Fuel 111 (2013) 114–119

Contents lists available at SciVerse ScienceDirect

Fuel

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

Perspectives of safflower oil as biodiesel source for South Eastern Europe (comparative study: Safflower, soybean and rapeseed)

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HIGHLIGHTS

- We promote safflower crop for South Eastern Europe.
- Resulted determinations shown that safflower can be a source for biodiesel.
- Safflower biodiesel improve cold flow properties of fuel obtained from other crops.
- Viscosity or oxidation stability were not influenced by elements content of oil or biodiesel.

ARTICLE INFO

Article history:
Received 18 May 2012
Received in revised form 31 March 2013
Accepted 4 April 2013
Available online 3 May 2013

Keywords:
Safflower (*Carthamus tinctorius*)
Vegetable oil properties
Alternative fuel
FAME parameters

ABSTRACT

Biodiesel is a non-polluting alternative fuel produced from renewable resources whose chemical and physical properties closely resemble those of the petroleum diesel fuel. Recently studies are being carried out for biodiesel production from less common or unconventional oilseeds. This paper highlights the perspectives of using safflower oil for the biodiesel industry to promote it as an alternative fuel. The safflower is widely grown in semi-arid and arid regions of the world. Advantages of cultivating safflower like drought resistance and salt tolerance were taken into account. The field experiments were placed in Romania, one of the South-Eastern Europe countries with a big agricultural potential.

Some attributes of oils and the corresponding biodiesels from safflower, soybean and rapeseed have been investigated. The fatty acids profile of safflower analyzed via GC shows a high amount of linoleic acid of 69.65%. This results in better low temperature properties like pour point, cloud point and cold filter plugging point of the FAME. Oxidation stability parameter does not meet the limit imposed by EN14214 European Standard, usually being improved by additives. Based on the global results, safflower (*Carthamus tinctorius*) was identified as a promising species for biodiesel feedstock which can be exploited with success on degraded lands of the world.

1. Introduction

There is an increasing interest in alternative energy sources, since the major part of the worldwide consumed energy in the transport sector is provided from resources which are limited and is going to exhaust in the next 40 years [8].

Biodiesel in Europe has led to a strong growth due to a rising interest of the EU for the environmental protection (Table 1).

The biodiesel industry in Romania is still at its inception compared with other EU markets, but shows over the last few years a considerable growth rate [3,11] (Fig. 1).

According to the latest EU decision, member states have to increase their share of biofuels up to 10% of the total transport fuel consumption (diesel and gasoline) by the year 2020 [4].

Romania, as the whole South-Eastern part of the EU and the Balkan region has a very high potential in terms of biodiesel crop production. It is estimated that the region could satisfy about 25% of the EU needs [10,11]. The country could theoretically produce 3–4 times more than is necessary to comply with the 5.75% target [1]. In the year 2008, 27 biodiesel producers were registered in Romania with a total capacity of 285,000 of tones biodiesel/year [2].

Abbreviations: FAME, fatty acid methyl ester; Wt.%, weight%; CFPP, cold filter plugging point; PP, pour point; CP, cloud point; SaOME, safflower oil methyl ester; SoOME, soybean oil methyl ester; ROME, rapeseed oil methyl ester; PUFA, polyunsaturated fatty acids; MUFA, monounsaturated fatty acid; s.a., active substance.

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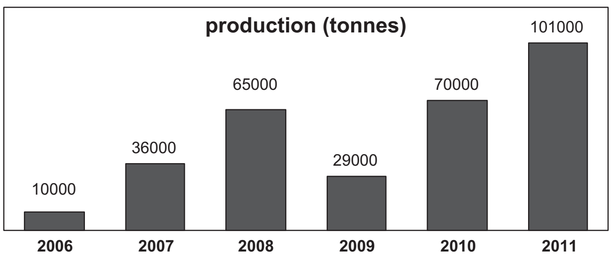
http://dx.doi.org/10.1016/j.fuel.2013.04.012

Table 1
EU biodiesel production –main producers (million liters). *Source*: The figures represent estimates by EU FAS posts.

Calendar year	2006	2007	2008	2009	2010	2011	2012
Germany	2730	3280	3250	2600	2830	2610	2610
France	650	1310	2370	2610	2500	2500	2500
Spain	140	170	280	700	1260	1360	1530
Benelux	50	290	430	840	910	1140	1360
Italy	680	530	760	680	680	680	990
Poland	100	60	310	490	490	510	570
Others	1060	1030	1680	2220	2220	3050	2660
Total	5410	6670	9080	10,680	10,680	11,655	11,930



Source: EBB European Biodiesel Board

Fig. 1. Biodiesel production trend in Romania.

Due to extreme weather conditions not all regions of Romania are suitable for the mainly used biodiesel crops (rapeseed, sunflower, soybean, and etc.). For these reasons it is necessary to develop and use alternative crops on land with unfavorable climate conditions (temperature, rainfall, soil type). Safflower (*Carthamus tinctorius*) is one of the proposed oil crops suitable for producing biodiesel, capable to exploit the specific land from the Southern part of Romania characterized by difficult climate conditions.

Safflower is one of humanity's oldest crops, but generally it has been grown on small plots for the grower's personal use, and it remains a minor crop, registering only 0.1% from the total agricultural world production. The estimated world production is about 0.6 million tons of seed per year from about 0.85 million ha (FAOSTAT, 2001). In 2009 registered a production of 650 Mt (FAO, 2010). The content of oil in hulled seeds is up to 23% [6]. Production per hectare is currently low, recording averages of 1000–1200 kg/ha under adequate technological conditions [10].

The largest safflower producing country is India but only small amounts are exported. In terms of world trade the USA and Mexico are the largest producers, followed by Australia and Argentina [8]. India occupies premier position in safflower in the world as it was cultivated over an area of 364,000 ha (50% of world area) and had a production of 229,000 tons (27% of world production) during 2005–2006 [31,32].

Safflower is recommended in areas where average annual rainfall is below 430 mm, if no dry wind occurs it may grow even below 300 mm annual rainfall [35]. During summer, 43 °C temperature is not causing problems to this crop, even in conditions of prolonged drought. Furthermore, in areas afflicted with dry land salinity, safflower uses surplus water from recharge areas, drawing down the moisture with the salts dissolved in it, preventing the expansion of saline seeps [30].

Currently the cultivation of safflower in Romania was publicized only in terms of its use in food, textiles and pharmaceuticals [11]. But the scientific papers from other countries show that this plant can be used successfully in the biofuels industry. The main breeding efforts are in the field of increasing the yield of safflower and optimizing the fatty acid profile. Newly created varieties produce oil with 80% monounsaturated oleic [31,32] acid which is stable at high temperature making them superior for frying and biodiesel.

Most current European cultivars are low in oleic acid and high in linoleic acid (about 70%) which leads to contradictory characteristics regarding biodiesel quality according to standard EN 14214. Iodine value and oxidation stability are two basic parameters in evaluating the quality of biodiesel. The respective results from safflower do not fall in the imposed limits. For fulfilling the limit of the oxidation stability additives can be added [7,8].

Interest in this crop will grow in the next years in Romania if authorities organize campaigns to promote this crop, offer strong technology information, introduce homologated varieties which have noble attributes and assure a market for farmers who decide to grow this plant.

2. Experimental section

2.1. Materials

Three different samples of raw material were collected from the experimental field placed at the Lovrin Research Station, Timis District, Romania. For analyzing the quality parameters of safflower biodiesel comparative determinations between this and two other biodiesel samples obtained from rape and soybean were made.

The used varieties were: Extend hybrid of rapeseed (Monsanto Company), PR92B63 soybean variety (Pioneer Company) and a not homologated variety of safflower provided from the Hungarian market.

Every plot had a size of 3000 m^2. For each crop the specific technological measures were applied. Fertilizers used were complex NPK16:16:16, 90 kg s.a./ha for rapeseed, and NPK 22:22:0, 50 kg s.a./ha for soybean and safflower crops. The total rainfall was 239 mm during the growing season and 389.6 mm for entire 2011 year and temperature recorded values of 27–28 °C in flowering time of safflower. For weed control, Galera 0.25 l/ha was applied in vegetation at rapeseed and Guardian 2 l/ha before emerge at soybean and safflower. Even were some problems regarding aphids at safflower crop, were not sprayed any insecticides. The yield obtained was 520 kg/ha at safflower, 1400 kg/ha at soybean and 2700 kg/ha at rapeseed.

Oil extraction was done with a continuous screw press at 60 °C in case of soybean and rapeseed, and a higher temperature for safflower, due to its very strong hulls. The other extraction was done with a Soxleth extractor fitted with a 1000 ml bottomed flask, condenser and a heating system. Petroleum ether was used as a solvent for the oil extraction. Selected properties of these oils were analyzed: fatty acid profile, water content, acid number, oxidation stability, iodine value, element content, viscosity and density. The samples used for biodiesel production were prepared via screw press extraction. From the produced biodiesel samples additional to the same analyses like for the initial oil samples the CFPP, PP and CP were determined.

The transforming reversible reaction of fats into biodiesel is revealed in Fig. 2 [8].

The reagents used were: methanol, n-hexane, 0.1 N potassium hydroxide in propanol, natrium hydrogen sulphat, p-naphtolbenzein 2% in propanol, toluol, and distilled water.

2.2. Reaction procedure of biodiesel production

The FAME production was carried out in a lab transesterification plant with a cross volume of 1 l equipped with thermostat, mechanical stirrer, heating system and vacuum.

The reaction was carried out at 55° and performed in two steps.