Biodiesel: A Promise of Sustainability

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The international oil crisis that occurred between 1970 and 1990, the increase in consumption and the advancement of green awareness and international agreements fighting the greenhouse effect, enabled the progress of alternative energy sources mainly from the use of pure vegetable oils, such as the use of triglycerides and fatty acids to produce biofuels. This paper analyses the Brazilian and Global perspective about manufacture and use of biodiesel, discussing the advantages, problems and main raw materials through four vectors (economic, environmental, social and institutional impacts) of production and consumption of biodiesel. The methodology uses the indicator system DSR (Driving-Force/State/Response) as the basic foundation to explain the cause/effect for each evaluated vector. This process enables the characterization of the main aspects involved in the production and consumption of biodiesel. We conclude that, despite not polluting the environment, biodiesel is still not sustainable because it requires government subsidies for the planting of oilseed processing and sale.

Palavras-chaves: Biodiesel, Clean energy, DSR, environmental
1. Introduction

The vegetable oil was first used as fuel in the world in 1900 (POUSA, et al. 2007), however, (is that fossil fuels became dominant in the world energy market) due to distribution logistics and engineered by OPEC, easy stored and a usage policy.

However, with (i) increased consumption, (ii) the advancement of green awareness and international agreements addressing global warming and (iii) the possible depletion of global oil inventories apparently began to show a deficit of supply, opening thus a new axis of the market for alternative energy sources, especially from reuse of pure vegetable oils, such as the use of triglycerides and fatty acids to produce biofuels, between the years 1930-40 (POUSA, et al. 2007).

The international oil crisis, which occurred between 1970-90, along with the depletion of the source of non-renewable energy, environmental concern with air quality and global warming, promoted the Increase of the interest in renewable energy sources, sparking the development of biofuels. In this environment of change, biofuels are emerging as the best alternative to be produced from renewable raw materials with lower environmental impacts compared to fossil fuels (JANULIS, 2003).

Biodiesel is defined as any type of biofuel derived from biological material that undergoes a chemical reaction between vegetable oils or animal fats, and alcohol (whether or not catalytic), to become a mono-alkyl ester formed by a long chain fatty acids (Ahmad, et al., 2010). The following equation is an example for the production of biodiesel from soybeans:

\[
\text{1 oil (triglyceride) + 3 methanol} \rightarrow \text{3 biodiesel + 1glicerol}
\]

\[
\begin{align*}
264.08\text{kg} & \quad 96\text{kg} & \quad 275.48\text{kg} & \quad 92\text{kg} \\
\end{align*}
\]

Source: Kenneth R. Szulczyk, et. al., 2010.

One of the most chemical reactions used to produce biodiesel is transesterification, which consists of the reaction between molecules of triglycerides and alcohol (eg methanol) in the presence of a caustic catalyst (eg potassium hydroxide) to form glycerol and mono- alkyl ester of fatty acids (WEN-TIEN TSAI, et al., 2005). Transesterification is basically the transformation of triglyceride molecules that are large with several branches in oils and fats with small organic molecules linear chain (PHALAKORNKULE, et. Al., 2008). The efficiency of this process depends on oil composition, the composition of fatty acids and the type of catalyst, alcohol, and other factors such as the observed percentage of water present in the sample, temperature and agitation rate (Sharma et al., 2008).

There is a wide diversity of raw materials used in biodiesel production, such as rapeseed, soybean oil, palm oil, jatropha oil, salmon, mahua, jojoba oil, tobacco seed, the remains of cooking oil and animal fats such as tallow, grease, pork, microalgae (AHMAD, et al., 2010) and Brazil mamona (MACHADO, 2006).

The main crops in the world for the production of biodiesel are presented below:

The United States of America (USA), the European Community, Malaysia and Indonesia are already self-dependent as the production of edible oils, mainly from the use of corn and soybeans in the U.S.; rapeseed in the EU; coconut in Malaysia and Indonesia, and orange and jatropha in India (Sharma, et al., 2008).

According to the International Energy Agency (IEA), global production of biodiesel increased by 295% between 2000 and 2005. In 2004 only 1% of biodiesel was used in public transport, but with the growing market for hybrid cars, this percentage has Already Increased.

The biodiesel market is a promisor for the peripheral countries and developing countries, so that in 2005 the EU accounted for 3.8 billion gallons of biodiesel, equivalent to 85% of world production, but with the entry of new players in this segment, there was a reduction of European participation, for not having such a diversity of raw materials (AHMAD, et al., 2010).

Two years later, in 2007, Europe produced 10 billion liters, but the biodiesel produced in the U.S. also totaled 10 billion liters. Only Germany was responsible for 42% of European production. Also some Eastern countries like Thailand possessed abundant feedstock for biodiesel production, primarily through the coconut palm, animal fats and waste cooking oil (PHALAKORNKULE, et al., 2008).

The following table shows the full potential of biodiesel production for various countries: Malaysia, Indonesia, Argentina, United States, Brazil, Holland, Germany, Philippines, Belgium and Spain.

Table 1:
Top 10 countries in terms of absolute biodiesel potential

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>Volume potential (L)</th>
<th>Production ($/L)^a</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Malaysia</td>
<td>14,540,000,000</td>
<td>$0.53</td>
</tr>
<tr>
<td>2</td>
<td>Indonesia</td>
<td>7,595,000,000</td>
<td>$0.49</td>
</tr>
<tr>
<td>3</td>
<td>Argentina</td>
<td>5,255,000,000</td>
<td>$0.62</td>
</tr>
<tr>
<td>4</td>
<td>USA</td>
<td>3,212,000,000</td>
<td>$0.70</td>
</tr>
<tr>
<td>5</td>
<td>Brazil</td>
<td>2,567,000,000</td>
<td>$0.62</td>
</tr>
<tr>
<td>6</td>
<td>Netherlands</td>
<td>2,496,000,000</td>
<td>$0.75</td>
</tr>
<tr>
<td>7</td>
<td>Germany</td>
<td>2,024,000,000</td>
<td>$0.79</td>
</tr>
<tr>
<td>8</td>
<td>Philippines</td>
<td>1,234,000,000</td>
<td>$0.53</td>
</tr>
<tr>
<td>9</td>
<td>Belgium</td>
<td>1,213,000,000</td>
<td>$0.78</td>
</tr>
<tr>
<td>10</td>
<td>Spain</td>
<td>1,073,000,000</td>
<td>$1.71</td>
</tr>
</tbody>
</table>


It can be observed that the country with greater production potential is Malaysia, followed by Indonesia and Argentina, these potentials are influenced by climatic aspects such as rain precipitation, temperature, height above the sea and soil.

In Brazil, the initial interest in renewable energy was in the years 40 through the use of babassu oil, coconut of the Bahia, *mamona* and *cotton*. Today, Brazil is the second largest producer of biodiesel in the world, based its matrix of production in soybeans in the Midwest, *mamona* in the Northeast and palm in Amazônia (POUSA, et al., 2007).

The production of biodiesel tend only to Increase in Brazil, due to the different conditions pro the development of this fuel in our country, such as: availability of agricultural area, tropical climate, abundant biodiversity, water resources, agricultural industry stable and large domestic market by using biofuel (via the Federal Government and Petrobras), which highlight the great supply capacity of Brazilian lands. (GARCEZ et al., 2007).

In this wide subject involving energy policy, global economy, a bit of strategy development and the environment, biofuels are located, and within them the biodiesel represents an important segment. This paper presents an analysis according to four vectors (economic, environmental, social and institutional) for production and consumption of biodiesel.

2. Methodology

The definition of sustainability involves several aspects. In general, it is the ability to supply the population, without harming future generations, so that we can reconcile society's concern with the environment and the desire of investors to obtain maximum profit. Sustainability also involves the concept of self-sustainability, which means the ability to achieve sustainability without external financial assistance (usually given through government tax).

The focus of this paper is not to discuss the sustainability of biodiesel, however the methodology of this study will be the basic foundation DSR indicator system (Driving-Force/State/Response) developed by OECD (2010) from the system PSR (Pressure-State - Response) object. This tool works with three vectors, namely: economic, environmental and social, always showing the driving force, the condition that the driving force generated and finally the response of society or government. That is why the terms driving force, state and...
response will appear many times in the analysis of each vector.

We say that the focus is not on sustainability, as it would need a deeper and larger study than these four vectors. Admittedly, to discuss sustainability as a whole, each of these vectors individually generate one or more items, and the goal here is to discuss the whole.

Thus, the first methodological step was to fill the table DSR, which is a system of sustainability indicators used in the best-known classification of environmental indicators, using a concept of aggregate view of causality (GONÇALVES et. al. 2004. P.38).

This type of classification of indicators is interesting because it explicitly establishes relations of causes and effects. In addition, capture the effects of human actions, the natural and social processes and relates them with the answers to some consolidated management policy.

The DSR assumes that human activities exert a driving force on the environment, altering the quality and quantity of natural resources. The company responds to these changes through environmental policies, economic and sector. The answers form a feedback loop to the driving force. Broadly, these steps are part of a cycle of environmental policies that include perception, formulation, monitoring and evaluation.

Once the DSR is completed (not presented in this article because of size), it might be explained each effect for cause presented, in each of the listed vectors. So in the end you can see the nuances that largely involve the production and consumption of biodiesel.

3. Economic Impacts

Regarding economic responses, in step planting of oilseeds for biodiesel production (driving force), there is a change in the system of employment and income (state) and a change in the rural areas (state).

Changing the system of employment and income in a region grower is observed in most cases, from the growth in the local economy, because the use of agricultural raw materials drives the development of local agricultural market, and promote social inclusion of the farmers in a productive system (Garcez et al., 2007).

This is the case of a study in a small community in Thailand, where it was observed that the substitution of imports of diesel by biodiesel production promoted the growth of local economy through the development of comércio and employment generation (PHALAKORNKULE, et al., 2008).

In Brazil, the adoption of policies to encourage the production led to an increased supply of raw materials in the northeast, and so between 2005 and 2008, biodiesel produced in the Northeast accounted for about 29% of biodiesel produced in the country as shown in Figure 1:

Figure 1: Percentage of biodiesel Acquired by ANP through competitive bidding between pubic 2005-2008
Already in the stage of processing soybeans in biodiesel oil (driving force), investment in technology (state) generates a reduction on the dependence on foreign oil, portability in the use of motors, decrease in the dependence on fossil fuels, fluctuations on the biodiesel price, and secondly the reduction of vehicular performance.

The international oil crisis, which occurred between 1970-90, along with the depletion of non-renewable energy led the worldwide search for new sources that were able to reduce dependence on foreign oil (Lays, et. al., 2007) increasing international financial markets and the energetic security (Phalakornkule, et. al., 2008). In this context, biodiesel was presented as a solution to the problem.

In response to these crises, some programs were created to encourage the development of alternative fuels in Brazil, such as: Pro-Alcohol in 1980, which regulated the use of hydrated ethanol as fuel and anhydrous ethanol to be blended with gasoline; Pro-oil well in 1980 with the goal of producing vegetable oil as fuel; Probiodiesel in 2002 with the aim of realizing ethanolsis vegetable oils (Pousas, et al., 2007).

Despite the commitment of the Brazilian government in creating programs, Brazil still depended on imported foreign oil until 2006, as shown in chart 1:

Chart 1: Consumption, production and import of oil products in Brazil.

Source: Lays, et al. (2007)
Other countries also aspired to reduce dependence on foreign oil, among them Thailand in 2006, through the Ministry of Energy, which established a policy of incentives to increase energy self-reliance by encouraging the production of oilseeds in small communities and its insertion on an industrial scale in the production chain in order to introduce the B5 (fuel formed from the combination of 95% regular diesel and 5% biodiesel), with the main objective of replacing the utilization of diesel fossil for biodiesel in agricultural engines (PHALAKORNKULE, et al., 2008).

From a more general sense, the use of biodiesel can reduce dependence on fossil fuels, controlling the rising price of these fuels (Szulczyk, et. al., 2010). This is an important factor for the development of biodiesel: The stabilization of prices, which are still heavily influenced by the oil barrel, as the rising price of that commodity in the international market increases the demand for biodiesel, since in this case, the biodiesel prices recorded more inviting for the consumer market.

In fact, Brazil still depends on imports for much of the diesel used by the population (about 80% for transportation and public consumption), as shown in chart 2:

Chart 2: Consumption, production and import of diesel in Brazil.


As we can see the trajectory of Brazilian production is not yet able to fully supply the domestic market, mainly having to import from neighboring countries like Venezuela and the Guianas. As for energy consumption, studies in China showed that the soy-based biodiesel consumes 76% less energy than regular diesel. (Zhiyuan Hu, et al., 2007).

One factor that weighs positively in the analysis of biodiesel is its portability in the use of motors, which means that biodiesel can be blended with regular diesel without any mechanical change, and may be used as an energy source for buses, trucks, garbage collection and agricultural machinery, for example (WEN-TIEN TSAI, et al., 2005).

However some of the disadvantages of biodiesel are that it reduces vehicular performance, because it generates less energy than regular diesel during combustion. One of the units used to measure energy is the lower heating value-LHV, which indicates the amount of energy generated from combustion in automobiles.

Biodiesel has 93.4% of LHV of diesel, this means that biodiesel has less power of combustion.
than fossil diesel, which reduces the mechanical torque, acceleration and miles per gallon in vehicles. But the fact is, nowadays, there is a predominance in increasing the supply of oil, since this tends to run out, what further boosts the interest in biodiesel (SZULCZYK, et al., 2010).

The greenhouse gas (GHG), also has a large impact on the price of biodiesel, because biofuels are affected by trade in carbon credits. A valuation of these claims implies a greater interest and biodiesel production. Szulczyk, et al. (2010) claim that with this appreciation, the industry would intensify the electrical generation from co-burn "(combustion of two types of materials at the same time) of agricultural waste, wood, coal, willow and, probably, this industry would be a strong competitor for the credits, since the raw materials have lower processing cost than the raw material of biodiesel.

In referring to burning and use of biodiesel (driving force) in cold climates, it was observed that this energy source has a low performance, since their properties related to the cold weather (cold properties) are bad when compared to regular diesel (AHMAD , et al., 2010). These properties are related to two parameters: cloud point, which is the temperature at which the fuel ends up as a wax and clogging the filter, and pour point, which is the temperature that the fuel becomes a gel, preventing its own flow (SZULCZYK, et al., 2010).

Biodiesel has higher cloud and pour points, much higher than diesel, as shown in table 2:

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Units</th>
<th>Diesel fuel #2</th>
<th>Soybean oil biodiesel</th>
<th>Tallow biodiesel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cetane number</td>
<td>%</td>
<td>40 to 52</td>
<td>45 to 56.9</td>
<td>58.8 to 70</td>
</tr>
<tr>
<td>Flash point</td>
<td>°C</td>
<td>60 to 72</td>
<td>131</td>
<td>117</td>
</tr>
<tr>
<td>Cloud point</td>
<td>°C</td>
<td>–15 to 5</td>
<td>–3 to 3</td>
<td>12 to 16</td>
</tr>
<tr>
<td>Pour point</td>
<td>°C</td>
<td>–35 to 15</td>
<td>–7 to 19</td>
<td>6 to 13</td>
</tr>
<tr>
<td>Higher heating value</td>
<td>BTU/Gal.</td>
<td>138,700</td>
<td>130,995</td>
<td>129,022</td>
</tr>
<tr>
<td>Lower heating value</td>
<td>BTU/Gal.</td>
<td>128,700</td>
<td>120,201</td>
<td>–</td>
</tr>
</tbody>
</table>

Source: Szulczyk, et al., 2010

Thus, as the temperature drops in winter, for example, the utilization of biodiesel becomes less viable, perceiving, then, that the performance of biodiesel depend on the specific environmental conditions of each region.

4. Environmental Impacts

In relation to environmental responses in step planting of oilseeds for biodiesel production, there is, first, the necessity of using large agricultural areas for certain raw materials, such as: Rapeseed oil, soybean oil, palm oil and daisy.

Some Asian countries have withdrawn some tropical hectares of its forests for expansion of plantations of oil, causing ecological imbalances (AHMAD, et al., 2010).

Another important environmental aspect is the renewability of the soil associated with the restoration of nutrients, that can help the producer to minimize energy costs to recover degraded or polluted soils and become self-sufficient in relation to energy (GARCEZ et al., 2007).
A renewable energy source is one that provides natural resources and of course renew. These conditions fit perfectly with biodiesel since this is achieved mainly by oil, which represent a natural resource and renew themselves naturally, because the byproducts generated in the process from oilseeds and microalgae, such as proteins, carbohydrates, polymers and waste biomass, can be used as fertilizers in agriculture or feed (AHMAD, et al., 2010). Also, byproducts obtained from the production of biodiesel from the Jatropha, salmon oil, mahua, jojoba oil, tobacco seed, mango sea, leftover cooking oil and animal fats, can be used in other reactions, being able to generate heat and power.

One of the downsides of biodiesel as vehicle fuel is that the sediments deposited in the fuel tank decrease the vehicular useful life of the filter, promoting their corrosion, contributing for the development of microbes besides the wear of engine gaskets and seals (SZULCZYK, et al., 2010).

The cited authors contend that the development of ethanol, has been stimulated by public and governmental concern about global warming, the fact that the oil used as feedstock for its production are responsible for clean emissions, with waste gases as oxygen, which associated with fossil fuels reduces the emission of greenhouse gases (GHG) emissions such as hydrocarbons (HC), carbon monoxide (CO), particulate matter (PM), mercury, and carbon dioxide (SO2).

Table 3 shows the amount of greenhouse gases in some of the tons that are recycled every 1000 gallons of biodiesel (soy-based). For example, each gallon of biodiesel soy-based, recycles approximately 78.5% carbon dioxide, with the remainder coming from fossil fuels.

Table 3:

<table>
<thead>
<tr>
<th>GHG</th>
<th>Amount (metric tons)</th>
<th>GHG efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon dioxide</td>
<td>-22.8629</td>
<td>78.5</td>
</tr>
<tr>
<td>Methane</td>
<td>-0.00021</td>
<td>2.57</td>
</tr>
<tr>
<td>Nitrous oxide</td>
<td>-0.00024</td>
<td>66.1</td>
</tr>
<tr>
<td>Total</td>
<td>-</td>
<td>77.9</td>
</tr>
</tbody>
</table>


Table 4 below presents a comparison of emissions from diesel (CD) and biodiesel (SB) based on soybean, showing that biodiesel has a better characteristic of degradation, 31% less hydrocarbons than the CD, 44% less carbon monoxide, 36% less particulate matter, 29% less oxides of sulfur and 67% less CO2.

Table 4:

<table>
<thead>
<tr>
<th>Fuel type</th>
<th>HC</th>
<th>CO</th>
<th>PM</th>
<th>NOX</th>
<th>SOX</th>
<th>CO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD</td>
<td>0.041</td>
<td>0.427</td>
<td>0.053</td>
<td>0.371</td>
<td>0.125</td>
<td>91.365</td>
</tr>
<tr>
<td>SB</td>
<td>0.028</td>
<td>0.240</td>
<td>0.034</td>
<td>0.663</td>
<td>0.089</td>
<td>29.749</td>
</tr>
</tbody>
</table>


In this case, the only disadvantage is the amount of NOx (oxides of nitrogen) emitted by
biodiesel which is 67% higher than that produced by diesel fuel. But there are several ways to reduce emissions of NOX, (such as through advanced injection techniques or the use of special additives).

Figure 3 shows the proportions of HC, CO, PM, NOX, SOX and CO2 at each stage of production cycle of regular diesel and biodiesel.

Chart 3: Proportion of the emission of CO2 in each stage of production cycle diesel.

So, it can be seen that soybean cultivation, the conversion of soybeans in biodiesel and biodiesel combustion are the phases of higher emissions of particulate matter and also the cultivation and the conversion of soybeans in biodiesel responsible for the emission of CO2 and SOx (ZHIYUAN HU, et al., 2007).

We will also see that the production and use of biodiesel can cause social impacts on the population, which will be explained in section 3.

5. Social Impacts

Regarding social impacts, in step planting of soybeans, biodiesel has interfered in the agricultural food matrix, causing the development of family farms, helping to restore polluted land. According to FAO (Food and Agriculture Organization) in recent years the food has recorded fluctuations in their prices more generally with decreasing trends. As can be seen below:

Chart 4: Index of food prices
The reduction in food prices was possible due to productivity gains and technical advances embedded in the cultures. An example of this is what happened in Brazil since 1990 had an increase of 131% in grain production and an increase of only 16.1% of cultivated area (Ministry of Agriculture, Livestock and Supply, 2010), as shown in Chart 5:

**Chart 5: Production and area planted with cereals, pulses and oilseeds, Brazil, 2000-2007.**

As can be seen from 2000 to 2007, the area was slightly enlarged, not following the evolution of productivity which in 2007 reached the mark of 133.3 tons per hectare. The growing demand for renewable source has raised discussions about production of food and energy.

Globally, the competition between food company and energy company has been given mainly by rape, soybean oil, palm oil and daisy. With population growth, countries increasingly find themselves in a situation of conflict between the two applications of bioenergy. There is then a challenge: Either you plant food or plant energy.

According the National Association for the Promotion of Fertilizers (ANDA) Brazil imports almost 60% of fertilizer consumed in the country mainly intended for the agricultural sector and intensive farming, as in the case of soy and cane sugar. We analyze the evolution from 1988 to 2005 in the graph below:

**Chart 6: Imports of fertilizer-Brazil (1988-2005).**
We can see that in much of the study period there was a growing demand for fertilizers, although the total input of only 11% is produced in the country, mainly through the small farmers.

But there are other problems: In China, biodiesel helps to reduce dependence on imported oil, reducing pollution and curb global warming, but soy-based biodiesel production cost is very high and demand for its use as cooking oil, used by the food company is very strong in Chinese culture, so that the country still has to import part of soybean.

In referring to family farming, the production of biodiesel brings great social advantages, through the development of regional economy. Brazil is the second largest producer of soybeans, but also produces mamona in the northeast and palm in the Amazon which generates a considerable development of these regions.

When you enter a culture adapted to the climatic characteristics and the odds of a natural region, the farmer expends less economical resources for the maintenance of crop as well as there is a reduction of production costs and thus he can achieve better prices on the world market. In Brazil, this situation could not be different; the amount earned by the production has reached significant levels, as presented in Figure 7:

Graph 7 - Average price fetched in the auctions of biodiesel - 2009.

The chart above shows the average price of biodiesel auctions, held by the National Agency of Petroleum, Natural Gas and Biofuels (ANP), during 2009, as can be seen, the price ranged between $ 1.90 and R $ 2.16 a gallon. The demand for bioenergy is likely to increase worldwide due to global warming and the search for reducing oil dependence.

Another use of biodiesel is the recuperation of polluted and poor in organic matter soils,
through techniques that deal with the genetic modification of plants and microorganisms capable of absorbing pollutants so as to delete them or turn them into a more lenient composition which does not harm the environment. In 2005, a successful experiment was employed by the Taiwan government through its Council of Agriculture (COA) in this project were selected 90 acres of contaminated soil, and later divided into three lots each cultivated with a type of oilseed sunflower, rapeseed and soybean. In this project it was found that those who were idle land (polluted soil) had a considerable reduction of heavy metals because of the production of oilseeds for biodiesel production (Yun-Hsun Huang, 2008).

6. Conclusions

Thus, from the analysis of the economic, environmental and social damage caused by biodiesel, it can be inferred that biodiesel is a sustainable energy source, because despite its high production cost, it reduces the environmental pollution and it brings social development for producing region.

Nevertheless, biodiesel cannot yet be considered self-sustaining as in many countries, as in Brazil, yet there must be incentives to ensure its production and purchase. Therefore, several steps must be taken so that there is a reduction of production cost and improvement of its properties, in order to replace completely diesel for biodiesel once that if the demand energy continues to grow like it grows today, in 45 years, oil reserves will be exhausted and it is estimated that in 2030 the world will need 60% more energy than it uses today (AHMAD, et al., 2010).

When the fossil fuel reserves are exhausted, the introduction of technologies that are able to replace it, will gain importance. It can be cited some of the measures to be taken to reduce the production cost and improve biodiesel properties: increase the power generation during combustion of biodiesel, so that it can improve engine efficiency; improve the properties related to the cold weather; reduction of poverty, in order to make their use feasible at low temperatures; seeking new materials with higher amount and productivity of vegetable oil pure for use in biodiesel production; develop methods to protect anti-oxidation and anti-microbial, in order to increase the life of engines; reduction in NOx emissions.

Such planting production costs can be reduced with the use of agricultural technologies more efficient, increase of productivity of oilseed, replacement of the drying of seeds for the preservation thereof, and substituting mineral fertilizers by biofertilizers in order to reduce the energy spent in the stages of planting and extraction of vegetable oil used in biodiesel production.

So, the biodiesel has shown economic characteristics and feasibility of production, but it still needs deeper research to achieve its better use in motors and to improve its efficiency in cold climates.

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