DROP-IN BIOFUELS TECHNOLOGIES: Jatropha curcas L., AN ALTERNATIVE CROP FOR BIODIESEL TO ENERGETICALLY ISOLATED FARMS IN ANGOLA

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ABSTRACT

The new drop-in fuels technologies stream deals with renewable fuels that can be blended with diesel or gasoline meeting current standards and being used in engines without major design modifications. In the last years, the crop of Jatropha (*Jatropha curcas* L.) has been introduced in the African countries like Tanzania, Zambia and South Africa, among others. The aim of this research is to determine the energy potential of Jatropha for biodiesel production in Angola, with a special focus on the reduction of current consumption of fossil fuels in energetically isolated farms. According to recent research Jatropha oil yield can achieve 2,625 L.ha^{-1} in optimal crop conditions, which represents 75.6 GJ.ha^{-1} in terms of primary energy and could supply about 7.7 MWh ha^{-1} electric power. The electric power consumption in Angola reached 5.32 TWh (5,320,000 MWh) in 2013. Therefore, the land area required to generate 10% electric power consumption from Jatropha biodiesel was estimated at 69,091 ha, which represented only 0.12% agricultural land area in Angola.

Key words: energy, liquid fuel, engines

INTRODUCTION

Jatropha (*Jatropha curcas*) can be described as a perennial shrub or small tree that reaches no more than 5 to 6 meters high. It is native to Central America and Mexico, with a distribution between 30º N and 35º S. It is well adapted to arid and semi-arid conditions, being used to improve degraded soils, to support crop of vanilla, and also to be used as living fence and for its medicinal properties. This crop has been significantly introduced, in terms of cultivated area, in countries like India and Tanzania due to its potential for biodiesel production from its seed oil. Seed oil is turned into biodiesel through a process of transesterification. According with existing literature, the life span of this shrub is approximately 30 to 50 years and its seeds contain 30 to 35% oil. The actual productive potential of Jatropha is not well known; it has been discussed in the scientific literature showing yields from 0.5 to 12 t.ha^{-1} (Pandey et al., 2012). As a perennial crop, yields are lower in the first years of the Jatropha crop. The biodiesel obtained from Jatropha crops belong to first generation biofuel category, which involves a cheaper and simple conversion process. It has been reported as a successful alternative for small scale farms in Tanzania, as long as a good management program is implemented (Brittaine and Lutaladio, 2010).The goal of this project is to determine the energy potential of Jatropha for the replacement of fossil fuels consumption used to generate electric power in an isolated farm in Angola, as a case study representative of what could be implemented in this African country. The field work aimed at the analysis of the electric power consumption is the farm named 'Aurora', a stage needed for the cabinet work, which objective was to assess the land requirements for the replacement of fossil fuels with biofuels.

In this work the introduction of an energy crop as Jatropha (*Jatropha curcas*) is proposed to obtain oil and subsequently, produce biodiesel with a view to the replacement of fossil fuels in energetically isolated farms. In a further research it will be undertaken the study of the blend options available for current electric power generators or their replacement by other engines running exclusively on pure vegetable oils (PVO). Whatever the biofuel is, it is important to know that the maximum admissible proportion of biofuel set in technical specifications of engines. It is possible to find in the market blends with increasing biodiesel proportion, like B2 (2% biodiesel blend), B4, B5, B7, B10, B20 and B100 (100% biodiesel).

MATERIALS AND METHODS

Case Study

Aurora farm is located in the province of Catete 71 km East Luanda which is the current capital of Angola. Their main activity is the yoghurt production, which involves a number of farming activities like land preparation, planting, irrigation, harvesting, machinery maintenance, industrial operations and others. The Farm runs 4 diesel generators; two of 400 KVA, one of 700 KVA and a little one of 150 KVA.

Land requirements for growing Jatropha

The project aims to the assessment of the Jatropha crop land needed for the replacement of diesel consumption in electric power generation in Aurora farm, as a case study; additionally, it was also estimated for the whole country, at a rough scale. In the case study, the basic formula for the calculation of land requirements (LR) was the following:

$$LR = (\sum \text{Fuel for electric power consumption}) / (\text{oil crop yield} \times \text{Biodiesel production efficiency} \times \text{Biodiesel energy value} \times \text{Generation efficiency})$$

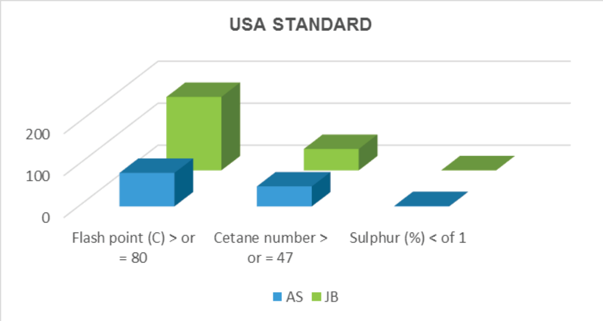
Where:

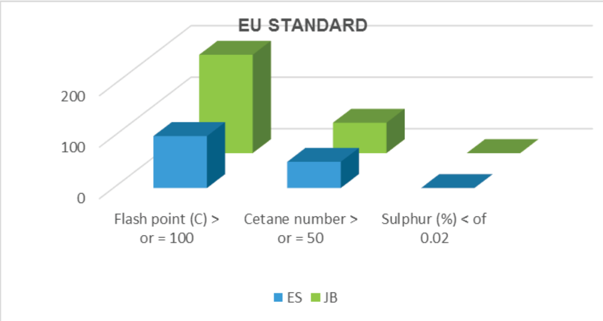
(i) Fuel for electric power consumption: Data and information on fuel and electric power consumption comes from the author's own measurements, by taking daily readings of working hours of generators in electrical displays and daily fuel consumption; (ii) Oil crop yield (L $oil.ha^{-1}$): Annual yields of Jatropha range from 0.2 to 2.0 kg seeds per tree (Francis et al.,2005); it has been estimated a production of 2.0-3.0 $t.ha^{-1}$ in semi-arid areas (Heller, 1996; Tewari, 2007). In our work, a hypothetical scenario was conducted, assuming 3 $t.ha^{-1}$ and 35% seed oil content; (iii) Biodiesel production efficiency: It was assumed a simplified factor: 0.8 l biodiesel produced from 1 l seed oil; (iv) Biodiesel energy value: It was taken from the Directive 2009/28/EC of the European Parliament and Council related to the promotion of the use of energy from renewable sources (EU, 2009); (v) Generation efficiency: It was assumed 40%, a common value for electric power generators; (vi) Measurements of fuel consumption and information on the energy consumption in Aurora Farm were made over a year, period of time in which the author of this study was working in Aurora farm. All data were taken in situ by the author.

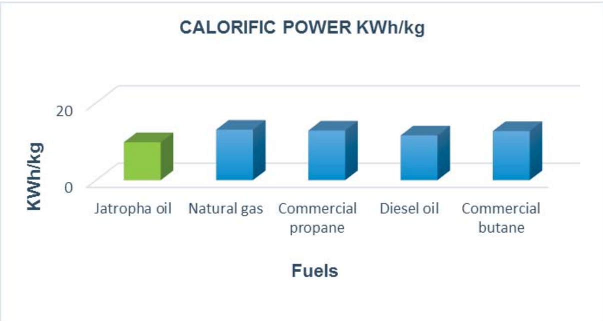
RESULTS AND DISCUSSION

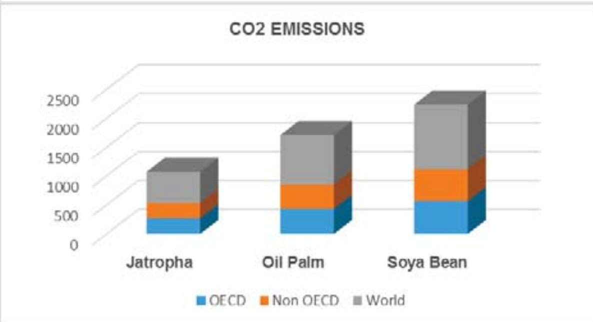
This energy crop has become a new true alternative of fossil fuel replacement, not only for its adaptation to poor soils subjected to significant levels of erosion, but also for the Jatropha biodiesel properties, which meet American (Fig.1) and European standards (Fig.2). The calorific power performance (Fig.3) and their contribution to reduce CO_2 emissions (Fig.4) in contrast to other energy crops grown for biodiesel production that have been published in recent years.

Figure 1 (above, left): Jatropha biodiesel (JB) vs American standard (AS). Source: Dominguez, 2012. Figure 2 (above, right): Jatropha biodiesel (JB) vs European standard, (ES). Source: Francis et al., 2005. Figure 3 (bellow, left): Calorific power of different energy sources (Jatropha oil column added). Source: Dominguez, 2012. Figure 4 (bellow, right): Emissions of CO_2 from land conversion for different types of biodiesel. Source: Ravindranath et al., 2009.









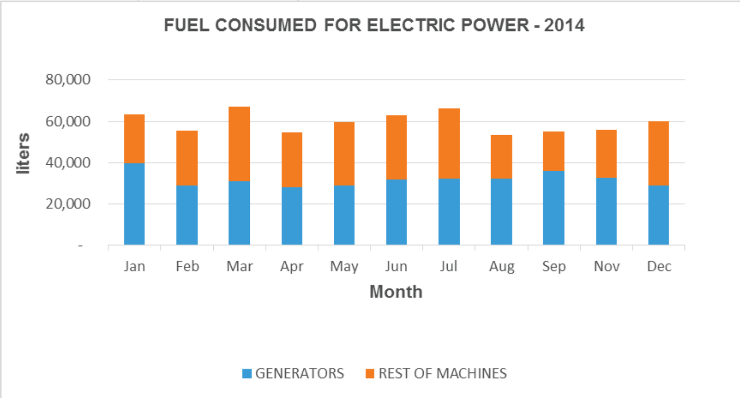
Fuel and electrical consumption

Aurora farm consumed a total of 607,834 L fuel in 2014 (Fig.5), from which 305,031 L were used exclusively for electric power generation, with an equivalent production of 5,550.4 MWh electric power in 2014. So, the four diesel power generators used for farm operations, consumed 55% of the total fuel demanded in one year. This item represented 7% of the total annual cost of the farm.

Assuming a plant density of 2.0 × 2.0 m and a yield of 3 kg of seeds per tree and year in optimal crop conditions, a Jatropha plantation might yield up to 7.5 t oil seeds.ha-1.year^{-1}. If the seed oil content were 35% (v/w) the oil crop yield in optimal crop conditions would be 2,625 L Jatropha oil per ha and year. Moreover it is important to take into account that the conversion factor of 1 L oil is approximately 0.8 L biodiesel and that the electric generation efficiency of a diesel engine is about 40% in energy terms. According to Directive 2009/28 EC the energy content of the biodiesel produced from vegetal oil is 33 MJ.L^{-1}; therefore the energy yield of Jatropha biodiesel may amount up to 69,300 MJ.ha^{-1}

(=2,625 L seed oil.ha^{-1} × 0.8 L biodiesel. L^{-1} seed oil x 33 MJ.L^{-1} biodiesel), in our scenario. Assuming 40% efficiency for electric power generation, the Jatropha crop could supply about 7.7 MWh.ha^{-1} electricity (1 MJ ↔ 0.277kwh). As a result, the total land area to supply the annual electric consumption of Aurora farm (5,550.4 MWh in 2014) would be 721 ha if 100% fossil diesel were replaced with Jatropha biodiesel. At a rough scale, the total land area needed to replace 10% electric consumption of the country -5.32 TWh in 2013 (IEA, 2013), would be 69,091 ha, which would mean 0.12% Angola agricultural land (573,000 km^2 in all).

Figure 5: Fuel consumption of electric power generation and agricultural machinery, according to own measurements in 2014.



CONCLUSIONS

The drop-in technologies is making great strides bringing to our life new energy alternatives that are more environmentally friendly than the current fossil fuels under use.Dedicated energy crops like Jatropha (*Jatropha curcas*) are currently under research in order to improve yields, together with lower costs per hectare. Jatropha is suitable to small scale farms having been successfully implemented in countries like Tanzania and India. Angola has a high potential as a biofuel producer due the extensive area available for agriculture, as well as for its natural resources and their economic potential. It would be possible to implement a B10 diesel blend to reduce CO_2 in the country. The scenario proposed in this project could be applied to small scale farms in Angola, with a B100 biofuel.

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