Industrial Crops and Products 43 (2013) 40–43

Contents lists available at SciVerse ScienceDirect

Industrial Crops and Products

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

Biodiesel production from *Phoenix dactylifera* as a new feedstock

Mohammad Ali Amani[a], Mahdieh Sadat Davoudi[b,*], Kambiz Tahvildari[b], Seyed Mohammad Nabavi[a], Mina Sadat Davoudi[b]

[a] *Applied Biotechnology Research Center, Baqiyatallah University of Medical Sciences, Tehran, Iran*
[b] *Faculty of Chemistry, Tehran North Branch, Islamic Azad University, Tehran, Iran*

ARTICLE INFO

Article history:
Received 24 January 2012
Received in revised form 8 June 2012
Accepted 14 June 2012

Keywords:
Biodiesel
Date seed
Phoenix dactylifera
Cetane number
Transesterification

ABSTRACT

Biodiesel is one of the renewable and clean burning fuels, which can be used in diesel engines. Biodiesel is usually generated from food-grade vegetable oils using transesterification process. Using the food-grade vegetable oils is not economical since they are more expensive than diesel fuel. Therefore, it is said that the main obstacle for commercialization of biodiesel is its high cost. The kind of feedstock, which is used is the most effective factor on the biodiesel characteristics and the price. So, at first finding a proper feedstock has an important role in different places. Therefore in this research the possibility of using date seed as a cheap feedstock for biodiesel production was investigated, because it is produced largely in the hot arid regions of southwestern Asia and northern Africa. After extracting oil and producing biodiesel from *Phoenix dactylifera* (date seed) oil, the properties of biodiesel were evaluated by fuel standard tests and the results were compared with EN14214 and ASTM D6751 standards and also compared with the properties of produced. According to the results, the important benefit of the biodiesel from the date seed oil is high cetane number (60.3), low iodine value (46), viscosity (3.84 mm^2/s) and flash point (140 °C) and the only weak point is its high pouring point (−1 °C) which limits the use of date seed biodiesel in cold weather in comparison with other vegetable biodiesel fuels.

1. Introduction

Biodiesel is presently the most widely accepted alternative fuel for diesel engines due to its technical, environmental and strategic advantages. Biodiesel is known as a carbon neutral fuel because the carbon present in the exhaust is originally fixed in the atmosphere. Biodiesel can be produced from vegetable oils like soybean oil (*Glycine max*), jatropha oil (*Jatropha curcas*), rapeseed oil (*Brassica napus*), palm oil (*Elaeis guineensis*), sunflower oil (*Helianthus annuus*), corn oil (*Zea mays*), peanut oil (*Arachis hypogaea*) and cottonseed oil (*Gossypium* spp.) or other sources like animal fats (beef tallow and lard), waste cooking oil, greases (trap grease and float grease) and microalgae (Peterson, 1986; Pearl, 2002). Compared to fossil-based diesel fuels, biodiesel possesses many advantages such as cleaner engine emissions, biodegradable, renewable and superior lubricating property (Hu et al., 2005; Junior et al., 2009; Xue et al., 2011).

In spite of its many advantages, biodiesel is not yet commercialized all over the world. The major problem is the cost of the raw material. Biodiesel obtained from neat vegetable oil is costly compared to the petroleum diesel fuels. Biodiesel Free on Board (FOB) costs between 0.65 and 1 U.S. dollars (USD) L^{-1}. Its costs are nearly 1.5–2 times to petroleum-based diesel depending upon feedstock oils (ICIS, 2011). It is reported that nearly 70–95% of the total cost of biodiesel production arises from the cost of raw material; i.e., vegetable oil or animal fats (Zhang et al., 2003). The cost of biodiesel can be reduced if we consider non-edible oils, used-frying oils, acid oils and agriculture waste oils instead of edible oils.

The *Phoenix dactylifera* (date palm) is one of the member of the genus *Phoenix*, widely cultivated for its edible fruit. Dates have been a staple diet in the Middle East for thousands of years. They are believed to have originated around the Persian Gulf, and have been cultivated since ancient times from Mesopotamia to prehistoric Egypt, possibly as early as 4000 B.C. (Zaid and de Wet, 2002).

Date is important as a staple food as well as a desert fruit, and its use in date products and industrial applications has increased. Date seeds are waste products of many industries based on the technological transformation of date fruits or their biological transformation. Then, a large quantity of date seeds could be easily collected from the date processing industries or from the waste products coming either directly from the palm grove or from the gap-conditioning stations. Date seeds are used chiefly for animal

* Corresponding author at: P.O. Box 19585/936, Iran. Tel.: +98 2182482549; fax: +98 2182482549.
E-mail address: masa_davoodi@yahoo.com (M.S. Davoudi).

0926-6690/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.indcrop.2012.06.024

Table 1
World date production by region and selected countries (FAO statistics, 2010).

Country	Production (tons)	% world
Egypt	1,352,950	17.2
Saudi Arabia	1,078,300	13.7
Iran	1,023,130	13
U.A.E.	775,000	9.8
Pakistan	759,200	9.6
Algeria	710,000	9
Iraq	566,829	7.2
Sudan	431,000	5.4
Oman	276,400	3.5
Libya	161,000	2
Asia	4,804,126	61.1
Africa	3,011,205	38.3
America	26,003	0.3
Europe	16,121	0.2
World	7,857,455	–

feed in sheep, poultry, camel and cattle industries (Al-Farsi and Lee, 2008).

It is well known that the average weight of a date seed is about 10–15% of the date fruit weight (Besbes et al., 2005). The reported composition was 3.1–7.1% moisture, 2.3–6.4% protein, 5.0–13.2% fat, 0.9–1.8% ash and 22.5–80.2% dietary fiber. Also, the seed contains high level of phenolic compounds (3102–4430 mg gallic acid equivalents/100 g of seed powder) and has high amounts of antioxidants (580–929 lm trolox equivalents/g) and dietary fiber (78–80 g/100 g) (Al-Farsi et al., 2007).

The major fatty acid found in date seed oil was oleic acid (between 11.9% and 58.8%) (Al-Hooti et al., 1998). Fair amounts of lauric acid, myristic acid and palmitic acid ranging between 13% and 25.8%; 7% and 13%; 6% and 13% were also observed (Al-Showiman, 1990; Al-Shahib and Marshall, 2003).

The date fruit is produced largely in the hot arid regions of southwestern Asia and northern Africa. According to FAO statistical data, 7.85 million tons of date fruits have been produced in 2010. The top ten countries producing date (Table 1) are Egypt, Iran, Saudi Arabia, United Arab Emirates (U.A.E), Pakistan, Algeria, Sudan, Iraq, Oman and Libya. They produce about 91% of the world's dates (FAO statistics, 2010).

In this research date seed, which is a kind of agricultural waste, has been used as a cheap feedstock for producing biodiesel. At first its potentials were assessed and then the extraction of the oil and biodiesel the production of were done. Finally various characteristics of this product were compared with the characteristics of other known biodiesel fuels in the world.

2. Materials and methods

2.1. Materials

The date fruits (about 10 kg from multiple trees) which were collected from farm lands in around Behbahan, South Iran, in last summer 2009, sodium hydroxide 99% (NaOH), n-hexane 99% and methanol 99% were purchased from Merck. Other chemical reagents and solvents were provided at analytical grade and purer.

2.2. Extracting oil from date seed

After separating and washing the date seeds, they were dried completely and were milled in a heavy-duty grinder in order to pass 1.2-mm screen. Oil extraction process was performed by n-hexane solvent and soxhlet device for 4 h. Particles and impurities were removed by passing through a filter and oil was separated from n-hexane by rotary evaporator.

2.3. Transesterification

Approximately 50 g of the date seed oil was pre-heated up to 60 °C and a mixture composed of 11 g methanol and 0.375 g NaOH was added. The reaction continued for 2 h at a temperature of 60–65 °C under reflux and while the mixture was being stirred. At the end biodiesel and glycerin were produced. The separation of alcohol from the mixture of biodiesel and glycerin was performed by the rotary evaporator. Later the glycerin and the biodiesel were separated according to the difference in their density by means of a separating funnel. For purifying biodiesel (removing catalysts and the remaining glycerin) washing operation was performed by hot water (70 °C). The biodiesel which contained some water was dehydrated in vacuum through distillation by means of a rotary evaporator.

2.4. Determination properties of date seed biodiesel

The fatty acid methyl esters of biodiesel were analyzed by GC/MS (GC: VARIAN CP-3800; MS: VARIAN Saturn 2200) (Pablo et al., 2006). Fatty acid compositions of biodiesel were collected from the GC/MS. Saponification value (SV) and iodine value (IV) of oil were calculated from fatty acid methyl ester compositions of oil with the help of Eqs. (1) and (2), respectively (Kalayasiri et al., 1996):

$$\mathrm{SV} = \frac{\Sigma(560 \times A_i)}{\mathrm{MW}_i} \quad (1)$$

$$\mathrm{IV} = \frac{\Sigma(254 \times D \times A_i)}{\mathrm{MW}_i} \quad (2)$$

where A_i is the percentage, D is the number of double bonds and MW_i is the molecular mass of each component.

Cetane number (CN) and higher heating value (HHV) of fatty acid methyl esters were calculated from Eqs. (3) and (4) (Krisnangkura, 1986):

$$\mathrm{CN} = \frac{46.3 + 5458}{\mathrm{SV} - 0.225} \times \mathrm{IV} \quad (3)$$

$$\mathrm{HHV} = 49.43 - [0.041(\mathrm{SV}) + 0.015(\mathrm{IV})] \quad (4)$$

Kinematic viscosity at 40 °C was obtained by using Cannon-Fenske viscometer while it was in warm water bath. Pour point and cloud point were determined simultaneously by using Tanaka Mini Pour/Cloud Point Tester Model MPC-101A. For flash point, Tanaka Automatic Cleveland Open Cup Flash Point Tester Model ACO-5 was used. The measurement of the density was done by Metler-Toledo densimeter at 15 °C.

3. Results and discussion

Biodiesel was produced by transesterification with the yield of about 98% and the fatty acid esters were analyzed by GC/MS. The results revealed that the fatty acid composition of date seed biodiesel was similar to biodiesel fuels obtained from other vegetable oils (Table 2). Therefore, date seed oil could be considered as a potential for being converted into a raw material for biodiesel production.

The viscosity of an engine fuel is one of the crucial features of the fuel. It plays a significant role in the fuel spray, mixture formation and combustion process. The high viscosity impedes the injection process and leads to inadequate fuel atomization. Moreover, the average diameter of the fuel driblets from the injector and their permeation increases with increasing fuel viscosity (Choi and Reitz, 1999). The inefficient mixture of fuel with air contributes to incomplete ignition in the engine. Also, high viscosity can cause early injection due to high line pressure, which moves the ignition of the fuel closer to the top dead center, increasing the peak