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Jatropha curcas as feedstock for green fuels production

Abstract

An increasing demand of energy and fuels for diverse applications, in addition to the depletion and negative effects of fossil resources, has raised the interest to use nonedible biomass or residual biomass as alternative raw material to produce renewable fuels for heavy vehicles. Currently, several projects around the world aim the sustainable production of green fuels and a major challenge to overcome is to guarantee the continuous supply or biomass required as raw materials. To this purpose, non-edible vegetable oils, such as *Jatropha curcas* (*JC*) oil, have been suggested as a very favorable feedstock. In this review, we briefly summarized the potential to produce *JC* seeds and oil in Mexico as well as the outcomes and challenges found when *JC* oil was used to biodiesel production. We also identify some the actions required to establish a *JC* supply chain, which is a basic premise to promote the development of green liquid fuels such as sustainable aviation fuel.

Keywords: *Jatropha curcas*, bioenergetics, green fuels, biodiesel, sustainable aviation fuel

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Introduction

In the last decades, rise of world´s population and society concerns to improve social and economic welfare have detonated a significant increase of energy and fuels for domestic, industrial and transportation needs.[1] For example, it is expected that in 2040 the demand for diesel and jet fuel will be increased by 30 and 50%, respectively.[2] On the other hand, it is well established that fossil sources used to generate energy and liquid fuels are being depleted; in addition, these sources contribute to emission of greenhouse gases (GHG) causing drastic harm to health and environment. In United States around 30% of total GHG are due to transportation sector and in Mexico GHG theses emissions will be around 28% by 2030.[3,4] Therefore, multiple international agreements have been established to mitigate climate impact by reducing GHG emissions from transportation sector.[5] Over the last 2 decades, there has been a strong incentive to develop alternatives to replace conventional fuels for light and heavy vehicles. In the mid-term, electrical and solar energy based light vehicles seem to be a suitable option, but these strategies are not technologically and economically convenient for heavy vehicles; to this purpose, renewable liquid fuels such as biodiesel and bio jet fuel are produced from non-edible oilseed biomass seem to be the top choice. To date, these fuels are being are being commercialized and the technologies focus on the development of green fuels that can be directly used in the current combustion engines.[6] However, bio fuels commercialization is very asymmetric around the world due to numerous and complex technological, economic and/or political barriers, which are solved in different ways in each region. In almost all cases, a very challenging task is to guarantee the supply of biomass required as raw material. For these reason the optimization of the cultivation process of non-edible oilseed biomass is a very relevant issue.[7,8]

Analysis

Jatropha Curcas (JC) cultivation has widely spread worldwide since the late 1990s, when its promising potential as a bioenergetic was recognized. JC is native to Mexico, Central and South America, Africa and India.[9,10] However, most of the Jatropha plantations are located in Asia (85%) and to a lesser extent in Africa (13%), with a growing increase in the areas planted with Jatropha in America (2%).[7,11] *JC* is a fast-growing small tree or large perennial shrub that reaches a normal height of 2 to 3 m and whose productive life ranges between 45 to 50 years.[12,13] *JC* cultivation is favored by tropical or subtropical climate over a relatively broad set of environmental conditions: an average annual temperature of 18 to 40 ºC, altitudes of 500 to 2150 mamsl, rainfalls of 300 to 3,000 mm. *JC* grows almost anywhere, although it prefers loamy-sandy-clayey soils, with soil depth not less than 45 cm and it requires soil nutrients such as nitrogen, phosphorus, and potassium.[12,14] *JC* seeds are typically develop for 3 months in a greenhouse before they are transplanted to field.[4,15] Five years old *JC* yields seeds from 0.1 to 15 ton/ha/year seeds and an average oil yield around 1590 kg/ha/year.[16,17] *JC* is a non-edible (toxic) oil that contains a high level of oleic and linoleic fatty acids and its main applications include the production of soap, biocides and biodiesel, which consist of a mixture of fatty acid alkyl esters.[18,19]

Mexico has a privileged opportunity to produce *JC*. In the last two decades, the Mexican government promoted and financially supported different initiatives to cultivate *JC* as raw material for biodiesel production with the main goal of reducing GHG, but also as an alternative to create better jobs and wages for farmers and to promote the development of rural areas.[20,21] A detailed study was conducted in Mexico to evaluate the potential availability of *JC* crop, based on official data reported by SAGARPA (Mexican Agriculture Agency), as well as surveys and field visits to *JC* producers[22]. Data included in Table 1 showed that Mexico has the potential to detonate an advantageous supply chain of *JC* oil to be used for bio fuels production. The highest *JC* oil production potential was validated for state of Chiapas, which represents 35% of the total production, with an estimated 121,037 ton of *JC* oil per cycle, followed by Jalisco d Michoacán with 28% and 24%.[22]

Table 1 Jatropha seed and oil production potential in Mexico (adapted from reference 22)

State or region	Sustainable Area (ha)	Estimated JC production at 4 year (ton/y)*	Estimated JC oil yield (ton/y)**
Chiapas	87,708.09	2,63,124.27	1,21,037.16
Guanajuato	128.21	384.63	176.93
Hidalgo	2,296.11	6,888.33	3,168.63
Jalisco	70,441.23	2,11,323.69	97,208.90
Michoacán	61,012.13	1,83,036.39	84,196.74
Sinaloa	31,945.93	95,837.79	44,085.38

*Seed production used as reference = 3 t/ha. **Average oil yield = 46%

The Mexican government made relevant efforts to spread *JC* cultivation in different edapho climatic regions, taking advantage that Jatropha is a highly adaptable crop that grows in marginal soils, resists drought, diseases and some pests reasonably well, and require relatively lower agronomic practices.[8] Mexican agriculture research centers enhanced JC native variety to increase *JC* seeds and oil production according to local soil and climate conditions.[5] This favorable scenario motivated Mexican farmers to switch from bean and maize to *JC* cultivation[23,24] and some local and foreign private companies promoted *JC* oil production at pilot plant scale.[5] However, despite all investments and favorable potential, benefits from *JC* seed and oil production in Mexico were very limited, especially for rural areas. One of the key factors for this drawback was that *JC* seeds and oil yields were lower than expected,[25] suggesting the need to implement and respect standardized *JC* cultivation practices. On the other hand, there was no sustained growth in *JC* oil demand because the biodiesel value chain failed to consolidate in Mexico. Several private biodiesel pilot plants were unable to scale production due to the lack of government´s fiscal and economic incentives, reduced private stakeholder's involvement and low demand from Mexican biodiesel market.[26] These issues, associated with the fact that biodiesel had to be blended with fossil diesel, made uncompetitive the biodiesel business and most of biodiesel companies established in Mexico were forced out of business .[27] A similar outcome occurred in several other developing countries, where it was not possible to launch a sustainable biodiesel production from *JC* oil.[25]

In this scenario, private and public actor in the aviation industry detonated an international commitment to mitigate the negative environmental impact caused by the use of conventional jet fuel. One of the most important initiatives was to developed sustainable aviation fuels (SAF) using non-edible biomass as raw materials.[7,28] To this purpose, UOP/Honeywell, Neste, Byogy, Lanzatech, among several other companies, are simultaneously developing technologies to produce SAF by means of the HEFA (Hidro processed Esters and Fatty Acids) process and the ATJ (Alcohol to Jet) process, which required non-edible vegetable oils and ethanol produced from residual lingo cellulosic biomass as raw materials, respectively.[29,30] The approached revitalized the interest in *JC* seed and oil production worldwide. In Mexico there have been various initiatives to validate the use of *JC* oil for SAF that, complying international standards, could be directly used in the current engines of aviation industry; these are the so-called "drop-in" or green fuels. Recently, the "Bioturbosina cluster" (BC), a research center based consortium financed by the Mexican government established the basis of a value chain for sustainable JC production.[31] BC also promoted the joint production of *JC* and *Castor* oil, and made preliminary validation of the production of *Salicornia* oil in arid and semi-arid regions of Mexican territory. BC clearly showed that a successful *JC* production value chain must include the optimization of the *JC* variety, as well as the cultivation, harvesting and oil extraction conditions. The development of technological packages to standardize the productivity of *JC* seeds and oil was other relevant product of BC that may now be transferred to local producers. To date, the indicated approach for *JC* seeds and oil production may now be incorporated as a key resource for the SAF production value chain.

Very importantly, a mid- and long-term strategy for SAF production in Mexico, as it could be the case in other developing countries cannot be local; rather, it must be the result of a state policy that strongly promotes the development of green liquid fuels. Operationally, it must include the participation of public and private sectors; companies associated with the aviation sector operating in the country should be considered as strategic allies in the development of the supply chain. It is also imperative the formal establishment of technical, environmental, economic and legal policies, strategies and programs, to promote:

The recovery of eroded, deforested or degraded land in productive areas.

The development of improved *JC* variety according to of climate and edaphic conditions of each region, including the alternative of genetically modified varieties.

i. The optimization of agricultural production process, focused on productivity and market profitability.
ii. The validation of local cultivation practices to promote sustainable process.
iii. Development of technological packages for producers.
iv. The promote the active participation of producers in the supply chain.
v. The mechanization of field processes.
vi. The logistics of seed collection and transport.
vii. The optimization of *JC* oil extraction methods.
viii. The recovery and valorization of waste from *JC* harvesting and processing.
ix. Subsidies and economic and fiscal incentives for *JC* production and extraction processes.

Final considerations

The establishment of a SAF production value chain requires a harmonious integration of public policies, technological development strategies, and effective cooperative programs between technicians,

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producers, and public and private entities. An appropriate integration of the links in the *JC* seeds and oil supply chain is a challenge when not formal federal policies are set. In this case, the creation of local supply chains remains as a feasible alternative as a proof of concept and as a source of valuable data to raise interest among private investors. It is clear that supply of bioenergetics represents a great opportunity for developing countries to promote sustainable development and social welfare in the immediate future.

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Conflicts of interest

Authors declare no conflict of interest.

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