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Article

Does Biodiesel from *Jatropha Curcas* Represent a Sustainable Alternative Energy Source?

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Abstract: Various government agencies around the world have proposed vegetable oils and their conversion to biodiesel as a renewable alternative to fossil fuels. Due to its adaptability to marginal soils and environments, the cultivation of *Jatropha curcas* is frequently mentioned as the best option for producing biodiesel. In the present work the current situation of proven and potential reserves of fossil fuel, and the production and consumption model for the same are analyzed, in order to later review the sustainability of the production process which begins with the cultivation of *J. curcas*, and culminates with the consumption of biodiesel. A review of the following topics is proposed in order to improve the sustainability of the process: areas destined for cultivation, use of external (chemical) inputs in cultivation, processes for converting the vegetable oil to biodiesel, and, above all, the location for ultimate consumption of the biofuel.

Keywords: biofuel; *Jatropha curcas*; petroleum

1. Introduction

The consumption of fossil fuels, above all petroleum and mineral coal, has been the foundation of the economic growth and the betterment of general levels of well-being for the so-called leading economies throughout the last century. At the same time, in the peripheral economies, like those of Latin America, a phenomenon has been presented of production of material primarily for exportation and to a lesser extent for internal transformation and consumption. There are two essential concerns which put at risk the viability of the model of growth based on export and/or excessive consumption of energy, both related with the lack of sustainability in said model: the apparent decreasing availability of fossil fuels and the notable increase in greenhouse gasses in the atmosphere caused most probably by human activity.

With regard to the proven and potential reserves of petroleum in the world, undoubtedly there exists a decline in the former since the decade of 1970–1980 [1-3], although apparently this is not significant [4,5]. During 2008 the international prices of petroleum rose to historically high levels, a situation utilized as an argument for the near-term emptying of the fuel reserves and for planning for the so-called energy transition, which includes, among other topics, the investigation and use of alternative sources of energy. Nevertheless, at the beginning of 2009, said prices fell substantially, which indicates that the price does not depend exclusively on the availability of petroleum, but also on multiple financial and geopolitical interests [5]. Over the potential reserves (possible and probable), the exploration in various parts of the world [5,6] and the application of new technologies [7-9] shows that it will be possible to extract petroleum at competitive costs for at least all of the 21st century.

On the other hand, the significant emission of carbon dioxide (and other greenhouse gasses) into the atmosphere by the combustion of petroleum in various human activities and its repercussion on global climate is a fact which only in the last two decades has been taken into account [10], but which recently has become a preoccupation even for petroleum exporting countries [5]. Proposals exist to reduce the emissions of CO_2, which include the design and use of more efficient machines and processes. Without considering if the foregoing may be achieved, the environmental economy postulates that technological solutions do not exist *ad infinitum* for the problems of the environment, and the second law of thermodynamics teaches that no completely efficient machines can exist.

The two discussed preoccupations have driven the investigation of alternative sources of energy, of which there exists a large list [11], although, since the substitutes most akin to petroleum are sought after, the options most prominent in the last decade are the liquid biofuels, specifically ethanol [12] and biodiesel [13-15]; these also have the advantage of being of photosynthetic origin (simple or complex sugars in the case of ethanol and greases or oils in the case of biodiesel) and, also, renewable, as part of the carbon cycle.

This present essay is focused on the biodiesel product from the oil of the tropical plant *Jatropha curcas* L. (Euphorbiaceae). There are a lot of oleaginous plants with potential for producing biodiesel, but *J. curcas* is frequently mentioned as the best option. Among several advantageous characteristics of this species is important to underline its adaptability to marginal soils and environments [13].

2. Regarding the Sustainability of Biodiesel

From the above, one concludes that governments and energy companies are not formulating profound changes in the model of consumption of petroleum fuels, but only technological solutions for (a) extending as much as possible the extraction of petroleum at non-prohibitive costs, (b) minimizing the emission of CO_2, and (c) substituting for petroleum with liquid biofuels.

Furthermore, biodiesel cannot replace petroleum, in the first place because it cannot be produced, without causing environmental damages greater than those for which it intends to give a solution [16], on a scale similar to that of petroleum, in accordance with the present and projected demand; in the second place because from biodiesel is not possible to extract the multitude of by-products which are produced by the petrochemical industry.

One fact which exemplifies the contradiction between a preoccupation with CO_2 emissions into the atmosphere and the plan to continue the model of economic development is that the leading economies, principally the United States, postulate that biofuels, in particular biodiesel, will permit a reduction in imports of petroleum [17], while the peripheral economies, especially those located in tropical zones, plan for the production of biodiesel for export [18] to countries like the United States and China, which are the largest emitters of CO_2 into the atmosphere. Another pattern in growth is the re-exportation of biodiesel [19], the vegetable oil is exported to one country, converted into biodiesel, and then re-exported to another country.

In any case, the photosynthetic origin of biodiesel is sufficient to justify its investigation as a renewable fuel, not only as a simple technological development, but also situating it as an element to play its part in the so-called global ecological crisis (*sensu* Iranzo [20]), taking into account the multitude of factors which affect the sustainability of its use. In this sense, Ovando *et al*. [21], put forward that the rising world interest in biodiesel, specifically that produced from "piñón" (*J. curcas*), can lead to non-sustainable practices. For this reason, they propose giving attention to at least four aspects for their importance in sustainability of the production process of "piñón"-consumption of biodiesel: (a) the area dedicated for cultivation, (b) the use of inputs in the cultivation, (c) the processes for converting vegetable oil to biodiesel, and d) the final destination of the biofuel.

Achten *et al*. [22] performed a qualitative evaluation of the future sustainability of cultivating *J. curcas*, focussing on the environmental impacts and socioeconomic aspects; they determined that the cultivation is sustainable when practiced in marginal or degraded lands, but not when fertile areas are dedicated which could serve to cultivate foodstuffs or other crops with greater profitability. One logical conclusion from the work of Achten *et al*. is that if areas of forest are clear-cut to convert them into "piñón" cultivation, the sustainability of the process is nonexistent. Nevertheless, it is possible to use areas considered as agriculturally high quality, if only one takes advantage of the periphery of the principal crops. It has been calculated, for example, that in the Mexican state of Chiapas, the cultivation of "piñón" could occupy a maximum of 230,000 hectares on the perimeters of the cultivated areas or used for cattle-grazing [21]. It was mentioned before that biodiesel cannot substitute for petroleum, not even for diesel, at the actual and projected levels of consumption; for example, the National Mission for Biodiesel in India has proposed the planting, by the year 2020, of an area of ten million hectares with *J. curcas* to produce 7.5 million tons of biodiesel each year; this volume represents only 20% of the demand for diesel in that country [3]. To substitute biodiesel for

the actual demand for diesel in Mexico (17.4 million metric tons [23]) would require close to 23 million hectares planted with *J. curcas*, which is equivalent to more than 90% of the cultivable ground surface. In this country there is a recent legislation that promotes the investigation and use of biofuels [24]; however, the corresponding bylaw has not yet been published.

To minimize the use of fossil energy and improve the energy balance it is required that the cultivation not include the use of chemical fertilizers, since these represent an elevated level of energy consumption. The data shows that 45% of commercial energy used in global agricultural production is due to the consumption of chemical fertilizers [25]; for that reason, implementing a bioenergy cultivation consuming a huge quantity of energy is, at the least, contradictory. For example, according to the same author, ammonia, the principal source of nitrogenous fertilizers, is produced from natural gas, and the petrochemical industry, which synthesizes it, consumes 1.2% of fossil fuels extracted on the global level.

The post-harvest processes for the majority of agroindustrial products imply a high consumption of energy derived from the use of indispensable machines; doubtless, in this case one should pay special attention to the energy efficiency of the machines for separating the husk of the seed, the extraction of the oil and the conversion to biodiesel. In this way, the husk can be used for fuel to heating the cauldrons if one opts for extraction of oil by extrusion by heat, or for heating the transesterification reactors for conversion to biodiesel. Regarding this last, it is greatly relevant to mention that although the reaction of transesterification has a high yield level (80%, that is to say that 800 mL of biodiesel are obtained from every liter of vegetable oil), the use of methanol reduces the energy gain. Methanol, which industrially is obtained from the distillation of petroleum, requires a proportion of 200 mL for each liter of processed oil. Among the alternatives one encounters the use of ethanol, which derives from the fermentation of sugar, although it has the inconvenience that on production it is dissolved in water with a distillation yielding a maximum of 96% alcohol to 4% water. The conversion of vegetable oil to biodiesel is favored by the absence of water, or by minimal quantities thereof. The production of completely anhydrous ethanol raises both costs and energy consumption.

Other topic requiring attention is the content of toxic substances of the *J. curcas* seed. Several toxic molecules have been reported in the seed [26-28], but the protein curcin and the phorbol esters are the most hazardous for human and animal health. After the oil extraction, the seed cake still contains those substances, representing a potential risk for the *J. curcas* biodiesel workers [29]. The potential of phorbol esters as carcinogens is known [30]. Although non-toxic genotypes of "piñón" exist in several parts of Mexico or improved non-toxic varieties could be obtained (by conventional breeding or by transgenic methods), toxic genotypes are being used for establishing extensive plantations around the world. However, a dilemma exists: if non-toxic genotypes are used, problems with pests could be a limitation, as the plant-herbivores interaction would be substantially modified. Alternatives to use the press cake are the physical or enzymatic detoxification for using as fodder, and the composting for using in the same plantation.

3. Conclusions

The aspects mentioned only refer to challenges to the sustainability of production, which can be overcome by means of technological development, while the true challenge is a reflection over the

viability of the model of exporting peripheral economies *vs*. leading economies in the consumption of fuel: namely, that given that the transport of biodiesel by whatever means entails the consumption of energy, then in order to maximize the energy efficiency of the process, the production of biodiesel derived from "piñón" should have a focus on local use in the rural environment, or in urban areas close to the sites for cultivation and industrialization of *J. curcas*, more than any export focus. The energy balance for a biofuel is a comparison of the energy contained in the fuel with the energy required to produce, process, and distribute it.

It does not mean that the proposal tends toward the so-called "Arcadian ecology" (*sensu* Iranzo [20]), but this could provide rural communities with energy to stimulate processes of improvement which at present they do not possess, whether due to lack of services or energy products or due to the high costs of these; for example, in some cases it would improve the preservation of foodstuffs at lower temperatures. Since transporting biofuels across large distances is not a sustainable result, the production for export, and later re-export, should be limited.

Our criticism to current approaches for the production and consumption of *J. curcas* biodiesel is not intended to disqualify the efforts of many people, but to contribute to a more sustainable productive chain. Of course, as Khan and Islam [31] explain, sustainability is not achieving only by minimizing risks and remediating problems engendered by the introduction of a given process or technology, but visualizing future potential problems, that is, having the time as main variable.

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