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Biodiesel Production from Waste Cooking Oil in Food Industries: An Economic Feasibility Study

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Abstract

Biodiesel can be produced from waste cooking oils which are obtained from food industries and many restaurants, in which processed foods have been passed through a deep frying process. While frying is continued for a long time with the constant oil, the oil changes its chemical and physical properties. The changes in the chemical properties of certain parameters cause a high health risk of the consumer. Some parameters that define the rejection of used cooking oil. The rejected waste cooking oils have to be disposed in the environment which incurs disposal costs. The study selects the optimum conditions (6:1 oil-to-methanol molar ratio and 0.7% w/v KOH at 60 °C for 1 hour) for a transesterification reaction and assesses an economic feasibility by estimating operating costs. Except for initial investment costs, it is found that the amount of money return after the conversion of 100L waste cooking oil is 7 times more than the operating costs.

Keywords: Waste cooking oil, transesterification, biodiesel, economical assessment

1. Introduction

In recent years, it has been increased significantly the demand of energy because of the increasing population, transportation, and rapid industrialization. These are highly dependent on the conventional source of energy such as petroleum and coal. Obtaining energy from these sources cause hamper of our climate, which is a prime concern. Biodiesel is an alternative fuel that can minimize this concern. As the chemical properties of biodiesel, it is non-toxic, degradable, and more feasible for combustion because of the emission of fewer particulates [1]. However, the challenge of biodiesel production is its higher production cost, which is mainly for raw materials. A competitive study shows that the costs of biodiesel production are approximately one and half times more than petroleum-based diesel which also depends on the feedstock oils [2]. It is reported that almost 70-95% costs of biodiesel production are for the raw materials [3]. Therefore, waste cooking oil (WCO) can be a convenient source of biodiesel production.

United States Department of Agriculture (USDA) published a report on the Bangladesh Oilseeds and Products Annual 2019. This report shows that the amount of edible oil (soybean and palm oil) consumption is increasing every year about 11%. It is predicted that the quantity will reach 1.85 lakh tones in this 2019-2020 economic year [4]. It uses a large proportion of this oil in food industries that involve deep-frying during food processing. To produce processed food hygienically, the industries have to change the oil used for deep frying after a certain frying cycle**.** Disposal of WCO is a problem because it involves the with contamination of environmental water and disposal costs [5]. On the other hand biodiesel, such an environmental friendly fuel will limit environment pollution [5]. Health is also a prime concern that is enormously related to the use of cooking oil. Despite of knowing the health hazard of WCO, food industries does not maintain any guideline to continue using cooking oil in most of the cases. Many researchers found that when a product is fried such a way that fresh oil is poured continuously with WCO to stable iodine value, pH, and peroxide value, it may cause cancer because of producing toxic contents [6]. If the idea is implied in the food industries, they can be benefited economically and, it will assure consumers health. Manufacturing biofuel is a batter option to utilize waste cooking oil.

The following section of this present study shows the physical and chemical changes of edible oil during frying. Then in section (3), it focuses on the selection of optimum reaction conditions for an economic assessment of operating costs**.**

2. Physical and chemical change in vegetable oil during frying

During frying, oil is continuously heated at a high temperature of about 160-200 ºC for a relatively long period. To be benefited economically the oil is used for several frying cycle that result in a physical and chemical changes [7].

2.1 Physical Changes

The physical changes during cooking of vegetable oil are observed as follows [9]:

1) Increase in viscosity
2) Increase in specific heat
3) Change in surface tension
4) Increase tendency of fat to foam [7]
5) Change in color

2.2 Chemical Changes

2.2.1 Thermolytic Reaction

In the absence of air (oil in the lower surface) heating at high temperature (180 ^{O}C) causes the formation of alkanes, alkenes, symmetric ketones, lower fatty acids, oxopropyl esters, carbon-mono-oxide and carbon-di-oxide. Unsaturated fatty acids are formed from saturated dimers, dehydrodimers, and polycyclic compounds [8].

2.2.2 Oxidative Reaction

In presence of oxygen, unsaturated fatty acid goes through a free radical mechanism and produce alkoxy free radicals. It can also produce oligomeric and dimetric compounds [8].

2.2.3 Hydrolytic Reaction

Steam produced during frying causes hydrolysis of the reaction, which causes the formation of glycerol, free fatty acid (FFA), monoglycerides and diglycerides [9]. It is mentioned that by measuring monoglycerides and diglycerides content, composition after frying oil can be obtained [10].

2.3 Standard Composition of cooking oil in Food Industries

In Bangladesh, food industries have to maintain a standard of edible oil for frying. According to Bangladesh Standards and Testing Institution (BSTI) the requirements for contents in cooking oil are iodine value 124-139, acid value 0.5 mg KOH/g (max), peroxide value 5.0 [11].

3. Methodology

Many researchers used several conditions for the conversion of biodiesel from waste cooking oil [1]. Firstly the optimum condition was selected to estimate the operating costs.

3.1 Overview of reactions

Many researchers worked for the chemical transformation of waste cooking oil (WCO) to biodiesel, which is a catalytic thermochemical reaction. Among them, the transesterification reaction achieved 71.2% yield of biodiesel under the condition of 1:1 volumetric oil-to-methanol ratio, 0.5% NaOH catalyst at 50 ºC [12]. A hydro-treating method at 330^{O}C gives 90.1% yield of biodiesel production [13]. A catalyst-free process obtained 84% biodiesel yield at 325 ºC and 35MPa pressure for 60 minutes in which the methanol-to-oil molar ratio is 43:1 [14]. Another process at 6:1 oil-to-methanol molar ratio and 0.7% w/v KOH catalyst [15], is done at 60ºC for 1 hour [1].
A transesterification reaction of triglyceride and methanol that produce Fatty Acid Methyl Ester (FAMA) and glycerol as by product. The reaction is following [16]:

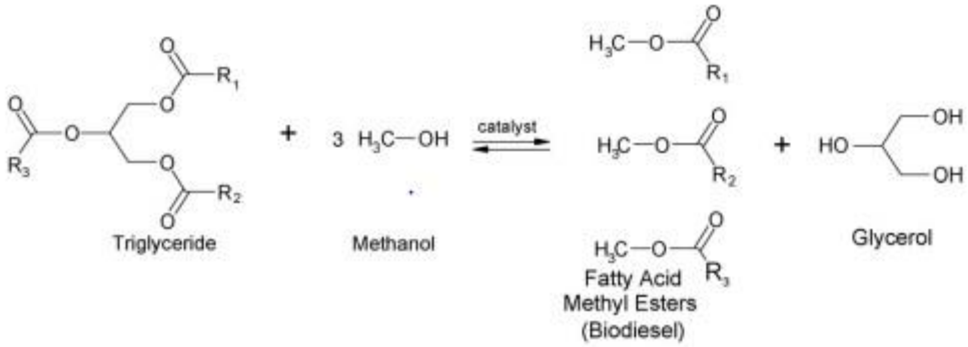

Fig. 1. A transesterification reaction of triglyceride and methanol to FAME and glycerol as by-product

3.2 Selection of optimum reaction conditions

Among the transesterification reaction conditions, the optimum condition for the biodiesel production was selected firstly. Most priority was given to less cost and energy consuming process. The reaction condition was 6:1 oil-to-methanol molar ratio and 0.7% w/v KOH catalyst at 60ºC for 1 hour [1, 15]. Since this process consumes less heat energy and do not require any additional energy to increase the pressure.

3.3 Assumptions for cost estimation

Some assumptions were considered for the cost estimation. Such as (1) WCO was obtained from deep frying in food industry (2) The cost estimation was included only operating costs (3) 100L of WCO was considered (4) The cost was calculated in Bangladeshi currency (taka) (5) All WCO was converted into biodiesel and glycerol (by-product) and (6) Electrical energy was used for heating purpose.

3.4 Cost estimation

Price of methanol was obtained from an international supplier Qingdao Highly Chemical New Materials Co. Ltd, an international exporter, which sells methanol at 36.7 taka/L and KOH at 32.6 taka/kg Biodiesel [17], compared to the current price of diesel in Bangladesh is 65 taka per liter [18]. After separating the by-product glycerol as industrial grade, it will return about 78 taka/L [17].

Table 1: Operating costs of biodiesel production from WCO

Expenses		
Item	Quantity	Amount (taka)
WCO	100 liter	0.00
Methanol	16.67 liter	612
KOH	700gm	23
Energy	2 KWh	20
Manpower and wages	2 person	300 taka/hour
Total expenses (in taka):		**955**

Table 2: Investment returns from biodiesel production from WCO

Return		
Item	Quantity	Amount (taka)
Biodiesel	70.13 liter	4558
Glycerol (unrefined)	28 liter	2184
Total return (in taka):		6742

According to the tables, there is a huge difference between the operating cost and the amount of return. The industry will get a more economical return from methanol, catalysts recovery and save WCO disposal cost. For the production of biodiesel, such an environmental friendly fuel, payable amount of a tax on the industry may be reduced by national or federal law. The equipment involved with this process are widely available. The industry can utilize the by-product itself as a raw material of manufacturing something else like soap or can be sold as industrial grade glycerol.

4. Results and Discussions

The reason behind the selection of this particular transesterification reaction, it was comparatively simple in the plant's installation. The ratio of total operating costs and money return was obtained about 955:6748 or 1:7.

For large scale biodiesel production, WCO can be collected from the hotels and restaurants, which incurs purchasing, transportation and man-power costs. It is observed that the price of WCO is a dependable function of the hygienic concern of general people. As much as people will concern about hygienic food, the producer will be enforced to avoid using excessively fried cooking oil. As a result WCO will be available more.

It is noted that the analysis is based on the operating costs. For a detailed costs for the process including the initial investment, a rigorous detail estimate should be made.

5. Conclusions

This study aims to analyze the economic feasibility of biodiesel production from WCO behind the industrial implementation. Waste cooking oil is expected to be more important in the future production of biodiesel than other edible or non-edible oil because of its low cost and wide availability. There are some alternatives to the transesterification reaction, but transesterification is a simple method of biodiesel production. After analyzing the properties of WCO, researchers suggest equipment to use are made of SS steel due to its high corrosiveness property than raw cooking oil. This may cause a relatively high cost of instrumentation.

6. Acknowledgement

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7. References

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