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Okra: A potential future bioenergy crop in Iran

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ABSTRACT

The Iranian energy sector has recently discovered a great interest in the concept of renewable and clean energy. The interest is motivated primarily by concerns about greenhouse gas (GHG) emissions and global climate change, as well as the desire to find alternative and sustainable energy sources and create potential job opportunities related to these new technologies for future generations of Iranians. This study supports the search for alternative, sustainable energy sources by assessing okra's usability as a biofuel.

Okra is an annual, warm season crop that provides a rich source of industrial oil and protein. According to our investigation, the seeds of Iranian okra ecotypes that have an oil content of 20% could produce up to 325 kg/ha oil yield. Our study on Iranian okra seed oil showed that, the most dominant fatty acids of are linoleic acid (C18:2) (38–40%), Palmitic acid (C16:0) (29–30%), and Oleic acid (C18:1) (19–22%). The biodiesel derived from okra via a transesterification reaction using an ultrasonic system could meet ASTM D6751 standards with satisfactory results in methyl ester content (more than 96%), viscosity (2.3–2.4 mm^{-2}/S, and flash point (155–158 °C)). Because of its high oil yield, quality, and large ecological adaptation window, okra is a strong contender to provide a new source of non-edible oil for biodiesel production in bioenergy farms.

1. Introduction

1.1. Energy demands and challenges ahead

Energy demand is increasing as the human population grows and urbanization expands [1]. Energy production and use increases each year to supply human activities, despite the fact that some energy sources are causing widespread environmental pollution. The latest report from the International Energy Agency and World Health Organizations reveals that 18,000 people die every day as the result of air pollution [2]. Furthermore, the use of fossil fuels has generated additional environmental concerns, particularly as concerns the effects of global climate change, and fossil fuel sources are limited and will not be able to continue to meet demand [1].

On the other hand, energy consumption has a direct relationship to economic activity, which brings better life quality and development opportunities to humans [3].

Countries with adequate land and other farming inputs, such as water, human resources, and good biodiversity, may be suitable producers of bioenergy [4]. Bioenergy is energy generated from the conversion of any organic matter available on a renewable basis, such as feedstock derived from animal and plants (i.e., animal fats or vegetable oils) [5]. It should be noted that land use for bioenergy expansion need not compete with land use for food and other needs [6].

So, there is a need to determine how to gain all benefits of bioenergy and reduce the landscape-scale tradeoffs. Intensive research on bioenergy sources, including crops with less food importance that are capable of high biomass production, can help to fill this gap.

The ideal bioenergy crop should be fast growing, water- and nutrient-efficient, have low invasive potential, and have high tolerance for stress [7].

1.1.1. Why okra?

Okra (*Abelmoschus esculentus* L.) is an annual, warm season food crop that is usually cultivated for its immature pods [8–10]. Okra prefers well-drained soils and can tolerate a pH range from 5.5 to 8 [11]. Flowers are located on axillary parts; they have five white to yellow petals with a dark, reddish violet center. The flowers rapidly turn to fruit within two or three days. Fruits contain rows of rounded, dark green to gray seeds. Depending on the cultivar, okra fruits mature within 60–180 days of sowing [12]. Generally, okra is an erect crop that becomes woody at maturity [13,14].

Recently, some reports suggest that okra seeds could provide a new source of oil and protein [12,15,16]. Studies of different varieties showed that okra seeds contain 21.72% crude oil, 31.4% crude fiber, and 27% crude protein (on average) [17–19]. Okra seed oil is very

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similar to cotton and peanut seed oil; it has a high content of palmitic, oleic, and linoleic acids [20,21].

Unfortunately, Okra is a forgotten crop in Iran's agriculture. Although it has considerable advantages, such as high drought tolerance, an indeterminate growth habit that decreases the risk of yield loss, and high seed oil content for a summer crop, its cultivation is very limited. In part, this is because farmers have a very limited window of three or four days to pick the crop before the pods become woody. This makes okra production for human consumption a high cost endeavor in terms of human labor, stress, and the costs of production.

Recently, we found that okra seeds are a valuable source of oil that may be suitable for bioenergy purposes. The labor requirements and harvest stress would be far less for okra grown for biofuel than for okra grown for human consumption, because the desired product of cultivation would be pods with mature seeds, and it would not matter if the pods became woody before the seed is harvested. Although a large number of genetic resources of the same genus as okra are known to exist [22–24] and the varietal effects on the chemical composition of okra seeds have been documented [18,25], there is a lack of information on the range of variation within the seed oil content of each Iranian okra ecotype in terms of fatty acid composition, biomass characteristics, and the potential application of the seed for bioenergy purposes.

This review will focus on okra as a potential bioenergy crop in Iran, based on research assessing the biofuel production possibilities from this crop.

1.1.2. Okra general statistics

The total world production of okra in 2013 was estimated to be 8.947 million tons, grown from 1.126 million ha [26]. Okra is primarily cultivated in Asia and Africa. India is the largest okra producer in the world, followed by Nigeria (Fig. 1). However, its high tolerance for unfavorable environmental conditions such as drought and salinity (Fig. 2) make okra a highly likely prospect for cultivation in Iran.

1.1.3. Okra in Iran

Okra cultivation in Iran was last officially recorded in 2002; the report showed that the total cultivation area of okra in Iran was 1038 ha [27]. The Khouzestan province was the largest site of okra production in Iran, with 993 ha of okra fields [27]. However, many provinces have favorable environmental conditions for growing okra, particularly in the summer (Fig. 2). Despite the high production potential of okra in Iran, the difficulty in harvesting and bringing the crop to market are barriers to production for most farmers who would grow it as a food crop. However, if the crop was cultivated to produce seed oil and protein, rather than fresh pods, then farmers would find this crop to be a much more attractive option.

Geographical distribution will affect okra plant characteristics. This study reviewed the oil, biomass, and biodiesel qualities of three Iranian okra ecotypes.

1.2. Literature section (Bioenergy crops in action)

1.2.1. Vegetable oils and biofuels

Since the invention of diesel engines, vegetable oils have been considered as potential liquid fuels. Rudolf Diesel used peanut oil as fuel in 1900 [28]. Researchers have investigated many vegetable oils and their derivatives, which are most commonly biodiesel or the mono-alkyl esters of oils or fats, for their potential application as fuel, whether for transportation or heating purposes [29–34].

Although biodiesel production is encouraged globally as an environmentally-friendly fuel and a short-term substitute for conventional diesel fuel [35], it also negatively influences food production and could cause food shortages. As a result, some researchers recommend blending conventional fuel with biodiesel in order to help minimize the emission of greenhouse gases while ensuring food security [36].

There are large potential feed stocks with which biodiesel could be produced from non-edible vegetable oils. USDA reports indicate that total vegetable oil production increased by 18.08% from 2011 to 2015. The main sources of vegetable oils are rapeseed, corn, and soybean, which are also largely used for food purposes [37,38]. The main hindrance to adopting biodiesel from vegetable oils is dedicating enough arable land to produce a sufficient volume of oil seed crops without affecting the food supply and cost of food production [39]. Most of these concerns relate to crops that primarily used for food purposes. Based on FAO reports, nearly 41.88 million km^2 of land is available for agriculture, but only 15.06 million km^2 is being used, and only 0.14 million km^2 is dedicated for biofuel production [40,41]. Crops that provide nonedible oil are under review to use as a feedstock for

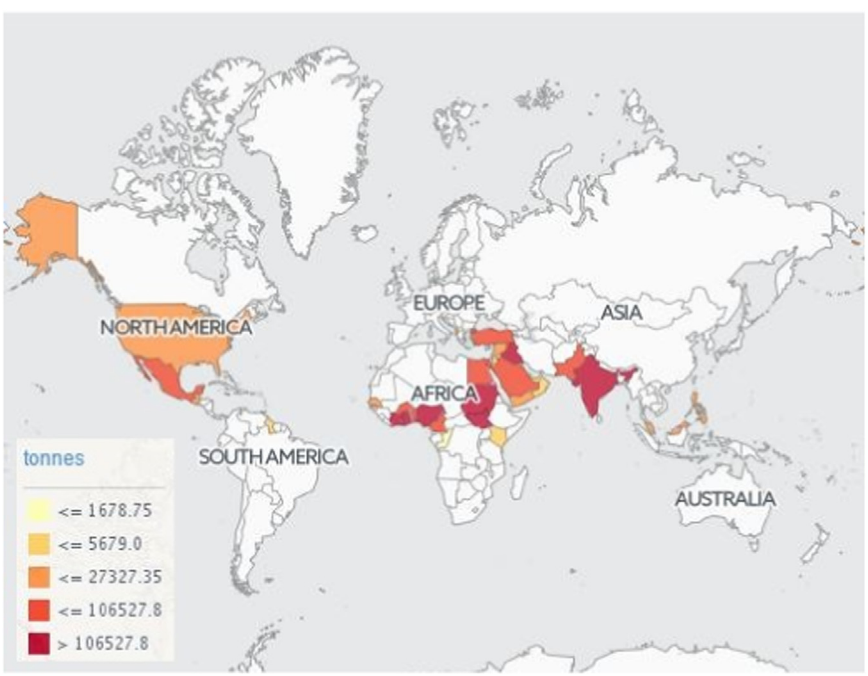

Fig. 1. Largest okra producers of the world (FAO, 2016).