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Biodiesel in Brazil: Policies, Resources and Trends

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Abstract:
The main focus of this paper is to describe the current situation of biodiesel in the Brazilian context. Within this objective it is also given an overview of the European Union demand for the Brazilian biodiesel. The body of this paper describes the Brazilian biodiesel program (history and policies). After that, a technical description related to production capacity and availability of feedstocks in Brazil is presented. Concluding this paper, the main trends for Brazilian biodiesel are discussed.
Keywords: *Supply Chain Management, Biodiesel, Mobility, Policy Making*

1. INTRODUCTION

The possibility of using vegetable oils as fuel has been recognized since the beginning of diesel engines. In 1911, Rudolph Diesel presented an engine based on compression-ignition: the diesel engine. At that time there was no specific fuel to feed this engine. Rudolph Diesel used groundnut oil. The predicted shortage of fossil fuel encouraged the search for substitutes for petroleum derivatives. This search resulted in an alternative fuel called "biodiesel".

The concept of biodiesel is still under discussion. Some definitions consider biodiesel as any mixture of vegetable oil and fossil diesel, while others take into account only mixtures of alkyl esters of vegetable oils or animal fats and diesel. The definition adopted by the Brazilian Biodiesel Programme is: "a fuel obtained from mixtures, in different proportions, of fossil diesel and alkyl esters of vegetable oils or animal fats". Technically speaking, biodiesel is the alkyl ester of fatty acids, made by the transesterification of oils or fats, from plants or animals, with short chain alcohols such as methanol and ethanol. Glycerine is, consequently, a by-product from biodiesel production.

There are several choices for vegetable oil sources. In Brazil, soybean oil is a source that is already scaled up for biodiesel production. Nevertheless, other sources, such as

Sunflower, peanut, cotton, palm oil, coconut, babassu and, especially, castor oil, may be used in the near future, once their cultivation could achieve an economic up-scaling.

The alcohol source in general is methanol. In Brazil, ethanol from sugar cane has a great potential as an alcohol source, since it may ally its non toxicity with a ready availability. But, it is less reactive than methanol and there are some technological problems in its industrial use.

The objective of this study is to describe the current situation of Biodiesel context in Brazil and the options for exporting it to European Union (EU). To achieve these targets some research questions are made:

What is the current situation of Brazilian biodiesel production?
What crops/feedstocks exist for biodiesel production in Brazil?
What options are available for exporting biodiesel to the EU?

Information in this paper was gathered by literature review, interviews with experts in Brazil and also from works being conducted in Brazilian universities and research institutes.

2. Brazilian Biodiesel Program

2.1 History of Biodiesel in Brazil

Brazil is well known for its very successful sugar cane ethanol program that was launched in 1975 and wich in 2007 replaced 50% (De Caro *et al.*, 2001) of gasoline (by volume). In 2007 19 billion liters of fuel ethanol were produced in Brazil (Fernando e Hanna, 2004). With almost 10 million flex-fuel vehicles nd up to 25% blending in gasoline the Brazilian fuel ethanol industry has become a mature industry that is an example for the world and for emerging biodiesel industry in Brazil.

The actual bioenergy policy targets are probably best described in the recent guidelines for Agro-energy policy 2006-2011 (MAPA *et al.*,2005) that was started in 2005 by the Ministries of Development, Industry and Foreign Trade (MDIC), Agriculture (MAPA), Science and Technology (MCT), Mining and Energy (MME). The aim of this policy is to offer guidelines to public policies and actions towards the development of renewable energy sources and expansion of their share in the Brazilian energy matrix. The following goals for bionenergy can be extracted from the document:

- Development of Agro-Energy through expansion of the ethanol sector;
- Implementation of the biodiesel production supply chain;
- Expansion of forests grown for energy production and use of agro-forestry waste;
- Expansion of crops that does not affect the production of food for domestic consumption;
- Technological development that promotes competition, reduces environmental impacts and contributes to economic and social inclusion, including the use of energy biomass in small scale; community-wide energy autonomy, specifically in remote areas;
- Generation of jobs an income (development towards the interior of Brazil, social inclusion and reduction of regional disparities, etc);
- Brazilian leadership in the international trade of agrofuels and adherence to the naional environmentsl policy and integration in the clean development mechanism of Kyoto Protocol.
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In 2004 Brazil has started a new program to develop biodiesel that is still imature compared to the ethanol program that started in 1975, so, it can be said that Ethanol is a product, ethanol is a project.

2.2 Biodiesel policies in Brazil

In December 2004 a new National Program for Production and Use of Biodiesel (PNPB) was launched that is the basis of current development in Brazil. The program has two main goals: Fuel supply diversification and social inclusion and regional development.

Secondary drivers for the biodiesel program wich can be found in documents include adding value to the soy production chain; soy oil is a by-product of protein production leading to an oil surplus that explains its low price in Brazil. For isolated areas that use diesel for electricity production, local biodiesel production provides an alternative of source because of high costs (mainly logistics) of fossile diesel in these areas. Anther secondary driver is the opportunity biodiesel provides in reducing air pollution in urban areas due to the reduction of emissions when biodiesel is blended with fosile diesel.

As part of the BNPB law nº 11.097 (january 13th , 2005) was adopted mandating a blend of 2% of biodiesel (B2) in the fossile diesel in 2006, 3% (B3) in 2010 increasing to 5% (B5) in 2013. The target of a blend of 5% was achieved in 2010. This represents the increasing of the whole chain of biodiesel in Brazil and consolisation of BNPB.

Biodiesel is expected to create 250.000 new jobs mainly for small farmes in the next two years. Another law was aproved in 2005 (nº 11.116/2005) that regulates federal tax exemptions for fuel producers wich source certain types of crops from small farmers in certain regions and gives access to credit lines (Almeida *et al.*, 2008; Pousa *et al.*, 2007) , the “Social Fuel Certificate”:

- 31% tax exemption is given to biodiesel from produced from castor and palm oil in North and Northeast regions of Brazil (The least developed ones).
- 68% tax exemptions is given to biodiesel produced in small family based agriculture
- 100% tax exemption is given to a combination of the two above.

For its market maturity, commercial and food source value, soybean is excluded for tax exemption.

3. Biodiesel Production and Technology

The Brazilian Biodiesel industry was reviewed by Almeida *et al.* (2008). The industry is increasing its capacity at very fast rate. At the end of 2007 there was about 4,5 million liters installed capacity, 2 million liters were under construction and 2 million liters capacity was being projected. Nowadays, there is 4 billion liters of installed capacity. The production of biodiesel in Brazil in the near future is expected to achieve 6 billion liters of capacity, that is more than the 2,4 billion liters mandated for 2013 in Brazil (Almeida *et al.*, 2008).

Most plants in Brazil use classical transesterification technology and methanol. The transesterification process in an industrial unit with 1,800 t year-1 is described here: the vegetable oil, animal fat or recycled oil is stored and, after acid correction, is transferred to the principal reactor. In a second reactor, the catalyst (KOH or NaOH) and the alcohol (MeOH or EtOH) are homogenized and transferred to the principal reactor. The reaction is completed in 40 min, in temperatures between 30 and 40 Celsius. The biodiesel (superior layer) is then separated from the raw glycerine (inferior layer) by decantation (on batch process) or by centrifugation (on continuous process). The inferior layer, beside raw glycerine, contains part of the alcohol that could be recovered and reused in the process. The raw glycerine could be purified and used, for example, in the cosmetic industry (Figure 1).

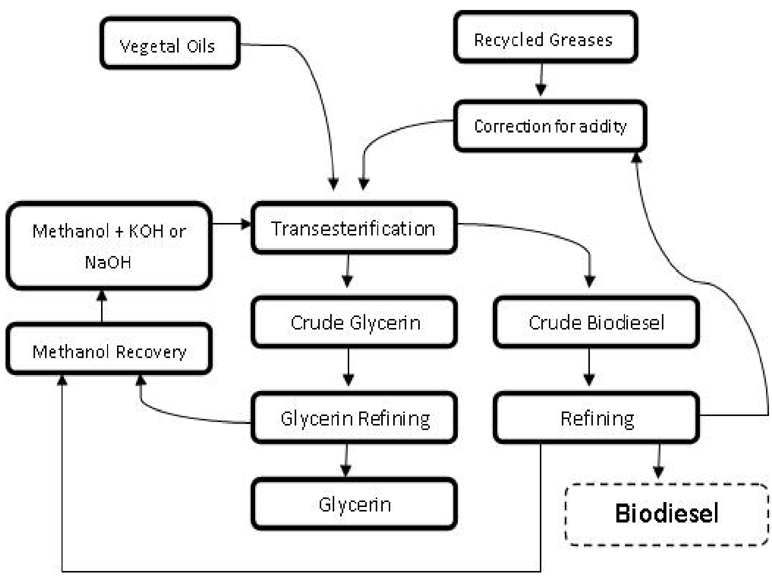

Figure 1: Scheme of Biodiesel Prodution and its by-products.

The separation step is one of the most important in the biodiesel production, since it is essential for the specification of the product according to legislation. The fuel should have similar characteristics to those of fossil diesel and, in case it does not reach the claimed specification, should be reprocessed. In order to assure the product purity and avoid engine and also environmental damage, levels of free fatty acid, alcohol, water, and glycerine should be at a minimum. The yield of biodiesel from the process can vary from 70 to 90% depending on the type of starting material, reagents and operational conditions. The transesterification is affected by alcohol: oil molar ratio, catalyst, temperature, reaction time and the content of water and free acids (Ma and Hanna, 1999).

In the 90's, some countries developed schemes to produce biofuels, using the methanol route and vegetable oil or residual fats as a starting material. In particular, Germany implemented a program for biodiesel production. The vegetable oil is extracted from rapeseed, which additionally fixes nutrients in the soil, in particular, nitrogen. In the extraction process, the seed is pressed and, beside the oil, tart is obtained as a by-product, which may be added to animal feed. The industrial units of biodiesel production, in Germany, have a high level of automation. However, they operate only during part of the year due to climatic conditions. There are over 1,000 gas stations for distribution of biodiesel. At the beginning, biodiesel was used mainly in vehicular fleet in big cities. The biodiesel price to the consumer is lower than fossil diesel. The difference can reach 12%, and this can be explained by the reduction of governmental taxes (Holanda, 2004). In France, for example, biodiesel also has been used in urban buses, in proportions up to 30% in fossil diesel (B30), in order to decrease vehicle emissions in big cities.

As it was stated before, most plants are projected to use a range of feedstocks. In Brazil, soy oil is the main source for biodiesel production. As is already observed in Europe overcapacity and high feedstock prices may also lead to a form of shake out and this should lead to a larger average production units. The cost of investment almost doubles rom 250$ per m3 per year for a 120.000 ton per year installation to 400$ per m3 per year for a 5000 ton per year installation (Nagib, 2006). Still some 80% of the biodiesel cost is due to feedstock cost. This make biodiesel very dependant on comodity prives. As the biodiesel program is still in it´s childhood several challenges can be defined including the availability of feedstock in adequate amount and quality.

Another challenger in Brazil is associated to the available infraestructure. Biodiesel requires specific infraestructure for transport and storage. Due to long distances between producing plants and final consumer market, the final cost can be higher than expected. These points are directly associated to setting up the supply chain for biodiesel. At last Brazil still lacks in finding uses for subproducts from biodiesel such as Glycerin and (toxic) protein cake.

4. Biodiesel feedstocks

The feedstock for biodiesel production is chosen according to the availability in each region or country. Any fatty acid source may be used to prepare biodiesel, but most scientific articles take soybean as a biodiesel source. Since the prices of edible vegetable oils, as soybean oil, are higher than that of diesel fuel, waste vegetable oils and non-edible crude vegetable oils are preferred as potential low priced biodiesel sources. Low-quality underused feedstocks have been used to produce biodiesel. This product is comparable in composition, similar in engine performance and emissions, and predicted to be more economical to produce than biodiesel from refined soybean oil (Haas, 2005). There are various other biodiesel sources: almond, andiroba (*Carapa guianensis*), babassu (*Orbignia sp*.), barley, camelina (*Camelina sativa*), coconut, copra, cumaru (*Dipteryx odorata*), *Cynara cardunculus*, fish oil, groundnut, *Jatropha curcas*, karanja (*Pongamia glabra*), laurel, *Lesquerella fendleri*, *Madhuca indica*, microalgae (*Chlorella vulgaris*), oat, piqui (*Caryocar sp*.), poppy seed, rice, rubber seed, sesame, sorghum, tobacco seed, wheat (Fröhlich and Rice, 2005; Encimar *et al.*, 2002; Tan *et al.*, 2004)

A suitable source to produce biodiesel should not compete with others applications that reach higher prices, for example pharmaceutical raw material. But the demand for pharmaceutical raw material is lower than for fuel sources. The selection of a source for fuel production must take into consideration the characteristics of oil market (Figure 2).

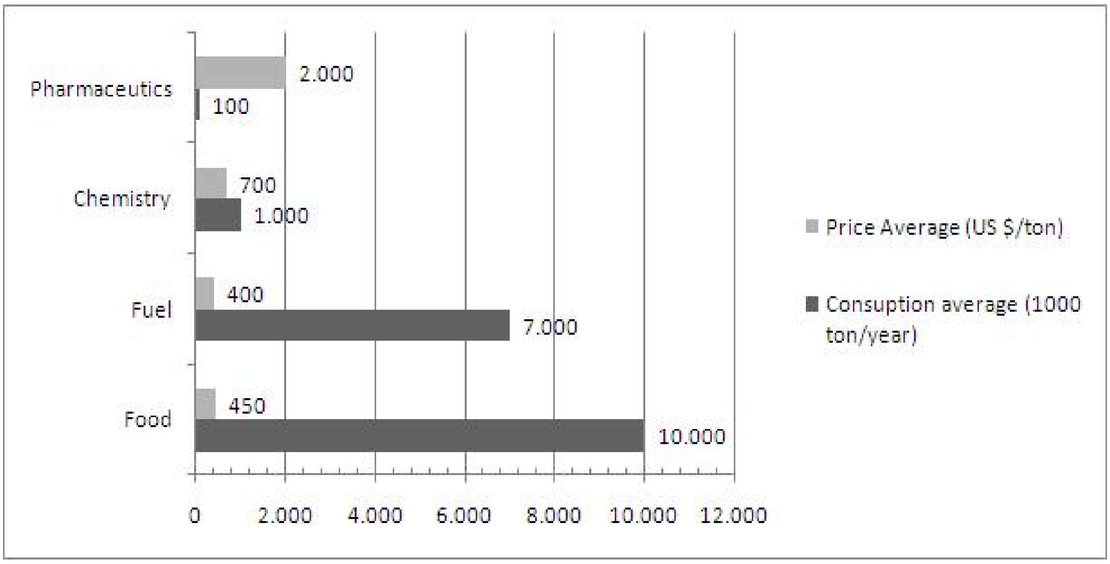

Figure 2: characteristics of oil market in therms of consumption and price.

As much as possible the biodiesel source should fulfil two requirements: low production costs and large production scale. Refined oils have high production costs, but low production scale; on the other side, seeds, algae and sewerage have low production costs and are more available than refined or recycled oils. To elect a biodiesel source it is necessary also to take into consideration the oil percentage in the plant and the yield of oil per hectare (Figure 3). The palm kernel, for example, has a great potential as a biodiesel source, and has been used by several countries (Malaysia, for example).

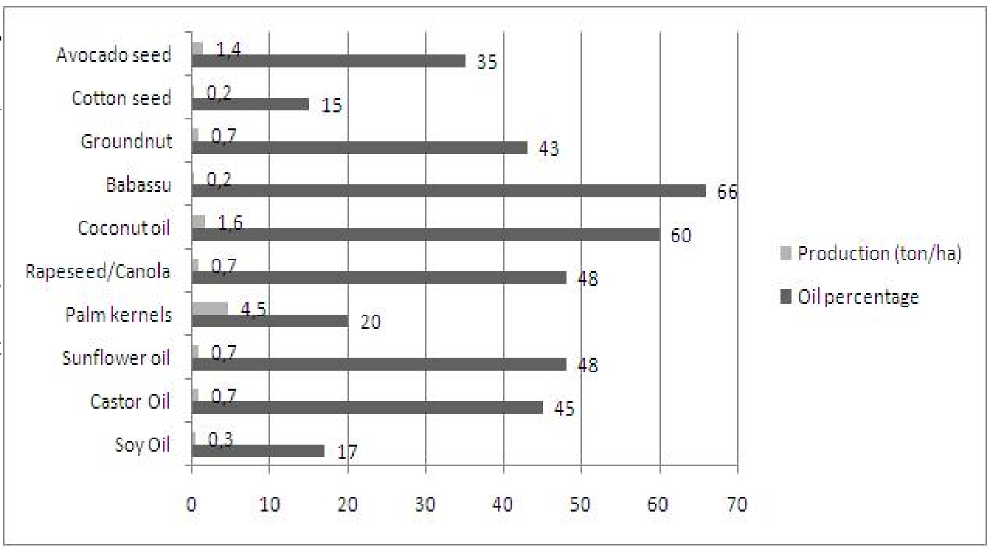

Figure 3: Production and oil percentage of the main feedstocks for biodiesel.

In

Brazil, biodiesel production has been adjusted to the available crop in each region (Figure 4). In the North, palm kernel and soybean are the most used sources; in the Northeast, castor bean, palm oil, palm kernel, babassu, soybean and cotton seed; in the Central-West, soybean, cotton seed, castor bean and sunflower seed; in the Southeast, soybean, castor bean, cotton seed and sunflower seed; in the South, sunflower seed, soybean, rapeseed and cotton seed (Tan *et al*., 2004; Barnwal and Sharma, 2005; Encinar *et al.*, 2002).

Soybean occupies a special place among the oil plants that grow in Brazil. This leguminous plant is cultivated in many states of the country and is responsible for 90% of the total of produced vegetable oils (Rodrigues and Macedo Beltrão, 2006). Its participation in the market is mainly related to exportation of seeds *in natura* and it is an important source of exchange value to Brazil. However, if the exported commodities were refined oil and tart, surely more value could be associated to the exported products. Soybean and castor seed, because of the large agriculture areas, and palm, especially because of the high level of oil, provide excellent options for expansion of vegetable oil production in Brazil. In the Northeast of Brazil, besides palm, sunflower, cotton and soybean, we could highlight castor seed, which can be cultivated in all states. Nevertheless, a castor seed has presented low productivity, between 600 and 1,000 kg /ha year. Studies show that this yield could reach 3,000 kg /ha year with genetic improvement and with possible introduction of irrigated cultivation (Holanda, 2005).

Palm oil (*Elaeis guineensis*) is an important alternative for the sustainable development of some regions of Brazil, including Amazonia. Elbersen (2008) reviewed palm oil production for biodiesel in Brazil. In short, African Palm Oil is the most productive oil crop available in Brazil with 4000 to 6000 liter per ha per year. Brazil produces only 0,5% of palm oil in the world, mainly in a few areas in the state of Pará (Amazonia) and near the Northeast Coast and actually is a net importer of palm oil. Still, it has the largest land area potentially available for palm oil production. Estimates vary widely from 70 million ha (Rodrigues and Macedo Beltrão, 2006); 20 million ha as mentioned by Kaltner et al. (2005) to 7 million ha by Gazzoni (2007). Much of the suitable land is covered by rainforest and should not be a sustainable or Greenhouse Gas positive option. Still, for degraded areas is seen as very promissing.

Another source oil/fat for biodiesel production is tallow. Tallow is a by-product of meat processing. Brazil is the worlds largest beef producer with more than 200 million heads, producing around 1 million tons of beef per year. Alternative uses include soap production. It has been reported that due to increased soy oil prices in recent years, some biodiesel plants are producing biodiesel from tallow as a feedstock. As a result, tallow price has increased (Almeida *et al.*, 2008). With conventional biodiesel production technology tallow can only be mixed to a small degree into biodiesel if current EU biodiesel regulations are to be observed.

Figure 3. Biodiesel feedstocks according to Brazilian regions.

3. The demand for biodiesel in the EU

The main driverd for bioenergy in the EU are sustainability and security of energy supply. Secondary drivers can be identified such as rural employment and new economic opportunities. Sustainability is mostly focused on mitigation of climate change and thus on the reducing of Green House Gas (GHS) emissions compared to fossil alternatives (IEA, 2007).

In 2003 the EU passed the Biofuels Directive (2003/30/EC) that establishes a target of replacing 5.75% of transport fuels by bio-fuels in 2010 (on a energy basis). More recently the EU proposed new Renewable Energy Directive (EU, 2008) that calls for 10% biofuels in 2020. To what extent these goals will be reached is uncertain considering the current high vegetable oil prices, GHG impact and competition with food. The EU Comission (EU, 2008) recently reported that 4,2% biofuel replacement is expected by 2010 compared to the goal of 5.75% in 2010.

The import needs have been estimated by MVO and Fediol (MVO, 2006) before the surge in commodity prices. It was estimated that by 2010 the EU vegetable oil demand for biodiesel would be 11,1 million tons and the food demand 2,9 million tons per year. This would lead to a production shortfall of 3,8 to 4,5 million tons by 2011. Even if the biofuel objectives are only reached partially a significant amount of the biodiesel or feedstocks will have to be imported in the coming years and are already being imported (i.e. rapeseed and soy).

Biodiesel imports have already taken off considerably in recent years, mainly due to the U$ 1,00 a gallon subsidy to biodiesel producers, by a procedure known as “splash-and-dash”; where biodiesel from Brazil and elsewhere is shipped to the United States (US), blended with fossil oil and re-exported to the EU. In 2007 between, 0.75 and 1 million tons of such biodiesel was imported from the US to the EU (EBB, 2008; USDA, 2008).

4. Brazilian Perspectives and Conclusions

Indirectly Brazil is already an important supplier of biodiesel (or feedstock) through re-export of soy biodiesel from the US to EU. Still this does not seem to be the way of the future. Direct Brazil/EU trade of biodiesel or feedstocks must be the goal for the near future.

Holding the 8th biggest GDP of the world, for the coming years Brazil will be developing its own biodiesel infrastructure and market that will demand much of the resources. Apart from soy most of the biodiesel production options require some time to be developed even if, as with Jatropha and Castor, progress is made fast.

Despite the potential in Brazil for oleaginous cultivation, and consequently for biodiesel production, there are challenges for setting up and consolidating a wide program of biodiesel use as fuel. The principal challenges and considerations focused technological, agronomic and infrastructure areas.

Technological perspectives

(*i*) Develop new process of transesterification (heterogeneous catalysts, ethylic route, etc.), with the possibility of reduction of by-products and costs with separation and purification of biodiesel;

(*ii*) improve the product stability by use of additives;

(*iii*) optimize the industrial plants to obtain control of the continuous process;

(*iv*) improve the quality standard of biodiesel to avoid motor and environmental damage;

(*v*) investigate new uses for glycerine;

(*vi*) evaluate and control the quality of vehicle emissions in motors using biodiesel as fuel.

Agro-economic perspectives

(*i*) Plan and execute an ecologically sustainable agricultural zoning of oleaginous cultivation;

(*ii*) assure supply of raw material with minimal costs to the producer;

(*iii*) establish financial support to amplify the cultivation of oil plants;

(*iv*) develop research to select new varieties and systems of tilling with low environmental impact;

(*v*) intensify search for genetic improvement of oil plants, with the purpose of increased productivity and yield of oil for biodiesel;

(*vi*) develop technology to use the tart castor bean and tart soy as animal feed.

Infrastructure perspectives

(*i*) Improve the infrastructure of transport and distribution;

(*ii*) improve the connections of the productive chain.

Environmental perspectives

(*i*) Reduce the emissions of harmful species (*e.g.* CO, particulate matter, sulphur compounds and THC);

(*ii*) get a clear diagnosis on the environmental impacts of biofuel uses, along with its advantages and benefits.

Although it is clear that public pressure is already relevant for biodiesel distributors, at this moment there are no specific demands on the sustainability of biodiesel in Brazil. It can be argued that the official sustainability demands will focus heavily on GHG performance of biofuels as this is a primary driver for the existence of biofuels in the EU.

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