many other countries such as the United States of America and some European Union countries [3], China is laying much effort in producing biofuel for vehicles and easing the great pressures from oil scarcity and environmental degradation, and at the same time promoting rural development. In 2006, the National Development and

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Reform Commission of China set a target of meeting 15% of transportation energy needs with biofuel by 2020 [4].

The production of first generation biofuels whose feedstock is agricultural crops will have a negative effect on food security if it is produced in large quantities [5,6]. However, using biomass crop produced from non-agricultural land as feedstock to produce second generation biofuels will not affect food security, and can be more conducive to improve the environment than the first generation biofuels. That is, sustainable biofuel production will be better achieved with a shift from the production of first generation biofuel to that of second generation biofuel [1,7].

Biodiesel is a mono-alkyl ester of long chain fatty acids produced from renewable feedstock. Biodiesel, having a chemical structure of fatty acid alkyl esters (usually fatty acid methyl ester, FAME), has recently become an alternative for petroleum-based diesel fuel. It is a non-toxic, biodegradable, relatively less inflammable fuel compared to the normal diesel and has significantly lower emissions than petroleum-based diesel [8]. In addition, biodiesel is better than diesel fuel in terms of sulfur content, flash point, aromatic content and cetane number [9]. Edible vegetable oils such as canola, soybean, and corn have been used for biodiesel production and found to be a diesel substitute [10,11]. However, a major obstacle in the commercialization of biodiesel production from edible vegetable oil is its high production cost, which is due to the high cost of edible oil. Waste cooking oil, which is much less expensive than edible vegetable oil, is a promising alternative for edible vegetable oil [12]. Waste cooking oil and fats set forth significant disposal problems in many parts of the world. This environmental problem could be solved by proper utilization and management of waste cooking oil as a fuel. Many developed countries have set policies that penalize the disposal of waste cooking oil the waste drainage [13]. The Energy Information Administration in the United States estimated that around 100 million gallons of waste cooking oil are produced per day in USA, where the average per capita waste cooking oil was reported to be 9 pounds [14]. The estimated amount of waste cooking oil collected in Europe is about 700,000–100,000 t/year [15].

Transesterification is the process by which the glycerides present in fats or oils react with an alcohol in the presence of a catalyst to form esters and glycerol [16,17].The conventional transesterification process has anyway, some drawbacks. First, it requires a lot of steps like the purification of the esters from the un-reacted reactants, separation of glycerol, which is the other product of the transesterification reaction, and catalyst recovery (Fig. 1). The free fatty acid (FFA) content of the vegetable oil should not exceed 2% when an alkaline catalyst is employed unless saponification reactions take place with a reduction in the catalyst activity. Also, the use of an acid catalyst has its own disadvantages because it is less efficient when compared to the alkaline one and the water produced by the FFA esterification with alcohol inhibits the transesterification of glycerides [18]. The acid-catalyzed process using waste cooking oil had less equipment pieces than the acid-catalyzed process for pretreatment of waste oils prior to alkali-catalyzed production of biodiesel, but the large methanol requirement resulted in more and larger transesterification reactors, as well as a larger methanol distillation column. Methanol distillation was carried out immediately following transesterification to reduce the load in downstream units in the acid-catalyzed process to produce biodiesel from waste oils but more pieces of equipment made from stainless steel material were necessary than in the alkali-catalyzed process to produce biodiesel from virgin oils and the acid-catalyzed process for pretreatment of waste oils prior to alkali-catalyzed production of biodiesel [19].

Another important drawback is connected to glycerol overproduction, which is a consequence of the increased biodiesel production achieved in the recent years. This has caused the price of glycerol to fall significantly while its cost of purification from alcohol, water and catalyst remains high [20].

It is important to evaluate the net energy balance of biomass as well as the biofuel that can be produced. Some researchers have estimated the net energy balance for biofuels derived from, corn ethanol [21–23], sugar cane ethanol [24], cassava ethanol [25,26], and soybean biodiesel [27], by calculating the net energy value (NEV) or net energy ratio (NER).

The conventional biodiesel production which involves the use of chemical catalyst is carried out at relatively high temperatures closer to the boiling point of the alcohol [28]. Energy is a fundamental ingredient in the process of economic development, as it provides essential services that maintain economic activity and the quality of human life. Thus, shortages of energy are a serious constraint on the development of low income countries. Shortages are caused or aggravated by widespread technical inefficiencies, capital constraints and a pattern of subsidies that undercut incentives for conservation [29].

Various studies and investigations have revealed that about 70–75%of the biodiesel fuel cost goes for the feedstock. The feedstock for biodiesel production differs from place to place and from country to country. In Iran, above 90% of edible oil is imported. Moreover, the cultivation of inedible plants has not been practiced so far. Therefore, a feasibility study was organized to find out the possible potential feedstock throughout the country [30]. The findings indicated that approximately 750 million liters (mL) of

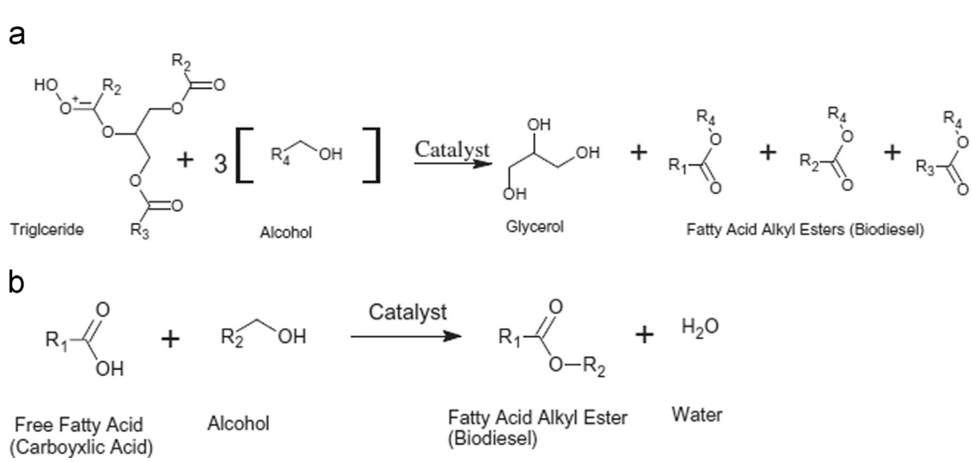

Fig. 1. Schematic representation of (a) transesterification and (b) esterification reactions.