Renewable Energy 122 (2018) 216–224

Contents lists available at ScienceDirect

Renewable Energy

journal homepage: www.elsevier.com/locate/renene

Two-step methyl ester production and characterization from the broiler rendering fat: The optimization of the first step

Ahmet Keskin

Abant Izzet Baysal University, Bolu Vocational School, Bolu, Turkey

A R T I C L E I N F O

Article history:
Received 15 March 2017
Received in revised form
17 December 2017
Accepted 31 January 2018
Available online 1 February 2018

Keywords:
Renewable energy
Methyl ester
Two-step production
Broiler rendering fat
Waste animal fats
Fuel properties

A B S T R A C T

In this study, broiler rendering fat obtained from a slaughterhouse was used to produce methyl ester. The acid value of the broiler rendering fat was 5.2 mg KOH g^{-1}. Therefore, it was needed to perform two-step treatment to broiler rendering fat. For this purpose, sulfuric acid was used as a catalyst and methanol was used as alcohol for the first treatment reactions. The variables affecting the free fatty acid level including the ratio of alcohol, catalyst amount, and reaction time were investigated to determine the best strategy for the first step process. After reducing the free fatty acid level of the broiler rendering fat to less than 1%, the transesterification reaction was completed with the alkaline catalyst. Potassium hydroxide was used as catalyst and methanol was used as alcohol for transesterification reaction. The measured fuel properties of the broiler rendering fat methyl ester (BRFME) were compared to EN 14214:2012 + A1:2014 and ASTM D6751−15 biodiesel standards. The BRFME meet ASTM D6751−15 biodiesel standard. Also, the BRFME meets EN 14214:2012 + A1:2014 biodiesel standard except for oxidation stability. According to the results, the oxidation stability property of the BRFME should be improved and should be investigated in detail.

1. Introduction

Rapid increase in energy requirements has led to the development of new, renewable, and clean energy sources. The decline in petroleum reserves and the increasing air pollution has led to many studies for alternative fuels. One of the important studies for the alternative fuels is biodiesel [1]. Although, diesel fuel is made up of hundreds of different hydrocarbons (roughly in the range of 14−18 carbons in length), and contains aromatics hydrocarbons (benzene, toluene, xylenes, etc.), sulfur and contamination of crude oil residues, biodiesel hydrocarbons chains are generally 16 to 20 carbons in length and contain 10% oxygen. Since, biodiesel does not contain any sulfur, aromatic hydrocarbons, metals and crude oil residues; it is called green fuel or clean fuel [2]. In addition, cetane number of biodiesels range between 49 and 62. These fuel properties affect the combustion efficiency and emission profile of a diesel engine. Previous studies have shown that biodiesel and blends of biodiesel with diesel fuel reduce particulate material, sulfur oxides, carbon monoxide, and hydrocarbon emissions. However, the nitrogen oxide emissions are slightly increased depending on biodiesel concentration in the fuel [3]. The use of biodiesel is a big advantage for countries that import petroleum [4].

In the biodiesel production, the oils or the fats react with alcohols (usually methyl or ethyl alcohol). This chemical reaction which requires alkali or acid catalysts is called as esterification (the reaction of the free fatty acids with an alcohol to produce an ester of a fatty acid) or transesterification (the reaction of the triglyceride with an alcohol to produce a mixture of fatty acid alcohol ester) [5]. Usually, alkaline catalysts such as sodium hydroxide and potassium hydroxide are used. Because alkaline catalyzed transesterification is much faster than an acid catalyzed reaction. Following the reaction, glycerin, which is a by-product of the reaction, was removed from the biodiesel with a settling tank or a centrifuge. The main factors for the transesterification reaction are the amount and type of alcohols and catalysts, reaction temperature, pressure, time, composition of free fatty acid, and water in oil or fat, which have been studied by researchers [6,7].

There are host of feedstocks for biodiesel production; however, judicious selection of feedstock should involve consideration of two vital factors i.e. low cost of production and production in bulk scale; and thus, selecting the cheapest source is crucial for minimizing production cost [8,9]. Biodiesel can be synthesized from different varieties of feedstocks such as edible vegetable oils (e.g. canola oil,

E-mail address: keskin_a@ibu.edu.tr.

https://doi.org/10.1016/j.renene.2018.01.123
0960-1481/

sunflower oil, etc.), non-edible vegetable oils (e.g. jatropha oil, pongamia oil, etc.), waste cooking oils, and animal fats [10–15].

The high cost of biodiesel production is the main reason for its limited commercial application. Generally the cost of raw materials consists of the 70–80% of the total biodiesel cost [16]. Since biodiesel from food-grade oils is not economically competitive with petroleum-based diesel fuel, it is necessary to use novel and lower-cost feedstocks for its production. The use of cheap waste cooking oils, waste oily by-products from the edible-oil refinery, non-edible oils and waste animal fats can improve the production economy [17].

Chicken meat has become one of the most widely consumed food products in the world [18,19]. In 2015, almost 9 billion broiler chickens, weighing 53 billion pounds (24 billion kilograms), live-weight, were produced in 2015 [20]. Broiler rendering fat is generated during rendering of broiler feathers and poultry by-products to produce feather meal (Fig. 1). Poultry by-products consist of ground dry or wet rendered portion of the clean carcass (e.g. heads, feet, undeveloped eggs, and intestines, exclusive of feathers). The amount of fat extracted from the feather meal varies from 2% to 12%, depending on feather type [21].

Rendering fats obtained from broiler slaughterhouses in Turkey constitutes a significant potential for biodiesel production. Turkey's chicken meat production in 2015 is 1 million 909 thousand tons and higher than the production of European Union (EU-28) countries. Chicken meat production in Turkey between the years 2010–2015 are shown in Fig. 2. Approximately 30% of chicken meat production is in Bolu, Turkey [22].

Broiler rendering fat is cheaper than high-grade vegetable oils for biodiesel production. In general, low cost raw materials contain large amounts of free fatty acids [7]. The free fatty acid (FFA) and moisture contents have significant effects on the transesterification of glycerides with alcohol using the catalyst. The high FFA content (>1% w/w) will result in serious saponification of the reaction mixture and the separation products will be exceedingly difficult, and as a result, it has a low yield of biodiesel product. The acid-catalyzed esterification of the oil is an alternative, but it is much slower than the base-catalyzed transesterification reaction. Therefore, an alternative process such as a two-step process was investigated for feedstock having the high FFA content [12,23–26]. The first step process is the esterification with an acid catalyst. The second step process is the transesterification with an alkaline catalyst. The advantage of this process is that the acid level of the high free fatty acids feedstocks could be reduced to less than 1%.

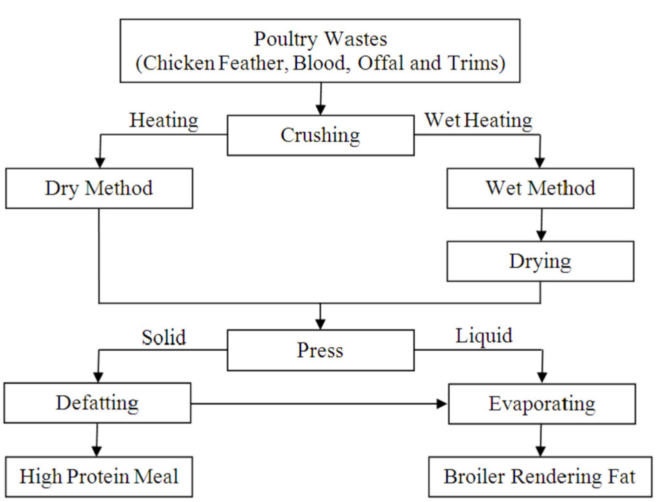

Fig. 1. Poultry wastes rendering process [21].

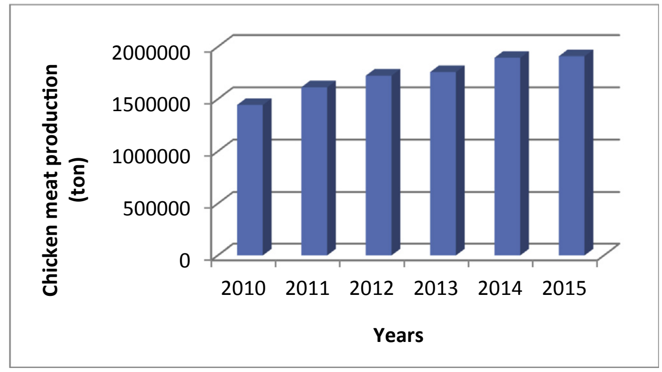

Fig. 2. Chicken meat production in Turkey between 2010 and 2015 (in tons) [22].

Thus, the two-step process makes it possible to produce esters from oils or fats containing high free fatty acids less expensive low-grade feedstocks. The two-step process prevents the saponification and makes it easier for the separation of products. As a result, it has a high yield of ester product.

In this experimental study, methyl ester was produced from a broiler rendering fat, which was obtained from a slaughterhouse, using a two-step process. Because the poultry rendering fat contains free fatty acid above 1%, two-step process has been preferred. Methanol was used as alcohol in two processes because of its low cost. Sulfuric acid was used as the catalyst for the first step and potassium hydroxide was used as the catalyst for the second step. The obtained methyl ester was characterized by determining its fuel properties according to the standard test methods, and fuel properties of the produced methyl ester were compared to biodiesel standards.

2. Materials and methods

Methanol, potassium hydroxide, and sulfuric acid were purchased from Merck (Darmstadt, Germany). All the chemicals used were analytical reagent grade. The broiler rendering fat was obtained from Erpiliç Slaughterhouse in Bolu, Turkey. The broiler rendering fat, which contains free fatty acids more than 1%, was obtained from Erpiliç Slaughterhouse in Bolu, Turkey. Erpiliç has an integrated production plant for chicken slaughtering capacity of 330 thousand per day [27]. The rendering fat was filtered to remove inorganic residues. Then it was subjected to heating at 110 °C for 1 h to remove any remaining water. After these processes, some properties of broiler rendering fat were determined. In Table 1, some properties of broiler rendering fat sample are shown. Table 2 shows the fatty acid distribution of broiler rendering fat, some edible, non-edible vegetable oils, and animal fats. The fatty acid composition of BRF was obtained by gas chromatography with flame ionization detector. 25.94% of the broiler rendering fat is saturated and 74.06% of the broiler rendering fat is unsaturated. Methanol was used as alcohol in this process because it is the most widely used alcohol for biodiesel production, it is easy to process, and is relatively low cost [28,29]. Because sulfuric acid gives very high yields in alkyl esters, it was referred as the catalyst for the first step process.

Table 1
Properties of poultry rendering fat.

Quality	Unit	Sample
Density	kgm^{-3}	0.8996
Viscosity (40 °C)	mm^2s^{-1}	37.4
Acid value	$mgKOHg^{-1}$	5.2