Fuel 184 (2016) 656–664

Contents lists available at ScienceDirect

Fuel

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

Full Length Article

Evaluation of *Sinapis alba* as feedstock for biodiesel production in Mediterranean climate

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HIGHLIGHTS

- A nitrogen fertilizer dose around 100 kg/ha leads to maximum grain yield.
- An increase of plant density influences C18:2 concentration in the oil.
- Properties of *Sinapis alba* biodiesel were predicted according to agricultural practices.

ARTICLE INFO

Article history:
Received 11 September 2015
Received in revised form 5 July 2016
Accepted 6 July 2016

Keywords:
Density plant
White mustard
Fatty acid composition

ABSTRACT

Most of oilseed crops used in biodiesel (BD) production are also suitable for human consumption and widely consumed in the world. For this reason, some non-governmental organizations and social movements controversially pinpoint the making of BD as the main cause of increased global edible oils prices, especially in developing countries. In this way, non-edible oilseed crops are gaining prominence for BD synthesis. Particularly, in the Mediterranean climate there is a crop that may have potential as raw material for biodiesel production, namely white mustard (*Sinapis alba*). In the present study, this species has been grown during two consecutive years optimizing two factors, plant density and nitrogen fertilizer dose. The influence of these factors on biomass yield and fatty acid composition is studied. *S. alba* oil was chemically extracted with hexane providing a yield of 25% (mass of extracted oil per mass of grain seed, on dry basis). Physical properties and FA profile of *S. alba* oil (by gas chromatography) were analyzed. Results show that both plant density and nitrogen fertilizer dose have influence on concentration of both linoleic acid (C18:2) and linolenic acid (C18:3). In addition, the presence of erucic acid (C22:1) was significantly high (above 50%). Important BD properties included in standard EN 14214 were predicted by means of mathematical models. Results showed that white mustard oil BD may provide a cetane number above 60, a density value lower than 900 kg/m^3 and a cold filter plugging point suitable for it use in temperate climates, where this plant mainly grows. However, kinematic viscosity predicted value was above the maximum one allowed by European regulation (5 mm^2/s).

1. Introduction

Bioenergy is defined as the chemical energy contained in the organic material. It can be transformable into other useful processes, i.e. heat and electricity generation or biofuels production for internal combustion engines [1]. Thus, the use of biomass resources for biofuel synthesis has involved the employment of crop/species that are also suitable for human and animal consumption. In this sense, there is controversy about its influence on the increase of food prices derived from these crops [1]. However, as traditionally land has been used for many purposes, including economical interests, there are also economical and environmental benefits, such as an increase of rural jobs, income taxes, local investments, higher combustion efficiency and carbon sequestration that should be taken into consideration [2]. In this sense, biodiesel has become one of biofuels mainly used to feed internal combustion engines. It provides some advantages over diesel fuel as its renewability, a greater lubricity and higher flash point values

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http://dx.doi.org/10.1016/j.fuel.2016.07.022
0016-2361/

[3]. The main raw materials for biodiesel (BD) synthesis are oilseeds like rapeseed, soybean, palm, and sunflower. However, in recent years, the interest on alternative oils that do not compete with human food has been increasing. Thus, transesterification of species like *Jatropha curcas*, *Pongamia pinnata* and *Moringa oleifera*, among others has been studied [4,5]. The search of new raw materials should be in accordance with geographical, economic and climate issues, in order to produce biofuels without incurring in a significant alteration of both agriculture and economy, trying to benefit as possible the local community [6]. In this sense, the Mediterranean climate houses the possibility of growing oilseed crops. This is the case of some species of wild crucifers. White mustard (*Sinapis alba*) is among the widest developed wild crucifers in the Mediterranean areas. In the south of Spain (Andalusia) its use is limited as a natural bioherbicide in olive grove plantations [7]. Moreover, its spontaneous presence is associated with abandoned land and they are frequently found in road ditches or not occupied lots. *S. alba* is a plant native to the Mediterranean region, currently distributed by central-southern Europe and western Asia. In other parts of the Mediterranean area, its cultivation in orchards, olive groves and vineyards improves the physical condition of the soil, providing nitrogen fertilizer when used as green manure during its decomposition. Its use, like other cruciferous species, helps to control weed and nematodes growth due to its content in sulfurized essential oils with antifungal properties, and its ability to inhibit the germination of other unwanted species.

The influence of plant density, nitrogen fertilization, tillage and crop rotation under Mediterranean rainfed conditions in semi-arid areas of southern Spain has already been studied in several crops. Some research has been focused on the influence of nitrogen fertilization, plant density and row spacing on growth, grain yield, yield components and fatty acid (FA) composition of several crucifers, including *S. alba* [8–11]. Additionally, Hassan and Arif [9] concluded that, under rainfed conditions, *S. alba* should be grown at 15 cm spacing, in rows spaced 20 cm, with projected plant population of over 300,000 per hectare to get significant yields. In Canada, the influence of nitrogen fertilization was studied by McKenzie et al. [10]. The main conclusion established that white mustard required 95 kg of available nitrogen to reach an adequate growth.

Although BD production from *S. alba* has not been deeply studied so far, transesterification has shown satisfactory results in terms of FAME yield and several properties. Issariyakul et al. [12] evaluated white mustard oil BD as potential diesel fuel additive, using KOH as catalyst. The production was held into a reactor fed with 6:1 methanol-to oil molar ratio and 1% w/w KOH. Temperature (60 °C) and stirring speed (600 rpm) of the reaction mixture were kept constant for 1.5 h. BD properties using methyl, ethyl, propyl and butyl alcohol during transesterification were reported; conversions ranged from 98 to 99.8% w/w. Ciubota-Rosie et al. [13] synthesized fatty acid methyl esters (FAME) from refined white mustard oil, reaction times varying from 1.5 to 4 h, providing FAME yields ranging from 98 to 99% w/w, respectively. In addition, most of the properties specified in the European (EN 14214) and USA (ASTM D6751) standards were determined. Results showed that white mustard oil BD provided FAME yields over 96.6% w/w, thus fulfilling the most important international standards, excepting kinematic viscosity and oxidation stability.

The present work is divided in three sections. Firstly, an agronomic study including three parameters of special importance in crops cultivation, i.e. plant density, nitrogen fertilizer dose and cultivation year on different plots was evaluated. The incidence of these parameters on grain production per hectare provides an idea of the amount of oil that can be obtained from *S. alba* and its viability for producing BD. Secondly, FA composition of each plot and its relation to the three agronomic parameters were determined. Once established FA composition, to predict BD properties mathematical models were applied.

2. Materials and methods

Then, for a better understanding of the process, a scheme of each stage is summarized in Fig. 1. As shown, the work include the processes of growth, grain milling, FA characterization, transesterification, and BD prediction properties by using mathematical models.

2.1. Experiment location

The study took place in the experimental field of Rabanales Campus, University of Córdoba (Spain). The geographical location is 37°54′N, 4°43′W, 135 m above the sea level. The soil was Vertisol clay, typical of the Mediterranean region, where the dry farming is the usual practice.

2.2. Crop management

Seeding was carried out with a drill machine testing in early November. The seeding dose was set on 8 kg/ha to ensure emergency and then make thinning to establish fixed density in the study. The chosen variety of *S. alba* (white mustard) was from "Albedino" ecotype selected for re-vegetation and establishment of cover crops by Alcántara et al. [7]. Weeds were removed by hand. An application of 100 kg/ha P_2O_5 was conducted at planting

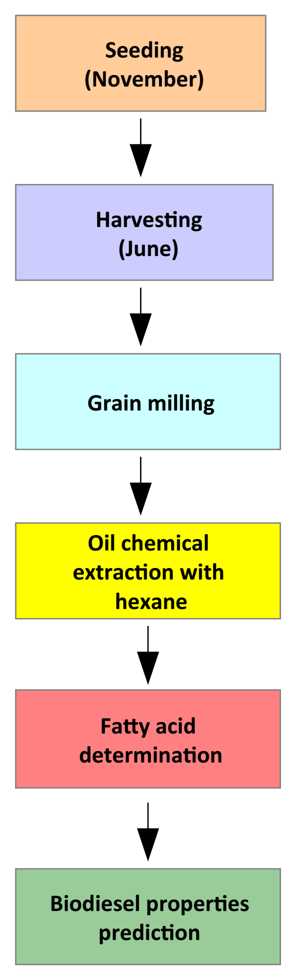

Fig. 1. Scheme of the process.