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Biodiesel: An Alternative Fuel in EU and Turkey

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Abstract *The energy issue is an extensively discussed subject. There are many concerns about the future of energy supply for human beings. Conventional sources are declining and the newcomers are starting to take place. Biodiesel is one of these alternatives and may be the most important one among the renewable energy sources for its convenience in usage as a fuel in the transportation sector. Although biodiesel was developed some two to three decades ago, it is not commonly used, mainly due to high production costs. Recently, increasing concerns on environmental protection have accelerated the popularity of biodiesel. In addition, interests in biodiesel have also been emerged with recent fluctuations in crude oil prices and uncertainities about the future energy security. The aim of this article is to make a review on the history, production techniques, and applications of biodiesel. The regulations concerning the biodiesel sector in European Union (EU) and Turkey with regional production histories are mentioned. The recommendations for developing the Turkish biodiesel sector are also given.*

Keywords alternative energy, biodiesel, EU, renewable energy source, Turkey

Introduction

Biodiesel is the name given to a fuel produced by some chemical processes from vegetable oils such as soybean, rapeseed, sunflower seed, cotton seed, corn, crambe, peanut, sesame, opium seed, or from animal fats. Chemically, biodiesel consists of monoalkyl esters formed by a catalyzed reaction of the triglycerides in the oil or fat with a simple monohydric alcohol (Gerpen, 2005). Some physical characteristics of biodiesel and petrodiesel are listed in Table 1.

Biodiesel is used as an alternative fuel to petrodiesel. It is directly used in diesel engines or is mixed with petrodiesel to obtain different blends. These blends generally have biodiesel amounts of 5%, 20%, or 50%, which are named as B5, B20, and B50, respectively. While others can be used safely in engines, the engine requires considerable modifications if B100 is to be used.

As stated by Ma and Hanna (1999), there are four primary ways to obtain biodiesel: (1) direct use and blending, where vegetable oil is directly used, (2) microemulsions, in which methanol and ethanol are added to solve the problem of high viscosity, and (3) thermal cracking (pyrolysis), where vegetable oils or fats are heated in the absence of oxygen to obtain biodiesel. The most commonly used technique is transesterification

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Table 1
Some physical properties of biodiesel and petrodiesel

Property	Biodiesel	Petrodiesel (No. 2)
Ash content	0.002–0.01 wt%	0.06–0.01 wt%
Cetane number	46–70	47–55
Density at 15°C	820–860 kg/m^3	840–860 kg/m^3
Flash point	135–150°C	52–77°C
Higher heating value	39.3–39.8 MJ/kg	45.3–46.7 MJ/kg
Sulfur content	0.0000–0.0024 wt%	0.04–0.01 wt%
Viscosity at 40°C	3.7–45.8 mm^2/s	1.9–3.8 mm^2/s

Source: Demirbas (2002).

(alcoholysis), which is the reaction of a fat or oil with an alcohol to form esters and glycerol.

Biodiesel, which is made from renewable biological sources, has become more attractive recently because of its environmental benefits of reduction of carbon monoxide, particulate matter, unburned hydrocarbons, and practically near zero sulfur content. Biodiesel emissions are compared to petrodiesel and are given in Table 2. Except for nitrous oxides, all other emissions are much less in biodiesel than petrodiesel.

Utilization of biodiesel is gaining popularity because of other benefits such as safety in transportation and storage, enhancement in engine lubrication, approval by vehicle manufacturers, support of agricultural facilities, and replacement of exhaust odor of regular diesel. However, biodiesel also has disadvantages in that its production cost is high, its production is land-limited, and it is available only for pilot projects. Also, due to its high viscosity, drying and thickening problems occur in cold weather conditions.

The idea of using vegetable oils as fuel for diesel engines is not new (Ma and Hanna, 1999). The concept dates back to 1895 when Rudolf Diesel developed the first biodiesel engine to run on peanut oil. His new engine was demonstrated at the Paris Expedition in 1900. In the 1930s and 1940s, vegetable oils were used as diesel fuels from time to time, especially in the years of economic depression and war. Following the oil crises,

Table 2
Biodiesel emissions compared to petrodiesel

Emissions	B100, %	B20, %
Hydrocarbons	−67	−20
Carbon monoxide	−48	−12
Particulates	−47	−12
PAH[a]	−80	−13
Sulfates	−100	−20
Nitrous oxides	+10	+2

[a]Polycylic aromatic hydrocarbons.
Source: EPA (2002).

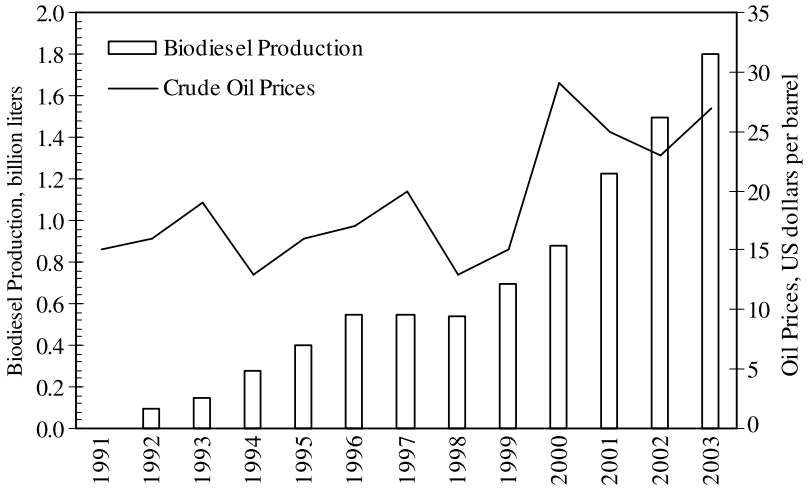

Figure 1. World total biodiesel production capacity and crude oil prices. (*Source:* Price data from BP, 2006 and production data from Fulton, 2005.)

the first biodiesel initiatives were reported in South Africa in 1981. The first international conference on the use of vegetable oils as fuel was held in North Dakota, USA, in 1982.

Figure 1 shows the relation between the inflation adjusted crude oil prices and world biodiesel production between 1991 and 2003. The world biodiesel production capacity has increased from zero in 1991 to 1.8 billion liters in 2003. The world biodiesel production has accelerated after the Rio Conference in 1992 and the Kyoto Protocol held in 1997. It can be inferred from Figure 1 that there exists no relationship between the crude oil prices and the world biodiesel production.

Biodiesel Sector in Turkey

Turkey started to take place in the biodiesel sector in the early 2000s. Before that, the use of biofuels (biogas, biochar, and biodiesel) as an alternative to petrodiesel could not play an important role in the transportation sector.

The Turkish biodiesel sector accelerated following the "Petroleum Market Law-5015" published December 20, 2003 (Acaroglu, 2005). After the position of biodiesel in this law and tax discount for biodiesel purchase, according to the report by ALBIYOBIR (The Union of Alternative Energy and Biodiesel Producers, 2006), the number of biodiesel production facilities reached 168 in 2006. The production capacity is reported as 450,000 ton/year by ALBIYOBIR. The biodiesel production in 2005 was around 60,000 tons (Acaroglu, 2005), and a rapid increase is expected in the following years. However, for biodiesel production in Turkey, different values can be encountered from various sources. In TOBB's (The Union of Chambers and Commodity Exchanges of Turkey) report, the production capacity is declared as 878,000 ton/year (Acaroglu, 2005). According to the report by Caglar (2006), the biodiesel production capacity in Turkey was 978,436 tons in November 2005, and production was around 90,000 tons by 90 companies in 2005 up to November.

In Figure 2, the profile for the licensed biodiesel production companies within the cities in Turkey is given (Acaroglu, 2005). The biodiesel production is standardized by

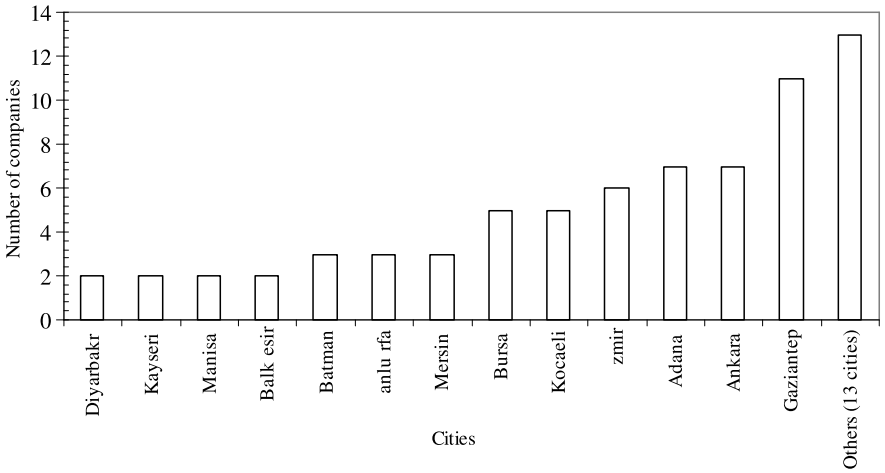

Figure 2. The distribution of biodiesel producing companies in Turkey. (*Source:* Acaroglu, 2005.)

the standard TS 14 214 (adopted from European Standard EN 14 214) published by TSE (Turkish Standards Institution) dated October 13, 2003.

The biodiesel sector has been developing since the first initiatives were introduced. The agricultural applications for rapeseed, sunflower seed, and soybean are supported by loans accommodated by the government. For Turkish national agricultural policy, the position of such agricultural support gives farmers and entrepreneurs big opportunities. Some Austrian, German, and Italian companies have also made attempts to participate in Turkish biodiesel sector within the near future (Acaroglu, 2005).

Biodiesel in the European Union

The milestones in the development of biodiesel in Europe was reported by Körbitz (1999). The first pilot plant was constructed in 1985 and production started in 1988 in Austria. In 1990 the first farmers' cooperative started commercial production in Europe. In the same year, the completion of engine tests led to engine warranties by some producers such as Ford, Massey-Ferguson, and Mercedes. In 2003 a European Biodiesel Standard (EN 14214) was introduced, which describes the necessary requirements to sell biodiesel around European countries (Körbitz, 1999).

The substitution of fossil fuels with biofuels has been proposed in the European Union (EU) as a part of the strategy to lessen the greenhouse gas emissions from road transport, increase security of energy supply, and support development of rural communities. Being highly dependent on imports of fossil fuels, the EU has to face increasing risks in security of energy supply for the transport sector (Körbitz, 1999). Biofuels take the attention of European Community members, as they account for the renewable and alternative fuels in the transportation sector. According to IEA, there will be a need for all types of alternative fuels in the transportation sector, and biodiesel will take the largest portion of all (Körbitz, 1999). But for the EU countries, the reduction of greenhouse gas emissions resulting from transportation is the most essential reason of encouraging the use of biodiesel.

The European Commission's White Paper on Renewable Energy intends to accelerate the use of renewable sources of energy in the EU to 12% by 2010 (Dorado et al., 2006). Besides, according to the Kyoto Protocol considerations, the EU countries have also agreed to reduce the CO_2 emissions by about 15% by the end of 2010. As a result of these efforts to promote cleaner fuels, according to Kyoto Protocol considerations, EU's biodiesel production capacity may exceed 4 million tons by mid-2006 (Bendz, 2005). As reported by Bendz (2005), 80% of the EU biodiesel is made with rapeseed oil, and about one-third of the rapeseed crop in 2004 was used for the production of biodiesel. Biodiesel production uses around 1.4 million hectares of arable land in EU, and more than 70 operational production sites are present across Europe (Garofalo, 2005). The plants are mainly located in Germany, Austria, the Czech Republic, France, and Sweden.

Some initiatives have already been introduced to promote the use of biodiesel in EU. As reported by Ryan et al. (2004), under the European directive (European Directive by European Parliament and European Council, 2003) on the promotion of the use of biofuels or other renewable fuels for transport, the member states are recommended to substitute a minimum of 2% by 2005 and 5.75% by 2010 of transport fuels with biofuels and other alternative fuels. Besides, the member states are permitted to reduce taxes on biofuels (European Directive by Council of the European Union, 2003). The directive also notes that if 10% of current agricultural land is dedicated to biofuel crops, 8% of current gasoline and diesel consumption can be replaced with biofuels rather than the current 0.5%. Thus, new employment opportunities, especially in rural areas, can be created.

At present, the European Community countries are the world leaders in world biodiesel production. In the EU, biodiesel is by far the biggest biofuel and represents 82% of the biofuel production (Bozbas, in press). Table 3 shows the EU member countries' biodiesel production in 2002, 2003, and 2004. The highest amount of biodiesel production has been recorded in Germany, France, and Italy, with values of 1.088, 0.505, and 0.419 million tons, respectively. Germany produces 40% of total EU biodiesel production.

Table 3
NEU biodiesel production between 2002–2004
(thousand tons)

Country	2002	2003	2004
Germany	450	715	1,088
France	366	357	502
Italy	210	273	419
Austria	25	32	100
Spain	0	6	70
Czech Republic	68.8	70	47
Denmark	10	41	44
UK	3	9	15
Sweden	1	1	8
Hungary	0	0	2
Poland	0	0	1.2
Total	1,133.8	1,504	2,296.2

Source: Bozbas, in press.

Recommendations for Turkish Biodiesel Sector

The attention paid to biodiesel in Turkey is growing significantly during the last few years. For Turkey, as a developing country, environmental considerations should also be covered within the government's schemes besides the technological and industrial issues. As in the EU case, the biodiesel sector is gaining more popularity as new directives and regulations are introduced progressively. Such applications should also be considered for Turkey; therefore, it will be convenient for biodiesel producers and entrepreneurs to participate in the sector.

There is an uncertainty in the biodiesel sector for Turkey, which is also inferred from the inconsistency in the exact statement of the production data. As mentioned previously, there are different production data from various sources. There is a necessity for an authorized community (as European Biodiesel Board in EU), which is responsible for the whole facilities in biodiesel sector. The absence of such community also causes illegalities in the foundation of new companies. This is also related to the regulations and directives introduced by the responsible institutions. It is obvious that there are numerous illegal companies that are not signed under the regulations, and thus the production data vary from source to source. The popularity of biodiesel attracts so many entrepreneurs, and they should be promoted to take licenses for their biodiesel productions. At this point, another issue is revealed, which is the taxes. Bringing a new product to the market requires careful considerations. Therefore, there are many challenges facing the biodiesel before it gains acceptance in the transportation fuel market. The existing petroleum market is standardized and has an extensive usage. Introduction of the biodiesel into the transportation market is supported by the lowering of taxes in EU. In Turkey, this strategy is also applied in the sector.

Turkey, as an oil importing country, is dependent on foreign sources and should consider its future energy supply. The transportation sector is still one of the major sectors in the country, and it is clear that this fact will not diminish within the following decades. The dependence on petrodiesel in transportation should be replaced by an alternative of biodiesel, even though there are still obstructions (cost, limited projects, social problems, etc.) in the applications. The consumers should be alerted about biodiesel, and the use of biodiesel should be necessarily encouraged as in EU.

Despite the increasing biodiesel production, if the market is considered, the quantities remain small compared to the total amount of petrodiesel sold. This is explained by the fact that the cost of biodiesel is still higher than that of petrodiesel, which is intended to be replaced. Having lower energy content than petrodiesel, it will require more fuel to produce the same power as petrodiesel in transportation. Production costs for biodiesel vary and they are dependent on the prices of raw materials. This drawback can be eliminated by giving more importance to research and development facilities, especially in the private sector and academic communities.

Turkey is economically dependent on the agricultural sector. The climate conditions are suitable for harvesting of raw materials such sugar cane, rapeseed, corn seed, etc. Although these crops are already produced in Turkey's arable lands, the production of canola (Canada oil-low acid) should be encouraged due to its high crop yield, as given in Table 4. Also, canola is a more suitable crop when Turkey's climate conditions are considered. Despite the fact that palm oil and coconut oil are more productive compared to other crops (Table 4), the production of these is limited by climate conditions. Besides, canola is compatible with the EN 14214 standard.

According to the report of DSI (General Directorate of State Hydraulic Works, 2006), the arable land in Turkey is 28.05 million hectares (Table 5). The economically

Table 4
Yield amounts of some oil crops

Oil crop	Yield per hectare, liters
Palm oil	5,940
Coconut	2,685
Canola	1,190
Peanut	1,100
Soybean	450
Corn	170

Source: Pahl (2005).

Table 5
Land resources of Turkey

Land resources	Million hectares
Arable land	28.05
Irrigable land	25.75
Economically irrigable	8.5
Presently irrigated	4.9

Source: DSI (2006).

usable area for irrigation in Turkey is about 8.5 million hectares, and 4.9 million of it is being utilized for agriculture. The rest, 3.6 million hectares, could provide approximately 4 billion liters biodiesel annually from canola crops, when the small losses in production processes are taken into account.

It must be Turkey's objective to derive more public attention to biodiesel, and new regulations should be immediately discussed.

Conclusions

Biodiesel, produced from vegetable oils or animal fats, possesses distinct advantages over petrodiesel, such as reduced emissions of greenhouse gases. It is renewable and an important alternative fuel for transportation. It is evident that petrodiesel dominates the transportation sector, and this is a very strong competitor to challenge due to its availability and low cost compared to its alternatives. However, the idea for biodiesel does not come from the need for getting cheaper fuel; instead, it has emerged from environmental concerns and future energy supply. When the environmental profits are considered, there should be no difficulties in adapting biodiesel in the transportation sector. The major obstacle is the higher cost, which can be eliminated through progressive research and development.

Turkey can produce 4 billion liters of biodiesel annually if unused irrigable lands are utilized for harvesting canola. If an authorized community is founded in Turkey, the biodiesel sector will probably advance in a short period. Once the incentives are promoted by governmental regulations and fiscal settings, biodiesel will be influential in the future of the transportation sector in Turkey.

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