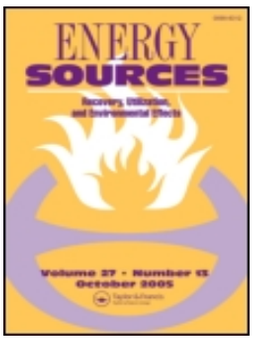

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Production of biodiesel: Source strategies and efficiency in the Brazilian energy matrix

Camila Almeida Martins[a] and Pedro Paulo de Andrade Júnior[b]

[a]Department of Mechanical Engineering, Federal University of Technology–Paraná, Ponta Grossa, Brazil; [b]Mobility Engineering Center, Federal University of Santa Catarina, Joinville, Brazil

ABSTRACT

This article aims to introduce biodiesel as a possible solution, describing its evolution in Brazilian energy. It was concluded that the use of biodiesel leads to several advantages, such as significant reductions in rates of emission of some greenhouse gases and wide job creation and social inclusion in the poorest regions of the country. Besides the aspects already mentioned, within a national situation of growing imports of diesel oil and with oil prices rising, the article shows that biodiesel becomes an interesting alternative, reducing diesel imports and resulting products, thus enabling development in other industrial chains.

KEYWORDS

Biodiesel; biodiesel production; Brazilian energy matrix; socioeconomic and environmental analysis

1. Introduction

Over the past 20 years, energy sources have played an important role in socioeconomic development and environmental performance of different countries. This phenomenon can be explained by the contributions that these energy sources provide, such as enabling the less favored countries to make innovations in energy sources; stimulating the progress of science and technology; and generating mechanisms of environmental and social sustainability.

Among the main energy sources used worldwide are the petroleum products. However, the high oil prices, as well as environmental, economic, and social impacts of the intensive use of nonrenewable sources of energy, encouraged the search for biofuels.

In order to be part of this ever-changing competitive environment, Brazil has encouraged the energy alternatives, aimed at socioeconomic development and environmental sustainability. The country's dependence on oil is evident in fuels like gasoline and diesel, which are crucial for the transport of cargo or passengers. The challenge is the search for strategic alternatives and incentives that ensure both the decision makers' support and their improvement actions.

In this context, fuel obtained from agricultural products offer an interesting alternative. Besides the success of ethanol as an alternative fuel to gasoline, biodiesel stands out.

In 2004, Brazil launched the National Program for Production and Use (Programa Nacional de Produção e Uso de Biodiesel [PNPB]) to ensure the production of biodiesel, and also aimed at regional development and social inclusion.

By Law No. 11097 of January 13, 2005, the PNPB authorized the introduction of biodiesel in the Brazilian energy matrix, and determined the optional use of B2 (2% biodiesel added to diesel oil) until 2008, then going to the mandatory and optional use of B5 between 2008 and 2013, and then being mandatory thereafter.

CONTACT Camila Almeida Martins cah.amartins@gmail.com Jacinto Lozza, 51 - Estrela, Ponta Grossa - PR, 84050-120, Brazil.

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However, in 2010 the diesel fuel sold in Brazil started to contain 5% biodiesel, and this percentage will increase steadily over the years.

The use of biodiesel as fuel becomes more and more a support for government policies in the environmental and social areas. It has introduced, as well, economic advantages, such as the use of byproducts and the possible reduction of imports of diesel oil.

Inside the context of a global search for energy alternatives in order for socioeconomic development and environmental sustainability, and a national situation of increasing imports of diesel fuel amid rising oil prices, biodiesel becomes an interesting alternative.

Brazil has adopted a gradual increase of the minimum percentage of biodiesel mixed with regular diesel as a biofuel development strategy of the country, aiming to stimulate production and bring social and environmental benefits. However, the rapid growth of biodiesel production in recent years has not been accompanied by judicious procedures able to ascertain, in a consistent manner, the role that the Brazilian energy matrix have played in the production of biodiesel in order to support decisions about the strategies' development and improvement actions.

Some studies have been made in this direction, such as: Vaccaro et al. (2010), Visser et al. (2011), Varanda et al. (2011), Marchetti (2011, 2012), Lopes et al. (2011), Basha and Gopal (2012), Padula et al. (2012), Yan (2012), Borugadda and Goud (2012), and Oh et al. (2012).

However, studies point to the need to conduct and check scientific research that formulates the conditions under which the agents involved in the production of renewable energy evaluate the production of biodiesel as an alternative strategy in the energy matrix, in order to remain competitive to the global market and combined with social and environmental issues, and from there, create actions that can maximize their results.

Thus, the main objective of this study is to present the development in the use of biodiesel in Brazilian energy, since its inception until the current scenario, in addition to its environmental, social, and economic benefits, thus analyzing the results obtained by the development strategy of biodiesel used in Brazil.

2. Methodology

The investigation was held, at first, through a literature review with primary and secondary sources on the subject of study in order to direct and conduct research, which required an overview of the theoretical problem, from the examination of the literature relevant to the question posed.

After a thorough review of the literature, forming a consistent base of knowledge and considering the question of this study, its objectives, and the available information on the subject, it was found that the qualitative approach seemed to be more appropriate to conduct the investigation, especially the proper way to understand and measure the nature of the phenomenon of energy sources.

First, a literature review was performed on the concept of biodiesel, always trying to gather as many definitions for the best understanding of the theme. Through the literature review, it was possible to know publications on the subject, information about the current status of biodiesel in Brazil and around the world, and see different opinions on the subject. Then, the subject was contextualized through a historical review and through a current overview of biodiesel in Brazil, presenting an analysis of the evolution of the studies on the subject.

The construction of this article was developed by addressing social, environmental, and economic aspects of this biofuel, showing its main strengths and weaknesses within each aspect analyzed. The environmental and economic issues were justified based on recent statistics. After presenting some practical examples of success, it is ended with a conclusive analysis of the article, containing an overview of its major benefits for Brazil and how some of their advantages can make differential development for specific regions of the country.

However, when dealing with a theoretical corpus, the problem of representation is present. However, it is not possible to determine how the body is determined. In this sense, is created a concept that the corpus will be balanced when the effort to increase the content adds little

variance in dialectic. The problem is to determine how much this increase will actually be an increase (Bauer and Aarts, 2002). Thus, the "arbitrary selection" of theoretical material in which the researchers will base their work is present and will be reported in the theoretical study. Also, the issue of the corpus can be interpreted as categories to be understood; hence, the arbitrary definition of who is leading the research, in an attempt of the researcher better understanding the problem/phenomenon that seeks understanding. Therefore, the need to enter in the theoretical framework arises because the contents therein categorized are inherent to the corpus' classification of Bauer and Aarts (2002).

3. Biodiesel

Biodegradable fuel, the biodiesel, can come from many different types of vegetable or animal oils, "in nature" or waste, and which have physical and chemical characteristics similar to diesel oil. Among the most common renewable sources are the oilseeds, such as soybeans, oil palm, castor, and sunflower, and the still little diffused sources, such as jatropha. Depending on the feedstock used, the physical and chemical oil characteristics vary (Neto et al., 2004).

This biofuel can be produced by three different procedures: cracking, esterification, and transesterification. The most currently used is transesterification, which is the reaction between vegetable oil and an active intermediary. This intermediary is the reaction product of an alcohol (usually ethanol or methanol) with a catalyst (Parente, 2003).

According to Law No. 11,097 (2005), biodiesel can be conceptualized as "biofuel derived from renewable biomass for use in internal combustion engines with compression ignition or, in accordance with regulations, to generate another type of energy that can partially or totally substitute fuels fossil."

The biodiesel can be added to petroleum fuels forming a mixture that can be used in compression ignition engines (diesel) without modification.

Another definition was established by the National Petroleum Agency (Agência Nacional do Petróleo [ANP]) by means of Article 2 of the ANP Resolution No. 42 of November 24, 2004:

> I—biodiesel–B100–fuel composed of alquilésteres of long chain fatty acids, derived from vegetable oils or animal fats as the specification contained in the Technical Regulation No. 4/2004, part of this Resolution;
>
> II—mixed diesel/biodiesel–B2–commercial fuel composed of 98% by volume of diesel fuel, as specified by the ANP, and 2% by volume of biodiesel, which will meet the specification provided by the ANP No. 310 of 27 December 2001 and its amendments. (Agência Nacional do Petróleo. 2004)

Chemically, biodiesel is a mixture of mono-alkyl esters of fatty acids. Its most common process is the transesterification, which is the reaction of a triglyceride with a short chain alcohol in the presence of an acid or basic catalyst, obtained as a result of fatty acid esters methyl or ethyl (biodiesel) and glycerin (Monteiro and Muñoz, 2011).

Biodiesel is technically viable as a fuel, and possibly with advantages over petroleum-based fuels. Among these advantages are the fact that it generates a lower environmental impact and it is produced from renewable sources (Almeida, 2006). Moreover, it has a high potential for biodegradability and low toxicity (Meyer, 2011).

4. History of biodiesel in Brazil

The use of vegetable oils as fuel is not new. Biodiesel has been studied since the 19th century, especially in Europe. According to historical records, the inventor Rudolf Diesel introduced the diesel engine in 1900 in Paris, using a peanut-oil-based fuel. According to the Ministry of Education (2006) made by the Government Diesel reportedly stated, in 1911, that "the diesel engine can be fed

with vegetable oils and will considerably help the development of agriculture in countries that will use it."

Pure vegetable oils, because of its high viscosity, had disadvantages, such as carbon deposits in cylinders and nozzles. The surveys resulted in the discovery of the transesterification process, patented by the Belgian scientist, G. Chavanne, in 1937, thereby avoiding the need for any modifications to the engines (Plá, 2005).

In subsequent years, the oil was abundant and affordable, determining the use of its derivatives as fuel. The oil, however, went through periods of falling production and supply, as in the crises of the 1970s and 1990s, encouraging the search for alternative energy sources (Souza and Fiorese, 2009).

In the 1970s, according to the Ministry of Education (2006), the Federal University of Ceará, along with Professor Expedito Parente, obtained a patent for the manufacture of biodiesel, but the patent has expired without the country adopting the biofuel. At the time, priority was given to PROALCOOL policy, implemented in 1975.

Biodiesel has been produced on a pilot scale in Brazil since the 1980s. At the time, experiments were performed using different oilseeds for biodiesel production, and different percentage mixtures of this biofuel with the traditional diesel (Souza and Fiorese, 2009).

In 1998, areas of research and development projects in Brazil regained the use of biodiesel. By Decree No. 702 of October 30, 2002, the Ministry of Science and Technology (Ministério da Ciência e Tecnologia [MCT], 2002) created the PROBIODIESEL, with the goal of using vegetable oils transesterified in the national energy matrix. According to Almeida (2006), this program aims at the development of production technologies and the harmonization of actions for the development of biodiesel, as well as to approve technical specifications and attest the economic, social, and environmental viability and competitiveness, having therefore a differentiated approach in relation to PROALCOOL, which was aimed primarily at the power supply, and, thus, not having the social and environmental issues as important factors in decision making (Lima, 2004).

By Decree of the Federal Government on July 2, 2003, the Interministerial Working Group, which had as its function to study about the viability of biofuels and make the necessary actions for its implementation, was established. In the same year, the Brazilian government created the Interministerial Executive Commission (IEC) and Management Group (GG), by Presidential Decree of 23 December 2003, charged with implementing the actions for the production and use of biodiesel (Rathamann et al., 2005).

The following year saw the release of the National Biodiesel Production and Use (PNPB) on December 4, 2004, having as its main objective to ensure the production of biodiesel, also aiming at regional development and social inclusion. By Law No. 11097 of January 13, 2005, the PNPB authorized the introduction of biodiesel in the Brazilian energy matrix and increased the administrative jurisdiction of the ANP, which is now called the National Petroleum, Natural Gas and Biofuels Agency. After the publication of the law, "the ANP took the assignment of regulating and supervising the activities related to production, quality control, distribution, sale and marketing of biodiesel and diesel-biodiesel mixture (BX)" (ANP, 2011).

In addition, Law No. 11097 ordered the optional use of B2 (2% biodiesel added to diesel oil) until 2008, then going to be mandatory and optional use of B5 between 2008 and 2013, being mandatory thereafter.

5. Discussion and analysis of biodiesel in Brazil

Although Law No. 11,097 declares the obligation of B5 only in 2013, diesel fuel sold in Brazil already contains 5% biodiesel since January 1, 2010. This rule was established on October 26, 2009 by Resolution No. 6/2009 of the National Energy Policy (CNPE). This percentage will be increased steadily over the years; the ANP authorizes, regulates, and monitors their trade (ANP, 2011).

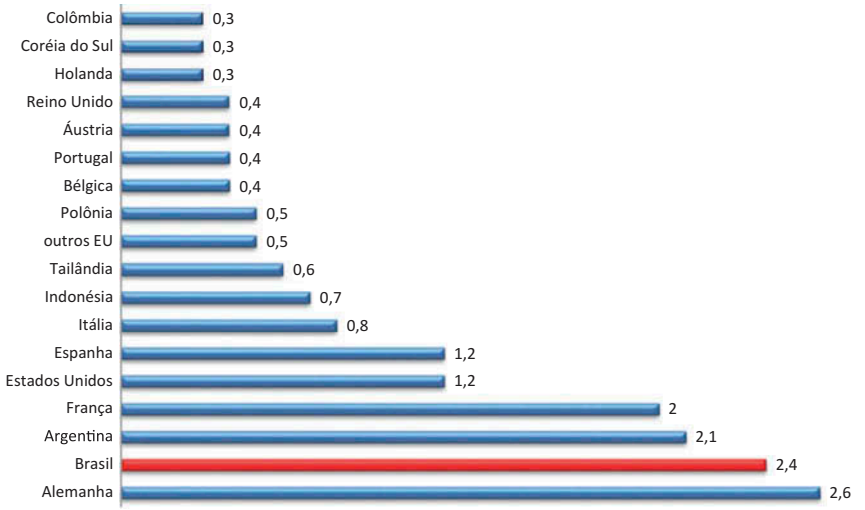

Figure 1. Production of biodiesel in 2010. (*Source*: Adapted from MME, 2011.)

In 2010, Brazil became the second largest producer of biodiesel in the world, second only to Germany (Figure 1). In 2011, it became the largest consumer of fuel among all countries (Ministry of Mines and Energy, 2011).

In some cities in the country, B20 biodiesel is already a reality. According to the Brazilian Biodiesel Union (União Brasileira do Biodiesel [UBRABIO]), an example of a city that is investing in the use of biodiesel in public transportation is Sao Paulo. The so-called Ecofrota, the largest fleet moved to B20 in the country, has about 3,070 buses on 200 lines using the biodiesel. Since 2009, the fleet of urban public transportation in Curitiba uses biodiesel. In March 2011, it launched a new model bus in the city, Mega BRT, which is fueled by B100.

6. Discussion and analysis of environmental, social, and economic aspects of biodiesel

The use of biodiesel as fuel becomes more and more a support for government policies environmentally and socially.

The reduction of emission rates of some greenhouse gases is already recognized, resulting in improvements in quality of life and public health. Although its use generates an increase in emission of nitrogen compounds, the biofuel reduces pollutants, such as hydrocarbons, carbon monoxide, sulfur oxides, aromatic hydrocarbons, and carbon dioxide as compared with diesel fuel oil.

The Environmental Protection Agency believes that the use of B20 in large cities provides a reduction of about 20% in the emission of hydrocarbons added to 10% of particulate materials and carbon dioxide. According to the same agency, B100 can reach 57% reduction in emissions of carbon dioxide (UBRABIO, 2011).

Besides the positive effect on the environment, this reduction avoids government spending for public health estimated at approximately $900 million per year. It is also important to mention that the production of renewable fuels favors international financing in the carbon credits market under the Kyoto Protocol (ANP, 2011).

As for the social point of view, the production of biodiesel has promoted the use of land unsuitable for food production, diversified the Brazilian energy matrix, and created jobs and income in rural areas, thus contributing to the social and regional inequalities.

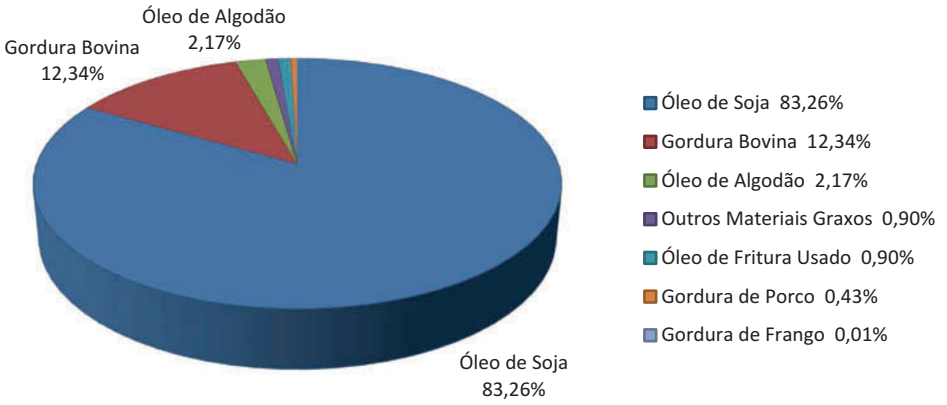

Figure 2. Raw materials used in biodiesel production. (*Source*: Adapted from ANP, 2011.)

The great biodiversity of Brazil, as well as various types of climates and soils throughout its territory, make it extremely rich in vegetable oils sources. In this context, in order to appreciate the full regional potential and to develop family farming in areas where underdevelopment is critical and generate job alternatives in areas unattractive to other economic activities, the diversification of raw materials used to produce biodiesel gains relative importance. However, according to ANP, in June 2011, 83.26% of biodiesel produced in the country was soybean (Figure 2).

It is undeniable that soy has a very important role for the production of biodiesel. However, this culture is already consolidated in the south (the region with the largest capacity to its development), therefore, it does not achieve the social objectives of the program.

The best alternatives for achieving social inclusion in the poorest areas of Brazil are the castor bean, the Semi-Arid, since it has high oil content and is adapted to conditions in the region, and palm, in the North, produced by agriculture family (UBRABIO, 2011).

To support family farming, the government created the Social Fuel Seal. This certificate is awarded to manufacturers who purchase raw material from family farmers and provide tax exemptions and access to better financing conditions (Cartilha do Governo Federal, 2007).

Despite all of the advantages and the great advance of biodiesel in Brazil, the economic viability for commercial use requires more detailed analyses.

For the biodiesel to be economically viable, it must be competitive with the low price of oil; the production cost of diesel is so low that it is not worth its production. However, this situation began to change due to abrupt changes in oil prices.

The competitiveness of biodiesel tends to increase more as the falls in the price of raw materials, vegetable oil, and alcohol are consolidated. The expansion of supply, based on the improvement of agricultural technology and efficiency of supply chains, leads to cheaper vegetable oil, the main component of the cost of biodiesel.

Another significant factor is the possibility of a reduction in production costs of biodiesel through the use of its byproducts, as has occurred with ethanol. The main byproduct of biodiesel is glycerin, however, its production chain generates a series of others byproducts, which are less widespread. The castor bean, for example, generates byproducts, such as pie, which is in the business market of agricultural fertilizers; the pulp for animal feed as well as soybean meal; and the stem for the production of paper and rustic fabrics. The use of this renewable fuel holds the prospect of reducing diesel imports, generating foreign currency for the country, and thus reducing dependence on oil.

According to the Ministry of Mines and Energy, in 2010 Brazil imported a monthly average of about 751,000 m^3 of diesel, which represents an increase of more than 150% over 2009, when the

average was about 290,000 m^3. Between January and May of this year, Brazil imported a monthly average of 511,000 m^3 of diesel fuel, a reduction of almost 20% over the same period last year, when an average of 626.4 thousand m^3 per month was recorded.

According to the data presented, a study conducted at the end of last year by the Getulio Vargas Foundation (Fundação Getúlio Vargas [FGV]) showed that the country no longer spent $2.84 billion with imports of diesel between 2005 and July 2010, thanks to the use of biodiesel blends.

Thus, it was proven that a higher percentage of biodiesel added to diesel can reduce the deficit in the Brazilian trade balance due to the increase in consumption of this fuel. In 2010, Brazil avoided importing 2.5 billion liters of diesel with the adoption of B5. According to the Social Communication (UBRABIO), the mandatory use of B10 would reduce diesel imports by about 30%.

Taking into account that biodiesel is more expensive than regular diesel, it was necessary to introduce a model that avoided direct competition between these two fuels within the rules of conventional marketing. To that end, a specific market for biodiesel was structured. In this context, the auctions organized by the ANP regulate the prices of the product and ensure their offering, aiming to generate a market and thus stimulate its production in sufficient quantity so that refiners and distributors could compose the mixture determined by law (ANP, 2011).

A success in the production of biodiesel, according to UBRABIO, is Fertibom Company of the agribusiness sector, which has its own production technology from various raw materials and a database with more than 3,000 formulations of ethanol. It presents an annual production capacity exceeding 120 million liters. Another example is JSB Biodiesel with a production capacity, both from plant oils and animal fats, of 201,600,000 liters per year. It has a fully automated system of production and laboratory testing to ensure the quality of the biofuel.

Some examples of international companies that are growing in the area are the Germans: Binatural and Fiagril, in addition to the producer of raw materials, Evonik Degussa, and the equipment supplier, Dedini. The latter maintains a laboratory in Belgium for research and testing of raw materials and a pilot plant in Rome with continuous production, where process improvements, new raw materials, additives, and reagents are tested.

Germany, currently the world's largest producer, has about 2,000 points of sale of biodiesel, distributing the B100 biodiesel in its pure form, without any mixing or additives. At service stations in the country, the same pump contains two nozzles, one for petrodiesel and another with a green seal for biodiesel, which is approximately 12% cheaper. Thus, users can mix, in various proportions, this biofuel with regular diesel. This high competitiveness of biodiesel compared to petrodiesel was basically due to tax exemption on its entire supply chain, as well as solid logistics infrastructure of the country. Given this development, as well as tax, legal, and environmental issues, automakers have adapted their vehicles to receive this fuel and engine manufacturers have ensured the quality of their products' yield (Roza and Freitas, 2010; Soares, 2010).

Other successful experiences, but with less emphasis, are France, which currently uses a mixture B30 in fleets of public transport, and Austria, which exempts pure biodiesel of approximately 95% of taxes, in addition to using B100 in public transport (Soares, 2010).

7. Conclusions

Biodiesel has become more attractive recently because of its environmental benefits, economic and social advantages, and the fact that it is made from renewable resources. The cost of biodiesel, however, is the principal obstacle to marketing and product competitiveness.

However, the increasing use of biodiesel in Brazil's energy matrix creates positive expectations in the pursuit of socioeconomic development and environmental sustainability, which is becoming more important and necessary in today's world.

The increased competitiveness of biodiesel depends on factors like the rising price of oil, and the reduction of the price of the B100 through the utilization of by-products and the production chain

development. The increased production of biodiesel reduces more and more the need to import diesel and the country's dependence on oil.

The South and Midwest regions of the country present themselves as particularly conducive to economic growth resulting from biodiesel, due to the fact that soy is the main raw material used for the production of this biofuel and this region fully develops the cultivation of grain. Furthermore, the two regions account for over 60% of the production capacity.

However, although the role of soy in the production of biodiesel is undeniable, this culture is already consolidated in the regions mentioned, showing, therefore, no significant social benefits.

Crops, such as castor and palm oil, in northeastern and northern Brazil, produced by family farms, become the best alternative for achieving social inclusion in the poorest areas of Brazil and create alternative jobs in areas not conducive to the other economic activities.

In addition to adding value to oilseeds raw materials cultivated in the country, the production of biodiesel has strengthened a new chain, generating income and jobs in the agricultural sector and in the markets for inputs and services.

This article highlighted the rapid development of biodiesel in Brazil and its relevance in the search of socioeconomic development and environmental sustainability, which has become more important and necessary in today's world.

As a result, to make the biodiesel economically viable, it must be increasingly competitive in that the falls in the price of the raw material, vegetable oil, and alcohol are consolidated. The expansion of supply is based on the improvement of agricultural technology and efficiency of supply chains, leading to cheaper vegetable oil, the main component of the cost of biodiesel.

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