Renewable and Sustainable Energy Reviews 66 (2016) 311–321

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

Oilseed crop crambe as a source of renewable energy in Brazil

Doglas Bassegio [a,*], Maurício Dutra Zanotto [a], Reginaldo Ferreira Santos [b], Ivan Werncke [c], Patrícia Pereira Dias [d], Mateus Olivo [a]

[a] São Paulo State University (UNESP), Department of Crop Science, CEP 18610-307 Botucatu, SP, Brazil
[b] Western Paraná State University (UNIOESTE), Department of Energy in Agriculture, CEP 85819-130 Cascavel, PR, Brazil
[c] Paraná Federal Technological University (UTFPR), CEP 85884-000 Medianeira, PR, Brazil
[d] São Paulo State University (UNESP), Department of Rural Engineering, CEP 18610-307 Botucatu, SP, Brazil

ARTICLE INFO

Article history:
Received 8 April 2015
Received in revised form
29 February 2016
Accepted 4 August 2016

Keywords:
Crambe abyssinica
Brassicaceae
Energy crops
Biodiesel
Renewable energy

ABSTRACT

Crambe (*Crambe abyssinica* Hochst. Ex R. E. Fries) is an oilseed with the potential for cultivation in Brazil as a source of renewable energy in areas with tropical conditions. Crambe oil contains erucic acid, giving it economic importance for use in the electricity sector. Crambe oil can be used in insulating fluids and in the manufacture of chemical products and biodiesel without competing with human food production. As it is a new crop in Brazil, the scientific literature on crambe is still scarce. This review discusses general aspects of agricultural production and the potential applications of crambe associated mainly with the manufacture of biodiesel. The topics discussed in this review include: (i) genetic improvement of crambe; (ii) agronomic practices of production, pests, diseases, harvesting, storage, and economic viability; (iii) industrial use of crambe oil as an electrical insulator and in biodiesel; (iv) detoxification of the co-product generated during oil extraction for use in animal feed and use of the co-product in the natural bioremediation of contaminants; and (v) the challenges of increasing crambe production. Crambe has a remarkable future as a source of renewable energy in Brazil. Strategies to boost its cultivation, such as the identification of improved varieties and optimization of production system logistics, marketing, and resource allocation, should be adopted.

Contents

* Corresponding author at: São Paulo State University (UNESP), Department of Crop Science, CEP 18610-307 Botucatu, SP, Brazil.
E-mail address: doglasbassegio@gmail.com (D. Bassegio).

http://dx.doi.org/10.1016/j.rser.2016.08.010
1364-0321/

1. Introduction

Given the growing energy demand, rising pollution levels, and more stringent regulatory requirements, Brazil has pursued the use of biodiesel as a key alternative energy source for the diversification of its energy matrix. In this scenario, Brazilian agriculture plays an important role as a supplier of biomass–based raw materials. Brazil's extensive land area and tropical and subtropical climate provide favorable conditions for several oilseeds; currently, soybean (73%) and cotton (4%) are the main oilseeds used in biodiesel production [1]. However, there is demand for using other oilseeds, especially oilseeds that are not food sources, unlike soybean, to reduce competition between crops [2]. Such oilseeds should grow well under tropical conditions, such as those in the Brazilian Cerrado (e.g., jatropha, castor, and crambe).

Since the establishment of the Brazilian Program of Biodiesel Production and Use (PNPB) [3], several alternative species have been used in oil production, including crambe (*Crambe abyssinica* Hochst Ex R. E. Fries), belonging to the Brassica genus, and canola/rapeseed (*Brassica napus* L.), which is commonly grown in Southern Brazil for the production of edible oil. Crambe has industrial properties because its oil (35–45% the weight of the seed) has a high content (55–60%) of erucic acid (C22:1) [4,5,6]. The erucic acid ($C_{22}H_{42}O_2$) and its derivatives (erucamide) are raw materials in lubricants, surfactants, plasticizers, surface coatings, and nylon. Moreover, erucic acid has a low flash point, and demonstrates good combustion and lubricating qualities, making it a valuable component for biodiesel [5]. Chapter 5 of this paper reviews the potential for using crambe as a biodiesel source and electric insulator. These properties make crambe relevant to the energy sector for the manufacture of chemical products and biodiesel. Additionally, the crambe production generates interesting by-products that will be discussed in chapter 6.

Currently, the cultivation of crambe in Brazil is concentrated in the Southeast Region (Minas Gerais–Triângulo Mineiro) and in the Central–West Region (Goiás and Mato Grosso do Sul), where the cultivated area is close to six thousand hectares [7] because of the shortage of crops of economic value that are capable of enduring the weather conditions in the autumn–winter season. Crambe is also an attractive crop in other regions of Brazil because new machinery and equipment for its cultivation are not required for its cultivation, because it is possible to cultivate crambe over large areas, and because it possesses hardy characteristics, such as high tolerance to drought [8,9].

In order to develop the production chain for crambe in Brazil, in recent years, researchers have focused on factors that would make large cultivation of crambe possible, such as obtaining genotypes that are more productive and adaptable to tropical conditions, developing fertilization recommendations and cultural practices, improving storage and processing methods, defining its uses as an industrial oil, and allocating resources. Given this context, this review will present the main advances and challenges for increasing crambe production in Brazil, and for the use of crambe oil in the manufacture of renewable fuels.

2. Breeding

Crambe abyssinica Hochst has 45 chromosomes (n=45) and is related to *C. hispanica* L. (n=30) and *C. glabrata* (n=15) [10]. It is a self–pollinated plant [11], but intercrosses may occur (roughly 9–14% of the time) [12]. Crambe has a low genetic diversity for important agronomic traits [13].

The genetic improvement of crambe began in the early 1950s, with selections of plants in Russia and Sweden [14]. The mass selection method was used to develop plants with large seeds and plants with small seeds, eventually yielding the cultivars 'Prophety' (*C. abyssinica*) and 'Indy' (*C. hispanica*) [15]. In subsequent studies, the individual selection method with progeny testing was used to evaluate 162 strains of *C. abyssinica* for six characteristics. Results showed that there were significant differences between the strains, except for their glucosinolate content, indicating that individual selection with progeny testing was an effective tool for separating the genetic variations present in the original germplasm [16].

The 'Meyer' cultivar most prevalently cultivated in the early to mid-1990s, was developed by progeny selection in the mid-1960s from the cross of *C. abyssinica* and *C. hispanica* [16].

The collections of germplasm, according to Francisco–Ortega et al. [17], are distributed across four major geographic regions: Macaronesia (12 species), Mediterranean (4 species), East Africa (3 species), and Euro–Siberian (20 species). To protect and conserve the biological diversity of these species, 251 accessions are conserved in European germplasm banks, mainly in Austria (EURISKO), and by the National Genetic Resources Program (NGRP) in the USA, which holds 333 accessions in the Germplasm Resources Information Network (GRIN).

The only recorded crambe cultivar developed in Brazil, FMS Brihante, was generated by Mato Grosso do Sul Foundation (Fundação–MS), through the mass selection method performed with genetic material from Mexico in 1995, and released in 2007 [9]. Recently, the MS Foundation has continued the crambe breeding program, obtaining other genotypes for selection and testing. According to Pitol et al. [18], the goal of the crambe breeding program is to develop cultivars with characteristics that increase the current crop production, as shown in strain FMS 11 02 CR.

The Vegetable Improvement Program of Universidade Estadual Paulista "Julio de Mesquita Filho" (UNESP), Botucatu, Brazil, has focused their research on examining potential oilseeds for oil production. Researchers have been developing studies with the goal of identifying more productive crambe genotypes. Lara–Fioreze et al. [19], part of this program, noted that the cultivar FMS Brilhante, commonly used in Brazil, presents variability for all traits, and also that the magnitude of its grain yield is sufficient to make genetic progress with the selection. In order to select more productive genotypes, Lara–Fioreze [20] assessed 82 progenies on the basis of interactions between genotype and environment, and conducted studies in Botucatu, São Paulo, and São Manuel, during the autumn-winter seasons over three agricultural years. According to the author, the individual selection method with progeny testing was effective in obtaining higher yielding progenies for tropical conditions. However, in Brazil, the genetic improvement of Brassica species (e.g., crambe, canola) is restricted to universities and government entities, and few private companies focus their research on these oilseed varieties. It should be noted that are very few studies of crambe hybridization in Brazil.