Utilization of Waste Cooking Oil for Biodiesel Production

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Abstract

Biodiesel, a fuel derived from vegetable oils or animal fats, is a renewable fuel with a growing presence in the alternative fuels market. First-generation biofuels, like ethanol from corn or sugar cane, or biodiesel from soybeans or other vegetable oils, have provoked intense backlash as they have been blamed for causing unintentional environmental damage and for displacing production of food crops. Second-generation Biodiesel from waste oil may be a better choice as it does not burden a country with some of the negative repercussions of oil from food crops noted above. Comprising monoalkyl esters of fatty acids, derived from vegetable oil like soybeans and recycled oils like cooking oil and/or animal fat, are extenders for combustion in compression ignition engines and can reduce exhaust emissions. The combustion of Biodiesel emits much less pollutants than petrodiesel, and is a biodegradable product. For some of these reasons, it has the potential to be a growing contributor to the alternative fuels portfolio.

Introduction

Biodiesel is modified vegetable oil that has combustion related properties closer to petroleum diesel. Due to increasing depletion of fossil fuel, biodiesel fuels are attracting increasing attention worldwide. This is due to its characteristics of being able to be blended as a component or be utilized directly in vehicle engines. Biodiesel, as an alternative fuel for internal combustion engines, is defined as a mixture of monoalkyl esters of long chain fatty acids (FAME) derived from a renewable lipid feedstock, such as vegetable oil or animal fat. It typically comprises of alkyl fatty

acid (chain length C14–C22) esters of short-chain alcohols, primarily, methanol or ethanol. Biodiesel is the best candidate for diesel fuels in diesel engines (Demirbas, 2009a).

Waste cooking oil (WCO) is any cooking oil that has become unsuitable for cooking due to the presence of impurities or the loss of its original properties. Generally, it refers to edible oil that have been utilized for frying at high temperatures, edible fat mixed in the kitchen and the oily waste water that is discharged in the sewer. WCO is categorized by its free fatty acid (FFA) content; for instance, if the FFA content of WCO is less than 15%, then it is called 'yellow grease'; alternatively, it is called 'brown grease' (Kulkarni, *et al*., 2006).

The manufacture of biodiesel from waste cooking oil (WCO) to partially substitute petroleum diesel is one of the measures for solving the problems of environment pollution and energy shortage (Chen *et al*., 2009). The manufacture of biodiesel from WCO offers a number of advantages.

Advantages of Using Waste Cooking Oil for Biodiesel

Food security: Biodiesel has been mainly produced from edible vegetable oils all over the world. Currently, more than 95% of the world's biodiesel is produced from edible oils which are easily available on a large scale from the agricultural industry (Gui *et al*., 2008). However, continuous and large-scale production of biodiesel from edible oils has recently been of great concern because they compete with food materials (the food versus fuel dispute). There are concerns that biodiesel feedstock may compete with food supply in the long-term (Refaat, 2010). Currently, biodiesel is mainly prepared from conventionally grown edible oils such as rapeseed, soybean, sunflower and palm, thus leading to alleviate food versus fuel issue (Anwar *et al*., 2010). About 7% of the global edible vegetable oil supplies were used for biodiesel production in 2007 (Mitchell, 2008). In addition to edible oils, non-edible oils are also utilized for biodiesel production and these include *Jatrophacurca*s seed oil, *Pongamiapinnata* oil, and *Simaroubaglauca* oil (Naresh *et al*., 2012). The rapidly growing world population and rising consumption of biofuels are increasing the demand for food and biofuels, leading to both food and fuel shortages. There is extensive utilization of edible oils for biodiesel production. This may lead to significant problems such as starvation in developing countries. With nearly 60% of humans in the world currently malnourished, the need for grains and other basic food crops continues to be critical. Growing crops for fuel utilizes land, water, and energy resources vital for the production of food for people (Pimentel *et al*., 2009; Pimentel *et al*., 2008).

Environmental Pollution*:* Massive amounts of WCO are generated in different countries. Management of WCOs poses a significant challenge because of its disposal problems and possible contamination of the water and land resources. Even though some of this waste cooking oil is used for soap production, a major part of it is discharged into the environment. As large amounts of WCO are illegally dumped into rivers and landfills, causing environmental pollution, the use of WCO to produce biodiesel as petroleum-based diesel fuel substitute offers significant advantages because of the reduction in environmental pollution (Chhetri *et al.*, 2008). Therefore, biodiesel derived from WCO has taken a commercial patent as an alternative fuel to petroleum-based diesel fuel for diesel engines in the markets of Europe and the United States (Canakcı *et al*., 2008). Every year, millions of tons of WCO are collected and used in a variety of ways throughout the world. This is a practically inexhaustible supply of energy which might also prove to be an additional line of production for 'green' companies (Zanz *et al*., 2006). In the United States, an estimate reveals that biodiesel production from 5.2 billion kg per year of greases and animal fats could replace 1.5 million gallons (5.7 million litres) of diesel fuel (Sharma *et al*., 2008). The amount of WCO collected for recycling in the EU is estimated to be approximately 0.7–1.0 million tons per year (Bautista *et al*., 2009). Approximately, 65,000 tons of the 80,000 tons of WCO collected in the UK from commercial and industrial sources originates from commercial catering establishments (81%), with the remaining arising from the food processing industry (Upham *et al*., 2009). Zhang *et al*. (2003) reported that approximately 120,000 tons per year of yellow grease is produced in Canada. According to Nas and Berktay (2007), Turkey produces over 350,000 tons of WCO per year.

Reducing Cost of Production: Lower-cost feedstock are needed since biodiesel from food grade oils is not economically competitive with petroleum-based diesel fuel. Inedible plant oils have been found to be promising crude oils for the production of biodiesel. The cost of biofuel and demand of vegetable oils can be reduced by used cooking oils and inedible oils instead of edible vegetable oil. Thus, WCO would be a good choice as raw material since it is cheaper than virgin vegetable oils (Hameed *et al*., 2009). Its price is two to three times cheaper than virgin vegetable oils (Phan *et al.*, 2008). In Fiji, according to a MacDonalds

chain employee, the price of waste cooking oil ranges from $1 to $2 per litre while virgin oil ranges from $3 to $4 per litre depending on the brand.

Fatty Acid Composition: Waste Cooking Oil vs Virgin Cooking Oil

The fatty acid compositions of WCO and sunflower seed oil have been reported (Demirbas, 2009) as follows. The linoleic acid contents of sunflower seed oil and WCO obtained from sunflower seed oil were 72.9% and 65.2% respectively (Table 1). The linoleic acid content increased and the contents of other fatty acids decreased in the cooking process (Demirbas, 2009b).

Table 1: Fatty Acid Composition of Sunflower Seed Oil and Waste Cooking Oil

Fatty acid	Sunflower seed oil	Waste cooking oil from sunflower seed oil
Palmitic (C16:0)	5.4	6.8
Palmitoleic (C16:1)	0.1	0.4
Stearic (C18:0)	2.9	3.7
Oleic (C18:1)	18.7	22.8
Linoleic (C18:2)	72.9	65.2
Linolenic (C18:3)	0	0.1

Properties of Waste Cooking Oil Biodiesel

The conversion of WCO into methyl esters through the transesterification process reduces the molecular weight to approximately one-third, reduces the viscosity by about one-seventh, slightly reduces the flash point, marginally increases the volatility, and considerably reduces the pour point (Demirbas, 2009a).

Results obtained by Demirbas (2009b), who investigated fuel properties of WCO and waste cooking oil methyl ester (WCOME), are summarized in Table 2. The properties of WCOME are generally similar to those of petroleum-based diesel fuel. Heating value of WCOME is lower compared to petroleum-based diesel fuel. However, cetane number and flash point of WCOME is higher than petroleum-based diesel fuel. Its viscosity is also slightly higher than the petroleum-based diesel fuels. Thus, WCOME can be used in diesel engines without any modification.

Table 2: Comparison of Fuel Properties of Waste Cooking Oil, Biodiesel from Waste Cooking Oil and Commercial Diesel Fuel

Property	Waste cooking oil	Biodiesel from WCO	Commercial Diesel Fuel
Kinematic viscosity (mm^2/s, at 313K)	36.4	5.3	1.9-4.1
Density (kg/L at 288K)	0.924	0.897	0.075-0.840
Flash point ((K)	485	469	340-358
Pour point (K)	284	262	254-260
Cetane number (K)	49	54	40-46
Ash content (%)	0.006	0.004	0.008-0.010
Sulfur content (%)	0.09	0.06	0.35-0.55
Carbon residue (%)	0.46	0.33	0.35-0.40
Water content (%)	0.42	0.04	0.02-0.05
Higher heating value (MJ/kg)	41.40	42.65	45-62-46.48
Free fatty acids (mg KOH/g oil)	1.32	0.10	-
Saponification value	186.2	-	-
Iodine value	141.5	-	-

(Source: Demirbas, 2009a)

Production of Biodiesel from Waste Cooking Oil

The production of biodiesel from WCO is challenging due to the presence of undesirable components such as FFAs and water (Jacobson *et al*., 2008). Base-catalyzed trans-esterification is the most prevalent method owing to the high purity and yield of biodiesel product and the short reaction times (30–60 min) (Zu *et al*., 2009). However, it is very sensitive to the purity of the reactants. Only well refined vegetable oil with less than 0.5 wt% of FFA can be used as the reactant in this process (Demirbas, 2009a, Wang *et al*., 2007).

When WCO with more than 10 wt% FFA is used, an acid catalyzed process is preferred, requiring an excess of methanol, high pressure (170–180 kPa) and high cost stainless steel equipment. In addition, the yield of product is low (82% of mass conversion with 200% excess of methanol) when the most common acid, H_2SO_4 is used (Wang *et al*., 2007). To avoid the problems associated with the use of acid and base catalysts separately, especially the problems of saponification and slow reaction time,

many researchers have developed the two stage acid- and alkali-catalyzed trans-esterification process. During the first stage, esterification of FFA present in WCO is carried out using acid to decrease the FFA level to less than 1% (Enweremadu *et al*., 2009). In the second stage, trans-esterification of the obtained oil is performed using an alkaline catalyst, i.e., NaOH or KOH. Wang et al. (2006) studied a traditional acid catalyzed trans-esterification using sulfuric acid as a catalyst and a two-stage trans-esterification of WCO and reported 97.22% conversion of FFA to FAME with ferric sulfate (2 wt%) as acid catalyst and KOH (1 wt%) as alkali catalyst at 368 K and 4 h with an oil to methanol molar ratio of 1:10. They argued that the two-step process showed the advantages of non-acidic waste water, high efficiency, low equipment cost and easy recovery of catalyst compared with the old processes. Issariyakul *et al*. (2007) obtained 90% ester yield in a methanol/ethanol mixture with two stage process using waste fryer grease. The oil contained approximately 5–6% weight of FFA.

Conclusion

Biodiesel is becoming important as an alternate fuel for diesel engines. This is mainly due to the environmental consequences of petrol fuel and its diminishing supply. Biodiesel can be sourced from a diverse range of edible and inedible vegetable oils, animal fats, used frying oil and waste cooking oil. Edible vegetables oils are not suitable for biodiesel production as they are more expensive than petroleum. Hence, waste cooking oil and non edible plant oils should be utilized for biodiesel production. Waste cooking oils offer a significant potential as low-cost raw material for biodiesel production. The price of waste cooking oil is 2.5 to 3.5 times cheaper than virgin vegetable oils, thus can significantly reduce the total manufacturing cost of biodiesel. As large amounts of waste cooking oils are dumped into rivers and landfills causing environmental pollution, the use of waste cooking oil to produce biodiesel as petroleum-based diesel fuel substitute offers significant advantages.

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