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Recent growth of Brazilian agribusiness

Luis Carlos Guedes Pinto¹

The recent growth of Brazilian agribusiness results from the skills of our farmers, wide availability of farmable lands at low prices, and generation and incorporation of more efficient production technologies, particularly tropical region technology. The federal government has done its part by adjusting the macroeconomy in order to encourage investments and, as regards agricultural policy, making farm loans available and creating other instruments to minimize the risks inherent to any agricultural activity.

Agribusiness regularly supplies food and other agricultural products at ever-lower prices to the vast Brazilian market. Cheaper food has helped fight hunger and strengthened people's income, particularly that of the poor, enabling increased participation in the consumption of other non-agricultural products and services.

The agricultural sector's competitiveness has provided an added thrust to exports, from US\$ 20.6 billion in 2000, to US\$ 43.6 billion in 2005, to US\$ 48.3 billion in the last 12 months (November 2005 through October 2006). The balance of trade of agribusiness steadily increased to US\$ 38.5 billion in 2005, from a total US\$ 137 billion from 2001 to 2005. The sector's balance of trade for the last 12 months was US\$ 41.9 billion. These results have enabled Brazil to overcome serious problems in its external accounts and, more recently, have permitted the import of technology and inputs essential to the country's development.

Not everything is good news in the road to development however. Many farmers have been excluded from the marketplace and others suffered income reductions that compromised their families' quality of life. Also, vast grain-producing regions have faced draughts over the last two years. Some environmental sustainability issues are still unresolved. Animal diseases, such as hoof-and-mouth disease and the threat of avian influenza, have limited our production and export potential. Many countries embargoed Brazilian meat for health or protectionist reasons. The crisis does not affect all agricultural sectors, however, since the export of other major products, such as sugar and alcohol, citrus fruits, coffee, wood and cellulose, and meat continued to grow and remunerate the producers.

In order to minimize the effects of the draughts that have afflicted grain producers, the government deferred debt payments and increased official credit resources. The objective was to support production and keep farmers from discontinuing grain farming. The government also implemented animal disease eradication and control measures. Together with the private sector, the government promotes quality programs and counters the protectionist actions of potential competitors. There are clear signs that the agricultural sector is beginning to surmount the crisis. Planting estimates for the next harvest (October 2006 data) from both the National Institute of Geography and Statistics (IBGE)

¹ Minister of Agriculture, Livestock and Food Supply.

and the National Food Supply Company (Conab) confirm that the next harvest outcomes will be close to those obtained in 2005-2006, and agricultural machinery and fertilizer sales are beginning to pick up. These signs prove the appropriateness of the policy measures adopted by the federal government last year.

Brazilian agriculture is competitive and has a high expansion potential, since land is plentiful - cheap, by international standards. In addition, a good stock of tropical and subtropical technology is readily available. Cost reductions due to gains in scale and better logistics and transportation will significantly increase Brazil's share of the world's food market.

In the field of agroenergy, the Ministry of Agriculture, Livestock and Food Supply, in

partnership with the ministries of Mines and Energy, Science and Technology, and Development, Industry and Commerce, has established national Agroenergy Policy Guidelines and, in the light of such policy, has drawn up a National Agroenergy Plan that involves both the private and government sectors in its execution.

The Brazilian agricultural policy seeks to reconcile agricultural growth with social and environmental objectives. The investments in research and development, food quality and safety, and infrastructure; the Brazilian producers' promotion efforts and sales and distribution schemes; and increased access to key-markets will continue to be part of the government's policies and actions aiming at ensuring the competitiveness of the Brazilian agribusiness.

National Program for the Production and Use of Biodiesel Guidelines, challenges and prospects

Frederique Rosa e Abreu¹
José Nilton de Souza Vieira²
Simone Yuri Ramos³

Introduction

Brazil is one of the main world references in the production and utilization of renewable sources of energy, because of the heavy investments made to exploit efficiently the country's natural advantages, such as enormous watersheds and natural conditions for agricultural biomass production. That combination of factors has led to the expressive share of the renewable sources in the Brazilian energy matrix or mix. According to data from the Ministry of Mines and Energy, hydroelectric power accounts for 14% of the energy produced in the country, while biomass represents another 27%.

In the area of biomass, the success of the National Alcohol Program stands out. Today, alcohol accounts for 40% of the fuel consumption of Otto cycle vehicles. Furthermore, having achieved energy self-sufficiency, many sugar & alcohol industries are now selling growing amounts of surplus electric power produced through cogeneration resulting from sugarcane bagasse burning.

Despite the success of the sugar & alcohol industry in producing ethanol, dependency on diesel oil from foreign petroleum is still a problem. More than 38 million cubic meters were consumed in 2005, or 57.7% of all liquid fuels. While the country exports increasing amounts of surplus gasoline, it continues to depend on imports to meet the domestic demand for diesel oil.

The country has long studied ways to overcome the problem, focusing on the production and mixture of biodiesel to the mineral fuel. Thus, not only would it be possible to diminish external dependence, but biodiesel would play an important environmental role by improving the fossil diesel burning process, such as occurs with the alcohol-gasoline blend.

Biodiesel has never been an economically attractive proposition because the market price of vegetable oils has been higher than that of mineral diesel. Now, however, the government has added a social component. Thus, the production of the raw material has become a means of social inclusion, generating job and

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income opportunities for the poorest among the rural population, especially family farmers/smallholders in the Semi-arid Northeast.

It should be emphasized that the success of the program will enable the country to strengthen its position as a major biodiesel exporter. The European Union's guidelines, which were drawn to ensure the fulfillment of the commitments made in the Kyoto Protocol, suggest that foreign suppliers would meet part of their biofuel demand. Likewise, the United States, which consumes one-fourth of all petroleum in the world, could resort to imports to ensure the domestic supply.

In addition to a huge opportunity to leverage agricultural activities, biodiesel would also promote increased agricultural revenues derived from the utilization of biomass byproducts and wastes. Furthermore, biodiesel would enable the country to obtain international funds by applying the Kyoto Protocol mechanisms, such as the Clean Development and Emissions Trading schemes.

Thus, the current government launched the National Program for the Production and Use of Biodiesel (PNPB) in December 2004. The PNPB contemplates the implementation of a set of initiatives, such as establishing a regulatory framework for the new fuel; structuring the technological base of the biodiesel production chain; defining funding lines; and organizing the production chains. These elements shall be discussed in more detail in the next sections.

Public policies for biodiesel in Brazil

National Program for the Production and Use of Biodiesel

Brazil has been researching biodiesel since the 1970s with special focus on African palm oil. The use of vegetable oils for energy purposes was first proposed in 1975 and led to the Plan for the Production of Vegetable oils for Energy Purposes (Pró-óleo), whose purpose was to produce vegetable oil surpluses that would

make oil production costs competitive with petroleum's. The idea was to mix 30% vegetable oil into fossil diesel initially and eventually replace the latter completely.

The country began playing a leading role in biodiesel research with those studies and, in 1980, became the first country to obtain a patent for a biodiesel production process. In 1983 the Brazilian government, driven by the spiraling petroleum prices, determined the implementation of the Vegetable Oils Project (Oveg Project) with a view to testing the use of pure biodiesel and various biodiesel/fossil diesel mixtures. The Ministry of Industry and Commerce (currently Ministry of Development, Industry and Commerce) coordinated the initiative, in which the automobile, auto parts, vegetable oils, and fuel and lubricants industries participated, in addition to various research centers.

More recently, in December 2004, the federal government launched the National Program for the Production and Use of Biodiesel (PNPB), whose objective is to foster biodiesel production and use in the country in a technical and economically sustainable manner. Fourteen ministries participate in the program, whose main guidelines are the following: a) setting up a sustainable program that promotes social inclusion and regional development; b) guaranteeing competitive prices, quality and a regular supply of the new fuel; and c) encouraging the utilization of different raw materials and technological pathways.

An Interministerial Work Group created in Decree dated 2 July 2003 drafted the program. The group submitted its report at the end of the year suggesting the instatement of an Interministerial Executive Commission and a Management Group responsible for carrying out actions within the public sphere, especially as regards structuring the regulatory framework and implementing the activities considered essential to solve the problems identified in the study.

The recommendations of the work group were accepted and an Interministerial Executive Commission and a Management Group were formally created in an unnumbered decree

dated 23 December 2003. The Commission took on the task of drafting, implementing and monitoring the program, proposing normative acts and defining the government actions and public policy guidelines. The Management Group is charged with executing the actions proposed by the Interministerial Executive Commission.

The Interministerial Executive Commission falls within the overview of the Civil Cabinet of the Presidency of the Republic and is constituted of two representatives (a delegate and his/her deputy) from each of the following agencies:

- Civil Cabinet of the Presidency of the Republic, to act as coordinator.
- Secretariat of Government Communications and Strategic Management of the Presidency of the Republic.
- Ministry of the Treasury (MF).
- Ministry of Transportation (MT).
- Ministry of Agriculture, Livestock and Food Supply (Mapa).
- Ministry of Labor and Employment (MTE).
- Ministry of Development, Industry and Foreign Trade (MDIC).
- Ministry of Mines and Energy (MME).
- Ministry of Planning, Budget and Management (MPOG).
- Ministry of Science and Technology (MCT).
- Ministry of Environment (MMA).
- Ministry of Agrarian Development (MDA).
- Ministry of National Integration (MI).
- Ministry of the Cities (MC).

The Ministry of Mines and Energy coordinates the Management Group, which is made up of two representatives (a delegate and his/her deputy) from each of the following agencies:

- Ministry of Mines and Energy (MME).
- Civil Cabinet of the Presidency of the Republic (CC).

- Ministry of Science and Technology (MCT).
- Ministry of Agrarian Development (MDA).
- Ministry of Development, Industry and Foreign Trade (MDIC).
- Ministry of Planning, Budget and Management (MPOG).
- Ministry of the Treasury (MF).
- Ministry of Environment (MMA).
- Ministry of National Integration (MI).
- Ministry of Agriculture, Livestock and Food Supply (Mapa).
- National Economic and Social Development Bank (BNDES).
- National Petroleum, Natural Gas and Biofuels Agency (ANP).
- Brazilian Petroleum Corporation (Petrobras).
- Brazilian Agricultural Research Corporation (Embrapa).

Figure 1 shows the main challenges to the implementation of the program raised by the Work Group, including the explicit need for coordinated work among the various government agencies to ensure that restrictions are surmounted in a concerted manner. Thus, the Interministerial Executive Commission is entrusted with monitoring the work to check whether the agencies involved are executing the tasks assigned to them.

Also in terms of structure, the government created the Brazilian Biodiesel Technology Network (RBTB), constituted of research organizations in 23 states of the Brazilian Federation. The objective of the RBTB is to provide technical assistance services and implement research in the various areas of production and commercialization of biodiesel and its coproducts and byproducts.

The program contemplates the specificities of each geographical region of the country in terms of raw materials produced and regional development needs as shown in Figure 2. It also includes the production of biodiesel through different technological pathways, such as

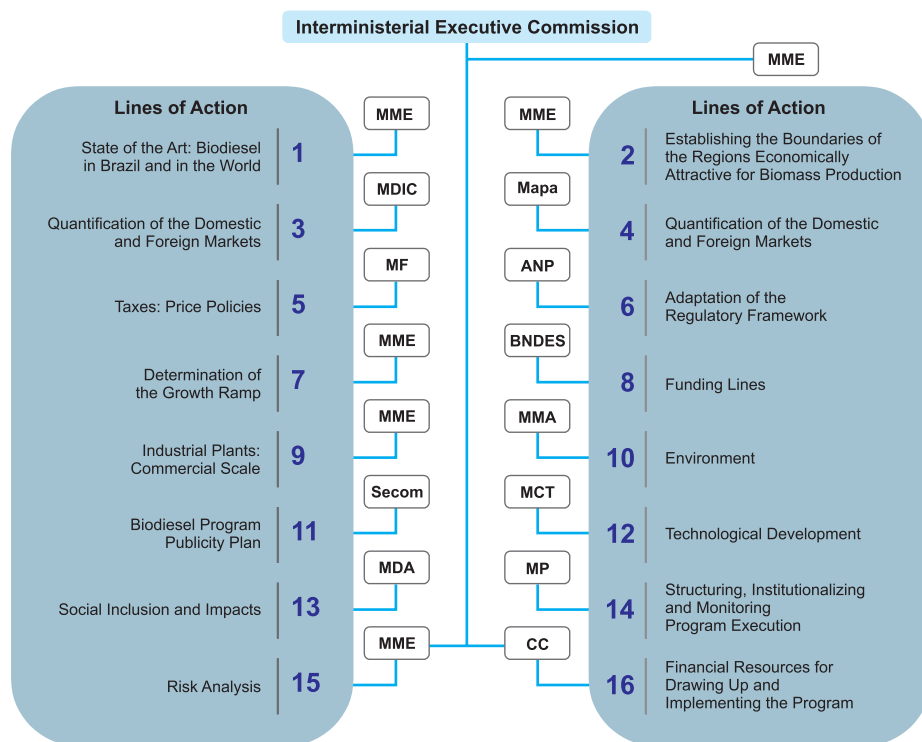


Figure 1. Work plan of the agencies participating in the PNPB.

Source: Programa Nacional de Produção e Uso do Biodiesel (2006).

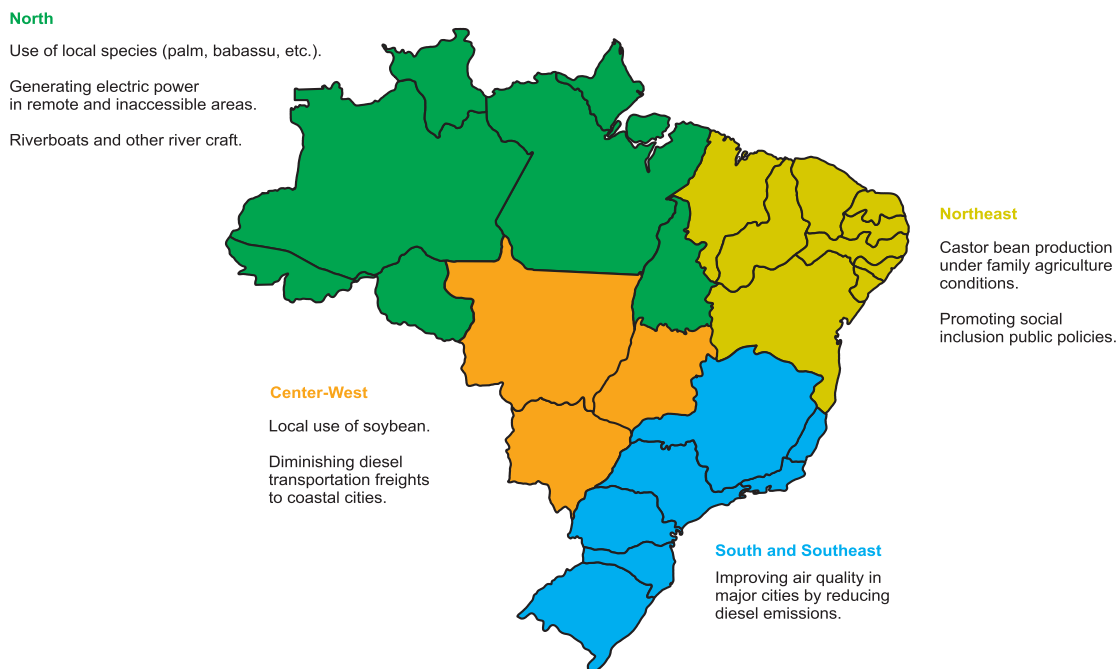


Figure 2. Regional motivations for biodiesel production.

cracking and ethylic or methylic transesterification. The objective is to achieve complementarity of agribusiness and family agriculture in supplying the raw materials and taking advantage of the prevailing regional conditions. Nevertheless, independently from either the raw material or the production technology involved, the biodiesel must meet the technical specifications established by the National Petroleum, Natural Gas and Biofuels Agency.

The structure seeks a balance among the economic, environmental and social components, that is, the goal is to introduce into the Brazilian energy mix a fuel whose production is economically viable (competitive costs), while providing environmental gains (reduction of liquid emissions) and creating new job opportunities in the rural areas, especially in family farms/smallholdings (social inclusion).

As stated in the guidelines, the government created a regulatory package regarding the percentages of biodiesel to be mixed to fossil diesel, the tax regime to be applied to the fuel and the criteria for obtaining a "Social Fuel Seal". The purpose of the latter is to increase the attractiveness of buying the raw material for the production of biodiesel from family farmers/smallholders. It is expected that new job and income opportunities will open in the rural areas. The measures are detailed in the next paragraphs.

Procedures for including biodiesel in the liquid fuel mix

The first step in building the regulatory framework for the PNPB was Provisional Measure Number 214 of 13 September 2004, which created the legal figure of biodiesel in the Brazilian energy mix and delegated the supervision of biodiesel production and commercialization to ANP. This enables the petroleum agency to hold public hearings on draft ordinances dealing with the technical specifications of both pure biodiesel and the biodiesel/fossil diesel fuel blend.

After consulting the automobile industry, it was decided that the voluntary mixture would begin with 2% biodiesel, which would forego prior experimental tests. When Congress examined the Provisional Measure, however, it was heavily amended, including an amendment making the use of biodiesel compulsory. Although requiring the use of biodiesel could reduce the uncertainties of private investors, this would demand setting up a production structure within a relative short period, particularly since the production technologies were still insipient.

Provisional Measure Number 214 became Law Number 11.097 of 13 January 2005, which establishes a minimum legal and compulsory percentage (5%) of biodiesel blended with fossil diesel throughout the national territory. The period for implementing the biodiesel blend would be 2013, but a 2% mixture would be required by 2008. This represents an annual demand for approximately 800 million liters of biodiesel. It is estimated that close to 1.5 million hectares would be required to produce enough raw material to add 2% biodiesel to the fossil diesel consumed in the country, the equivalent of 1% of the farmable land in Brazil, or 150 million hectares.

If the biodiesel percentage were optional, businessmen would have to seek efficiency in order to compete with one another because the price of biodiesel could not exceed that of fossil diesel. Since the percentage is established in the law the fossil diesel price is no longer the ceiling and possible cost increases can be passed on to the consumer.

In order to reduce uncertainties the National Council for Energy Policy issued Resolution Number 3 of 23 September 2005 that anticipated the implementation of the mixture to January 1st 2006. By that date, however, the production of the companies that have the Social Fuel Seal, which should participate in the auctions, will probably fall short of the required amount of biodiesel to be added to the normal diesel consumption in the country.

The purpose of the auctions is to ensure the economic viability of ongoing undertakings. The ANP sets the terms and date of the auction and

oversees it. Participants are either already installed companies having received the Social Seal or companies with a production project that meets the requirements to obtain such seal. To that end, interested parties must be duly registered at ANP and the Secretariat of Federal Revenues.

Characteristics of the tax model

In Brazil the federal tax regime on fuels was established in Constitutional Amendment Number 33 and Law Number 10.336, which created the Contribution for Intervention in the Economic Domain (Cide). The regulation, however, did not contemplate biodiesel, so that levying Cide on biodiesel would depend on a new constitutional amendment.

The alternative adopted to make up for possible tax revenue losses at the federal level due to the impossibility of collecting Cide from biodiesel operations was to establish higher tax brackets for the Social Integration Program (PIS) and Social Security Contribution (Cofins) tax headings. As in the case of that contribution, Law Number 11.116 established the maximum rates for those taxes and mandated the Executive Branch of Government to alter them within that limit. Thus, Decree Number 5.297 established tax benefits for companies that use castor oil or African palm tree oil (whose production is manpower intensive) or even other raw materials, provided such raw material is produced by family farmers eligible for participation in the National Family Agriculture Support Program (Pronaf). The benefits are even more substantial when the raw material is produced in the North, Northeast and Semi-arid regions.

It was also established that the sum total of the federal taxes on biodiesel (PIS and Cofins) could not exceed those on fossil fuels (PIS, Cofins and Cide). The abatement coefficients for those tax rates are applicable depending on the origin of the raw material used by the industry producing biodiesel. In the extreme case (African palm tree fruits or castor beans produced by family

farmers/smallholders in the North, Northeast or Semi-arid regions), the abatement coefficient is equal to one, which means no federal taxes are levied.

Decree Number 5.298 of 6 December 2004 established exemption from the Industrialized Product Tax (IPI). Therefore, the tax incentives for biodiesel can be summed up as follows.

1. A 32% abatement for biodiesel produced from African palm tree fruits or castor beans produced in the North, Northeast and Semi-arid regions.
2. A 68% abatement for biodiesel from raw materials produced in family farms/smallholdings in any region of the country.
3. A 100% abatement for biodiesel from African palm tree fruits or castor beans produced in family farms/smallholdings in the North, Northeast and Semi-arid regions.

Table 1 shows the total taxes applied to biodiesel and mineral diesel. It should be emphasized that the tax model sets up differentiated PIS/Pasep and Cofins tax rates depending on the region where the biodiesel raw material was produced and whether it was produced under family farming conditions.

Social Fuel Seal

One of the guidelines established by federal government for the PNPB was to focus on social problems and actions. The purpose of the tax incentives was to foster increased participation of family agriculture in supplying raw materials. Since there is no legal definition for the term 'family agriculture', the criterion selected was for the 'family farmer' to be a beneficiary of the National Family Agriculture Support Program (Pronaf).

Decree Number 5.297 created a "Social Fuel Seal", which would be required before a biodiesel producer could be eligible for the tax benefits, which are proportional to the share of raw materials bought from family farmers. The criteria for obtaining the seal were defined by

Table 1. Taxes levied on biodiesel and fossil diesel.

	Biodiesel				Fossil diesel
	Family agriculture in the North, Northeast and Semi-arid with castor beans or palm fruits	Family agriculture in general	Intensive agriculture in the North, Northeast and Semi-arid with castor beans and palm fruits	General rule	
	R\$/L	R\$/L	R\$/L	R\$/L	R\$/L
Cide	Non-existent	Non-existent	Non-existent	Non-existent	0.07
PIS/Cofins	0.0	0.07	0.148	0.218	0.148
Sum total of federal taxes	0.0	0.07	0.148	0.218	0.218

the Ministry of Agrarian Development in Normative Instruction Number 1 of 5 July 2005.

The purpose of the seal is to encourage partnerships of companies and family farmers/smallholders involving the guaranteed purchase of the raw material at pre-established prices, technical assistance, support to the organization of family farmers into associations, rural cooperatives/mutual companies, etc. In order to receive the seal the company must prove a partnership has been established, as well as purchase from said farmers a given percentage of the raw material to be processed, namely, 50% in the Northeast and Semi-arid regions; 30% in the Southeast and South regions; and 10% in the North and Center-West regions.

In addition to the tax benefits, the company can access special credit lines with exceptional loan terms and participate in biodiesel auctions until the biodiesel/fossil diesel mixture is compulsory. The seal shows that the biodiesel producer has established a partnership with a family agriculture scheme and can be used as a marketing instrument.

The concern with supporting family agriculture is based on joint studies carried out by the ministries of Agrarian Development; Agriculture, Livestock and Food Supply; National Integration; and the Cities. The studies concluded that replacing 1% of the fossil diesel

fuel consumed in Brazil with biodiesel produced from raw material originating in family agriculture would help create 45,000 jobs in the rural areas, at an average cost slightly over R\$ 4,900.00 per job (HOLANDA, 2004).

Estimating that for every job in the rural areas three jobs are created along the remaining production chain, the studies concluded that 180,000 new jobs would be created for each 1% fossil fuel replaced with biodiesel. The production of the raw material for biodiesel production would be an additional activity, a way to obtain a monetary income and keep the family members working in the family farm longer.

It should be emphasized that commercial agriculture employs, on average, one worker for every 100 hectares planted, while family agriculture employs one worker per 10 hectares. Also, it has been estimated that every R\$ 1.00 invested in family agriculture adds R\$ 2.13 to the family's annual gross income. This explains the importance of supporting the inclusion of family farmers as suppliers of raw material.

Credit lines for the biodiesel chain of production

The National Economic and Social Development Bank (BNDES) and the Banco do

Brazil has credit lines for biodiesel production and commercialization operations. Those credit lines include financing for both industrial and agricultural production. In the case of family agriculture, funds can be obtained from Pronaf, which made close to R\$ 100 million available to family farmers in 2005, at interest rates varying from 1% to 4% p.a.

The Financial Support Program for Biodiesel Investments finances up to 90% of loan-worthy investments for projects with the Social Fuel Seal and up to 80% for the rest. Loans can be taken for any biodiesel production phase, including storage, logistics and byproduct processing. In operations with micro, small and medium-size companies the principal amount is corrected for inflation using the TJLP plus 1% p.a. (for projects with the Social Fuel Seal) or TJLP plus 2% p.a. In the case of large companies, the banks use the TJLP plus 3% p.a. There is some flexibility regarding loan collaterals, with the possibility of a waiver when the borrower has a long-term biodiesel purchase and sales contract.

The purpose of Banco do Brasil's BB Biodiesel program is to support the production, commercialization and use of biodiesel. BB Biodiesel offers credit lines for both agricultural production (running expenses, investments and commercialization available to both family farmers/smallholders and commercial agricultural operations) and industrial production (BNDES Biodiesel, Pronaf Agroindustry, Prodecoop, and Agroindustrial Credit for the purchase of the raw material).

In order to minimize operational risks, the banks usually require a commercialization guaranty, obtained through commercialization. This means that the farmer should only ask for a loan to invest in a given oleaginous crop if he already has a buyer for his production. Likewise, industries must also sign contracts

with the fuel distributors responsible for mixing and distributing biodiesel.

Biodiesel production in Brazil

Biodiesel is a fuel synthesized from new or residual vegetable oils, animal fats or fatty acids from vegetable oil refining operations and can be obtained by means of a series of chemical processes, such as transesterification⁴, cracking⁵ and esterification⁶. In Brazil, because of the widespread availability of ethanol, research has focused on the utilization of ethanol in the transesterification process, wherein sodium or potassium hydroxide is used as catalyst to obtain glycerin as a byproduct (Figure 3).

It should be emphasized that, in Brazil, most of the biodiesel, including biodiesel for self-consumption, will be produced through transesterification. There are, however, some cases of production by esterification (such as Agropalma, which uses the wastes from the African palm tree oil refining process as raw material) and special projects could arise using cracking in isolated communities.

Despite the interest in developing an ethylic pathway, the transesterification process can also use methanol in a better-known industrial process already used in several countries. The methylic pathway facilitates the reaction when castor oil is used as raw material. Consequently, it is much more likely to be used in the Northeast and Semi-arid regions.

Nevertheless, as research progresses the Central-Southern region of the country will probably be able to take advantage of the relative abundance of ethanol, which does not face technical restriction when combined with soybean, sunflower or wild radish (*Raphanus sativus*) oils. Methanol might come to be necessary in industrial plants using bovine suet,

⁴ Transesterification: chemical reaction of triglycerides (plant or animal oils and fats, in which the fatty acids form esters with glycerol) with alcohols (methanol or ethanol), in the presence of a catalyst (acid, base or enzyme) resulting in the substitution of the ester group by the ethanol or methanol group.

⁵ Catalytic or thermal cracking: reaction that breaks the molecules through heating at very high temperatures, forming a chemical compound mixture with properties very similar to those of petroleum derivatives.

⁶ Esterification: reaction involving the production of esters (biodiesel) from alcohols and fatty acids or their derivatives.

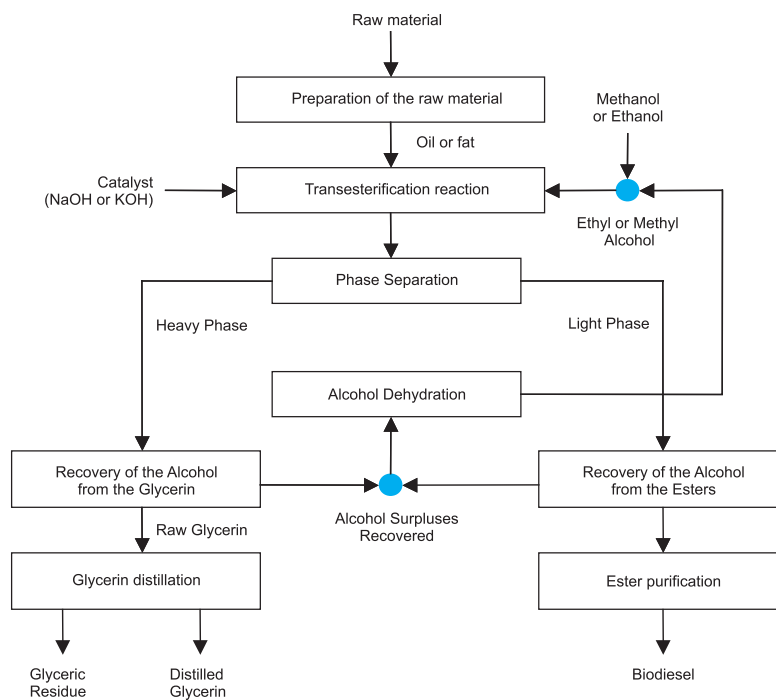


Figure 3. Biodiesel production by transesterification.
Source: Holanda (2004).

although research has made much progress in overcoming the obstacles to ethanol use.

In addition to the aforementioned research fronts, Petrobras recently announced a technology that uses refined vegetable oil to purify fossil diesel. Such technology, known as Hbio, could be another important way of including vegetable oils in liquid fuel blends.

Thus, it is possible to forecast that within a very short period of time biodiesel will stop being a merely experimental product to become a de facto energy alternative. Biodiesel production is still small, but ANP estimates indicate that the existing installed production capacity comes close to 1.2 billion liters per annum.

Production profile according to the geographical regions of the country

The size of the Brazilian territory, its geographical location and the prevailing soil and climate conditions are perfect for the

production of energy from agricultural biomass. In the case of biodiesel, there are countless plants that produce oil and could be used as alternative sources. That is one of the many positive differences in structuring a biodiesel production program.

The biodiesel production program raises the challenge of taking advantage of the potential of each region, especially in a context in which plentiful farmable land contributes to reducing the pressures of finding increased technical efficiency. At the same time, the social bias of the program requires that emphasis be given to a competitive inclusion of the production chains based on more intensive use of labor, especially in the case of African palm tree fruits and castor beans.

Thus, there is a natural conflict between promoting regional development, as set forth in the tax model, and the need to achieve increased economic efficiency, which suggests giving priority to more mature technological alternatives, such as soybean, which accounts

for 90% of the country's current oil production. So that each region is faced with a sort of options basket that demands technical rigor when structuring development actions that take into account the existing diversity. The next paragraphs focus on this problem.

North Region

The North Region has rather peculiar characteristics. It is the largest region in the country, where native forests prevail. Although there are areas for both intensive (rice, corn and cassava) and subsistence (mostly beans and cassava) agriculture, its greatest potential lies in the exploitation of forests, particularly due to the predominant humid equatorial climate. In such conditions, palm trees become the best alternative raw material for biodiesel production.

In addition to a great diversity of native palm trees, the Brazilian Amazon has the greatest potential for African palm tree plantations in the world, with an area estimated at 70 million hectares. This represents a production potential equivalent to 350 million cubic meters of petroleum per year.

There are approximately 40,000 communities in the region, and for some of them biodiesel can be a local energy alternative. Since it is not connected to the Brazilian Integrated Electric Grid, the region depends on diesel-fueled stationary generators. As Zylberstajn et al. emphasized (1996), those generators are located so far from the petroleum refineries that the risk of running out of fuel is an ever-present threat. Thus, African palm tree oil, which can be produced locally, is an extremely relevant alternative.

Palm trees can be also be planted over the existing deforested areas, particularly in the State of Pará, which already accounts for more than 80% of the current African palm tree oil production in the country. According to Peres et al. (2005) palm trees are the raw material option with the highest productivity: 4 to 6 tons of oil

per hectare. In addition to palm fruit oil it is possible to extract palm-kernel oil, whose byproduct is the palm cake used in animal feeds. The solids from palm fruit processing can also be used to generate thermal or electric energy for the processing plant or local communities.

Another alternative is exploiting the native varieties under both extractivist and forestry management conditions. Those activities are typically manpower intensive and would involve large numbers of family farmers/smallholders. In the case of palm plantations, it is necessary to develop complementary activities, particularly subsistence farming, because of the long maturation cycles of the investments.

In addition to replacing diesel oil in stationary generators and riverboats, the region could potentially become an important diesel export base. To that end, it would be necessary to structure programs that promote in loco production, as well as programs to test the biodiesel in different types of motors with a view to identifying the technical limits of the biodiesel/fossil diesel mixture.

Lastly, it should be emphasized that the African palm tree is eligible under the Clean Development Mechanism of the Kyoto Protocol to receive carbon credit investments, which could contribute significantly to the viability of the investment projects. Thus, the challenge is to organize the local communities to produce the raw material for palm oil through either plain extractivism or agroforestry exploitation.

Northeast Region

The Northeast Region accounts for approximately 15% of the diesel oil consumed in the country. It is also known for its groundbreaking research on biodiesel. At the present time, because of the social connotations of the program, the Northeast Region researchers are focusing on castor beans, which explains the large number of castor bean

plantations and commercial production projects. Despite the great expansion of the castor bean cropped area, it is necessary to study other alternatives and to intensify the efforts to increase the bean processing capacity.

The region is characterized by great climatic diversity. Although the Northeast has always been subdivided into three macro-regions (Zona da Mata, Semi-arid and Sertão) there are sizable areas of Cerrado, as well as areas in the transition zone into the Amazon Region where the humid equatorial climate prevails. This climatic diversity results in various alternative sources of raw material.

The Zona da Mata is the most developed sub-region. It has a long commercial agriculture history based on sugarcane monoculture and accounts for 15% of the national sugarcane production. The farmed area is approximately one million hectares. There are areas where oleaginous crops could be farmed, especially in sugarcane crop renovation areas. This represents an annual potential of 200,000 hectares, or a production of up to 100,000 tons of oil, depending on the alternative selected.

Nevertheless, one of the limiting factors is the lack of complementary crop farming, which would require breaking the taboo of monoculture and involve not only training the farmers but also fixed capital investments. Another important aspect to be considered is the lack of research to identify agricultural alternatives and later development of the varieties most appropriate for the climatic characteristics of the region. Although sunflower, peanuts and sesame have been considered, there are few experimental plantations, especially operations focusing on the integration of the sugar and alcohol production and biodiesel raw material production.

Regarding the Semi-arid, the climatic adversities constitute the most important inhibiting factor to the incorporation of capital and technology, so that farming activities in this sub-region have always been based on more rustic crops such as

castor beans and moco cotton or short-cycle subsistence crops such as beans, corn and cassava. Because of its production capacity in semi-arid areas, which makes it an alternative crop under family farming conditions, castor beans have become the leading crop during the initial phase of the PNPB and the main oleaginous crop option for the Northeast. Peres et al. (2005) emphasized that castor beans have great social appeal since in addition to producing oil they can be planted associated with other crops, such as beans, peanuts and corn.

There are more than 3 million hectares of land where castor beans could be farmed in the region under dry-farming conditions, which would produce 1,200 kilograms of castor beans per hectare with an oil content of 47% (PERES et al., 2005). The Northeast Region accounts for 96% of the Brazilian castor bean production (200,000 tons). Most of the production comes from the State of Bahia, where castor beans have become an acknowledged alternative, especially in the central region. The farmed area in Bahia is approximately 130,000 hectares, with a production in excess of 90,000 tons of beans, or 70% of the national production.

In addition to the production potential of the Zona da Mata and the interest in castor beans becoming economically viable in the Semi-arid for social reasons, it is also necessary to consider the Cerrado areas, particularly in Western Bahia and the southern areas of the states of Maranhão and Piauí, as well as in the transition zone, where palm trees such as babassu (*Orbignia phalerata*) can become an important option. In Maranhão, babassu palms grow over close to 18 million hectares. Although the babassu oil is excellent source of biodiesel there are some restrictions, such as the extraction costs, since the oil represents only 4-5% of the fruit, which is enveloped by a very hard skin. In addition, babassu production is based on extractivism and very poorly organized.

There has been a large increase in the agricultural production of the Cerrado areas of

the Northeast Region, particularly soybean, under advanced technology conditions. There are also experimental mechanized plantations of castor beans, with an agronomic potential significantly higher than that seen in the Semi-arid. Nevertheless, research on new varieties and management techniques is barely beginning.

It is also necessary to consider that although the regional production of soybean oil is still lower than its consumption as food, the fast expansion of the agricultural production, together with investments in industrial processing, will probably change that trend, and soybean production would help meet the biodiesel production plants' demand for raw material.

Center-South

For the purpose of this study, the following analyses consider the South, Southeast and Center-West regions as a single unit herein called Center-South. These geographical regions share some characteristics that are reflected on the agricultural exploitation of a common agricultural product basket. It is the case of soybean and sugarcane, which are the main crops in the states of Rio Grande do Sul and Paraná and in the states of Paraná and Minas Gerais, respectively. Both are extensively farmed in the Center-West.

From the point of view of alternative raw materials for the production of biodiesel, the region also has considerable potential for castor beans, peanuts and sunflower, the latter two already being planted in this mega-region although their respective farmed areas are still limited. In connection with the former, the experiments in the State of Mato Grosso and research at IAC (Instituto Agronômico de Campinas) have had satisfactory results with the so-called dwarf varieties, which in addition to showing high field yields (up to 4 tons of beans per hectare) can be mechanically harvested.

Despite the wide range of potential crops available, the two main alternatives in the short

term are bovine suet (with the lowest costs) and soybean (largest available supply). Since soybean is the main food oil source available and considering the logistics involved in transporting the production from the new agricultural frontiers (northern Mato Grosso, for example) to consumption centers, biodiesel production has awakened much interest. In the last harvest, the regional soybean production was more than 45 million tons over a farmed area of slightly less than 20 million hectares.

It is acknowledged that oil is a secondary product and, therefore, as important as encouraging grain processing in those regions farthest from the ports is creating the necessary conditions to develop the meat production chain and subsequent use of the bran also locally. Some food companies are reversing their strategies, not only transferring their meat processing plants to those frontiers, but also investing in new uses for wastes like bovine suet and poultry fat to feed the boilers of their cold-storage units.

Bovine suet, as a matter of fact, is the cheapest raw material at the present time. This has led both the meatpacking houses and the industrial plants producing biodiesel to consider using bovine suet alone or mixed with vegetable oils. Nevertheless, bovine suet is a byproduct with a limited supply and its prices could increase as the demand rises.

It should also be emphasized that biodiesel production is located near the main sugar and alcohol plants. On the one hand, the sugarcane renovation areas could be used to farm oleaginous plants, like soybean, sunflower or peanuts. On the other, since the industrial units already have alcohol and energy, essential ingredients in biodiesel production, there are technical and economic advantages in coupling transesterification units to said plants.

Another important consideration is that soybean, sunflower and peanut oils have an already developed market, where the price formation process is transparent. Thus, biodiesel production competes with the alternative of

selling these oils in both domestic and foreign food markets. This becomes a source of uncertainty for businessmen even in the Center-South region, which accounts for almost 80% of the national diesel oil consumption.

The need to assign priority to the social component leads to conflicts between the energy issues and the economic questions. Such conflicts result from the lower tax incentives applicable to biodiesel production in the Center-South, as set forth in the Regulatory Framework. Thus, although the production potential is considerable, the prevailing trend is to give investment priority to self-consumption, especially in grain farms and some sugar and alcohol plants located far from the refineries and the fuel mixing and distributing centers.

Conclusion

Brazil is one of the world references for the production and use of renewable sources of energy. In this area, the agricultural sector plays a leading role, whether with wood (charcoal and firewood accounting for 13.2% of the primary sources of energy), or sugarcane (alcohol and bagasse, which account for another 13.5%). These figures demonstrate the country's effective use of one of the natural advantages of tropical regions: producing energy from biomass.

The purpose of the National Program for the Production and Use of Biodiesel is to create the necessary conditions for the consolidation of the country's leading position in the use of renewable energy sources. It raises the challenge of obtaining an alternative fuel to petroleum diesel in the energy mix, an alternative that can play as important a role as alcohol plays with regard to gasoline.

Nevertheless, as opposed to the National Alcohol Program, in which the economic interests won over the social interests, one of the priorities of the biodiesel program is to create the conditions required for a competitive insertion of family agriculture and smallholders

into the base of the production chain. It also aims at ensuring the participation of the raw material produced in less developed regions, such as the Semi-arid, in order to contribute to the reversion of historical poverty patterns.

Such purpose, although indisputably legitimate, finds a great obstacle in the availability of farmable lands in other regions of the country that offer better conditions for intensive agriculture. So that defining a tax model bestowing tax benefits for the biodiesel produced under those special conditions (labor-intensive raw material from family farms/smallholdings, particularly in the poorer states) places the process at risk of low economic efficiency.

Consequently, considering that the federal tax load on fossil diesel is not as high as that on gasoline the tax dispensation for biodiesel produced in contexts of social inclusion could be insufficient to ensure competitiveness vis-à-vis production based on the use of raw materials from commercial plantations. This means that even without offering tax benefits for biofuel produced under commercial conditions, it could be more competitive than that based on raw material originating in family agriculture.

It should be emphasized that in other countries, like Germany, France and the United States, renewable fuels enjoy not only a different tax regime but also, in some cases, their production is directly subsidized. The prevalence of the environmental component allied to the issue of energy security, however, will not be seen during the initial phase of the Brazilian program.

It is also necessary to consider the need to think about biodiesel in a broader context. The compulsory fuel blend defined in Law Number 11.097 of 2005 creates a compulsory demand for a small fraction of the potential market. Thus, there is space for more concrete actions to enable higher levels of diesel substitution in specific market segments. It is the case of stationary generators in remote regions, self-consumption in rural operations far from fossil fuel refining and distribution centers, and some

types of large consumers, such as freight transportation companies.

Lastly, biodiesel has great business potential for the rural areas of Brazil. It will make it possible to conciliate developmental actions that aim at greater inclusion of the family farmers into the raw material production process with measures addressing economic and energy issues, whose purpose is to effectively insert the new fuel into the Brazilian energy mix with a view to reducing the country's dependency on fossil diesel.

The guidelines for the initial phase have already been established, but many adjustments will certainly have to be made to achieve the harmonization of the economic, environmental and social interests. The technological development process may offer new solutions to questions still unanswered. It is the case of the opportunities opened by the Hbio and cracking technologies and the research to arrive at a full control of the ethylic pathway in the transesterification process.

The government must remain watchful and be flexible enough to opportunely adopt any measures required to diminish investor risks and final consumer costs. The more effective and efficient the governmental actions, the faster and lower will the cost of the learning process be.

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Brazilian alcohol Prospects

Paulo Morceli¹

Generally speaking Brazilian agribusiness has had some rather difficult times, and a few sectors barely managed to survive. In turn, the sugar & alcohol industry has been going through a fantastic period, with sugar and alcohol highly valued in domestic and foreign markets. An in-depth analysis is required to understand the reasons of the current situation, consider the likelihood of such growth lasting, and forecast the sugar and alcohol industry's future.

In fact, the Kyoto Protocol has opened a window of opportunity for the Brazilian agribusiness in the biomass area (ethanol, biodiesel, cogeneration, etc.), and the country should strive to keep that window open. The purpose of this study is to draw the attention of the agents involved in the ethanol production chain to the need of grasping the excellent, albeit brief, opportunities opening before us.

The search for ways to reduce environmental pollution and achieve sustainability in the production sector, particularly in agriculture, is gaining momentum. The pressure is increasing for agricultural production to use practices that are less aggressive, or even not aggressive, to the environment. In the field of energy production and use, particularly onboard energy, scientists are looking for energy sources that cause less pollution and have higher productivities and lower costs, i.e., sources with a higher cost/benefit ratio.

Because of the large, farmable land tracks available without the need for deforestation

(deforestation no longer being acceptable) and its excellent climatic conditions, including high insolation rates, Brazil can take advantage of the prevailing conditions by supplying ethanol, animal fats and vegetable oils to produce biodiesel. Scientists, however, continue to work hard based on the certainty that finding an energy source that does not depend on nature is not far away.

In order to understand fully the purpose of this study, it is necessary to revisit the history of alcohol in Brazil and then return to the present time and current situation and, lastly, analyze the country's prospects.

The past

After an analysis of the data from the recent past it must be acknowledged that the sugar and alcohol industry has had a brilliant economic and technological performance, although that does not correspond to the prevailing opinion of the Brazilian public. Figure 1 shows that 82.22% of the total amount of sugarcane harvested in 1970-1971 went to produce sugar, mostly for the domestic market. Industry also produced 252,000 cubic meters of anhydrous alcohol (Brazil has used anhydrous alcohol mixed to gasoline since 1931) and 385,000 cubic meters of hydrated alcohol for other uses, especially in the pharmaceutical industry. At the time, Brazil processed 79.8 million tons of sugarcane, i.e., only 18.85% of the amount currently being industrialized.

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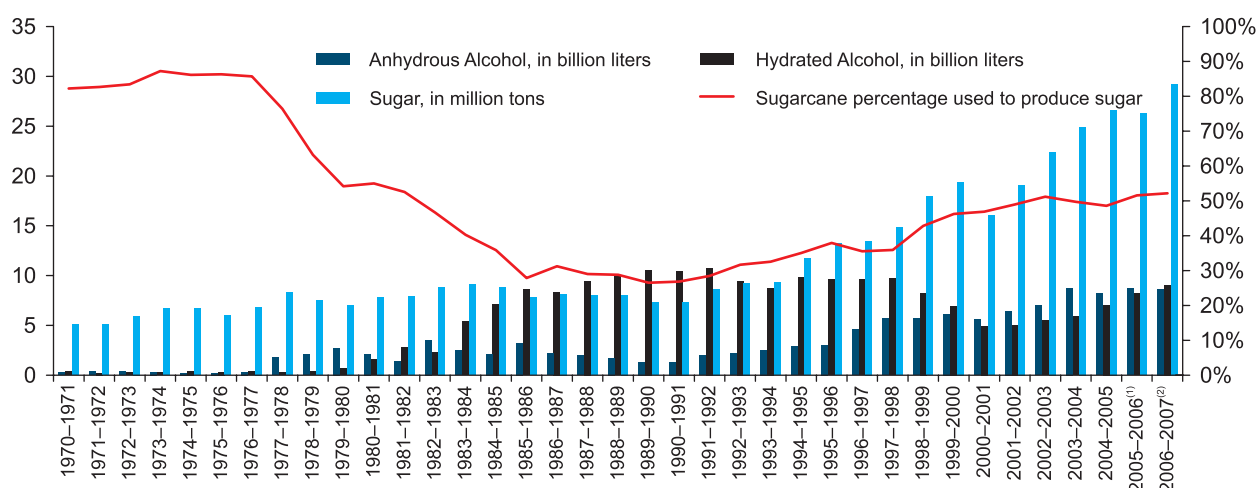


Figure 1. Sugarcane in Brazil: milled amount, sugar and alcohol produced.

⁽¹⁾ Estimated. ⁽²⁾ Predicted.

With the emergence of alcohol fueled cars in the late 1970s and a mandatory percentage increase in the alcohol mixed with gasoline, more sugarcane was planted and the 1979-1980 harvest totaled 138.9 million tons, with only 54.16% going to sugar production. Production at the time comprised 2,712,000 liters of anhydrous alcohol, since the amount of alcohol mixed to gasoline varied from 20% to 23%, and 671,000 cubic meters of hydrated alcohol, because the first, Brazilian-technology cars fueled with hydrated alcohol were already being manufactured and sold.

The growth of the light, alcohol-fueled vehicle fleet, as shown in Figure 2, and the substantial increase in the amount of sugarcane harvested led to a change in the profile of the sugar and alcohol product mix. In the 1985-1986 harvest, when the alcohol/gasoline car sales ratio was highest, sugarcane production rose to 224.4 million tons, of which 27.87% went to produce sugar and the remainder was transformed into 3,208,000 cubic meters of anhydrous alcohol and 8,612,000 cubic meters of hydrated alcohol. At the time, 697,049 units or 85.51% of all light cars sold in Brazil ran on alcohol.

The largest fuel sugarcane harvest was 1991-1992, when 228.8 million tons of sugarcane were processed, 64.72% more than when fuel alcohol use began. Only 28.50% of the raw

material was used to sugar (8.7 million tons), i.e., sugar production increased only 24.64%. Alcohol production had the largest increment, with anhydrous alcohol production diminishing by 26.84% and hydrated alcohol increasing by 1,460.95%. Thus, the total volume of alcohol produced increased by 248.20% when compared with the 1979-1980 production. Such growth was due to a change in the profile of the Brazilian car fleet: more hydrated alcohol cars and fewer gasoline cars.

In the late 1980s, the alcohol supply failed, disappointing Brazilian consumers and discrediting the country's capacity to ensure a steady supply of biofuel for the Brazilian car fleet. It is not the purpose of this study, however, to advance any hypotheses about who was responsible for the problems. The fact is that Brazilian consumers felt deceived when, having purchased an alcohol vehicle, they were unable to find the fuel to run it.

The discredit reached such levels that alcohol car sales dropped to only .08% of total sales in 1997, as compared with 85.51% of all cars sold in 1986. To further aggravate the situation, the lack of alcohol in the filling stations led consumers to believe that fuel retailers were unreliable, seeking only profits and having no commitment to the consumers' needs. This feeling is strongly rooted and emerges every

time prices go up without a convincing explanation, such as it happened in February 2003 and from January to March 2006. In order to exert some degree of damage control in the first case the Brazilian government made an agreement with industry, which was fully met and helped surmount the crisis. In the second instance, despite an agreement involving four ministries (Agriculture, Civil Cabinet, Treasury and Energy), industry did not comply, prices continued to increase, and the Brazilian consumer was left to shoulder the losses, with the terrible impression of having made a bad deal in buying a flex fuel car (the sugar and alcohol industry "sells" the idea that flex fuel cars are "alcohol" cars, which is not true, but increases the negative feelings regarding the supply of biofuels in Brazil).

It should not be forgotten, however, that Brazil, through the alcohol and automobile industries and with the support of government projects and research, was able to "invent" a substitute for petroleum fuel. This substitute fuel not only uses mostly Brazilian input, but also has great

ecologic appeal. As regards the Brazilian balance of payments, studies show that during the 1979-2000 period the country saved US\$ 43.5 billion by reducing petroleum imports. The savings were particularly relevant since that period corresponds to one of the darkest in Brazilian economic history, when the country did not have enough hard currency to import goods essential to its development.

The present

An analysis of Figure 2 leads to an erroneous impression of the current situation. Beginning in 2000, due to some governmental incentive programs such as, for example, the so-called "green fleet program" that encouraged the use of alcohol cars in order to increase alcohol consumption, there was some growth, albeit incipient, of alcohol car sales, so that, by 2003, 4.61% of all cars sold in the country were alcohol fueled. Volkswagen's release of flex fuel cars in November 2003 was a veritable landmark. Since then, the sales of cars that can

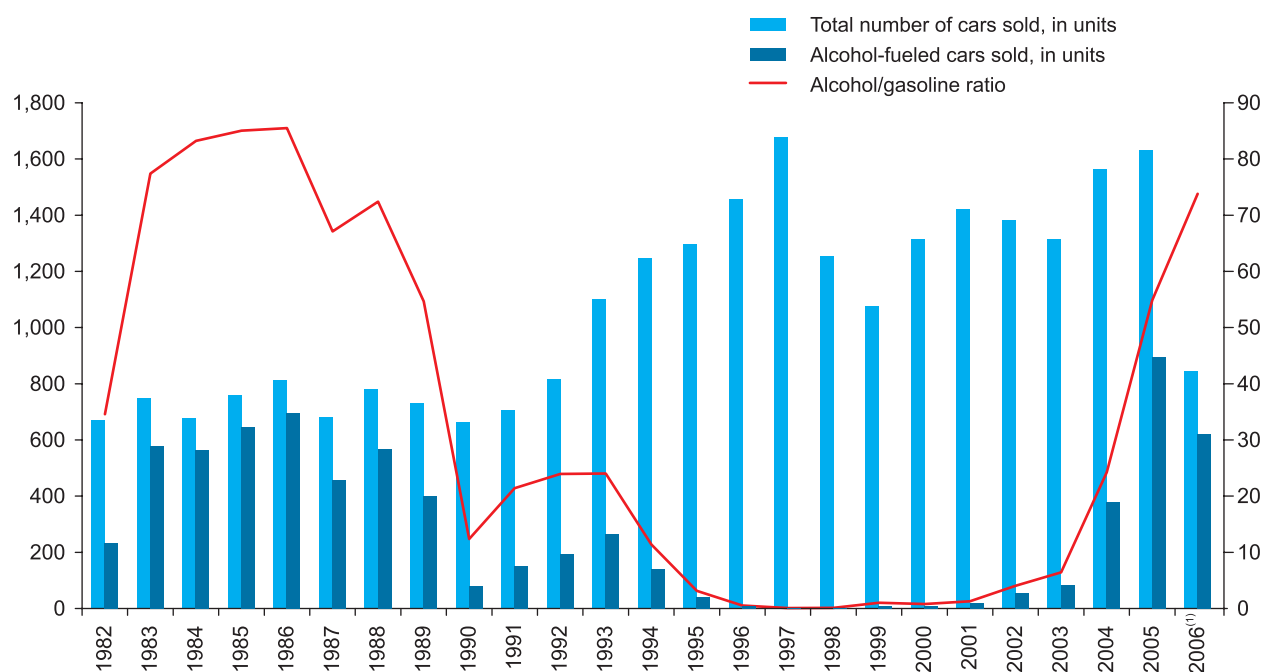


Figure 2. Light cars: sales of alcohol and C gasoline cars.

Design: Conab.⁽¹⁾ By June 2006.

Source: Anfavea.

either consume C gasoline or hydrated alcohol have grown substantially: of 1,631,217 new cars sold in 2005 in Brazil, 895,002 units were either alcohol or flex fuel, i.e., 54.87%. In 2006, based on the data for the January-June period, that percentage increased to 73.80%, or 622,508 alcohol or flex fuel units, from a total of 843,521 cars sold during the same period.

The current growth in "alcohol" car use is quite different from that of former years. Firstly, flex fuel cars were not manufactured to use only alcohol as fuel, despite the alcohol producers' efforts to "sell" that idea. The technology was developed to give consumers greater flexibility of choice, keep them from depending on a single fuel and letting them use the fuel that best meets their needs from the economic and ecological standpoints. Another important point is the motivation of the automobile industry. In the past, the design and manufacture of alcohol cars was a strong institutional imposition, with the federal government being the major inductor of the alcohol cars' implementation.

Now, automobile manufacturers are interested in that technology because they have "discovered" the great marketing appeal of giving consumers this type of option and an excellent technological advantage, since consumers can stop worrying about adjusting the engine to the different alcohol/gasoline mixtures resulting from the constantly varying blend ratios. Consumers do not actually have much choice, since industry, for a good number of models, only offers the flex fuel engine. This is the embryo of the so-called universal engine, whereby the same platform can be used in countries that mix 20% alcohol to gasoline, like Brazil; 10%, 5%, 7%, or nothing, like the USA; 3% as proposed for Japan; or nothing at all, as in most countries.

Fuel alcohol producers believe that the success of the flex fuel engine will bring along a greater demand for that fuel. With the addition of flex fuel cars to the alcohol car fleet, which was almost being discarded due to obsolescence, there are new hopes for hydrated alcohol

consumption in Brazil. As Figure 1 shows, hydrated alcohol production will exceed that of anhydrous alcohol in the 2006-2007 crop year, a situation unheard of since the 1999-2000 harvest.

Nevertheless, the flex fuel car fleet may lead alcohol producers into making serious mistakes. One cannot lose from sight the fact that those car owners are becoming aware, albeit gradually, that they do not own an alcohol-fueled car but, rather, a vehicle with an engine that offers them the choice of buying the cheapest fuel, without endangering their vehicle. A different situation from when the cars had an engine designed to run only on alcohol and, regardless of any price increase, the consumers could do nothing but pay more for the fuel in order to use their vehicles, or worse, stop using their cars when the filling stations ran out of alcohol.

With this in mind, let us examine Figure 3, which shows the comparative prices of hydrated alcohol in the State of São Paulo, home of the largest light vehicle fleet in the country, and in the Federal District, which imports all the fuel consumed there, although it owns a representative fleet. It can be observed that for a good part of the period under analysis São Paulo car owners preferred alcohol, since there were some financial advantages involved. In the Federal District, on the other hand, as a rule flex fuel car owners will only fill up with alcohol if they desire to be politically correct as regards the environment, unconcerned about spending a little more money to use their cars, or not even perceiving the economic aspects involved.

Another important issue in the fuel market relates to the transfer of price increases among the agents in the fuel production/distribution/retail chain. Looking once more to the two states in the previous comparison, Figure 4 shows the effects of price changes in the alcohol industry, starting from the Esalq Index, and what happens at the distribution and retail levels according to data made available by the National Petroleum Agency (ANP). It is easy to

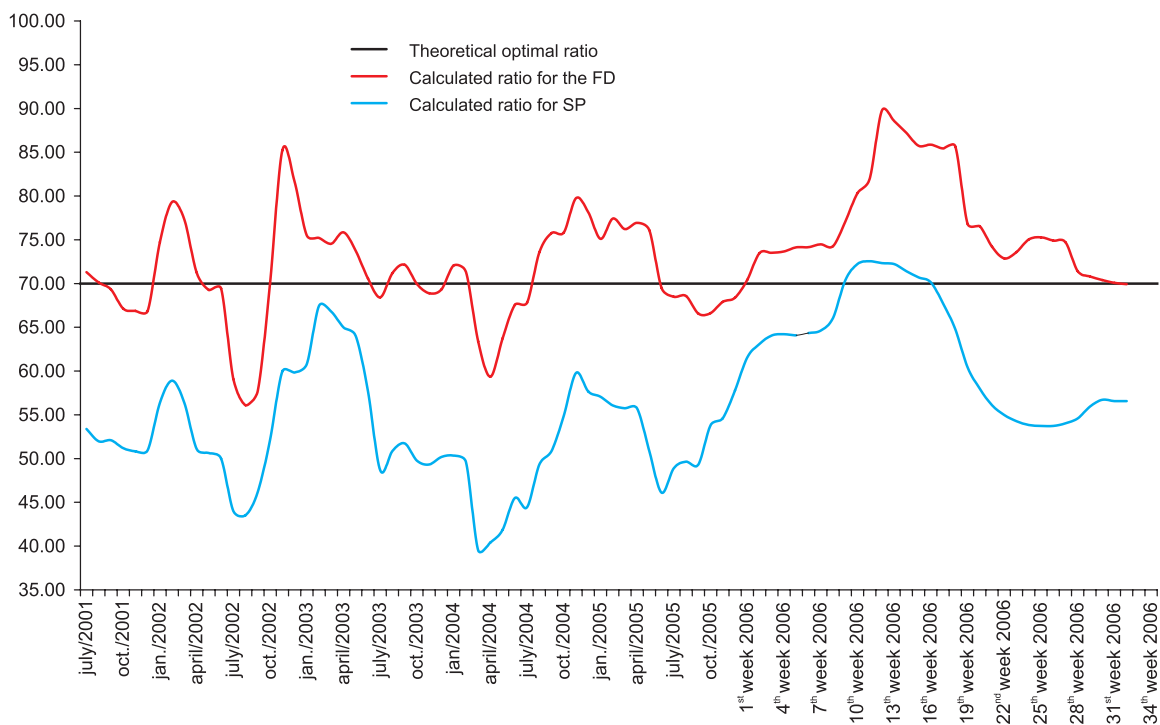


Figure 3. Hydrated fuel alcohol and type C gasoline: fuel price ratio in %.

Source: ANP. Design: CONAB.

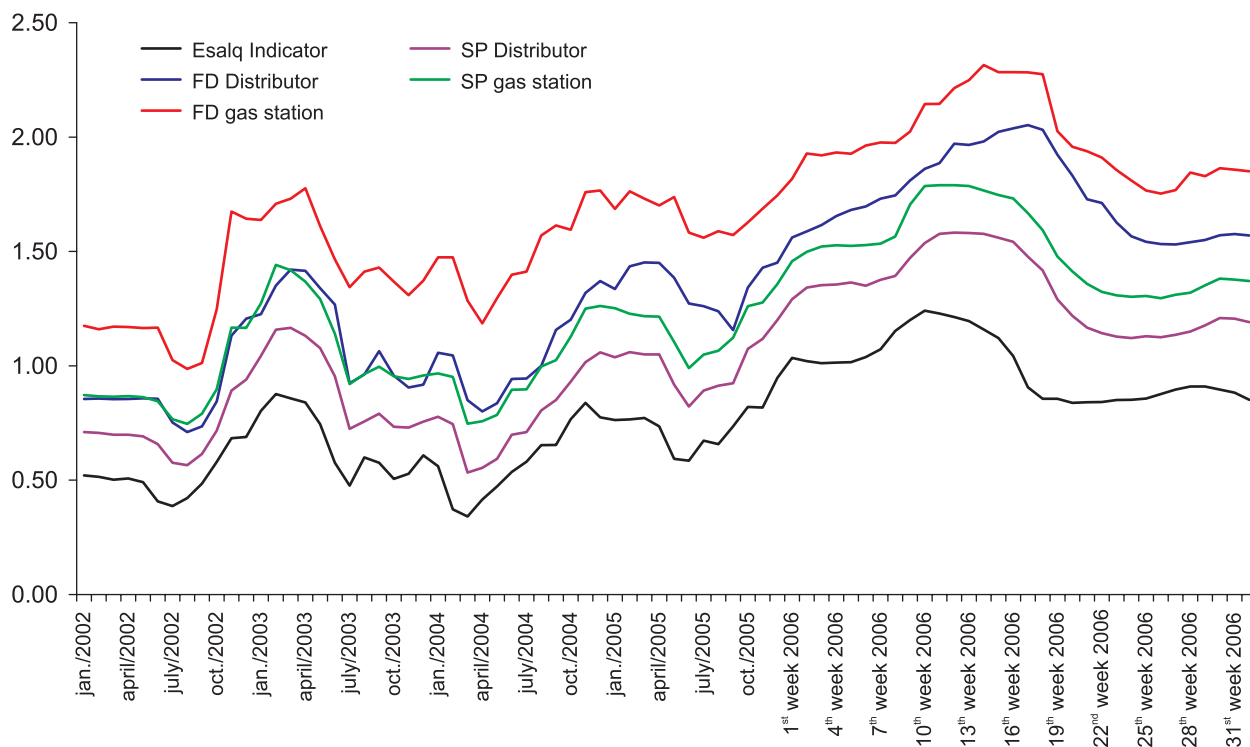


Figure 4. Hydrated fuel alcohol: price transfer from industry to distributors to gas stations in the FD and SP, in R\$/L.

Source of the basic data: ANP and Esalq/Cepea.

Design: Conab.

see that in São Paulo, due to the industries, distributing companies and filling stations being located close to one another, price changes are rapidly reflected along the whole chain. In the Federal District, since all fuel consumed is imported, the delivery, availability and sales times involved result in slower price change transfers.

Considering the economic growth some important countries are undergoing and the new rules that the World Trade Organization (WTO) has imposed on the European Union, Brazil emerges as a major sugar exporter in the near future. According to projections of the International Sugar Organization, MECAS(05)20, November 2005, for the total exports during the 2005-2006 harvest (October and September), out of 46.5 million tons raw cane sugar Brazil will contribute 19.1 million tons, or 41.08% of the total amount. So that the international market quotations strengthened the industry's remuneration, since Sugar 11 contract quotations at NYBOT, for example, reached US\$¢ 19.30 per pound on 3 February 2006, while on that same date, the previous year, the quotation was US\$¢ 8.94 per pound, or the equivalent to a 115.88% valorization.

In fact, Brazilian sugar exports have continued to rise rapidly. In 2005 the country shipped 18.1 million tons at an average price of US\$ 215.95 per ton, for a total of US\$ 3.9 billion. The previous year, shipments had totaled 15.8 million tons at an average price of US\$ 167.89 per ton, adding up to US\$ 2.6 billion. These data provide a perfect idea of how well the market has remunerated the sugar and alcohol industry's sugar exports.

Regarding the alcohol market, the larger fleet of vehicles technologically prepared to use that fuel directly in the tank already represents an important factor in the growth of the domestic demand. Furthermore, the world is discovering that alcohol is an excellent addition to gasoline and expects Brazil to supply it. In 2004, alcohol shipments totaled 2.4 million cubic meters, sold at an average price of US\$ 322.94 per cubic meter, adding up to US\$ 497.4 million. Last year, shipments totaled 2.6 million cubic meters

(an increase of only 8,33%). The average price was US\$ 459.95 per cubic meter (a 42.43% increase), or US\$ 765.5 million (a 53.90% increase).

An analysis of alcohol exports' performance explains why sugar and alcohol businessmen are so motivated to make new investments. According to Informativo Única, January/February 2006, 19 new industries will contribute to the 2006-2007 harvest in the Center-South, of which 11 are located in the State of São Paulo. According to the JBIC Report on the potential of the Brazilian bioenergy market, there are 50 new plants being built in the states of Goiás, Minas Gerais, Mato Grosso do Sul, Paraná, Rio de Janeiro, and São Paulo. These new plants will process 75.5 tons of sugarcane in the 2011-2012 crop year. There is information about 104 new sugar plants almost ready to operate, currently being assembled, designed, or in the consultation phase, in the Center-South region.

One could say, therefore, that for the next few harvests there will be businessmen prepared to set up 150 sugar and alcohol plants with a joint capacity for milling 225 million tons of sugarcane. The big question is: what will the final destination of all that production be? As regards the use of the raw material, if the sugar/alcohol ratio were maintained, 14.6 million tons of sugar and 10.1 billion liters of alcohol would be produced. The growth capacity of the domestic market is limited for both products. In the case of sugar, consumption growth is negligible, below the vegetative growth of the population, while in the case of alcohol, even if flex fuel cars used only alcohol, the increased demand would certainly be insufficient to absorb the total supply, which might take us back to the May 1999 situation, when hydrated alcohol was being sold for R\$ 0,16532/liter at the distilleries.

The future

Despite the growing world demand for sugar resulting from the growth and development of

countries previously at the margin of consumption of foods and beverages that use sugar as raw material, the sugar export potential is more limited, contrary to that of alcohol as a gasoline additive. The largest market for the products of the sugar and alcohol industry, therefore, is the international biofuels market.

With regard to alcohol as a gasoline additive, with the implementation of the Kyoto Protocol and the growing world concern over atmospheric pollution, the supply of a less polluting fuel is politically and ecologically welcomed. According to American Government data available at <http://www.eia.doe.gov/ipm/demand.html>, during the first quarter of 2006 the average petroleum consumption was 85.3 million barrels per day. After making the necessary conversions, this comes to 998 billion liters of gasoline per year for the whole world. If we consider the entirely feasible possibility of adding an average 10% anhydrous alcohol to gasoline, we come up with a total demand of 99.8 million cubic meters of alcohol per year.

As was previously emphasized, the appeal of alcohol as a gasoline additive is associated with concern for the environment. Thus, it is worthwhile providing some indication of alcohol's ecological impact. According to studies, each cubic meter of anhydrous alcohol decreases emissions by 2.7 CO₂-equivalent tons. Considering the previously estimated total demand the result would be 269.5 million CO₂-equivalent tons removed from the atmosphere every year. Imagine a world from which that amount of carbon dioxide is removed annually, and what that would mean in terms of improving the environment.

For alcohol to become the additive used by most countries instead of methyl tertiary-butyl ether (MTBE) much must be done in the sugar and alcohol industry, as emphasized in the study "Internacionalização do Álcool Anidro para Uso como Aditivo à Gasolina"², whose main lines are worth mentioning.

a) Establishing credibility. Fuels are strategic goods in any country of the world. The supply of

the additives currently being used is already stable and associated with the same rules of supply of petroleum products. Governments will be reluctant to change their energy mix unless long-term contracts guaranteeing supply and pre-established price rules are available. Consequently, the sugar and alcohol industry should be aware that the relative ease with which it is possible to switch the product being produced in their industrial plants may be a short-term advantage, but might not bring good results in the future. The alcohol price scenario in Brazil this year, with producers defaulting on their agreement with the federal government and forcing a reduction from 25% to 20% anhydrous alcohol mixed into gasoline, has seriously harmed their credibility as a steady source of fuel. Such state of affairs would have to change before international decision-makers see Brazil as a safe and reliable supplier.

b) Need of partnerships. In such a huge undertaking it is not possible for the Brazilian sugar and alcohol industry to be the sole world supplier. It is necessary to establish partnerships with other countries that can produce anhydrous alcohol and do away with the idea of dependence on a single supply source. Having several supply sources should counter the idea that Brazil would control alcohol supplies and assure countries that the product would be available and no price cartels would be formed. In addition, meeting the world demand would require amounts of anhydrous alcohol beyond Brazil's production possibilities for quite some time and the adhesion of other producing countries would greatly help countries for which supply security is still the prevailing factor make the decision to add alcohol to gasoline. In this process, since Brazil masters all the phases of the agricultural, industrial and logistics technologies, the country would be able to sell the technologies to those interested and add, therefore, another rather lucrative branch of business.

² Translator's Note: Internationalization of Anhydrous Alcohol for Use as Gasoline Additive.

c) Improving the production technologies. At the present time, the existing technologies enable the sugar and alcohol industry to produce an average 6,000 liters of anhydrous alcohol per hectare. The country has more than 60 million hectares of idle lands available for sugarcane farming, and those agricultural areas are already available and pose no threat to the environment. Nevertheless, if Brazil were to supply 30% of the total alcohol calculated previously and considering present yields, it would be necessary to farm sugarcane over approximately 5 million hectares, which added to the current 3 million hectares, would come to 8 million hectares, which could be considered a very large area for a single crop. There are agricultural and industrial technologies available that permit doubling the production per hectare, so that Brazil could export approximately 30 million cubic meters of anhydrous alcohol and only incorporate 1/3 of new sugarcane areas.

d) Logistics issues. At present, alcohol is transported mainly by truck. This means of transportation has some advantages, but it is expensive and its transport capacity is low. For an operation of the volume intended it would be necessary for Brazil to adopt a very efficient and inexpensive transportation system. The best idea is to use the infrastructure available in the Transpetro duct corridors and build a parallel alcohol duct. The Transpetro ducts start in Brasília, go through the Triângulo Mineiro, cross the main sugarcane region in São Paulo, and arrive at the Alemoa Terminal in the Port of Santos and at the Port of São Sebastião, both specializing in fuel logistics, as seen in Figure 5. Using that route would solve several problems: no new environmental licenses would be needed, since the petroleum ducts have already been authorized; no safety and security issues would arise, since Transpetro has already dealt with them for the existing ducts; no expropriations would be needed, so no new major expenses would be required; and a highly specialized and efficient fuel transport operator is already in place. Thus, alcohol would reach very low cost, highly efficient ports, enabling the sugar and alcohol industry to enter into

contracts for large volumes of anhydrous alcohol, at prices not only highly profitable but also competitive in comparison with those of the petroleum products.

e) Institutional Security. In the 1990s Brazil completely deregulated the sugar and alcohol industry and the supply of biofuels. That is one of the reasons there has been occasional difficulties in meeting the goal of supplying fuel for Brazilian vehicles at affordable prices. It is possible, and desirable, for the same rules to apply to fuel exports, i.e., that there be no institutional interference on the part of the government. Nevertheless, were there any difficulties showing that the market expansion is not taking place at the expected rate, a joint venture of the government and the private initiative could be formed for the purpose of seeking and guaranteeing fuel alcohol exports. The joint venture would also aim at finding potential partner countries for alcohol production and export, providing the technologies required for the endeavor and attracting alcohol buyers.

Conclusion

The sugar and alcohol industry has arrived at a sensational point in time. There is high demand for the two products, particularly in foreign markets. The growth scenarios for the international market are very good, especially for anhydrous alcohol. Nevertheless, the industry is faced with problems of credibility, partnerships, technological development, and logistics solutions that must be solved rapidly. If the sugar and alcohol industry has no ready answers by the time that half the new plants become operational, the possibility of prices dropping to undesirable levels is considerable. It is a fundamental issue for the sugar and alcohol industry to solve, with the help of the government.

It should be noted that this open window for the use of liquid biofuel must be grasped as soon as possible. Research for more efficient and less



Figure 5. Alcohol transfers in Brazil – Transpetro Duct Network.

Source: www.transpetro.com.br/portugues/empresa/dutosTerminais/mapas/mpdctcs.gif

expensive alternatives is proceeding rapidly. The scientists are engaged in dozens of projects and, very soon, a cheaper and ecologically better alternative will emerge and make the use of alcohol or any other onboard liquid fuel completely unviable. Ideas are welling up in several research centers and new solutions will be available in 20 or 30 years time. Thus, if Brazil and the sugar and alcohol industry want to take advantage of the current situation and reap large profits from exporting a product for

which Brazil has taken the lead, this is the time to do it. They must proceed at once and very efficiently. Nature has bestowed many bounties on Brazil and, thus, the country can contribute to reducing world pollution by supplying the best light-vehicle fuel ever conceived and, at the same time, derive appreciable gains. To that end, government leaders and the private initiative must join forces and together seek that market. It is hoped, therefore, that Brazilians are indeed prepared to meet this challenge.

Use of animal wastes to generate biogas

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Paulo Armando V. de Oliveira²

Abstract: While the momentous changes in the confined animal production systems (Caps) have brought significant progress to the animal production industry they have also caused environmental problems due to the pronounced concentration and increased scale of the activities. As a result, new alternative solutions are necessary to mitigate the problems and aggregate value to the wastes from production. The generation and use of biogas obtained from animal wastes emerges as an interesting alternative, since it enables the use of the biogas generated in the farm as a source of thermal and electric power, decreasing the energy cost of the farm.

Key words: environmental impact, energy, animal wastes.

Introduction

Animal production has undergone extensive changes in the last decades. Pig production, which was formerly based on large scale outdoor operations, now emphasizes intensive housing-based systems, also called confined animal production systems (Caps). The main purpose of the latter is to reduce production costs and increase production efficiency. Brazil stands out in the confined animal model and, as a result, has substantially increased its exports to international markets. Nevertheless, environmental problems have also grown due to the high concentration of animals in relatively small areas and, therefore, new alternatives are necessary to minimize the problems and aggregate value to Caps wastes to the extent possible. To that end, the generation and use of biogas is an interesting alternative for mitigating environmental problems.

Anaerobic digestion is an old, well-known process traditionally used to produce biogas as a

source of energy for cooking and lighting and of biofertilizer. It is very popular in China and India, for example.

Interest for biogas in Brazil grew in the 1970s and 1980s, particularly among pig farmers. Official programs promoted the implementation of many biodigesters that focused, in particular, on the generation of energy and the production of biofertilizer, as well as on decreasing environmental impacts. The purpose of the governmental programs was to reduce the small farmers' dependence on purchased chemical fertilizers and thermal energy for various uses (cooking, lighting, heating, and cooling), as well as reducing the pollution caused by animal wastes and increasing farm incomes. There were some unforeseen results, unfortunately, and most of the existing systems were shut down.

Several factors coming together led to the failure of the biodigester programs at the time, as follows.

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- a) Lack of technological knowledge about the construction and operation of the biodigesters.
- b) High implementation and operation costs (masonry, concrete or stone chambers, metal gasometers).
- c) Using the biofertilizer produced required equipment for distributing liquids, with high purchase, transportation and distribution costs.
- d) Lack of equipment developed for use with the biogas exclusively and low durability of the equipment adapted to convert the biogas into energy (burners, heaters and motors).
- e) Lack of water condensers and filters for the corrosive gases generated in the biodigestion process.
- f) Availability of low cost electric power and LPG.
- g) Non-resolution of the environmental issues, since biodigesters, in and of themselves, cannot be considered a complete treatment system. Other determining factors of the biodigesters' failure included crass mistakes in biodigester sizing, construction and operation.

Thirty years later biodigesters emerge as an alternative for farmers thanks to the availability of new materials to build the biodigesters and, obviously, the farmers' growing dependence on energy resulting from production scale increases, energy mix (required by automation) and the higher cost of traditional energy sources (electric power, firewood and petroleum). The use of plastic sheets, a very versatile and low cost material, for building the biodigesters has undoubtedly been instrumental in lowering the investment costs and making biodigesters more popular (OLIVEIRA, 2005).

Anaerobic biodigestion

Understanding the process involved in obtaining biogas is very important for success, since biogas production and utilization complement each other. If care is not taken in generating biogas, its use will be seriously compromised.

Anaerobic decomposition is enabled by the action of microorganisms, and one of its final products is methane (Figure 1). The biogas produced during anaerobic degradation is mainly methane (50%-70%) and CO₂. The gas can be collected from the anaerobic degradation system and used as a fuel (heat or energy generation). The most representative systems for treating animal wastes through anaerobic degradation are the biodigesters.

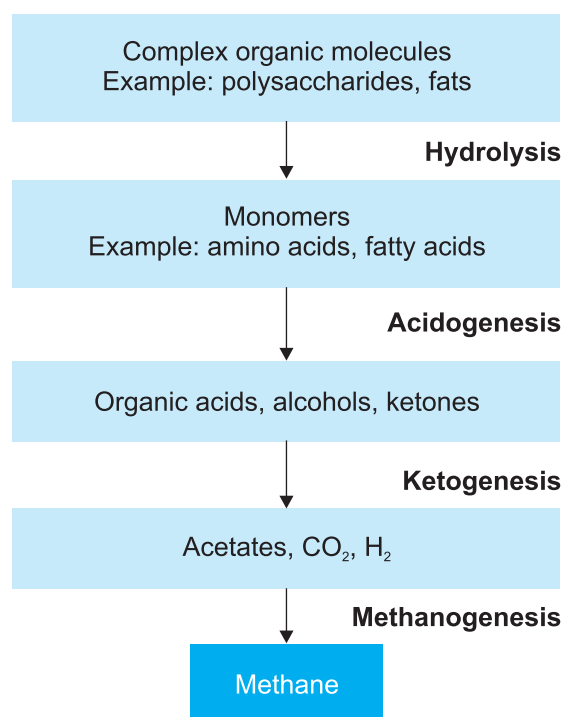


Figure 1. Anaerobic degradation stages.
Source: Bitton (2005).

Biodigesters are closed anaerobic degradation systems in which the gases produced are collected and stored in a compartment called the gasometer for later use or simply for burning. Several models of gasometers have been developed and adapted with a view to increasing the efficiency of the systems and decreasing equipment costs (REUNIÃO TÉCNICA SOBRE BIODIGESTORES PARA TRATAMENTO DE DEJETOS DE SUÍNOS E USO DE BIOGAS, 2006).

The main models are the Indian, Chinese and Canadian biodigesters. The Canadian model has been extensively used lately because of the development of geomembranes that facilitate the installation of the biodigester.

Biodigesters sometimes have efficiency problems due to incorrect management or to the influence of the environmental temperature. The latter variable can alter the temperature of the biomass inside the biodigester and, during the winter months, reduce microorganism activity, since their optimal growth temperature is around 35 °C (OLIVEIRA, 2005). In Brazil, the temperature factor is more significant in the southern states, where the prevailing conditions include wider temperature variations and more rigorous winters, precisely when the thermal energy demand is highest (KUNZ et al. 2005).

In using biodigesters care must be taken with the disposal of its highly polluting effluent (Table 1), mainly because of its nitrogen and phosphorus contents.

Table 1. Average (gL⁻¹) organic and nutrient loads calculated for biodigester inflow and outflow.

Parameter	Inflow	Outflow
DQO	66.9 ± 13.5	8.5 ± 1.0
DBO ₅ ²⁰	34.8 ± 7.4	3.2 ± 1.2
N-NH ₃	2.6 ± 0.8	2.3 ± 0.7
N _{Total}	4.8 ± 1.1	3.2 ± 0.5
P _{Total}	1.60 ± 0.41	0.22 ± 0.14
Volatile Solids	41.7 ± 15.6	9.7 ± 4.9

Source: Kunz et al. (2004).

Biogas generation capacity as a function of the type of waste being used

The generation of biogas from animal wastes depends not only on the Caps' temperature, pH, alkalinity, and management system, but also on the characteristics of the waste itself, which is the substrate that supports microorganism growth in the biodigester (Table 2).

This difference in biogas generation capacity is associated with several factors, such as the animals' diet and their digestive system, which produce wastes with distinct characteristics and diverse biogas production potential.

A study was made from July to December 2004 to evaluate biogas production. The study was conducted in a farm with 400 pigs in the growth-termination phase and with a Canadian-model biodigester whose digestion chamber capacity was 100 cubic meters (m³) of biomass (OLIVEIRA, 2004; OLIVEIRA et al., 2005). The biodigester's biomass chamber was excavated in the soil and lined with a PVC vinyl blanket .8mm thick. The biogas deposit was also lined with PVC vinyl blanket, 1mm-thick in this case. The biodigester had been designed with a Hydraulic Retention Time (HRT) of 30 days, during which 2.45 m³ of wastes were fed on a daily basis. The amount of biogas generated was recorded with a Liceu MG-4 measuring device with a maximum capacity of 4 m³/hour. Physicochemical analyses were performed on waste samples collected every week at the biodigester's entry and exit points. During the observation period, the average and mean deviation of the weekly density measurements (kg/m³) of incoming pig wastes were 1,032.15 ±

Table 2. Biogas generation potential by type of organic animal waste.

Animal (Live weight)	Kg manure/Animal/Day	M ³ biogas/Kg manure	M ³ biogas/Kg VS	M ³ biogas/animal/day
Bovine (500 kg)	10–15	0.038	0.094–0.31	0.36
Swine (90 kg)	2.3–2.8	0.079	0.37–0.50	0.24
Poultry (2.5 kg)	0.12–0.18	0.050	0.31–0.62	0.014

Source: Oliveira (1993). VS: Volatile solids.

15.38, and those of outgoing wastes were $1,010.32 \pm 2.24$. The average density of incoming wastes (8.77 % total solids) can be considered high when compared with the average 2.5% total solids observed in other pig farms in Western Santa Catarina. The waste density in the farm studied was obtained through appropriate management of pig wastes (dry scrapping and cleaning only after the animals had left the facilities) and use of a new drinking device that wastes very little water. The density numbers correlate with the total solids (TS) and volatile solids (VS) numbers, so that the higher the density, the higher the TS and VS concentrations. The average biomass temperature in the biodigester was 23 °C, which indicates that the anaerobic digestion of the biomass occurred, predominantly, in the presence of mesophilic bacteria. At the entry point, the average and standard deviation for the solids' concentrations were $65.12 \text{ g/L} \pm 23.7$ for TS and $53.1 \text{ g/L} \pm 20.8$ for VS. The minimum biogas production recorded was 40 m^3 in August, while the maximum production was 60 m^3 in December (OLIVEIRA et al., 2005).

The mathematical model developed by Chen in 1983 and described by LA FARGE in 1995 was used to estimate the biogas production of the biodigester in the study (100 m^3). Figure 2 shows the biogas production numbers estimated using the Chen model (1983), at the operating temperature (23 °C), for different load concentrations.

When appropriately managed, biodigesters installed in pig farms can produce biogas with a production efficiency that varies from .35 to .60 cubic meters of biogas per cubic meter of biomass. For an economically acceptable biogas production, waste management at the pig farm should aim for the highest concentration possible of volatile solids and avoid waste dilution resulting from rain, water spilled from the drinking troughs and too much water used for cleaning the facilities (OLIVEIRA et al., 2005).

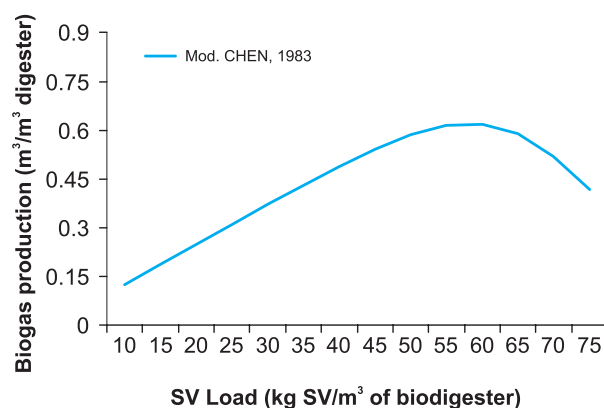


Figure 2. Specific biogas production (m^3/m^3 of biomass) estimated using the CHEN Model (1983), using the temperature, volatile solids (g/L), waste outflow (liter/day), and biodigester food load values recorded.

Biogas uses

Generation of thermal energy

Two major challenges in regions with high animal concentrations are reducing greenhouse gas emissions and, particularly, using methane (CH_4) as a source of thermal energy to replace liquefied petroleum gas (LPG) in the pig and poultry producing systems. Embrapa Pig and Poultry, one of Embrapa's research units, studied the use of biogas for heating poultry housing in July 2004. The farm has 400 pigs in the growth-termination phase and a 1200 m^2 ($12 \times 100 \text{ m}$) poultry shelter with 14,400 birds ($12 \text{ birds}/\text{m}^2$) (OLIVEIRA; HIGARASHI, 2006). The farm also has a Canadian-type biodigester. Eight bell jars fabricated for use with LPG were adapted for biogas by increasing the diameter of the gas injector nozzles to 1.5 mm (1.7672 mm^2). The bell jars were managed as follows: five bell jars were used during the day (12 hours) and eight, at night (12 hours). The pressure in the biogas feed line to the bell jars was $.517 \text{ kg}/\text{cm}^2$ (523.85 Pa) (OLIVEIRA; HIGARASHI, 2006).

The heat generation capacity of biogas was tested in the broiler production part of the farm. The temperatures in the poultry housing were

recorded every 15 minutes using a Testo-175 data logger. The temperature of the biomass in the biodigester was 25 °C. The average TS concentration and the standard deviation recorded at the incoming point were 75.12 g/L ± 16.7 and those of the VS concentration, 56.31 g/L ± 18.8. The average biogas production during the observation period (July 2004) was 52 ± 10 m³. The average biogas consumption recorded for the bell jars was .226 m³/h (for a total daily average of 35.256 m³).

The average dry bulb temperature inside the poultry housing was 28.09 °C, ranging from a 32.86 °C maximum to a 21.68 °C minimum. Outside the poultry housing the average dry bulb temperature was 11.29 °C, ranging from a 22.5 °C maximum to a 2.47 °C minimum. The heat fluxes were estimated as a function of the observed values for temperature, relative humidity, air velocity, and the body mass of the animals, the total heat flux being 42.52 W/m²; the sensitive heat flux, 76.51 W/m²; and the latent heat flow, 23.17 W/m² (OLIVEIRA; HIGARASHI, 2006).

Figure 3 shows the dry bulb (°C) temperatures inside and outside the poultry housing in the broiler farm on days 14 and 21 of the production cycle.

The studies carried out by Oliveira e Higarashi (2006) showed that the biogas produced daily from the wastes of 400 pigs in the growth-termination phase can replace LPG as heat source. The biogas can generate enough thermal energy to heat the poultry housing, keeping the temperature within the thermal comfort range for the production of 14,400 broilers.

Generation of electric power

Pig production systems generate large amounts of wastes that can be treated to transform organic matter into an alternative energy source - biogas - for the purpose of feeding electric power generators. Nevertheless, it should be

emphasized that despite the favorable prospects the use of biodigesters in farms is not common due to the lack of both knowledge and technological information about those systems.

Studies by La Farge (1995) and Bleicher (2000) evaluating electric power generation using biogas in pig farms concluded that this type of energy generation is both technically and economically viable.

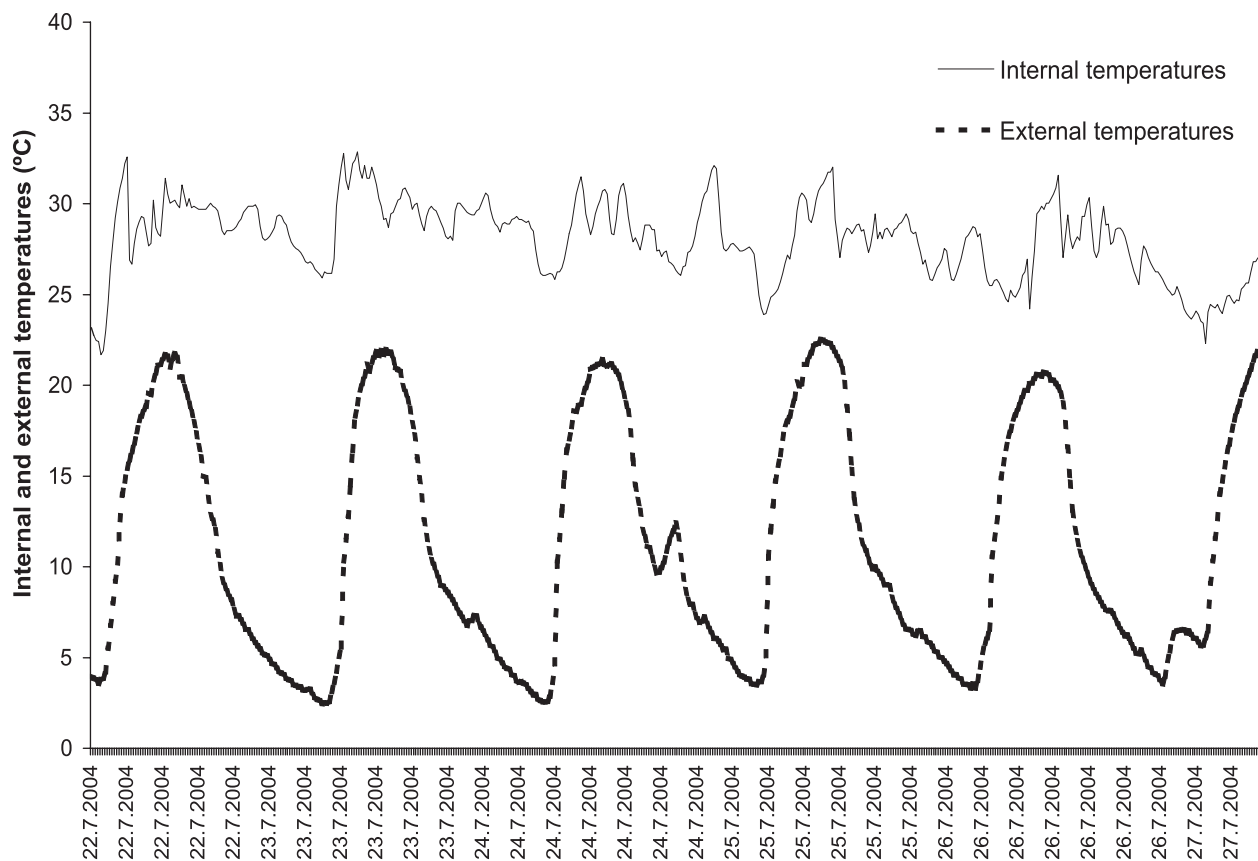
According to OLIVEIRA, 2004, electric power generation using biogas as fuel can be divided into the following already available technologies.

1- Electric power generator set – It consists of an Otto Cycle internal combustion engine (alcohol, gasoline or diesel) adapted to use biogas as fuel, attached to a stand-alone electric power generator.

2- Alternative electric power generator set – It consists of an Otto Cycle internal combustion engine (alcohol, gasoline or diesel) adapted to use biogas as fuel, attached to an asynchronous, two- or four-pole motor that generates energy when connected to the local electric power grid.

In the first case, the power generator set is independent of the local electric power grid. It generates energy within the farm using a separate internal electric grid. In the second case, the equipment only generates electric power when connected to the local electric power grid and stops working in the event of interruptions in the supply, which eliminates the possibility of accidents during maintenance work in the external power grid. In this case, the energy generated can be distributed throughout the farm and to the external power grid up to the closest transformer.

A study by Zago (2003) evaluating the biogas' potential to produce integrated energy in the midwest of Santa Catarina concluded that the average energy consumption of farms varies from 600 to 1,800 kWh/month. The study only considered pig production (an average of 50 m³/day of biogas). Theoretically, the energy



Temperature recordings over a 6-day period (July 2004)

Figure 3. Internal and external dry bulb temperatures (°C) recorded at the broiler production facility on days 14 and 21.

Source: Oliveira e Higarashi (2006).

generation capacity per farm was 2,700 KVA/month, or the equivalent of approximately 2,160 kWh/month. This production level enables farms to become self-sufficient in electric power, provided they adopt a system that generates 25 KVA/h of electric power.

Some European Community countries and Australia have specific legislation contemplating energy production from renewable sources. In Australia, for example, electric power companies must produce at least 2% of the energy sold from a renewable source, so that the market value of this type of energy is higher.

Biogas consumption varies from 16 to 25 m³/hour in the generator/stationary motor system depending on the amount of power generated.

It should be emphasized that when the energy contained in the biogas is transformed into electricity, the yields vary from 25% to 65% when the electricity is transformed into thermal energy. On the other hand, electric power is a type of energy easy to use and also, in the case of biogas, with a rather low production cost.

A pig farm producing 80 to 100 m³/day of biogas can generate approximately 120 to 150 KVAh/day of electricity from the biogas. If its average consumption were 1,000 kWh/month, the farm would have an idle generating capacity of approximately 3,000 kVAh/month provided the system operated an average 6 hours/day. To pay for the investment, the farmer would have to find ways of spending the surplus energy or selling it to the local electric power company, which is

technically possible. According to estimates, the undertaking becomes economically viable when the farm's biogas production capacity is 200 m³/day, which would come to an electric power generation of approximately 300 kVAh/day (ZAGO, 2003). Since most pig farms do not meet that prerequisite the farmers could establish a cooperative or mutual company to purchase the equipment, and everyone would benefit. The farmers would add value to their products and have another source of income; the government would have an alternative source of electric power in times of energy crisis; and the environment would benefit from lower pollution levels. The use of biodigesters to generate electric power would encourage small pig farmers to manage and treat adequately the wastes from the animals produced in their property (OLIVEIRA, 2004).

Final considerations

The use of biodigesters to generate biogas in the farms and produce heat and energy is a viable alternative that has awakened great interest from farmers due to the possibility of aggregating value to animal wastes. Nevertheless, the issues involving the final disposal of biodigester effluents should be approached using technical criteria in order to prevent any environmental impact of the effluents, since the final residues are highly polluting.

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Biodiesel production costs in Brazil¹

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Leandro Augusto Ponchio³
Lucilio Rogério Aparecido Alves³
Mauro Osaki³
Mariano Cenamo³

Abstract: This study calculates and analyzes biodiesel production costs from farming to the processing stages. The study considered the biofuel produced from six agricultural raw materials in the five geopolitical regions of Brazil and in three industrial scales. In one instance the cost was calculated taking into account the inclusion of the agricultural raw material as a production cost and, in the other, on the basis of the respective regional market price. The study considers the processing plants that comprise both raw material crushing to obtain the oil and biodiesel processing. In the biodiesel calculations and analyses the costs and yields of the byproducts during the raw material crushing and biodiesel production operations were included in the total costs, whether positive or negative, without including commercialization margins. In this case, therefore, the cost of biodiesel can increase to make up for byproduct-related losses or decrease as byproduct-related gains are incorporated. The overall results show that the biodiesel produced from cottonseed in the Northeast Region of Brazil is the most competitive in the country.

Key words: biodiesel; biofuel; renewable energy; economic analysis; production costs; trade.

Introduction

The purpose of the study is to calculate the production cost of biodiesel produced from different agricultural raw materials in the five geopolitical regions of Brazil and in different industrial scales. The study is expected to provide input for the formulation of policies regarding biodiesel. It is acknowledged that the broadness of the study implies the use of averages for some variables, which could compromise the precision of the results. On the other hand, it has the merit of being unbiased about the costs of biodiesel for all interested parties.

The analysis of inter-sectoral and inter-regional impacts resulting from the installation of

biodiesel production plants was not included in the study. For the evaluation of such impacts, an overall balance analysis is recommended.

The study also considered the use of the raw materials produced or producible in each region. This means that biodiesel production was studied on the basis of the following raw material/region combinations: soybean and sunflower in the South; soybean, sunflower and peanuts in the Southeast; soybean, cottonseed and sunflower in the Center-West; soybean, cottonseed and castor beans in the Northeast; and soybean, castor bean and African palm tree in the North.

For each region, the calculations included three industrial production scales: 10,000 tons; 40,000

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tons; and 100,000 tons of biodiesel per year. Regardless of the scale, the study considered integrated industrial units, i.e., plants that both extract the oil and produce the biodiesel.

The main criterion for locating the industrial plant was the availability of the agricultural raw material to produce the oil. To that end, the agricultural calendars of the five regions were carefully examined, as well as the average yields during the 1999-2000 to 2003-2004 crop years (the 2004-2005 harvest data for all cultures had not yet been consolidated in June 2005).

The next step was to make a detailed calculation of the production costs of each agricultural raw material - the cost of the raw product arriving at the oil extraction plant. At the same time, the market prices of the same products were surveyed in order to carry out a comparative analysis of the final costs of biodiesel depending on the type of acquisition, i.e., whether formed using the production cost or the market price.

After the analysis of the agricultural sector, the study focused on the industrial cost centers, subdivided into the crushing and biodiesel processing phases. All costs and revenues from byproducts, during both oil extraction and biodiesel production, were included in the analysis.

In addition to these initial considerations, the study was subdivided into another seven parts. In the second part, the agricultural calendar of the crops considered in the study is presented, followed by the location of the industrial plants (part three) in each region. The methodological procedures are described in part four, while the costs of the various farming, raw material crushing and biodiesel processing stages are considered in part five. The results of the study are described and discussed in part six and part seven summarizes the study and offers some recommendations.

⁴ National Agricultural Supply Company. (Translator's Note)

⁵ Brazilian Institute of Geography and Statistics. (Translator's Note)

Agricultural calendar

Table 1 compiles the harvest production - supply - for the raw materials selected for the study. In preparing the table, the information from research entities, government institutions and private companies were combined.

In the case of soybean and cotton, the official information, which is clearly validated by the market, was considered directly; in the case of peanuts, sunflower, castor beans, and African palm tree oil, the harvest periods, particularly the monthly percentages, were calculated on the basis of a set of information from the previously mentioned sources.

The graphic representation of the harvest periods clearly shows that the supply of raw materials concentrates on the first half of the year. Given the ease of storage of cotton seeds and soybean grain, it is assumed from the beginning that those two crops will be the basic raw materials for the biodiesel industries in the second half of the year in the South, Southeast, Center-West, and Northeast regions. To supplement the basic raw materials, biodiesel would be produced from a blend containing a greater percentage of the oil seeds in the first half of the year in those four regions. In the North Region, it is estimated outright that the soybean supply would be gradually consumed along the year, but always complementing African palm tree oil, which is the effective base contemplated for that region. In the interim, it should be noted that the study did not include an examination of possible raw material mixtures with a view to finding the mix that would ensure the lowest cost at the various times of the year.

Analysis of the agricultural raw material supply

The following values are based on information for the 1999-2000 and 2003-2004 crop years published by the Companhia Nacional de Abastecimento⁴ (Conab) and the Instituto Brasileiro de Geografia e Estatística⁵ (IBGE), the latter

Table 1. Harvest calendar for soybean, sunflower, cotton, peanuts, castor beans, and African palm tree in the five macro-regions of Brazil.

Region	Crop	Harvest Period (%)											
		Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
South	Soybean Sunflower ⁽¹⁾	15.5	32.8	34.5	17.2								
Southeast	Soybean		20.5	39.2	29.5	10.8							
	Sunflower ⁽¹⁾												
	Peanuts ⁽²⁾ Peanuts ⁽³⁾	16.2	33.1	33.8	16.9		12.1	44.3	36.5	7.1			
Center-West	Soybean Sunflower ⁽¹⁾	4.3	23.5	42.1	24.4	5.8							
	Cotton		0.2	1.5	2.2	8.8	29.7	36.9	19.1	1.6			
Northeast	Soybean		14.5	36.9	33.0	13.1	2.6						
	Cotton				3.6	30.1	31.5	31.3	2.2	0.6	0.4	0.3	
	Castor bean	23.6	47.6	25.0	1.9	1.0	0.4	0.3	0.2				
North	Soybean African palm tree	10.0	27.2 9.0	43.3 10.0	22.8 9.0	6.7 12.0	9.0	8.0	7.5	6.5	5.5	4.5	9.0

⁽¹⁾ Information was imprecise or insufficient.

⁽²⁾ Harvested during the rainy season.

⁽³⁾ Harvested during the dry season.

Source of data: Conab (2005), IBGE (2005), Unicamp (2005), Embrapa Eastern Amazon (2005), and Ferrari (2004).

in the specific case of African palm tree oil. The official data for the most recent harvest (2004-2005) have not been included since they were still preliminary for some products at the time this paper was prepared (Table 2).

Using the data for five crop years to calculate minimum, average and maximum supplies of each raw material under consideration should be a safe indicator of the amounts to be considered for each biodiesel unit. The authors believe that using the data for five crop years makes it possible to attenuate the impact of abrupt variations in a single cycle caused, for example, by extraordinarily adverse or favorable climatic events.

One of the major restrictions to biodiesel production could be ensuring the supply of the various raw materials in the different regions. In the regions studied only soybean and cottonseed stocks were sufficient to supply a 100,000-ton biodiesel plant for a year. Together,

the five plants would produce 435 million liters or 435,000 cubic meters (m³) of biodiesel.

Assuming that the average diesel consumption from 2000 to 2004 was 37.2 million m³/year, those 435,000 m³ would represent 1.7% of the demand. Nevertheless, beginning in 2008, according to Law Number 11.097 of 13 January 2005, all diesel oil sold in Brazil must be 2% biodiesel, so that the estimated demand would be 743 million m³ of biodiesel, to be processed in at least eight 100,000-ton/year plants. It should be further noted that the law determines a 5% blend beginning in 2013.

Location of the biodiesel industrial units

The main, albeit not the only, criterion to determine the location of the raw material crushing and biodiesel production plants, also called integrated units, was the availability of

Table 2. Raw material production – from 1999-2000 to 2003-2004 (in tons).

Region	Crop	Minimum	Maximum	Average	kg/ha
South	Soybean	3.900	10.400	6.880	1.300
	Sunflower	12.614.900	21.340.600	160.415.060	2.385
Southeast	Soybean	2.569.700	4.474.400	3.487.600	2.512
	Sunflower	2.600	3.000	2.820	1.531
	Peanuts ⁽¹⁾	129.000	162.300	144.120	2.188
	Peanuts ⁽²⁾	18.700	26.500	23.140	696
Center-West	Soybean	14.945.300	24.613.100	20.097.720	2.746
	Sunflower	46.300	90.800	63.680	1.476
	Cotton	760.700	1.371.800	1.020.380	2.011
Northeast	Soybean	2.064.000	3.538.900	2.458.820	2.267
	Cotton	127.300	467.500	226.440	765
	Castor bean	68.100	104.500	84.620	770
North	Soybean	150.700	913.700	441.700	2.431
	African palm tree	361.656	729.184	579.334	14.500

⁽¹⁾ Shelled peanuts harvested during the rainy season.

⁽²⁾ Shelled peanuts harvested during the dry season.

Source of data: Conab (2005) and IBGE (2005).

the vegetable raw material in each region. This analysis was based on a detailed examination of the harvest calendar and the amount of each raw material harvested in recent years.

Another factor considered was the structure of the collection points or depots of the distributors registered at the National Petroleum Agency (ANP). In the case of alcohol, the Brazilian Petroleum Corporation (Petrobras) does not have a monopoly on the purchase of this fuel. The various registered distributors can even mix anhydrous alcohol with pure gasoline (grade A gasoline) to make up grade C gasoline. The legislation is similar in the case of biodiesel, since the refineries and distributors registered at ANP are authorized to mix 2% biodiesel to petroleum diesel (B2 blend of biodiesel).

The industrial plants for the economic studies would be located as follows.

- South Region - Carazinho, State Rio Grande do Sul (RS).
- Southeast Region - Piracicaba, State of São Paulo (SP).

- Center-West Region - Rondonópolis, State of Mato Grosso (MT).
- Northeast Region - Luiz Eduardo Magalhães, State of Bahia (BA).
- North Region - Marabá, State of Pará (PA).

Methodological procedures

The structure of the study can be seen as an integration of three main cost centers: agricultural costs, crushing costs (to obtain oil) and biodiesel processing, as shown in Figure 1.

The definition of agricultural costs includes all production inputs, including land-related costs and machinery depreciation, but neither the technical assistance costs, nor the remuneration of the farmers or of the investment capital was contemplated. Those calculations were made for soybean, sunflower seeds, peanuts, castor beans, and African palm tree oil. In the case of cottonseed, the study considered market prices instead of the agricultural costs. It should be clarified that, in a second calculation front, all

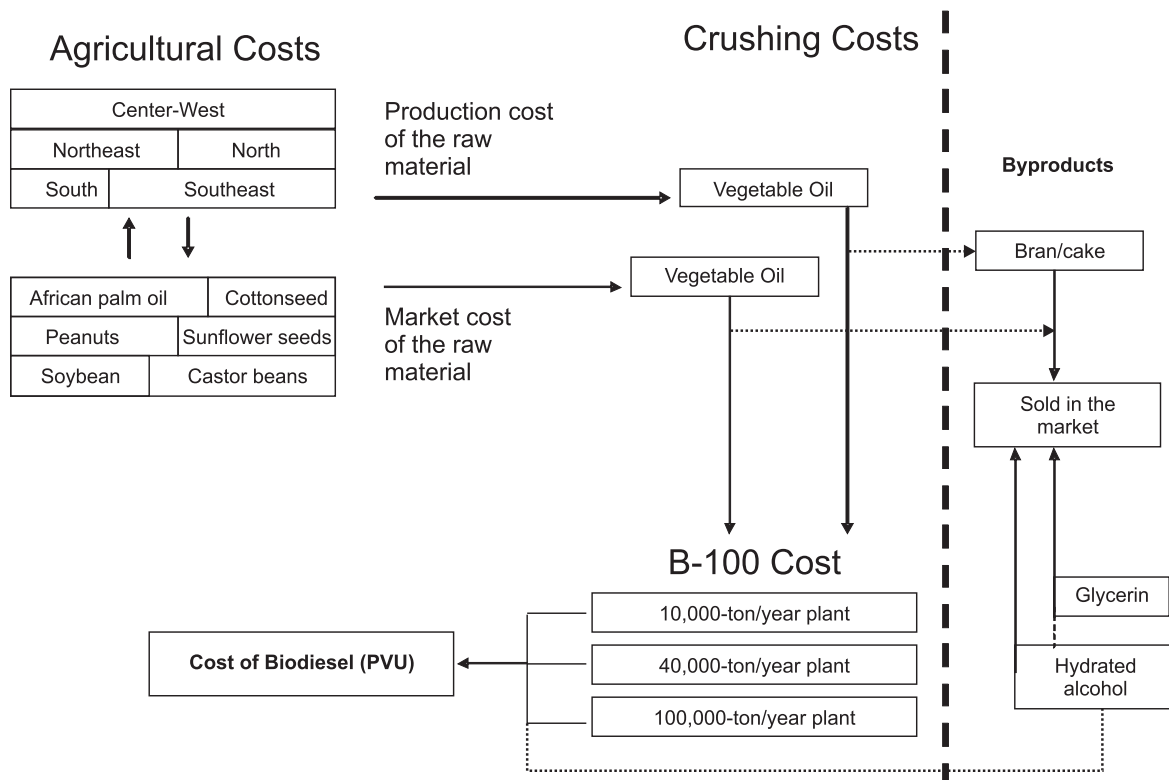


Figure 1. Cost centers used to calculate the PVU (Posto Veículo Usina) cost of biodiesel.
Source: Research data.

agricultural raw material were also ascribed market prices.

In dealing with the acquisition of the agricultural raw material calculated on the basis of the production costs, the study established that the raw material would be purchased directly from the farmers, which would result in a more onerous scenario in terms of taxes (2.3% INSS⁶).

The study's cost structure is normally used by research institutes such as Centro de Estudos Avançados em Economia Aplicada⁷ (Cepea) and, therefore, frequently subjected to the analysis of and validated by the agents of the agribusiness sectors. Soybean and sunflower costs in all the regions were calculated using the panel technique⁸, i.e., meetings with producers and technicians in the various

regions. Some coefficients, however, were obtained through market agents and adapted for use in the spreadsheet in order to homogenize the calculations, particularly in some regions where it was not possible to hold meetings. The peanut costs were provided by the Cooperativa Agrícola Mista da Alta Paulista⁹ (Comap) of Tupã, State of São Paulo (SP), and the castor bean and African palm tree oil costs derived from technical coefficients (about the amounts used) published by the Brazilian Agricultural Research Corporation (Embrapa) in particular, with some contributions from Agropalma, in the case of African palm tree oil.

Agricultural input prices, in turn, were obtained from Cepea (2005) in each of the regions. Only cash-payment prices were considered. Once

⁶ Social security contribution. (Translator's Note)

⁷ Center for Advanced Studies in Applied Economics. (Translator's Note)

⁸ DEBLITZ, C. The International Farm Comparison Network (IFCN).

⁹ Mixed Agricultural Cooperative of Alta Paulista. (Translator's Note)

the locations of the industrial units were defined, the prices were preferably surveyed in the states where the industrial units would theoretically be installed.

The production cost criterion used is that of Overall Operational Cost. According to this criterion, the calculations include all variable costs (inputs, labor, fuels, and equipment maintenance) together with machinery and equipment depreciation. Consequently, the remuneration of the diverse fixed costs, like the depreciation of the various facilities, remuneration and opportunity costs of the businessman, and other fixed and semi-fixed costs, notably the administrative costs, are not included. The items included, however, are sufficiently characteristic of the production processes and, therefore, vary less among producers.

The cost of the machinery and implements were allocated to each crop as a function of their time of usage in farming, including the manpower required for each activity. Maintenance, depreciation and fuel costs were included as well. Labor costs were calculated using the same rationale used in calculating the cost of using the machinery, i.e., the time each worker devotes to a given crop.

The calculations also included land-related costs in each region. Simulations were made including and excluding land-related costs for comparative analysis purposes only.

The type of industrial structure used in the study is the integrated industry, namely, a plant encompassing both the crushing and oil extraction phases and actual biodiesel production (ethylic pathway). Dedini S/A Indústrias de Base supplied all the coefficients for the industrial processes. It should also be emphasized that, in terms of biodiesel production, the study considered three continuous plants with processing capacities of 10,000 tons, 40,000 tons and 100,000 tons of biodiesel per year. In terms of the crushing phase, the same industrial coefficients were provided for integrated crushers in the various biodiesel plant scales.

The study comprised the calculation of the biodiesel production costs at the plant, namely, price for delivery at the industrial unit (PVU, Posto Veículo Usina), with all inputs at retail prices.

Agricultural production, crushing and biodiesel processing costs

A summary of the economic production costs for soybean, sunflower seeds, peanuts, castor beans, and African palm tree oil in the different regions is presented in this section. Regarding cottonseed, only average nominal prices for cash payments during the March-June 2005 period were taken into account (Table 3).

To calculate the industrial production costs of the vegetable oils to be used in biodiesel processing, it is possible to apply either the production cost or the market price of the

Table 3. Agricultural costs and productivities in the five macro-regions.

	Cost	Productivity kg/ha
Soybean	R\$/60-kg bag	
South	36.98	2,400
Southeast	30.28	2,700
Center-West	24.67	3,120
Northeast	35.53	2,500
North	29.42	2,500
Sunflower seeds	R\$/60-kg bag	
South	38.14	1,600
Southeast	36.84	1,800
Center-West	24.69	1,800
Peanuts	R\$/25-kg bag	
Southeast	18.68	3,500
Castor beans	R\$/60-kg bag	
Northeast	35.17	770
African palm tree	R\$/ton (CFF⁽¹⁾)	
North	135.93	14,500

⁽¹⁾ CFF: Fresh fruit bunch.

Note: Cost does not include social security contribution (INSS), freight and storage.

Source: Research data.

agricultural raw material. When the raw material is purchased from a mutual company/cooperative or legal entity, the market price is considered.

In the case of cottonseed and castor beans, if the biodiesel industry purchases the raw material from a cooperative (available market), the business value already includes 3.65% for PIS/Cofins¹⁰, but enables the buyer to rebate the 9.25% paid by the legal entities selling the product.

The market price used in this study is an average of the agricultural product's prices during the June 2004 to July 2005 period in the state where the industrial plant is located. As previously noted, the market price is always used for cottonseed, which includes the 9.25% PIS/Cofins taxes. For the latter product, the market price represents an average of the prices paid from March to June 2005 only (series available from Cepea (2005)). For African palm

tree oil, the market price corresponds to the price practiced in August 2005.

Table 4 shows the production costs and market prices of the agricultural raw materials considered in the comparison of the final biodiesel prices.

Dedini S/A Indústrias de Base supplied the coefficients for the industrial processes - from crushing to obtain the vegetable oil to actual biodiesel production. It should be emphasized that scale gains in the oil extraction process were not taken into account; identical extraction costs and yields were used¹¹ for all biodiesel plants (10,000, 40,000 and 100,000 tons/year).

For soybean, cottonseed and castor beans, the process is considered a chemical extraction. For peanuts and sunflower, the extraction involves only pressing followed by a chemical process. For African palm tree oil, the oil press is followed by steam extraction.

Table 4. Raw material production costs and market prices.

State	Raw material	Production cost ⁽²⁾ 2004-2005 crop year	Average market cost June 2004 to June 2005
RS	Soybean	R\$ 39.10/60-kg bag	R\$ 34.60/60-kg bag
	Sunflower seeds	R\$ 40.31/60-kg bag	R\$ 20.30/60-kg bag
SP	Soybean	R\$ 32.32/60-kg bag	R\$ 33.94/60-kg bag
	Sunflower seeds	R\$ 38.95/60-kg bag	R\$ 21.10/60-kg bag
	Peanuts	R\$ 22.33/25-kg bag	R\$ 25.50/25-kg bag
MT	Soybean	R\$ 27.72/60-kg bag	R\$ 29.80/60-kg bag
	Sunflower seeds	R\$ 26.06/60-kg bag	R\$ 24.70/60-kg bag
	Cottonseed	-	R\$ 214.25/ton ⁽¹⁾
BA	Soybean	R\$ 37.56/60-kg bag	R\$ 28.57/60-kg bag
	Castor beans	R\$ 37.21/60-kg bag	R\$ 54.00/60-kg bag
	Cottonseed	-	R\$ 180.00/ton ⁽¹⁾
PA	Soybean	R\$ 31.36/60-kg bag	R\$ 28.05/60-kg bag
	African palm tree	R\$ 135.93/ton of CFF	R\$ 150.00/ton ⁽³⁾

⁽¹⁾ Cottonseed prices: from February to May 2005 (period of more intense negotiations).

⁽²⁾ Cost includes social security contribution (INSS), freight and storage.

⁽³⁾ African palm tree oil prices: only for August 2005.

Source: Cepea (2005) (soybean and cottonseed); Conab (2005) (sunflower seed in the Center-West and castor beans in the Northeast); Instituto de Economia Agrícola (2005) (sunflower seed and peanuts, State of São Paulo); and Paraná (2005).

¹⁰ Both indirect taxes of a social nature. PIS - Social Integration Program; Cofins - Social Financial Contribution. (Translator's Note)

¹¹ Industrial yield for soybean (19% oil and 72% meal); cottonseed (16% oil and 52% cake); sunflower (39% oil and 53% bran); peanuts (44% oil and 50% cake); castor beans (42% oil and 54% cake), and African palm tree oil (17% oil and 80% bran).

In the case of African palm tree oil, there is much less information in Brazil about the various processes involved than for the other crops. Consequently, the study was conducted on the basis of estimates made at Dedini and Cepea on the basis of information obtained from companies working in that market sector.

In this study, the crushing process and costs correspond to oil extraction for the sole purpose of producing biodiesel, which is different from the oil extraction process used by the companies currently working with African palm tree oil, which require a more refined final product obtained using a different process.

Concerning biodiesel processing costs, the study starts the cost calculations from the neutralized starchless oil. In this section, the calculations are divided according to the biodiesel processing industrial scales (10,000, 40,000 and 100,000 tons/year of biodiesel).

The industrial coefficients vary depending on the industrial scale; the prices of some inputs used in the direct production of biodiesel differ depending on the region. In this study, however, all calculations took into account the prices of chemical products, machinery repair and maintenance, labor, and depreciation (over 10 years), as well as other processing costs. Those items add up to R\$ 278 per ton of biodiesel processed in a 10,000-ton/year plant; R\$ 168.01 per ton of biodiesel processed in a 40,000-ton/year plant; and R\$ 136.00 per ton/year of biodiesel processed in a 100,000-ton/year plant.

When examining biodiesel production, it is necessary to consider the byproducts from the oil extraction and the biodiesel production processes. To that end, a three-step procedure was adopted in this study.

- a) Calculating the production cost of the agricultural raw materials.
- b) Calculating the value of the vegetable oil.
- c) Calculating the cost of the biodiesel.

In step (a) it is possible to use, as previously pointed out, the production cost itself or the purchase price of the raw material in the

market. In step (b) the calculation starts with the cost of the raw material, to which the industrialization costs are then added and from which the values (market prices) of the byproducts are subtracted, to reach the value of the vegetable oil. Similarly, in step (c) the calculation starts from the value of the vegetable oil, to which the industrial costs are added and from which the values of the byproducts (market prices) are subtracted, thus arriving at the cost of the biodiesel.

Results and discussion

In this section the costs of biodiesel at the industrial plant are analyzed in two different situations depending on the price of the raw material for delivery at the industrial unit: production costs and market prices.

In these theoretical considerations it is important to add that the implementation of an industrial plant, regardless of the raw material processed, would increase local prices, thus the strategic importance of having a production cost basis.

South Region

Despite the long standing tradition of soybean farming in the State of Rio Grande do Sul, this oil seed is less competitive than sunflower in southern Brazil. Actually, soybean-based biodiesel in that region has the highest cost of all raw materials'. In an integrated calculation of the industrial unit's costs, for which the starting point is the agricultural production cost, biodiesel from soybean would cost R\$ 2,053 per ton (or R\$ 1.786/liter) in the 40,000-ton/year plant. When the market price of the grain is the basis of the calculations, biodiesel costs 25% less. See Table 5.

Another oleaginous plant selected for this study was sunflower. The biodiesel produced from sunflower seeds was 7.6% cheaper than that produced from soybean, averaging the results of the three industrial scales. A great advantage of sunflower when compared with soybean is its

Table 5. Biodiesel costs based on agricultural production costs and market prices for production in three industrial scales in the South Region.

South – Carazinho, RS	10,000-ton/year plant		40,000-ton/year plant		100,000-ton/year plant	
	Soybean	Sunflower	Soybean	Sunflower	Soybean	Sunflower
Raw material at agricultural production costs						
Biodiesel cost ⁽¹⁾	2,195.81	2,036.04	2,053.07	1,894.99	1,970.21	1,815.41
Biodiesel cost ⁽²⁾	1.910	1.771	1.786	1.649	1.714	1.579
Raw material at market prices						
Biodiesel cost ⁽¹⁾	1,775.46	1,153.25	1,637.12	1,021.48	1,562.79	959.87
Biodiesel cost ⁽²⁾	1.545	1.003	1.424	.889	1.360	.835

⁽¹⁾ PVU in R\$/ton.

⁽²⁾ PVU in R\$/liter.

Note: Assuming zero profits for the integrated industrial plant.

Source: Research data.

oil yield, herein estimated at 39%, while soybean's is only 19%.

In the case of sunflower seeds, the obstacle to its development as biodiesel production source is a very irregular supply. In the 2003-2004 crop year 10,400 tons of sunflower seeds were produced in southern Brazil, which would supply a 10,000-ton/year plant for 141 days and a 40,000-ton/year plant for only 35 days.

Processing soybean requires higher capital investments per ton of biodiesel produced than sunflower seed processing. For a 10,000-ton/year industrial plant, the capital required would be R\$ 4,652.00 per ton, including expenses with the grain and all other inputs used in the industrial process (crushing operation plus biodiesel production). In the case of sunflower seeds, only R\$ 2,819.00 per ton would be required.

Regarding sunflower seeds, the cost of biodiesel could be reduced by as much as 47%, dropping from R\$ 1.58/liter to R\$.83/liter in the 100,000-ton/year unit. When the raw material is purchased in the market place, sunflower seeds are still more competitive than soybean - close to 37% less in a 40,000-ton/year unit (when production costs are used instead of market prices, the difference is 29%).

It is very important to note that, at market prices, the industrialist would require 9.2% less capital to produce biodiesel from soybean and 32.3%

less when using sunflower seeds, when the three industrial scales are averaged. To compensate, there is the risk of supply problems, since the undertaking would be subject to market fluctuations.

Southeast Region

On the basis of the production cost of the raw material one ton of biodiesel from peanuts would cost R\$ 1,990.00 per ton (R\$ 1.732/liter) in a 10,000-ton/year plant. In the 100,000-ton/year plant costs would come down by 12% (Table 6). Biodiesel from soybean is more competitive in the Southeast Region provided all costs and all byproduct revenues are included in the equation (R\$ 1,432.00 per ton or R\$ 1.25/liter in the 40,000-ton/year unit).

When the calculations are based on the market price of the raw material, however, sunflower seeds would be strikingly more advantageous: biodiesel costs (R\$ 987 per ton or R\$.86/liter) would be more than 50% lower than those of peanuts and 35% lower than soybean's.

In comparative terms, therefore, peanuts are the least competitive and sunflower seeds have an intermediate performance in the Southeast Region. Both have problems regarding scale and regularity of supply, especially sunflower. Although sunflower has a great development

Table 6. Biodiesel costs based on agricultural production costs and market prices for production in three industrial scales in the Southeast Region.

Southeast Piracicaba, SP	10,000-ton/year plant			40,000-ton/year plant			100,000-ton/year plant		
	Soybean	Peanuts	Sunflower	Soybean	Peanuts	Sunflower	Soybean	Peanuts	Sunflower
Raw material at agricultural production costs									
Biodiesel cost ⁽¹⁾	1,569.01	1,990.94	1,903.14	1,432.83	1,850.37	1,763.48	1,362.68	1,771.72	1,686.60
Biodiesel cost ⁽²⁾	1.365	1.732	1.656	1.247	1.610	1.534	1.186	1.541	1.467
Raw material at market prices									
Biodiesel cost ⁽¹⁾	1,714.24	2,297.63	1,118.45	1,576.54	2,153.84	987.04	1,503.45	2,068.96	927.12
Biodiesel cost ⁽²⁾	1.491	1.999	0.973	1.372	1.874	0.859	1.308	1.800	0.806

⁽¹⁾ PVU in R\$/ton.

⁽²⁾ PVU in R\$/liter.

Note: Assuming zero profits for the integrated industrial plant.

Source: Research data.

potential in the Southeast the amount of sunflower seeds harvested in 2003/04 over almost 2,000 hectares of sunflower crops in the Southeast would only be sufficient to operate a 10,000-ton/year plant for 40 days.

Sunflower farming is still rare in Brazil, although private and governmental investments and incentives could make the crop an economically viable source of biodiesel in the Southeast Region.

The total amount of peanuts produced in the Southeast, in turn, could meet the needs of a 40,000-ton/year biodiesel plant -188,800 tons of peanuts were produced in the 2003-2004 crop year (Conab) - provided competition with the food industry could be overcome.

As regards the need for cash, the requirements of a sunflower-based industrial unit would be the lowest per ton of biodiesel produced: close to R\$ 2,700.00 in the case of a 10,000-ton/year plant. That amount includes expenses with the grain and all inputs used in the industrial process (crushing plus biodiesel output) in a 10,000-ton/year plant. This means that the annual turnover of a 10,000-ton/year plant using sunflower seeds as raw material would be R\$ 27 million. At the other extreme, the turnover of a 100,000-ton/year industrial plant processing soybean to produce biodiesel would be R\$ 375 million per year, i.e., the CPMF¹² revenue alone would be R\$ 1.42 million.

Center-West Region

For the Center-West, the study considered an industrial plant located in the region of Rondonópolis, State of Mato Grosso, processing neutralized starchless oil from soybean, sunflower seed and cottonseed (Table 7).

Regardless of the scale of production the use of soybean oil helps lower the cost of biodiesel, followed by sunflower and cottonseed. In a 100,000-ton/year plant, for example, the cost of the biodiesel from soybean would be R\$.829/liter. The cost rises to R\$.90/liter when the market price is used in the calculation. While the soybean production cost was R\$ 27.72/60-kg bag, its market price was R\$ 29.80/60-kg bag.

Concerning the supply of the raw material, there seem to be no problems for soybean and cottonseed - this study does not include, however, impacts due to increased demand arising from biodiesel production. Nevertheless, the supply of sunflower seeds (until the 2003-2004 crop year) would not be sufficient to meet the annual demand of the 40,000-ton/year and 100,000-ton/year plants. At most, considering the average supply from 1999-2000 to 2003-2004, it would be possible to set up two 10,000-ton/year biodiesel plants.

¹² CPMF is a federal tax on the transfer of money, as well as credits and rights of a financial nature. (Translator's Note).

Table 7. Biodiesel costs based on agricultural production costs and market prices for production in three industrial scales in the Center-West Region.

Center-West Rondonópolis, MT	10,000-ton/year plant			40,000-ton/year plant			100,000-ton/year plant		
	Soybean	Sunflower	Cottonseed	Soybean	Sunflower	Cottonseed	Soybean	Sunflower	Cottonseed
Raw material at agricultural production costs									
Biodiesel cost ⁽¹⁾	1,146.44	1,321.78	1,258.04	1,014.68	1,188.23	1,120.48	953.11	1,123.18	1,061.35
Biodiesel cost ⁽²⁾	0.997	1.150	1.094	0.883	1.034	0.975	0.829	0.977	0.923
Raw material at market prices									
Biodiesel cost ⁽¹⁾	1,226.59	1,575.93	1,258.04	1,094.00	1,439.70	1,120.48	1,030.81	1,369.48	1,061.35
Biodiesel cost ⁽²⁾	1.067	1.371	1.904	0.952	1.253	0.975	0.897	1.191	0.923

⁽¹⁾ PVU in R\$/ton.

⁽²⁾ PVU in R\$/liter.

Note: Assuming zero profits for the integrated industrial plant.

Source: Research data.

Northeast Region

The costs of producing biodiesel from castor beans, soybean and cottonseed were evaluated in this region. Table 8 shows the results of the calculations made using agricultural production costs and market prices.

Biodiesel output from cottonseed in the Northeast is the cheapest in Brazil. Considering the overall process, i.e., all expenses and revenues of an integrated industrial unit (crushing + biodiesel production) one liter of biodiesel would cost R\$.662 in a 100,000-ton/year plant.

The cottonseed supply in the Northeast also favors biodiesel production. According to the Companhia Nacional de Abastecimento (Conab), approximately 467,500 tons of cottonseed were produced in the 2003/04 crop year, a sufficient amount to supply the 10,000-ton/year and 40,000-ton/year plants, since their annual demand would come to about 66,000 and 260,000 tons, respectively, with a surplus left for other uses.

For castor beans to be as competitive as cottonseed, castor bean productivity would have to be about 2,500 kg/ha when the calculations are based on the production costs.

Table 8. Biodiesel costs based on agricultural production costs and market prices for production in three industrial scales in the Northeast Region.

Northeast Luiz Eduardo Magalhães, BA	10,000-ton/year plant			40,000-ton/year plant			100,000-ton/year plant		
	Soybean	Sunflower	Cottonseed	Soybean	Sunflower	Cottonseed	Soybean	Sunflower	Cottonseed
Raw material at agricultural production costs									
Biodiesel cost ⁽¹⁾	2,061.45	1,962.08	947.62	1,920.10	1,821.81	817.95	1,839.96	1,743.72	760.42
Biodiesel cost ⁽²⁾	1.793	1.707	0.824	1.670	1.585	0.712	1.601	1.517	0.662
Raw material at market prices									
Biodiesel cost ⁽¹⁾	1,225.73	2,698.83	947.62	1,093.14	2,550.82	817.95	1,029.95	2,457.74	760.42
Biodiesel cost ⁽²⁾	1.066	2.348	0.824	0.951	2.219	0.712	0.896	2.138	0.662

⁽¹⁾ PVU in R\$/ton.

⁽²⁾ PVU in R\$/liter.

Note: Assuming zero profits for the integrated industrial plant.

Source: Research data.

Otherwise, the price of the 60kg-bag of castor fruit would have to be R\$ 12.35, much lower than the minimum price stipulated by the Ministry of Agriculture, Livestock and Food Supply.

Soybean, in turn, is the least competitive raw material in the Northeast Region. The cost of biodiesel from soybean would be more than twice that of diesel from cottonseed. When compared with biodiesel from castor beans, the advantage of cottonseed is very close to 100%. Once again, the explanation is associated with the outlay for the agricultural raw material. Soybean loses due to its low productivity (2,500 kg/ha or 41 60-kg bags/ha) in the region, while cottonseed wins out because of its low market price.

For soybean to become more competitive in the Northeast - prevailing over cottonseed and castor beans - the crushing unit would have to buy the grain for R\$ 25.00/60-kg bag, or less, which is not impossible provided one considers purchasing the raw material in the market, instead of in the farm.

On the basis of the agricultural cost of soybean, in a 40,000-ton/year plant, biodiesel would cost R\$ 1.67/liter, while the cost based on the market price would be R\$.95.

North Region

Following a trend observed in the crushing unit cost center, to a great extent due to soybean's low cost and high yields, biodiesel from soybean would be the most competitive. In this case the cost of biodiesel was estimated at R\$ 1.17/liter in 40,000-ton/year plants. That cost drops to R\$.90 when the calculation is based on the market price of the raw material (R\$ 28.05/60-kg bag, average price from June 2004 to July 2005). See Table 9.

In connection with the raw material demand and cropped area, it is necessary to highlight the enormous difference between African palm tree oil and soybean and the other crops being analyzed. In order to meet the demand of a plant producing 10,000 tons per year of biodiesel from soybean, it would be necessary to farm 22,161 hectares, while 4,270 hectares of African palm tree oil would meet that demand.

Summary of the final results

Figures 2 and 3 summarize the production costs in 40,000-ton/year industrial units. The values shown were obtained in calculations that considered the cost of the raw material on the basis of the agricultural production costs,

Table 9. Biodiesel costs based on agricultural production costs and market prices for production in three industrial scales in the North Region.

North Marabá, PA	10,000-ton/year plant		40,000-ton/year plant		100,000-ton/year plant	
	Soybean	African palm tree	Soybean	African palm tree	Soybean	African palm tree
Raw material at agricultural production costs						
Biodiesel cost ⁽¹⁾	1,476.09	1,550.75	1,340.88	1,414.83	1,272.62	1,345.16
Biodiesel cost ⁽²⁾	1.284	1.349	1.167	1.231	1.107	1.170
Raw material at market prices						
Biodiesel cost ⁽¹⁾						
Biodiesel cost ⁽²⁾	1,168.33	1,659.41	1,036.34	1,522.35	974.33	1,450.48
	1.016	1.444	0.902	1.324	0.848	1.262

⁽¹⁾ PVU in R\$/ton.

⁽²⁾ PVU in R\$/liter.

Note: Assuming zero profits for the integrated industrial plant.

Source: Research data.

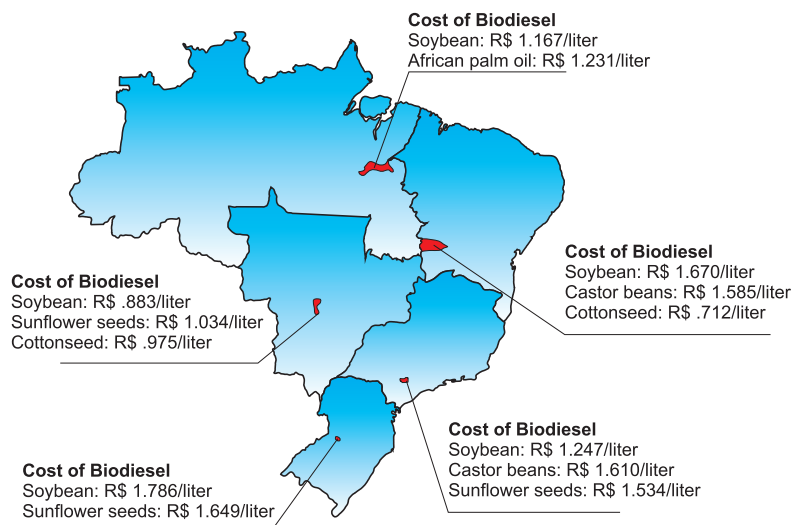


Figure 2. Biodiesel cost calculated on the basis of the agricultural cost of the raw material (including land-related costs) in a 40,000-ton/year plant – 2004–2005 crop year.

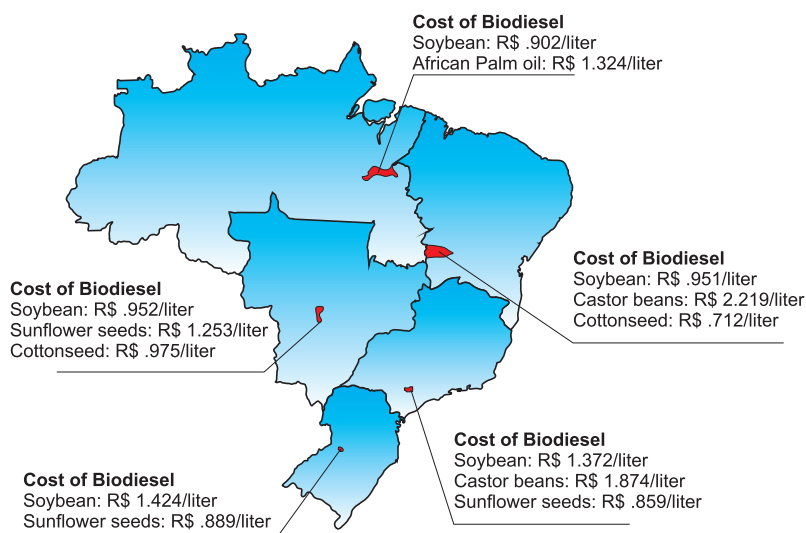


Figure 3. Biodiesel cost calculated on the basis of the market price of the raw material in a 40,000-ton/year plant – 2004–2005 crop year.

including land-related costs, and, in the industrial stages, the possibility of selling the hydrated alcohol resulting from biodiesel processing - without dehydration column, therefore.

Some of the simulations in this paper show that, when the land-related costs are not included in the agricultural production costs, the final cost of the biodiesel at the industrial plant - without considering the byproducts - drops by 8% on the average in the 40,000-ton/year plant. If an alcohol dehydration column were installed,

there would be a further cost reduction: an average 12% in the 40,000-ton/year plant.

Final considerations

The purpose of this study was to serve as a cost reference for biodiesel output from six agricultural raw materials – soybean, sunflower seeds, peanuts, castor beans, African palm tree oil, and cottonseed – in the five macro-regions of the country. Although such a broad approach does have some limitations, it is necessary to

emphasize the pioneering nature of calculating the costs of biodiesel in all the regions of the country and the importance of the data as parameters in defining sectoral policies.

One of the difficulties faced was obtaining field data on the production costs and productivity of castor beans and African palm tree oil. To counter those problems the calculations were based on data from the literature and information collected by sectoral agents. In addition, the industrial information on the extraction of African palm tree oil, as well as its processing to produce biodiesel, are based on estimates made by Dedini S/A.

The scope of the study did not include an analysis of the inter-sectoral and inter-regional impacts resulting from the installation of a biodiesel plant. To evaluate such impacts, the authors recommend a general balance analysis.

Nor did the study include an analysis of the financial cost of the capital invested in order to check the viability and longevity of the biodiesel business. Such limitations could be overcome in future research projects, increasing the usefulness of the study for both the private initiative and government agents, particularly concerning the investments and the definition of the rules of the National Biofuel Program.

The agricultural production costs used in the study could be slightly higher than the effective costs of farmers in some regions due to the fact that the input prices were obtained at retail stores, while some farmers can get lower prices by buying large quantities of inputs.

Regarding market prices, it should be noted that in order to update the study the authors chose to work with averages for the June 2004-July 2005 period, when the quotations for some products, especially soybean and cottonseed, were low. Consequently, the results are conditioned by the average prices practiced during that period, specifically. Because of temporal limitations, calculations were carried out using the average price of soybean during the last five years, beginning in January 2000, in the South,

Southeast and Center-West regions. In this case, the cost of the biodiesel was lower in all units and regions studied, i.e., the biodiesel produced from soybean calculated on the basis of the average price paid during the January 2000-July 2005 period was 3.19% cheaper than that obtained from soybean at the price practiced during the 2004-2005 crop year.

The study also considered the possibility of the biodiesel plant selling the hydrated alcohol resulting from the process although such operations have not yet been regulated. Consequently, the calculations also took into account the technical alternative of setting up a dehydration column in the biodiesel processing plant to use that byproduct (alcohol). Given the investments necessary to install an alcohol dehydration column, the equipment was only considered for the 40,000-ton/year and 100,000-ton/year plants.

When working with the alcohol dehydration column, the amount of anhydrous alcohol required for other purposes was included as input at the beginning of the biodiesel process. On the other hand, the amount of electric power and the number of workers would necessarily increase, together with the capital investments. An analysis of the impact of setting up an alcohol dehydration column on the biodiesel costs only shows that costs are reduced by approximately 4%. Nevertheless, the calculations in the study are not sufficient to ascertain the economic viability of using a dehydration column.

Together with an analysis of the biodiesel costs, businessmen interested in this market should also analyze the availability of the raw material and future competition for the raw material with other markets, including the food industry.

The opportunity cost of vegetable oil as a source of raw material to produce biodiesel would be high. In the case of castor oil the average international market price was US\$ 1,091/t from June 2004 to July 2005, i.e., almost R\$ 2,980.00/t (the exchange rate used was R\$ 2.73/US\$ - average rate for the same period). According to

Conab, the parity import price of castor oil in July 2005 was US\$ 916.09/t (or R\$ 2,160/t; average exchange rate for the period: R\$ 2.36/US\$). Those prices would result in biodiesel costing more than R\$ 2.35/L at the plant.

Another item not to be forgotten in analyzing integrated industrial plants are the administrative costs, which include various elements, from specialized manpower to infrastructure, and must be specific to that branch of business. The study, however, does not include an evaluation of such expenses. Nor are the calculations to determine the economic-financial viability of the project included. In fact, the study basically takes into account the operational production cost of biodiesel, from previously selected raw materials, in different industrial production scales, and in various regions.

The integration of the production chain, all the way from farming to the industrial operations, which is considered strategic to ensure the supply of the biodiesel industry, would also increase the administrative costs of a structure having such a high degree of verticalization, as well as the capital investments - facilities and cash flow.

The 40,000-ton/year plant had the best cost/benefit ratio since it showed significant gains when compared with the 10,000-ton/year plant, albeit not really expressive when compared with the 100,000-ton/year plant, which requires much higher capital investments and greater amounts of raw material, in addition to increased risks.

In the case of soybean in the South, Northeast and North and sunflower in the South and Southeast, the acquisition of the raw material was more viable at market prices - an analysis conditioned to the 2004-2005 crop year values. Even so, it would be important to consider a partial integration at least, in view of how easy the raw materials contemplated in the study could be sold for other purposes. In the soybean

market, for example, breaches of contract are not rare. Negotiations with farmers' mutual companies or cooperatives could be an alternative to diminish such risks and costs.

In connection with the environmental aspects, the amount of bran/cake generated in the crushing process is worthy of attention. A more precise evaluation of the allocation of such byproducts, especially castor oil cake, should be carried out from both the environmental and the economic standpoints.

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Ethanol, environment and technology

Reflections on the Brazilian experience

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Abstract: The purpose of this paper is to reflect upon the main environmental and technological aspects of producing and consuming ethanol from sugarcane in Brazil. An analysis of the entire ethanol production chain makes clear that the strategic use of the byproducts is essential to ensure the sustainability of the production chain. Two additional issues should be addressed, namely, burning sugarcane before the harvest and expanding the sugarcane monoculture area. The study demonstrates that ethanol production from sugarcane contributes to environmental sustainability and that this renewable fuel compares favorably with fossil fuels.

Key words: ethanol, sugarcane, environment, energy.

Introduction

The impending petroleum scarcity predicted for the next decades has driven the growth of various renewable energy sources, such as biomass, hydrogen and solar and wind energy, throughout the world. In 2005, the world's petroleum consumption totaled 81.1 million barrels/day and the overall proven reserves amounted to 1,201 billion barrels. In other words: considering the current reserve/production ratio the existing petroleum would only suffice for the next 40.6 years (BRITISH PETROLEUM, 2006). Nevertheless, a more precise analysis would require consideration of other factors, including increased use of other sources of energy; identification of new reserves; increased or decreased petroleum consumption in the next few years; sale and

purchase contracts; extraction costs; resale prices; international conflicts; logistics limitations; world economic growth; environmental commitments; technological advances; energy efficiency; and reutilization of old petroleum fields using new technologies.

In practice, however, it is difficult to determine precisely how long the world will have petroleum. Regardless of it being 40, 60 or 100 years, increasing the share of the renewable energy sources in the world energy mix is both necessary and pressing. It is even possible that some specific reserves will be preserved in the future if their exploitation costs are too high or due to environmental restriction like climatic changes.

In the case of Brazil, the total retrievable petroleum reserves total almost 24 billion

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barrels. A study by Ferreira (2005) estimates that production will peak in 2011, which would mean self-sufficiency for 8-13 years according to mathematical modeling based on the Hubbert Curve.

Out of the total world petroleum consumption, close to 50% goes to transportation, wherein petroleum accounts for more than 95% of the energy demand (INTERNATIONAL ENERGY AGENCY, 2004). The scenario becomes even more critical because the world petroleum demand tends to grow until 2030, even in the transportation industry, particularly in developing countries like China and India (FULTON, 2004). Consequently, finding alternative sources of energy to complement and replace gasoline and diesel oil is a matter of global security and strategy.

Since the world vehicle fleet runs basically on liquid fuels and its renewal is a slow and gradual process, biofuels become the natural substitutes of fossil fuels during the period of global transition from conventional Otto Cycle and diesel engines to a new technological generation of vehicles. To that end, ethanol has proven to be one of the most viable and strategic fuels for that transition process and can even integrate future technologies in the long term. In view of the growing concern over the environment, ethanol has significant advantages over fossil fuels, especially gasoline, along the three main pillars of sustainable development, namely, environmental, social and economic issues.

Brazil is the world's leader in large-scale biofuel production and consumption. The country has more than 30 years of commercial experience with ethanol. In the last sugarcane crop year (2005-2006) 426 million tons of sugarcane were harvested, of which 384 million tons went to sugar and alcohol production and the remainder to other uses, such as animal feeds, cachaça (the most popular distilled alcohol beverage in Brazil) and cuttings for new sugarcane plantations. Ethanol production totaled 15.8 million cubic meters, of which 7.7 million cubic

meters were anhydrous alcohol (to blend with gasoline) and 8.1 million cubic meters, hydrated alcohol. The domestic market accounted for 13.5 million cubic meters, and exports for most of the remaining production; a small part went to building temporary stocks. Nevertheless, the country will probably increase both its domestic consumption and export capacity - a trend observed over the last few years. Brazil could transform ethanol into a major international commodity with the cooperation of other countries.

To that end, the federal government launched the National Agroenergy Plan (BRASIL, 2005a) in 2005. The plan is coordinated by the Ministry of Agriculture, Livestock and Food Supply (Mapa) and the Brazilian Agricultural Research Corporation (Embrapa) and its purpose is to expand biofuel production in the country even further, in a planned and sustainable manner. Agroenergy consists in the agricultural production of biomass for the purpose of generating energy, with special emphasis on ethanol, biodiesel, planted energy forests, and the use of agrosilvopastoral residues. The program contemplates the participation of those energy sources in the national energy mix, especially ethanol, an already consolidated and economically viable product.

Agroenergy represents a new paradigm for world agriculture and energy. It can be produced in practically all countries on Earth, whether developed or developing, and has relevant potential for reducing international dependence on petroleum. Furthermore, agroenergy can help achieve better income distribution among countries and reduce international conflicts associated with energy, while fostering sustainable development and diminishing unemployment, particularly in rural areas.

The study does not cover all aspects of ethanol and its relation with technology and the environment and, therefore, due notice should be taken of the limitations of the analyses presented herein. The study simply consolidates

information about the main environmental and technological issues relating to the sugarcane agroindustry in order to provide elements for a systematic consideration of ethanol. The authors have never intended to perform a scientific or conceptual analysis of the topic, nor include discussions of a political or economic nature.

Objective

The objective of this study was to discuss the main environmental and technological aspects associated with the ethanol production chain in Brazil, as well as the limitations to the expansion of the sugarcane agroindustry and the possibilities of expanding it in a sustainable manner.

Ethanol, environment and technology

The main environmental advantages and disadvantages associated with large-scale alcohol production and consumption are discussed below, together with the technological aspects pertaining to its three main phases, namely, agricultural, industrial, and distribution and consumption.

Agricultural phase

The main difference between the ethanol produced from sugarcane and fossil energy sources is ethanol's low environmental impact. It would be appropriate to emphasize at the outset that any type of agriculture has some environmental impact, since it interferes with the natural dynamics of the local biodiversity. However, this does not invalidate its strategic and sustainable use. By enforcing adequate management practices and specific environmental criteria for each crop and region, it is possible to reduce considerably any possible environmental impacts and ensure the sustainability of the medium for future generations.

Under agronomic supervision sugarcane production protects the soil against erosion and degradation. Since sugarcane is a densely planted grass the soil is not exposed after the crop develops, particularly because of its high growth rate, typical of C4 plants, a characteristic associated with its photosynthesis efficiency. Even after harvest, provided sugarcane burning is not practiced, the soil will still be protected from erosion since practically all the stubble is left behind, covering the soil partially or totally depending on the technique used. This material helps increase the amount of organic matter in the soil and has a positive impact on the nutrient balance and the soil's microbial population. According to Bertoni et al. (1972) soil losses in sugarcane farming are less than 12.5 t/ha/year, quite below those of soybean, cotton, beans, and castor beans, among other crops.

The stubble covering the field also reduces the incidence of light on the soil, thus inhibiting photosynthesis and the germination of weeds present in the soil's seed bank. With very few exceptions even plants that do not respond to light stimulation to break the dormancy cycle except in the presence of photosynthesis do not have sufficient energy to traverse the vegetable cover solely on the basis of the seed's energy reserves. In the case of sugarcane the reserves in the roots and in the node of the cutting not only produce new tillers but also enable the transposition of the plant cover. As an average, sugarcane is cut five times: the first at 15-18 months (plant-cane) and the others (ratoon-cane) every 12 months thereafter. Thus, the soil is hardly disturbed until it is time to completely renew the sugarcane plantation.

Burning sugarcane residues facilitates both manual and mechanical harvesting and eliminates practically all residues that would remain covering the soil. Harvesting the green sugarcane without prior burning significantly reduces the efficiency of manual harvesting and increases the risk of work-related accidents. Consequently, prohibiting sugarcane burning has encouraged the use of mechanical harvesters, which result in environmental gains

and employment losses in the rural areas. As an average, each sugarcane harvester does the work of approximately 70 workers.

On the basis of historical data from the Annual List of Social Information (Rais) of the Ministry of Labor and Employment (MTE) it is estimated that the sugar and alcohol industry generates approximately one million direct formal jobs in Brazil. Most are rural workers hired to harvest and manage sugarcane during the harvest season. As a rule these are unskilled workers with very little formal education. Nevertheless, their average remuneration exceeds that obtained in similar farming activities. The challenge is to have these workers actually hired on a permanent basis and provide them better living conditions. It should be emphasized that the sugar and alcohol industry, as well as non-governmental organizations, the Public Prosecutor's Office and the Executive Branch of Government have made significant progress in that direction in the last few years, although much remains to be done in terms of corporate awareness and ethics.

In connection with environmental issues, sugarcane burning adds an intense polluting load to the atmosphere that has a direct impact on the population of nearby cities and causes a large number of respiratory tract problems. The main harmful substances released into the atmosphere are nitrous (NO_x) and sulfur (SO_x) oxides; carbon monoxide (CO); aromatic compounds; particulate materials; and hydrocarbons. Some of these harmful substances are precursors of tropospheric ozone when exposed to solar radiation.

In addition to the direct impact on human health of nitrogen and sulfur oxides, these compounds react with the moisture contained in the atmosphere to produce acids that can be carried over long distances before being deposited as acid rain. Some of the consequences of acid rain are acidification of rivers and lakes, corrosion of structures, and damage to agriculture and to the natural dynamics of the environment. Burning sugarcane stubble

generates aerosols that upon being transported to the high atmosphere can interfere with the balance of the climatic systems even across long distances. Furthermore, burning affects the local biodiversity, particularly through the elimination of natural predators of species harmful to agricultural production.

In the State of São Paulo, Law Number 11.241 of 19 September 2002 determined a gradual phasing out of sugarcane burnings. That law stipulates that no burning will be allowed in sugarcane areas that can be mechanically harvested after 2021 and no sugarcane burning at all will be allowed after 2031. In both cases burnings will be gradually eliminated according to a calendar comprising those deadlines.

Similar measures have been studied for other states, although there seems to be a natural trend favoring mechanical harvesting without burning in both old plantations and new sugarcane expansion areas. Slopes with gradients above 12% constitute the greatest obstacle to reducing controlled burnings. The usefulness of mechanical harvesters is limited in slopes and, therefore, manual harvesting prevails. New harvesters are being developed to work on steeper slopes.

At the federal level, Decree Number 2.661 of 8 July 1998, which regulates the sole paragraph of article 27 of Law Number 4.771 of 15 September 1965, known as the Forest Code, establishes precautionary rules for using fire in agrosilvopastoral practices, but does not establish specific rules for the use of fire in sugarcane management.

Another environmental problem seen in the agricultural phase is soil compaction when appropriate agronomic techniques are not used. The intense movement of heavy machinery during planting and harvesting can cause soil compaction, which in extreme cases can only be mitigated through deep plowing or even subsoil ripping or subsoiling. The use of lighter, more modern machinery helps reduce that kind of problem, together with crop rotation and maintaining the straw or stubble over the soil.

Crop rotation also contributes to improve the biological balance of the soil by preventing excessive selection pressure on the local biodiversity and, consequently, the emergence of pests and diseases. In addition, crop rotation using leguminous plants promotes nitrogen fixation in the soil through symbiosis between the bacteria and the root system of the legumes.

Concerning the use of pesticides, sugarcane requires few sprayings when compared with other crops planted over large extensions of land mainly because of its rusticity and adaptation to the prevailing soil and climatic conditions in Brazil. Herbicides are used more often. Insecticide use is relatively low and fungicides are practically never used. Furthermore, many producers already use commercial-scale, biological pest control. Organic farming has also increased in view of the growth of the organic sugar market both in Brazil and abroad.

Terracing is recommended for steep slopes in order to prevent soil losses and silting of water resources. Some measures contemplated in the effective environmental code, such as maintaining existing native forests and planting perennial plant species, are recommended for steep gradients and hilltops. Protecting the existing canopy forests along watercourses and setting aside natural vegetation areas as environmental reserves are required by the environmental legislation. It is essential that the protected areas connect with each other forming the so-called "ecological corridors", which enable the migration and reproduction of the local species, especially endemic species. Brazil's environmental legislation is among the most rigorous in the world, although much remains to be done about enforcement, control, monitoring, and environmental education.

Despite the limitation and problems described above sugarcane is planted in traditional sugarcane areas, such as the Zona da Mata in the Northeast Region of the country or in former cattle ranching or monoculture (soybean, corn, citrus, and coffee) areas, such as the Center-

South of Brazil. Therefore, sugarcane is seldom found in agricultural frontier areas. The main reason is that sugarcane is usually produced within a 30-40 km radius from the sugar mills to a great extent due to the rising costs of transportation over longer distances. In turn, the mills must be located where final product transportation conditions are adequate, which has led to choosing areas with ready infrastructure and near ports and consumer centers. Thus, the sites for the new industrial units must have appropriate logistics and infrastructure, as well as adequate soil and climate conditions.

In the case of the Amazon Region, logistics are rather precarious and distances to the major consumer centers are considerable, all of which leads to higher transportation costs. In addition, the sugarcane varieties currently used are ill adapted to the climatic conditions of the Amazon Region. The phenologic cycle of sugarcane requires a water stress period to inhibit growth and concentrate sucrose, which the Amazon rainfall pattern does not provide. Thus, the steady, year-round rainfall promotes excessive growth and the sugarcane stalks store very little sucrose. Consequently, the Amazon Region is never considered when expanding sugarcane production, the choice falling on areas already being farmed or ranching, or on degraded areas, in the Center-West and Northeast regions of the country, particularly the western part of São Paulo, the Minas Gerais 'triangle' and southern Goiás.

The largest challenge to diminishing deforestation in the Amazon Region is reducing the unregulated expansion of cattle ranching and illegal wood exploitation by providing other sustainable development opportunities in the region. To that end, the federal government has had expressive results in the last few years: a decrease in deforestation of more than 60% in a two year period (2005-2006), although more progress would be needed.

Embrapa estimates that 90 million hectares are available for agricultural expansion in Brazil,

out of a total 852 million hectares. The current sugarcane area is slightly more than 6 million hectares (2005-2006 crop year), i.e., less than 1% of the national territory. Another 30 million hectares occupied by underutilized pastures could be released for other farming activities in the next few years without any impact on meat and milk production, a fact already made apparent in the State of São Paulo.

Thus, agroenergy would not necessarily compete with food farming in the short and medium term in Brazil. Furthermore, in the case of sugarcane energy and food are farmed together. Although this is a strategic discussion at the world level, especially in connection with the countries in Southeast Asia, Oceania, North America, and Europe, where no agricultural frontiers remain, the demand for both energy and food steadily increases. The use of biomass for energy purposes must be seen within a broader framework. The focal point of the new energy paradigm is a Civilization of Renewable Energies, rather than only biomass energy.

Although large extensions of land are available for the expansion of the sugar and alcohol industry in Brazil, in the case of São Paulo, which accounts for almost 62% of the national sugarcane production, and in some regions of the states of Paraná, Minas Gerais and Mato Grosso do Sul, the expansion of sugarcane plantations causes some concern about excessive intensive monoculture in some areas, a fact already observed in the Zona da Mata in the Northeast Region, particularly in the states of Pernambuco, Alagoas and Paraíba (CANASAT, 2006).

Ethanol can be produced from crops other than sugarcane, such as cassava, corn, sorghum, wheat, and sugar beets. Although the production of ethanol from different raw materials was encouraged immediately after the creation of the National Alcohol Program (Proalcool) in 1975, it was soon demonstrated that sugarcane had the best agricultural and industrial yields when compared with other sources. Other countries produce alcohol from other raw

materials, such as corn in the USA and wheat in the European Union, but the energy efficiency of sugarcane is sensibly superior to the other crops' (Table 1), especially when sugarcane residues are utilized in the production process.

Table 1. Energy efficiency of different raw materials used to produce ethanol.

Raw material to produce ethanol	Energy balance (output/input)
Wheat ⁽¹⁾	1.2
Corn (USA) ⁽¹⁾	1.3 - 1.8
Sugar beets (EU) ⁽¹⁾	1.9
Sugarcane (Brazil) ⁽²⁾	8.3

⁽¹⁾ F. O. Licht (2004).

⁽²⁾ Macedo (2005).

The energy efficiency of ethanol production from sugarcane is even greater when potential breeding and biotechnology advances are taken into account, including the possibility of extracting alcohol from sugarcane bagasse (lignocellulose hydrolysis), taking better advantage of sugarcane stubble, using more efficient energy conversion equipment and processes, and ensuring more efficient use of industrial wastes.

One hectare usually yields approximately 6,500 liters of ethanol on average. In order to produce 1 billion liter of ethanol approximately 200,000 hectares would be needed, including areas for the production of sugarcane cuttings and plantation renewal. Yields should tend to increase in the near future as better management practices and new technologies are implemented.

Industrial phase

Sugarcane industrialization generates large amounts of wastes that can cause serious environmental damage when inadequately treated. Nevertheless, great strides have been made in sugarcane waste management driven by recent research outcomes and growing concern for the environment. The two main residues from sugarcane production - bagasse

and stillage - have become powerful allies of the production process as a whole. The utilization of those residues is an essential condition to ensure sustainable sugarcane and ethanol production.

Sugarcane stubble accounts for one-third of the overall sugarcane harvested. The stubble is either burnt during harvesting or left behind as soil cover. Another third is sugarcane juice, which is used in alcohol and sugar production. And the final third is a solid residue from sugarcane crushing called bagasse (HASSUANI et al., 2005).

After the sugar-bearing juice is used to produce sugar or alcohol, the liquid effluent is called stillage. For many years the stillage was improperly disposed of in the soil and nearby watercourses. Because of its high biochemical oxygen demand (BOD), stillage caused dramatic reductions of the aerobic species, as well as eutrophication due to excess nutrients. At present, however, stillage is only applied to the soil in a controlled manner, as organic fertilizer, and is not longer an undesirable product. Stillage is normally applied to areas where sugarcane has been harvested using pumps or canals to deliver the fertilizer. Concentrated applications in any single area should be avoided in order to prevent excessive amounts of nutrients and possible contamination of the ground water table in saturated areas.

Stillage is rich in many macro and micronutrients required for plant growth,

particularly potassium (K_2O). Since potassium deficiency is common in most sugarcane plantation soils, the use of stillage reduces the need for chemical fertilizers and, therefore, diminishes production costs, internalizing into the production process what previously was an environmental externality.

Stillage can also be fermented in bioreactors that produce methane gas through anaerobic decomposition, although the nutrient concentration is not significantly reduced. Thus, it would still be possible to use the wastes for fertilizing purposes, as seen in Table 2. The methane produced has many potential uses. It can be used as an additional energy source in the industrial operations or converted into electric power that can be exported to the electric grid.

Some ongoing studies are focusing on concentrating stillage further to produce a new, easily transported commercial product to be used as fertilizer or in the chemical industry. Although Brazil has already solved that problem, stillage is an undesirable waste in many other countries, particularly those that produce sugarcane in small areas, often far from the industrial plants. The greatest challenge to the advancement of the ethanol production technology is the energy requirements of stillage dehydration, which can be met using the energy sources in the production process itself, such as sugarcane bagasse.

Table 2. Contents of the main components of sugarcane stillage before and after biodigestion.

Parameter	Unit	Raw	Sediment	Digested	% Removed
STS	g/L	20	6	0.3	98
DCO	g/L	25	22	4	84
BDO	g/L	12	10	0.5	96
pH	-	3.5	3.5	7	-
Alkalinity	meq/L	-80	-80	40	-
VFA	meq/L	120	120	2.5	98
N	mg/L	250	250	230	8
P	mg/L	200	200	190	5
K	mg/L	1,000	1,000	1,000	1
Temperature	°C	95	30	30	-

Source: Haandel and Lier (2006).

Like stillage, for many years sugarcane bagasse was not adequately utilized. At present, the bagasse is used to produce the thermal, mechanical and/or electric energy necessary to make sugar and alcohol and to maintain other plant activities. Plants are rapidly becoming self-sufficient and in many cases are exporting electric power to the electric grid. According to data from the National Energy Balance (BRASIL, 2005b), sugarcane products account for 15.4% of the Brazilian energy mix in terms of primary energy production. Sugarcane bagasse accounts for 1.8% of the electric power supply in the country, including the electricity consumed by the sugar mills, an average 80% of the total amount generated.

Despite the huge amounts of alcohol being generated the potential production is still greater because of the obsolete systems and equipment still being used. A Sugarcane Technology Center study (HASSUANI et al., 2005) carried out in partnership with the United Nations Development Program (UNDP) (BRA96/G31) and coordinated by the Ministry of Science and Technology estimates the current, additional energy-generation potential at 700 MW to 12,000 MW, depending on the technology used. The study contemplated from conventional 22bar/300 °C steam boilers to biomass gasifier/gas turbine (BIG-GT) systems for steam/electricity co-generation and included the partial use of sugarcane stubble. The same authors believe that approximately 50% of the sugarcane stubble left on the ground after the harvest could be used to produce additional energy, without compromising sugarcane production. The remaining straw would be sufficient to benefit and protect the soil. The challenge is finding viable solutions to transport the low density/high volume stubble from the fields to the mill. The current installed energy production capacity tends to increase as new industrial plants are commissioned.

Among other uses of sugarcane bagasse and stubble being studied are extracting alcohol from cellulose and obtaining chemical products, such as biooil, and other compounds for the

chemical industry. Those technologies would further increase the energy efficiency of sugarcane.

There is also a market for some byproducts like filter cake and fermentation wastes. Filter cake is used as organic fertilizer in the sugarcane plantations, while the fermentation wastes have high protein contents and, therefore, can be mixed with animal feeds to increase their nutritional value. Carbon dioxide (CO₂) from alcohol fermentation has not attracted much attention, but can be used to produce dry ice and to make soft drinks in the beverage industry, or even as raw material in the chemical industry in view of its high level of purity.

By using the renewable energy from the sugarcane industry, the country can also obtain the so-called carbon credits under the Clean Development Mechanism (CDM) in the Kyoto Protocol of the United Nations Framework Convention on Climate Change. By preventing the emission of additional greenhouse effect gases, such as carbon dioxide, methane (CH₄) and nitrous oxide (N₂O), as related to a baseline (trend) scenario, it is possible to obtain a certificate equivalent to the emissions avoided by the project, also called Certified Emissions Reduction (CER), or sell such credits in the international carbon market, either directly or in a stock exchange or futures market.

The design of a CDM project must follow some pre-established basic procedures. Initially, the methodology for measuring project emissions must be established. The CDM Executive Council, which is an international Climate Convention body with headquarters in Bonn, Germany, must approve the methodology. Next, it is necessary to prepare the Project Design Document (PDD), which is then submitted to the Designated National Authority (DNA) of the host country for approval, together with a Validation Report from an accredited Designated Operational Entity (DOE). In the case of Brazil, the DNA is the Interministerial Commission on Global Climate Change chaired by the Ministry of Science and Technology. The

DNA analyzes the environmental sustainability of the project and, if satisfied, issues a Letter of Approval (LoA) stating that the project is hosted in Brazil, is based on a voluntary arrangement and supports sustainable development in the country. The following step is to submit the documentation to the CDM Executive Council for registration. Once registered, the project is monitored by a second DOE and, after a period obtaining corroborative evidence of emission reduction, after having the right to one carbon credit validated, the Certified Emission Reduction Certificates (CERs) can be requested. These are calculated on the basis of carbon dioxide equivalents (CO₂eq) to be included in the greenhouse effect gas emission balance of the purchasing country.

In Brazil most projects approved by the Interministerial Commission on Global Climate Change are related to the bioenergy area and to the use of biogas from urban solid wastes decomposition in landfills, which has an enormous growth potential (BRASIL, 2004). Among the agroenergy projects special mention should be made of bagasse co-generation projects, which represent 32% of all approved projects. Those projects usually request credits for emissions avoided through the non-utilization of other energy sources to meet the demands of an industrial plant, such as, for example, diesel; fuel oil; and electricity from the electric grid, a part of which comes from fossil generation.

Although sugarcane bagasse co-generation is one of the main types of project submitted to the Interministerial Commission, the ground has barely been scratched if one considers the number of registered sugar and alcohol plants in the country (almost 360). Co-generation is another environmental contribution of the sugarcane agroindustry to the fight against the escalation of the greenhouse effect at the world level and, consequently, against climatic changes: the greatest global environmental problem of the 21st century.

A good illustration would be the case of biogas from pig farming wastes, which accounts for 26% of all approved projects. The main outputs of biogas production are methane, which can be

used to generate renewable thermal or electric energy; organic fertilizer; and a low-BOD liquid effluent. Reforestation projects and the use of biomass residues are barely beginning, although some projects already in the initial phases show great potential.

Figure 1 shows the profile of one of the ongoing CDM projects in Brazil. The Commission approved 81 projects from February 2005 to June 2006.

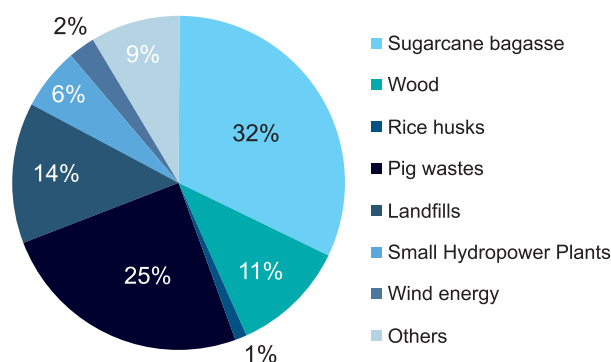


Figure 1. Profile of the CDM projects approved by the Brazilian Designated National Authority. Source: Brasil (2006).

Another important issue pertaining to the industrial phase is the possibility of using ethanol in the alcohol industry. The high petroleum prices have given renewed vigor to the alcohol industry, which was developed during the 1970s and 1980s and produced dichloro-ethane, acetic acid, acetaldehyde, PVC, and ethyl acetate, among other products. In the 1990s, the Brazilian alcohol industry manufactured approximately 30 products, with special emphasis on dichloro-ethylene, LD polyethylene, ethylbenzene, PVC, and HD polyethylene (BOTO, 1988; MACEDO et al., 2005).

Distribution and consumption

Ethyl alcohol is biodegradable, miscible in water, hygroscopic, and volatile when exposed

to air. Consequently, the environmental impact of eventual alcohol leaks or spills during storage and transportation, whether land or maritime, is much lower than that of petroleum and petroleum products. Exception is made of leaks or spills of gasoline/alcohol blends into the ground, especially at filling stations, in which the "co-solvency effect" increases ground water table contamination by the fuel and migration of the more dangerous and soluble gasoline compounds, such as benzene, toluene, ethylbenzene, and xylene (CORDAZZO et al., 2006).

As regards fuel alcohol consumption, the polluting gas emissions of alcohol-fueled engines are lower than those of gasoline. It should be emphasized, however, that the pollutants from vehicle emissions are the main source of negative impacts on the quality of urban air.

Some countries still add tetra-ethyl lead to gasoline to enhance performance, but that additive is unnecessary when anhydrous alcohol/gasoline blends are used. In 1992 Brazil was the first country in the world to completely stop adding lead to gasoline, although most of the petroleum refined in the country had been unleaded since 1989. Continuous contamination and exposure to lead results in serious damage to human health, leaving permanent sequelae or killing the individual in cases of extreme contamination.

Blumberg and Walsh (2004) showed a direct relation between the average blood lead concentration in the urban population and the amount of lead in gasoline. The authors worked with USA data from 1976 to 1991, when unleaded gasoline became mandatory, and observed that lead contents in blood dramatically dropped by 78%.

Furthermore, with the ethanol-gasoline blend there is also no need to use other additives like MTBE (methyl tert-butyl ether) and ETBE (ethyl tert-butyl ether), thus avoiding the specific environmental impacts of those emissions.

As regards gasoline, ethanol consumption causes lower carbon monoxide, sulfur dioxide and particulate emissions. According to Apace Research (1998), studies carried out in Australia with a 10% ethanol/gasoline blend identified the following emission reductions: 32% for CO; 12% for total hydrocarbons (THC); and 7% for CO₂. Nitrogen oxide emissions were similar for both fuels.

In the case of aldehydes, ethanol emissions are slightly higher than those of gasoline, but not higher than diesel's. Even so, according to Szwarc (2006) most of the aldehyde emissions from ethanol are acetaldehyde, a less toxic product than those emitted by gasoline and diesel. Studies conducted in Denver, Colorado, (ANDERSON, 1997) and California (CALIFORNIA AIR RESOURCES BOARD, 1999) using 10% ethanol-gasoline blends showed that the aldehyde contents of ambient air remained practically unchanged when compared with the pure gasoline situation. On the other hand, those emissions can be easily prevented using automobile catalyzers. Brazil made catalyzers mandatory in new vehicles in 1992.

Small amounts of ethanol can also be mixed with diesel by using specific additives. According to Ahmed (2002) tests carried out in USA highways in which freight trucks used 10%-15% alcohol-diesel blends showed significant reductions of most polluting gases when compared with emissions from pure diesel oil, as shown in Figure 2. Similar results were obtained in simulations carried out in Brazil. Another interesting outcome was the reduction of sulfur emissions observed in the AEP102 and MAD-08 Alcohol-Diesel Blend projects sponsored by the federal government and developed in partnership with research institutions and entities from the sugar and alcohol industry.

In connection with greenhouse effect gas emissions from ethanol fuel combustion, especially carbon dioxide, their effect is practically nil, because they result from a renewable process whereby the carbon dioxide

is fixed again during photosynthesis as sugarcane grows. Furthermore, ethanol has demonstrated its strategic importance in reducing greenhouse effect gas emissions on a global scale (Macedo et al., 2004).

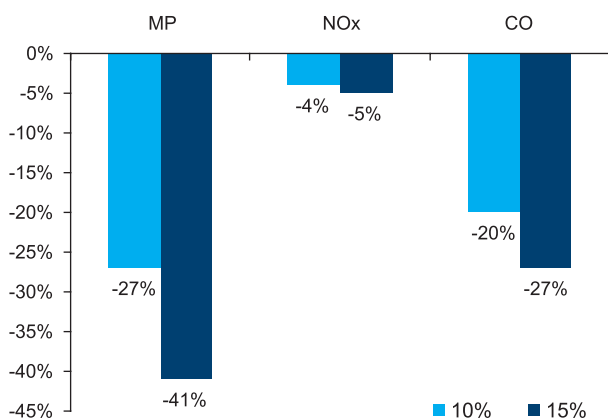


Figure 2. Emission reduction in alcohol/diesel blends (10% and 15%) when compared with pure fossil diesel. Source: Ahmed (2002).

Consuming ethanol-gasoline blends or pure ethanol is a relatively simple way of reducing greenhouse effect gases, particularly in developed countries with Kyoto Protocol commitments to meet. It should also be emphasized that the transportation industry accounts for almost 25% of global CO₂ emissions (IPCC, 2001). Macedo et al. (2005) estimated that it would be possible to avoid 12.6 million tons of CO₂eq emissions for every 100 million tons of sugarcane through the use of ethanol, bagasse and additional sugarcane-related electric power.

When less than 10% alcohol is mixed with gasoline, there is no need to make adjustments in traditional gasoline-fueled vehicles except for carburetor engines, where blends with less than 5% alcohol are recommended, as shown in Table 3. In Brazil, Law Number 10.464 of 24 May 2002 makes a 20%-25% blend compulsory.

In recent years, with the advent of flex fuel vehicles, which can use any mixture of alcohol and gasoline (from 0% to 100%), the domestic ethanol demand has risen substantially, and

tends to grow in the short and medium term. In 2005, 50.2% of new light vehicles sold in Brazil were flex fuel, and by June 2006 the proportion had risen to 76.3% of all sales (CARTA DA ANFAVEA, 2006).

Table 3. Potentially required modifications in light, Otto Cycle vehicles, depending on the anhydrous alcohol percentage blended to gasoline.

Engine	Carburetor	Fuel Injection	Fuel pump	Fuel pressure device	Fuel filter	Ignition system	Evaporation system	Fuel tank	Catalytic converter	Basic engine	Engine oil	Feed system	Exhaust system	Cold start system
% Blend														
< 5%														
5% - 10%														
10% - 25%														
25% - 85%														

Source: Anfaeva (2006a).

Final considerations

Sugarcane and ethanol production has very little environmental impact, particularly when accompanied by rigorous planning, control and enforcement measures. The environmental impacts of both ethanol and fossil fuels should be analyzed along the whole production chain and not by stages. Thus, it should be possible to ascertain that ethanol benefits the environment, the economy and society at large in diverse ways.

Although two of the main environmental problems associated with ethanol production have been solved by using the stillage and bagasse in different stages of the production chain itself, there remain some problems that require attention. Among said problems are pre-harvest burning of the crop and sugarcane encroachment in saturated regions. Sugarcane burnings could greatly diminish as the State of São Paulo assigns priority to enforcing the timetable in Law Number 11.241, since São Paulo accounts for the largest share of sugarcane production in the country, even though other states should also target burnings.

On the other hand, eliminating sugarcane burning has an unfavorable, albeit indirect, effect on employment rates. Although sugarcane harvesting is frequently temporary and always extremely hard work, it is often the only work opportunity open to a large number of rural workers, most of whom are unskilled. There are simply no other jobs that pay as much in the rural areas. It would be necessary, therefore, that the enforcement of the environmental control measures comes accompanied by upgrading the farming skills of workers and finding jobs for them in other activities, as well as guaranteeing their citizens' rights and social inclusion.

Sugarcane production should not expand into saturated areas such as some Center-South and Northeast regions, particularly in the states of São Paulo, Alagoas and Pernambuco, in order to prevent an escalation of agronomical and environmental problems and to reduce the economic and plant health vulnerability of those states to possible agricultural crises in the sugarcane plantations. Although most new investments are being made precisely in the State of São Paulo, the number of sugarcane production projects is also growing in other states, particularly Goiás and Minas Gerais. New sugarcane development hubs should be planned particularly in the states of Maranhão, Piauí and Tocantins.

There are some important mechanisms that could ensure the sustainability of the sugarcane agroindustry, namely, agro-ecological zoning for sugarcane production at the national level; strategic environmental assessments; federal orientation to the State Environmental Agencies about environmental licensing of sugarcane mills and distilleries; sugarcane expansion that takes into account existing infrastructure and logistics; and the development of incentive policies that focus on sustainable sugarcane expansion in strategic areas.

Ethanol's prospects are promising in both domestic and international markets. Ethanol has proven to be an important alternative to

petroleum at the world level when compared with other sources. Furthermore, ongoing research focusing on the commercial development of technologies to produce alcohol from cellulose, as well as on biotechnology, promise to give a new thrust to ethanol production throughout the world in the next decades.

On the basis of the information presented in this study it is possible to see that the sugarcane ethanol produced in Brazil is a consolidated and viable product. Its large-scale production and consumption show that sugarcane ethanol is competitive and strategically important and contributes to reducing the fossil fuel demand. It provides a cleaner and renewable energy mix, it can help create jobs and income opportunities, and it ensures environmental sustainability for future generations.

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Fuel alcohol production from carbohydrates

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Abstract: Since the earliest times of the automobile industry ethanol has been considered a viable fuel. In fact, Henry Ford's engine was built to operate with either alcohol or gasoline. Gasoline became cheaper and more readily available, and alcohol remained behind until the 1929 economic crash and the petroleum crises of the 1970s. Thus, political considerations were the initial justification for ethanol production, which is now driven by the current emphasis on reducing pollution and limiting global warming. Although ethanol production from sugarcane has been very successful in Brazil, other raw materials should also be considered in the future to enable ethanol production in regions less appropriate for sugarcane farming, include small farmers who produce starchy products such as cassava and sweet potatoes in the renewable fuel production chain and use lignocellulose materials as raw materials when that production path becomes commercially available. Thus, the study focuses on the technical aspects of ethanol production from carbohydrates and discusses the main advantages, difficulties and technical innovations associated with ethanol use.

Key words: ethanol, manufacture, renewable fuels, carbohydrates.

Introduction

Ethyl alcohol (ethanol) is a colorless liquid with a sharp smell. It is easily flammable and its flame is blue. It is highly hygroscopic.

Anhydrous alcohol is perfectly soluble in diverse organic and mineral substances, such as esters, carburetants, ketones, etc. Its solubility diminishes as its water content increases. In a water mixture, alcohol's freezing point is lower than water's.

Ethanol is an excellent automotive fuel. Its octane number is higher and its vapor pressure lower than gasoline's, which results in lessened evaporative emissions. It is less combustible than gasoline in the presence of air, which reduces the number of fires and the intensity of such fires in vehicles. The lower and higher

calorific power of anhydrous ethanol are 21.2 and 23.4 megajoules per liter (L), respectively, as against 30.1 and 34.9 megajoules/L of gasoline's.

Ethanol's fuel properties has led to the development of automobiles fueled by either alcohol or alcohol-gasoline blends in Brazil. Until 1988 the automobile industry (GM, Ford, Volkswagen, Fiat) sold such automobiles only with carbureted systems; at present they are available with electronic injection systems; and more recently, flex fuel automobiles became available.

In Brazil two types of fuel ethanol are used: anhydrous alcohol and hydrated alcohol. Anhydrous alcohol contains less water and is more appropriate for fuel blends with gasoline. Adding fuel alcohol to gasoline increases the

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metric volume consumed by 2%. Thus, 100 liters of gasoline-anhydrous alcohol mixture contain 81.6 liters of gasoline and 20.4 liters of anhydrous alcohol. So that 20.4 liters of anhydrous alcohol can save 18.4 liters of gasoline. In 1992 Brazil became the first country in the world to ban tetra-ethyl lead completely from its fuel mix, although almost 99% of the petroleum refined in the country had not contain that additive since 1989. Adding alcohol to gasoline made that achievement possible. Anhydrous alcohol acts as antiknock agent when added to gasoline because of its high octane rating. It has been shown to be a good replacement for both tetra-ethyl lead and MTBE, enabling the elimination of the harmful environmental effects of those products.

Hydrated alcohol is appropriate for vehicles fueled exclusively by alcohol and for flex fuel vehicles. Since its production requires fewer industrial operations, hydrated alcohol is an average 4.5% cheaper than anhydrous alcohol. The yield of hydrated alcohol-fueled engines is from 20% to 27% lower than that of gasoline engines. This means that the volumetric consumption of alcohol will follow that ratio for every kilometer driven with gasoline. In order to compensate the difference, the current price of alcohol is 21.4% lower than gasoline's. The main properties of gasoline and alcohol are shown in Table 1.

Table 1. Properties and characteristics of fuels.

	Gasoline	Ethanol
Specific heat (kJ/kg)	34,900	26,700
Octane number (RON/MON) ⁽¹⁾	91/80	109/98
Latent vaporization heat (kJ/kg)	376 ~ 502	903
Ignition temperature (°C)	220	420
Air/Fuel		
Stoichiometric ratio	14.5	9

⁽¹⁾ Research Octane Number (RON); Motor Octane Number (MON). Source: Goldemberg and Macedo (1994).

Background

Since the earliest times of the automobile industry ethanol has been considered a viable

fuel. In fact, Henry Ford's first engine model was built to operate with either alcohol or gasoline. In 1917 Alexander Graham Bell proclaimed the benefits of alcohol as a fuel in an article published in the National Geographic Magazine. The inventor cited the large number of raw materials that could be used to produce alcohol, including "sawdust, corncobs and most vegetables, even seeds... the residues from our farms... and even urban wastes".

Nevertheless, as gasoline became cheaper and more readily available, alcohol fell behind. In 1929, however, a major international financial crisis adversely affected the economies of all countries and, in Brazil, the government did not have enough hard currency to purchase liquid fuels in the international market. The first anhydrous alcohol distillery was installed and in 1931 the federal government established a compulsory 5% ethanol blend with gasoline (Decree Number 19.717) in order to save hard currency in fuel imports and to boost sugarcane production. At that time also, and for the same reasons, alcohol began accounting for a fraction of the fuel market in other countries, such as the United States, Germany, New Zealand, and France.

The National Alcohol Program (Procalcool) was created in 1975, two years after the Israeli-Arab war, when petroleum prices more than tripled within a 12-month period with a strong impact on the Brazilian Trade Balance. As a reaction to the situation, the federal government adopted a broad policy that included the Procalcool Program and whose purpose was to overcome the so-called "energy bottleneck". In the mid-1970s the National Alcohol Commission (Cenal) listed the five basic objectives of Procalcool as follows:

- To save hard currency by diminishing petroleum imports to produce gasoline and raw materials.
- To diminish income disparities among the regions by broadening production in areas with high unemployment rates. The production of alcohol from cassava was included to enable

the alcohol program to reach more people, the so-called democratization of the program, since cassava is mostly produced by small farmers.

- To reduce individual income disparities by increasing employment rates in the agricultural sector in an activity whose wages are higher than average farm-worker wages.
- To increase the domestic product through more intense use of land and labor, which at the time were seen as idle assets.
- To expand capital-good industries (tractors, agricultural machinery, factories producing and building distilleries, chemical industry, etc.) by raising the demand of the alcohol industry.

It is easy to see, therefore, that Procalcool had various social objectives woven into the more immediate economic objectives like reducing petroleum consumption and overcoming the energy collapse, for example. On the other hand, no environmental objective was mentioned during the first phase of Procalcool. Environmental concerns would only emerge years later.

Another aspect worth mentioning is that the first phase of Procalcool contemplated the production of alcohol from other agricultural raw materials, like cassava, a crop that is almost exclusively produced by small farmers. Using cassava roots would enable smaller distilleries to foster energy self-sufficiency of transportation in the rural areas. Six alcohol distilleries using cassava as raw material were built in Brazil in the 1980s with public funding and tax incentives. They were installed, however, in non-traditional regions or towards the end of the cassava development hub cycle, so that the undertakings became unviable and the idea was abandoned.

Thirty years after Procalcool, Brazil is once again expanding sugarcane production for the purpose of ensuring a large-scale alternative-fuel supply. Sugarcane plantations are spreading beyond the traditional sugarcane areas in the hinterland of the State of São Paulo and the Northeast Region, and encroaching on the

Cerrado. The flex fuel engine technology has given a new thrust to the domestic alcohol consumption. These cars, which move on gasoline, alcohol, or a mixture of both fuels, were introduced in Brazil in March 2003 and rapidly won consumers over. Flex fuel cars were accepted much more readily than the automobile industry expected, and flex fuel car sales already exceed gasoline car sales. Flex fuel cars account for 49.5% of all automobiles and light commercial vehicles sold every month, while gasoline cars account for 43.3% according to the National Association of Automotive Vehicle Manufacturers (ANFAVEA). The market preference led the Sugar and Alcohol Sectoral Chamber, a government agency, to review its forecast and predict that the market share of the new technology would reach 75% of cars sold in 2006.

Environmental and economic aspects

The main advantage of ethanol when compared with gasoline is being a renewable source of energy and, in principle, a totally sustainable and less polluting fuel. The most important point is that the CO₂ released when ethanol is burned had been recently fixed by the sugarcane plants, which are the raw material for producing ethanol, so that it can be argued that there is no net contribution to global warming. Nevertheless, energy (most of which comes from fossil fuels) is required during all stages of the process, i.e., production (farming, fertilization and harvesting) of the raw material, fermentation of the sugarcane juice to transform it into ethanol and distillation. Since sugarcane bagasse is used as fuel in Brazil, the energy generated by the ethanol produced is almost twice the amount of energy spent in producing it.

The initial criticisms to ethanol production in Brazil focused on the low process efficiency and the environmental problems associated with sugarcane farming. As regards low efficiency, advances in research have enabled ethanol production in Brazil to grow approximately 4%

per year (Figure 1). On the other hand costs have been reduced by about 3% p.a. since the beginning of the Procalcool program, due to improved sugarcane varieties, more adequate crop management techniques and enhancements in the industrial fermentation, extraction and distillation processes.

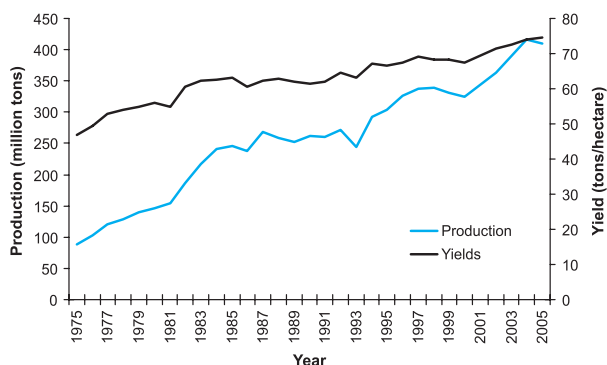


Figure 1. Evolution of sugarcane production and yield in the last 30 years.

Source: IBGE (2006).

In connection with the environmental problems caused by the intensive cropping regimes used in sugarcane production, it is possible to argue that sugarcane has become an important example of sustainable agriculture, especially in the State of São Paulo. It is an agricultural activity with one of the lowest soil erosion indexes in the world. The use of pesticides and chemical fertilizers in sugarcane is also among the lowest in the world since biological pest control and fertirrigation using residues from the industrial sugarcane processing are common practices. The biological control of sugarcane results in very low use of pesticides and herbicides, which are applied in doses specific to each site. In addition, leaving sugarcane stubble in adequate locations and techniques derived from "organic" farming can further improve the picture. Lesser amounts of mineral fertilizer are used in sugarcane than in corn or soybean farming, and the better management of the residues (filter cake, stillage and some stubble) currently being practiced could lead to

further substantial reductions. In terms of soil and water protection the initial problems have been attenuated by the rapid growth of the crop, crop rotation systems and multi-harvesting. There is practically no consumption of raw water in sugarcane plantations; the water is basically supplied by the various effluents generated in the production process (treated and untreated) and through rainfall. Nevertheless, it would be necessary to increase the number of permanent reserve areas and adopt already existing techniques to reduce the capture of water for industrial use. The pollution caused by the sugar mills has been drastically reduced since the bagasse began being used as fuel and the stillage and filter cake, as fertilizer. All these residues are now valuable inputs.

Production paths

Two different paths are used to produce ethanol: chemical synthesis and fermentation.

In chemical synthesis, ethanol is obtained from unsaturated hydrocarbons, such as ethylene and acetylene, and from petroleum gases and mineral coal. The latter is only economically significant in countries with large petroleum reserves and an advanced petrochemical industry. The ethanol thus obtained is obviously not produced from a renewable source of raw material, nor can it be considered an alternative fuel.

Consequently, fermentation is the preferred method of obtaining ethanol in Brazil and most other countries. Fermentation can be divided into three stages: substrate preparation, fermentation and fermentate distillation. During the preparation of the substrate the raw material is treated to obtain fermentable sugars. This stage depends on the type of raw material used, as described below. Fermentation is the process whereby microorganisms transform the carbohydrates into alcohol and carbon dioxide. Lastly, the ethanol is separated from the fermentation broth and purified in the distillation process.

Stages of the ethanol production process

A large number of variables intervene in ethanol production, which can radically differ depending on the raw material and microorganisms used. Ethanol production usually involves upstream, fermentation, and downstream operations. The upstream phase includes all the procedures necessary to ensure successful fermentation followed by retrieval of the product or downstream phase. Thus, alcohol production involves the following operations: substrate preparation, inoculum preparation, fermentation, distillation, and rectification, all of which are separately described in this paper.

Raw materials

Any product containing a considerable amount of carbohydrates (sugars) can be used to produce alcohol. Nevertheless, the economical viability of alcohol production depends on the production volume, industrial yield and manufacturing costs. Potential raw material can be divided into three groups depending on the type of carbohydrate.

Sugary materials - They contain simple sugars, i.e., carbohydrates with six (monosaccharides) or 12 carbon atoms (disaccharides), such as glucose, fructose and maltose. Monosaccharides are only found in

fruit juices and are directly fermentable. They are used only to produce alcohol in beverages such as wine and cider. Disaccharides are fermented after hydrolysis with an enzyme called invertase or saccharase, which is produced by the fermentation agent itself. For example: sugarcane, sugar beet, molasses, honey, and fruits.

Starchy or amylaceous materials - They contain more complex hydrocarbons, such as starch and inulin, which can be broken down into glucose through acid hydrolysis or the action of enzymes in a process called malting or saccharification. For example: starchy grains (corn, sorghum, barley, and wheat), roots and tubers (potatoes, sweet potatoes and cassava).

Cellulosic materials - Their main component is cellulose and although available in large amounts cannot be used to produce ethanol because they require a complex, acid hydrolysis process in order to be fermentable. For example: straw, wood, agricultural residues, and paper industry wastes.

Table 2 shows a comparison of potential substrates for ethanol production in Brazil considering their productivity in the regions where they are usually farmed and their average total hydrocarbon contents. It should be noted that those are not the only parameters used in selecting a raw material, since ethanol production costs also depend on the farming, transportation and processing costs, as well as other non-economic considerations.

Table 2. Potentiality of some sugary raw materials and amylaceous in carbohydrates and ethanol.

Raw material	Total carbohydrates (%)	Agricultural productivity (t/ha)	Carbohydrate Productivity (t/ha)	Potentiality in ethanol (m ³ /ha)
Arrowroot	28,9	12	3,5	2,5
Potato	12	20	2,4	1,6
Sweet potato	26,1	17	4,4	3,2
Beet	15	15	2,2	1,6
Sugarcane	12-17	77	9,2-13	6,0 - 9,0 ⁽¹⁾
Old cocoyam	26,8	25	6,7	4,8
Cassava	34	13,5	6,8	4,9
Corn	66	3,5	2,3	1,6
Sorghum	67	2,3	1,6	1,1
Wheat	65	2,3	1,5	1,1

⁽¹⁾ Ethanol real production from the sugarcane. Source: Leonel and Cereda (2002); BNDES (2003); IBGE (2006).

Preparation of the substrate (must)

In technological terms any liquid susceptible to fermentation is called must. The preparation of natural must requires the extraction of the hydrocarbons (sugars) in the raw material and, when necessary, making them available for fermentation. By knowing the physiological properties and nutritional demands of yeasts it is possible to provide optimum conditions for the microorganisms and favor alcoholic fermentation in order to ensure its regularity, homogeneity and purity. Such fermentation can be obtained by adding the necessary nutrients to the must, correcting the reaction medium, using antiseptics or antibiotics, and conducting the fermentation process at the appropriate temperature. The nutritional elements, the amounts and the need to add, or not, other corrective elements depend on the raw material being used.

Sugary materials

As previously observed fewer stages are required to produce ethanol from substrates containing saccharose or glucose than from other types of substrate. Actually, molasses and other syrups with high sugar contents only need to be diluted and have their pH adjusted before fermentation. For other materials, such as fruits, sugar beets and sugarcane, an extraction stage is necessary. The extraction consists of crushing and subsequent filtering the material.

Fruits - The average sugar contents of some fruits are: grapes, 15%; bananas, 13.8%; apples, 12.2%; pineapples, 11.7%; oranges, 5.4%; melons, 2.5%; and tomatoes, 2.0%. Assuming 75% extraction efficiency with apples, for example, approximately 9% of the material obtained from the original product would be fermentable. Thus, one ton of apples would produce 56 liters of alcohol. Regardless of the fruit used, no dilution is necessary because the sugar content of the substrate is low. Quite the contrary, dilution is undesirable. This means that the preparation of fruit must requires only the

extraction of the juice before adjusting the pH. Nevertheless, the alcoholic fermentation of fruits is not used to produce fuel ethanol but, rather, to produce beverages for which the high cost of the raw material is justified by the aroma and flavor characteristics generated in the process.

Molasses - Molasses are dark (brown to black) liquors of variable composition. One of the production byproducts is sugar, from both sugarcane and sugar beets. When available, this material is an excellent substrate for alcohol production because of its fermentable sugar contents (50% to 55%). In other words, one ton of molasses produces from 250 to 300 liters of alcohol. In this case, must preparation requires only dilution and pH correction. In special cases, phosphates and ammonium salts are added in the proportion of one gram of salt to one liter of must.

Sugarcane - Sugarcane's total sugar content varies from 12% to 17%. The extraction efficiency is 95% and the solid residue is called bagasse. To produce ethanol, the sugarcane juice is first heated to 110 °C to reduce microbial contamination, decanted, concentrated by evaporation if necessary, and then receives superphosphates and ammonium sulfate (1 g/L of must), magnesium salts (0,1 g/L) and manganese and cobalt salts (0.01 g/L). After the must has been diluted and the nutrients added, the temperature and pH are adjusted.

Sugar beets - Beets can be an excellent raw material for ethanol production because of their high sugar contents (15%). Beet juice is extracted by crushing and, since it contains some starch, adding a small amount of malt (1% to 2% by weight) leads to a significant increase in yield. It is necessary to adjust the pH. One ton of beets can produce almost 100 liters of alcohol.

Starchy materials

Starchy material can be divided into amylaceous (grain) and feculent (roots and tubers). Grains are initially ground in order to

expose the starch. They contain adequate amounts of fermentable material, which sometimes offsets the additional processing stages required. The average convertible starch and sugar contents of some typical grains are the following: barley, 50%; corn, 66%; oats, 50%; rye, 59%; sorghum, 67%; and wheat, 65%. Alcohol yield depends on the conversion of starch, but it usually varies from 260 to 380 liters per ton (L/t). An advantage of roots and tubers is that rejects, irregular, bruised, and even sprouted roots and tubers can be used. Actually, sprouted potatoes require less malt (or enzymes) for the malting process. Potatoes contain from 15% to 18% fermentable material; sweet potatoes, about 22% starch and 5% to 6% reducing sugars; and cassava, from 30% to 35%. All of these feculent materials are traditional sources of alcohol. On average, one ton of potatoes produces from 85 L to 95 L of alcohol, and sweet potatoes, up to 150 L.

All starchy materials require cooking to dilute and gelatinize the starch and, then, saccharification or hydrolysis to transform the starch into fermentable sugars. The hydrolysis can be done through malting, adding enzymes, or the action of acids. Each method has its own advantages, disadvantages and applications, as follows.

Cooking - All starchy materials must be cooked in water in order to dissolve water-soluble starches and, to the extent possible, to gelatinize them. In industry, the material is cooked using steam, which is almost always applied under pressure and in a continuous flow. For small-scale processes, the material can be cooked at normal atmospheric pressure, keeping the material at a low boil for 30 to 60 minutes. (As a rule, grains take longer to gelatinize than roots and tubers). Since large amounts of energy are necessary for the cooking process, the least possible amount of water should be used. Instead, an adequate concentration for fermentation can be achieved by subsequently adding water to the broth.

Acid hydrolysis - The advantages of this process are the small time taken with saccharification,

while obvious disadvantages include corrosion of the equipment, the need to neutralize the sugary solution after hydrolysis, and some destruction of the sugars. An additional factor is that the process generates non-fermentable sugars, which reduce the yield of the fermentation process. Actually, acid hydrolysis is more frequently used for cellulosic materials. That process will be detailed in a specific section.

Malting - Malt is a cereal germinated under special humidity, temperature and aeration conditions. The cereal undergoes various physical, biochemical and chemical modifications during germination, one of which is caused by the action of the enzymes (amylases) that convert the starch to a form of fermentable sugar called maltose. All grain cereals produce those enzymes to a greater or lesser extent, and malt from the substrate itself (if in grain form) or from barley can be used for fermentation. Barley malt is better and cheaper to use because of its higher amylase contents. Two processes are involved in converting starch to maltose using malt enzymes: liquefaction and saccharification. The intensity of those activities depends on the processing temperature. Liquefaction is more intense at 70 °C, slows down at 80 °C and stops at 93 °C.

Saccharification, on the other hand, takes place at lower temperatures (50 °C-55 °C) and stops at 80 °C. Since these actions are desirable, the conversion process is usually carried out at 65 °C. The material is kept at that temperature for some time and when conversion has been completed the material is cooled down to 20 °C-24 °C to begin the fermentation process. The amount of malt and the conversion time depend on the raw material. For the malting process, corn and wheat will require 8% to 10% malt (by weight); rye, 10% to 12%; and other grains, something in between. Roots and tubers only need 3% to 4% malt. The conversion will be completed after 5-15 minutes in the case of wheat; 30 minutes for corn; 30-60 minutes for barley; and 15-20 minutes for roots and tubers. In order to determine the exact malting time, as

well as the minimum amount of malt needed for good conversion, it is best to test the raw material before setting the process parameters.

Use of enzyme-producing microorganisms -

Enzymatic meals are produced by cultivating microorganisms that produce enzymes capable of hydrolyzing starchy material, such as *Aspergillus oryzae*, which grows on previously gelatinized corn, wheat, rice, or barley meal. Enzymatic meal is both easier to produce and has higher glucose-equivalent yield (percentage of glucose production in relation to the amount of starch present in the material) than malt. Nevertheless, for small-scale systems, the use of industrial enzymes is more profitable.

Use of industrial enzymes - The enzymes contained in malt are usually produced by fermentation with the microorganisms *Bacillus subtilis*, *Aspergillus niger* and *Aspergillus awamori* and are commercially available from different companies. Their use is very similar to that of saccharization by malting. The advantages of using this method are that enzymatic extracts are cheaper, produce more predictable results because they are specifically designed for this purpose, and have higher yields. The three enzymes commercially available are α - and β -amylase and amyloglucosidase. α -amylase breaks down the starch to produce dextrose and a β -amylase produces maltose (both fermentable sugars). Together, the two enzymes can convert approximately 85% of the starch, and amyloglucosidase converts the remaining starch. By using the three enzymes it is possible to convert all the starch.

Cellulosic materials

The availability of cellulosic residues, such as straw, leaves, wood processing waste, etc., has awakened people's interest in using them as raw material to produce alcohol. The advantages of those substrates are their enormous availability, low cost (free, sometimes) and, more recently, environmental issues.

Cellulosic materials are made up of lignin, hemicellulose and cellulose in different proportions (Table 3) and are therefore called lignocellulosic biomass.

One of the main functions of lignin is providing structural support to plants. Thus, trees have more lignin than grasses. Unfortunately, lignin, which does not contain sugars, coats the cellulose and hemicellulose molecules, making access to them more difficult. The cellulose molecules consist of long chains of glucose molecules linked to each other, as well as to the starch, so that they have a different structural configuration. This structural difference, together with the lignin coating, makes cellulosic materials harder to hydrolyze than starchy materials. Hemicellulose is also made of long chains of sugar molecules, but contains both glucose (a six-carbon sugar) and pentoses (five-carbon sugars). The problem is that the precise composition of the sugars in hemicellulose varies depending on the type of plant. Since pentoses contain a higher percentage of available sugars, process efficiency and economy depend on the retrieval and fermentation operations. The treatment of cellulosic materials for fermentation can follow either the enzymatic or the acid hydrolysis path. Both processes are explained in detail below.

Use of enzymes

This method has probably the highest development potential despite its high cost. To ensure the efficiency of the process it is necessary that the enzymes have access to the molecules to be hydrolyzed. Thus, a pre-treatment is necessary to break down the crystalline structure of the lignocellulose and remove the lignin in order to expose the cellulose and hemicellulose molecules. In order to break down or dissolve the lignin structure it is possible to use physical methods like pressure, crushing, radiation, or freezing, or chemical products like solvents.

The material is then mixed with enough water to form a thick paste, the pH is adjusted to 4.5-6.0

Table 3. Content of cellulose, hemicellulose and lignin of some materials.

Lignocellulosic materials	Cellulose (%)	Hemicellulose (%)	Lignin (%)
Tree trunk	40-55	25-40	18-35
Nutshell	25-30	25-30	30-40
Corn cob	45	35	15
Grass	25-40	35-50	10-30
Paper	85-99	0	0-15
Wheat husk	30	50	15
Leaves	15-20	80-85	0
Newspaper	40-55	25-40	18-30
Cattle solid excrement	1,6-4,7	1,4-3,3	2,7-5,7

Source: Sun and Cheng (2002).

and the enzymes are added. As a rule, an enzyme consortium (endoglucanase, exoglucanase and β -glucosidase, collectively known as celulase) is used. Together the enzymes produce almost 100% conversion. The optimal process temperature is 60 °C, and the mixture must be kept at that temperature for approximately 16 hours. It might be necessary to adjust the pH before initiating fermentation.

In addition to the cost of the enzymes, one of the difficulties of this process is knowing the cellulose and hemicellulose contents of a given raw material in order to estimate the amount of enzymes to be added to ensure adequate process efficiency. The most common procedure is doing initial tests beginning with 2% enzyme by weight. On the other hand, there are some advantages, such as high efficiency and low waste production; relatively low energy costs; and soft processing conditions that eliminate the need for expensive construction material.

Acid process

The acid process is relatively simple and can be used with either diluted or concentrate acid solutions as described below.

Diluted acid and relatively high temperature -

The process begins by adding 1%-4% diluted sulfuric acid by weight/weight to the substrate and heating the mixture to almost 175 °C at 10 Atm of pressure. The resulting material is then neutralized with calcium hydroxide, or another

base, and washed. One of the method's limitations is the high cost of the equipment, which must stand the high temperatures (150 °C-250 °C) and pressure (10 Atm) of the process. The reaction time, however, is restricted to some seconds or minutes, at most, in order to facilitate continuous processing. For example, processing pure cellulose in a continuous reactor, at 237 °C and with 1% sulfuric acid, produces approximately 50% sugar conversion over a residence time of .22 minutes. The problem is that the combination of high temperatures and high pressures makes it necessary to use special materials and, therefore, the investment cost of the reactor is also high. In addition, conversion is relatively low (close to 50%). In the case of medium- and large-scale reactors the greatest advantage of this process is the high reaction rate, which facilitates continuous processing.

Strong acid and relatively low temperature -

Initially the material is mixed with a 10% dilution of sulfuric acid and heated at 100 °C for 2 to 6 hours in the first hydrolysis reactor. The low temperatures and pressures minimize sugar degradation. In order to retrieve the sugars the hydrolyzed material from the first reactor is initially washed several times with water. The solid residue is then dried and a 30% concentration of sulfuric acid is added and allowed to react for 1 to 4 hours in order to complete the cellulose hydrolysis stage. The material is then drained and filtered to remove the solids and retrieve the sugars and the acid. The acid and sugar solution from the second

stage is put through the first reactor again. The sugars from the second hydrolysis stage are then retrieved in the liquid of the repeated hydrolysis stage. The main advantage of the concentrated acid process is the efficiency of sugar retrieval, which can reach 90% for cellulose and hemicellulose. The low temperatures and pressures make it possible to use lower cost materials, such as fiberglass. Unfortunately, it is a relatively slow process that requires both very rigorous control and an effective acid retrieval system, since otherwise it would be necessary to add large amounts of base to neutralize the sugar solution before fermentation. The salts (usually sodium or calcium sulfates) formed during the neutralization operation require treatment, which makes for an additional expense.

Fermentation

Yeasts are usually single round-cell microorganisms called fungi. Although yeasts are not the only microorganisms capable of producing alcohol, their specific properties, such as tolerance to high alcohol and CO₂ concentrations, rapid growth and fermentation capacity make them the preferred microorganisms for industrial operations. The most important strains are *Saccharomyces cerevisiae* and *Saccharomyces carlsbergensis*. Their biomass can be retrieved as a fermentation byproduct and transformed into dry yeast and used to manufacture animal feeds and human vitamin supplements. Various strains (stocks) of these microorganisms have been selected along time because of their greater tolerance to pH variations, increased alcohol resistance, and fermentation yield. In order to ensure adequate industrial alcohol production, the yeasts must show high productivity (ratio between the alcohol produced and the sugar available to the yeast); high fermentation velocity; high tolerance to alcohol; tolerance to high temperatures; and stability. (In addition, the yeast strain must maintain those characteristics over several generations.)

To initiate fermentation it is only necessary to mix inocula in the yeast and maintain the conditions necessary for growth and ethanol production. The fermentation time can vary depending on the raw material, microorganism, pH, temperature, and various other factors. Fermentation usually takes 2 to 5 days. Various physical (temperature and osmotic pressure), chemical (pH, oxygenation, mineral and organic nutrients, and inhibitors) and microbiological (yeast species, strain, concentration, and bacterial contamination) factors affect fermentation yield, i.e., the efficiency of converting sugar into ethanol. As a rule, reductions in fermentation efficiency originate in changes in the balance of the process, which lead to the formation of secondary products (especially glycerol, organic acids and biomass), or in contamination with other microorganisms, such as bacteria, which compete for the substrate to produce other compounds.

Distillation

Fermented must (wine) from fermentation contains 7% to 10% alcohol by volume, as well as other liquid, solid and gaseous compounds. The alcohol in wine is retrieved through distillation, which involves separating the components of a mixture on the basis of their evaporation capacity (volatility) at a given temperature and pressure. In distillation the mixture is heated to the boiling point and the vapors cooled until they condensate. This process is based on the fact that in a solution of volatile liquids, the fractioning of said liquids occurs in such a way that those with the lowest boiling points are separated first, followed by the other components in a sequence corresponding to their respective volatilities. Thus, the final effect is an increased concentration of the more volatile component in the vapor phase and of the least volatile component in the liquid phase. Because of the gravity difference between the liquid and vapor phases the liquid flows down the distillation column while the vapor rises, so that the two phases are collected separately.

In the case of homogeneous mixtures (such as water and alcohol), the composition of the distillate will be that of the two components, with the more volatile prevailing over the less volatile component. A series process is used in order to separate them, whereby the amount of alcohol in the rising liquid flow is gradually increased. This process makes it possible to obtain almost 96% alcohol from wine containing 7% to 9% alcohol. At that point a phenomenon called "azeotropy" occurs and fraction distillation no longer works. The mixture in that composition is called an "azeotropic mixture". The formation of an azeotrope in the distillery determines the existence of two classes of alcohol: hydrated alcohol and anhydrous or absolute alcohol. The specifications for the types of hydrated alcohol and anhydrous alcohol depend basically on the destination of the alcohol.

Drying alcohol

Hydrated alcohol is the final product of the distillation and rectification processes. It is a binary alcohol-water mixture that reaches of up to 96 °GL. This occurs due to the formation of an azeotropic mixture, a physical phenomenon in which the components are not separated during distillation. Hydrated alcohol can be sold as such or can be dehydrated. Actually, since alcohol drying is another production step and requires additional labor, costs and energy, serious consideration should be given to the advantages and disadvantages of manufacturing hydrated or anhydrous alcohol. At present, three main methods are used to obtain anhydrous ethanol.

Azeotropic distillation - It consists of adding a third component to the top product flow, which will form another azeotrope with a lower boiling point. This method was first used in the 1970s with benzene as the third component. At present 65% of Brazilian anhydrous alcohol is obtained using azeotropic distillation, especially with cyclo-hexane, which replaced benzene more than 15 years ago and brought along

environmental and occupational health gains. Nevertheless, azeotropic distillation consumes too much energy.

Extractive distillation - This alcohol dehydration technique is not new and was used in Brazil until the mid-1970s, when it was replaced by azeotropic distillation with benzene, because of the low installation cost of the latter. In extractive distillation, mono-ethyl glycol (MEG) or glycerin is added to the bottom product flow to separate the phases, eliminating the anhydrous alcohol through the top of the column. Although the initial cost is rather high, the process becomes advantageous when savings (about 30%) with the energy (steam and water) consumed by the hexane cycle are taken into account. Furthermore, the process produces better quality alcohol, plant operation is simpler and the solvent can be easily recuperated. Thus, with the development of technologies to adapt the plants using azeotropic distillation to extractive distillation, the use of the latter method has steadily grown in the last few years. At present extractive distillation accounts for 25% of the national anhydrous alcohol production, but estimates point to a 33% share by the end of the 2004-2005 crop year.

Distillation using molecular sieves - The system was developed in the United States in the 1970s. It is the alcohol dehydration process with the least energy consumption, although with a high initial investment. It consists of the absorption of hydrated alcohol into zeolites (micro-porous material very similar to ceramics) with subsequent vacuum extraction of the water from the zeolites. When molecular sieves are used no chemical products are required and, therefore, the anhydrous alcohol obtained has no trace of such products. Thus, the process is specifically indicated when producing anhydrous alcohol for more demanding applications, such as the pharmaceutical, chemical and food industries. The production cost of anhydrous alcohol (R\$/m³ of alcohol) through the molecular sieve process is about 30% higher than that of azeotropic distillation and twice as much as that of extractive distillation.

Use of fermentation byproducts

Use of stillage

Stillage is the final residue from ethyl alcohol production through the fermentation pathway. It is called by different names in Brazil, such as vinhoto, restilo, broth, or garapão, depending on the region. For every liter of alcohol produced, 10 to 15 liters of stillage are produced. Its composition varies greatly depending mainly on the composition of the wine, which in turn varies depending on factors such as the nature and composition of the raw material, the system used to prepare the must, the fermentation method, the distillation method and equipment, and the type of phlegm drawn off.

It can be characterized as a highly polluting distillery effluent (almost 100 times more polluting than domestic wastes). Its polluting power derives from its high organic material contents and, particularly, its nitrogen, phosphorus and potassium concentrations. Despite its polluting potential for many years stillage was simply dumped into rivers or open channels, which significantly compromised the flora and fauna of neighboring regions.

When the pollution control agencies began systematically enforcing the environmental legislation, some transitional measures were adopted and stillage began being stored in the ground. Sacrifice areas immediately emerged, together with compromised soil and deteriorated ground water quality, making it necessary to improve stillage disposal methods. Ultimately, the high potassium contents of stillage encouraged integrated studies on the use of the product in agricultural areas as a fertilizer source for sugarcane plantations. This has become current practice in many sugarcane mills and the use of raw stillage through fertirrigation delivering rational amounts of the product not only has a positive effect on sugarcane farming but also prevents the residue being disposed of in watercourses.

Another alternative is direct combustion or total incineration of the stillage. This process consists of stillage burning and subsequent economic

retrieval of some salts, like potassium salts, which can be reused to fertilize crops. This method has three advantages: eliminates completely the polluting effluent, enables the economic retrieval of some salts for later use in farming and permits the generation of energy in the burning process.

The anaerobic biodigestion of stillage is another possible disposal method, albeit seldom used by the sugarcane mills. It consists of treating stillage in anaerobic reactors, a process widely known and used for treating domestic urban wastes. The advantages of anaerobic biodigestion are its low energy consumption, small amount of wastes (sludge), great efficiency in diminishing the organic load, and the retrieval of the ethanol involved in the process and its use in power generation. Furthermore, the stillage thus treated has very low polluting potential when reused in fertirrigation.

Use of raw material residues

After sugar or starch extraction, the remaining products are usually rich in minerals, highly energetic and easily digestible. Thus, most of the time they can be used in animal nutrition, complementing regular feeds.

Various uses have been studied for the various raw materials most frequently used to produce alcohol, such as sugar beets, sugarcane and grains, especially corn. A brief discussion of these materials follows.

Beets - The pulp is highly nutritious for meat and milk cattle production, so that it is usually sold to the animal feed industry. It can be made available in dry or granulate forms and in both cases the dry matter content is about 90%, or then as a moist pressed pulp, with a dry matter content of approximately 22%.

Sugarcane - Sugarcane bagasse is a byproduct of the juice extraction process, whether to produce sugar or alcohol. The main characteristic of sugarcane bagasse is its high fiber content since the amount of bagasse obtained per sugarcane mass unit depends of

the fiber content. When compared with other agroindustrial residues, bagasse is considered a valuable byproduct. It has always been used as boiler fuel to produce steam and electric power for the various sugar and alcohol industry operations. In fact, one ton of crushed sugarcane generates approximately 250 kg of bagasse, which converted into caloric energy is equivalent to 560,000 kcal. The same amount of sugarcane produces 70 liters of alcohol, which provide about 392,000 kcal of energy, i.e., there is more energy in sugarcane bagasse than in alcohol. Burning bagasse is a cleaner operation, causes less environmental impact and does not release sulfur compounds (SO_2 or SO_3) than burning other fossil fuels. Sulfur compounds are relatively common when fuel oils are burnt. Furthermore, bagasse burns slowly, at a low flame temperature, so that only small amounts of nitrous oxide are formed. Bagasse can also be used as organic fertilizer and as raw material to produce paper, cellulose, and wood boards and plates. More recently, in parallel to the development of hydrolysis techniques for cellulosic products, studies have been carried out on the use of bagasse as substrate in alcohol production.

Grain - The grain residues left after starch extraction have been successfully used to supplement pig, poultry, sheep, and cattle feeds. Those residues are a good source of vitamin B and their protein content is relatively high.

Use of yeasts

Dry yeasts from alcohol fermentation are excellent nutrition sources for animal feeds and advantageously replace soybean bran. They can also be used as leavens in the baking, pharmaceutical and beverage industries.

New technologies for the production of fuel

Although most of the fuel ethanol production technology was developed 30-40 years ago,

there is ongoing research focusing mainly on enabling the use of cellulosic material and agroindustrial residues as raw materials. Actually, in the current processes raw material costs account for approximately 40% of the total ethanol production value. Thus, the development of appropriate technologies to use cheaper raw materials, such as lignocellulosic materials, would contribute significantly to reducing production costs and expanding the use of fuel ethanol. Some of those new technologies are described below.

Immobilized enzymes

One of the most important current research areas focuses on the use of enzymes to convert starch and cellulose into fermentable sugars. As previously discussed, the use of enzymes increases conversion considerably, is relatively simple and consumes little energy. Enzymes are expensive, however, and the prevailing technology does not permit enzyme retrieval and reutilization after the enzymes are mixed with the broth. One of the solutions being studied is immobilizing the enzymes, i.e., "fixing" them to an inert substrate. Thus, the broth resulting from the conversion operation would be filtered and the enzymes retrieved and reused, permitting substantial savings.

Pretreatment of cellulose

For lignocellulose to be available for fermentation, it must be treated so as to release short-chain sugars, which microorganisms can then convert into ethanol. The pretreatments now available for that conversion are not 100% efficient, but various methods are being studied and optimized.

Steam explosion (autohydrolysis)

The steam explosion method is reasonably common for treating lignocellulosic materials. The method calls for treating the crushed or

ground biomass with saturated steam under high pressure, followed by an abrupt pressure reduction that produces explosive decompression of the material. The initial temperature of the steam explosion varies from 160 °C to 260 °C (which corresponds to pressures varying from .69 to 4.83 MPa) and the explosion lasts for only a few seconds, after which the material is exposed to atmospheric pressure. The limitations of this method include the destruction of the xylan fraction, incomplete disruption of the lignin-hydrocarbon matrix and generation of compounds that can act as inhibitors of microorganism growth.

Simultaneous saccharification and fermentation

In this process the enzymes that transform lignocellulose into fermentable sugars and the microorganism that will ferment the material are added simultaneously in the same reactor. As the lignocellulose is transformed into short-chain sugars by the enzymes, the microorganism transforms the sugars into ethanol. This process increases ethanol conversion by diminishing the production of microorganism growth inhibitors, as well as eliminates the need for two different reactors for saccharification (conversion of lignocellulose into short-chain sugars) and fermentation. Furthermore, the greatest limitation of the process is that the optimal temperatures for saccharification (50 °C) and fermentation (35 °C) are different. In addition, the ethanol produced can also inhibit the saccharification process.

Genetic modification

The absence of microorganisms capable of both fermenting long-chain sugars and producing ethanol in appropriate concentrations is the worse obstacle to using lignocellulosic materials as substrate in alcoholic fermentation. Thus, an important objective of genetic engineering research has been to develop a microorganism

that combines the advantages of the different species.

Final considerations

Alcohol could be the oldest and best-known product obtained with traditional biotechnology. Alcohol applications include its use as beverage, chemical product and fuel alcohol. In fact, Henry Ford planned alcohol-fueled cars in the 1889s, when he developed his first car model (Model T), which ran on corn ethanol. In the 20th century, however, petroleum fuels, the so-called fossil fuels, emerged and rapidly assumed control of the market. The low fuel prices persisted for quite some time, until the petroleum crises of the 1970s, which highlighted the importance of using alternative energy sources, among which ethanol.

In addition to the economic issues, the environmental advantages of alcohol are universally acknowledged, whether used alone as hydrated alcohol or in its anhydrous form mixed with gasoline. In both cases, alcohol has the huge advantage of reducing carbon monoxide emissions and foregoing the use of tetra ethyl lead as fuel additive. The latter is one of the most toxic air pollutants in large cities. Thanks to alcohol, Brazil does not contribute to an effective increase of the greenhouse effect and was the first country to ban tetra ethyl lead. Fuel alcohol helps reduce primary pollutant emissions. It also reduces considerably the so-called reactive pollutant emissions. In general terms, therefore, alcohol generates an increasingly "clean" energy, an enviable and attractive characteristic in a world always concerned with total pollutant emissions.

More than 20 years ago the first United National World Conference on Environment determined as a condition for good international coexistence the establishment of a more balanced relation between humankind and the environment. Ever since, achieving that equilibrium has become an irreversible trend

throughout the planet. Some countries have created taxes on CO₂ emissions. A series of mechanisms will make it possible to invest the amounts thus levied on projects that contribute to diminish total gas emissions. Because of its positive contribution to the environmental issue, alcohol could benefit from similar mechanisms.

At the present time ethanol is produced from substrates like cornstarch and sugarcane. Since they are food crops that require agricultural management, those raw materials can account for up to 40% of the ethanol production costs. Thus, a comprehensive utilization of the existing technology and of new developments, together with the use of lignocellulosic raw materials in particular, should make ethanol production much more economical and promising in the near future.

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Agroenergy for automotive vehicles

Henry Joseph Jr.¹

There is no denying: Brazil is a privileged country!

While the world seeks independence from petroleum, which is currently used by almost one billion vehicles and will some day, inexorably, end, our country, early this year, gave itself the luxury of reducing the amount of alcohol mixed into gasoline, because pure alcohol consumption had increased so much, as a result of its low price and acceptance by flex fuel vehicles, that production could not keep up with demand and forced us to spend more fossil fuel in order to save the renewable fuel.

This would be regrettable were it permanent. But no: after a few months, alcohol production is growing so rapidly that it can be asserted that normalcy will shortly be achieved. Furthermore, the country has reached self-sufficiency in petroleum extraction and production, enabling such changes to take place without affecting the balance of payments.

This is a good example of the possible impact that renewable fuels produced from biomass will have throughout the world in the next few years and of the ease with which Brazil could respond to demands for a new fuel suitable for mixing with conventional fuels, since nobody expects that said one-billion vehicle fleet could be replaced overnight by another not fueled by petroleum products, or that their owners would agree to leave them in the garage because of a lack of fuel. Thus, mixing new products with conventional fuels would be the fastest way to

lengthen the availability of petroleum products and, consequently, the use of existing vehicles, since 10% alcohol in gasoline or 5% plant oil in diesel would save a lot of petroleum.

It is accurate to say that vehicles will be absolutely soundless in the future and have non-polluting electric motors, that they will use hydrogen to generate energy and that this gas will be obtained in an environmentally correct and sustainable manner.

A huge desert must be crossed, however, between today's reality and the perfect world of tomorrow, since the vehicle fleet using petroleum products continues to grow - see China, India and the entire growth potential of developing countries - and the world automobile industry, because of the absolute lack of economically or technically feasible options, continues to manufacture 65 million vehicle per year, equipped with internal combustion engines, ecologically polluting and thermodynamically inefficient, albeit reliable and affordable. That is, instead of decreasing petroleum consumption, humankind is swiftly running in the opposite direction.

Today, the only exception to this picture is Brazil.

Our country produces almost 1.5 million light vehicles per year for the domestic market. These vehicles, as in other countries, have internal combustion engines, but their engines have been adapted to burn pure alcohol or

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gasoline mixed with more than 20% alcohol. Even the diesel engines, used in trucks, buses, tractors, or pickups, are expected to burn diesel oil containing 2-5% transesterified (without glycerin) vegetable oil and, in the future, the vegetable oil contents will increase to 15% or 20%, or perhaps even 100%.

Thus, although apparently manufacturing conventional vehicles, we are in fact building a fleet of more petroleum-independent vehicles, enabling Brazil to achieve significant hard-currency savings and prepare itself to cross the aforementioned desert. While automotive vehicle manufacturers and the international scientific community work to design and produce the vehicle of the future, Brazil will be minimizing its need for petroleum products through large-scale use of fuels derived from biomass. And, probably, many other countries will follow that trail.

Our position was neither unearned, nor immediately achieved. Thirty years ago, faced with a temporary international situation of marked reduction in the supply of petroleum, the country decided to effect deep changes in its energy mix and, ever since, alternating positive and negative periods depending on promising or not-so-promising scenarios, researchers, alcohol producers, automobile and component manufacturers, etc. have worked hard to attain our current position.

The release in March 2003 of the flex fuel vehicles, popularly known as bifuel, undoubtedly was a landmark in the history of our energy mix and a turnabout point in the alternative fuel market of our country. After several years of success with the Proálcool program, having produced 5 million alcohol-fueled vehicles from 1975 to 1992, the Brazilian automobile industry produced 1.5 million flex fuel vehicles in three years. At the present time, seven manufacturers are making available more than 70 'flex' models to the Brazilian market, at prices equivalent to those of similar conventional vehicles.

Thanks to the enormous acceptance of flex fuel vehicles and alcohol's competitive price vis-à-

vis gasoline, the Brazilian alcohol production, which had been dropping at a rate of 11% per year, received a forceful thrust forward and began growing more than 10% p.a.

Nevertheless, despite the growth rates demand in the last months exceeded supply, pressuring alcohol prices and leading the government to try to intervene in that market, setting up agreements to establish price ceilings and diminishing the alcohol contents of the fuel gasoline sold in the country, in order to increase its availability. It was useless. Prices did not go down as expected. But since the rules of supply and demand prevail in free markets, as the harvest began and production increased the price of alcohol has finally begun to drop and distribution has gone back to normal.

Concomitantly, the last few years have been marked by unbridled increases in petroleum prices in the international markets, where they rose from US\$ 25 to more than US\$ 70 a barrel, making Brazilian refineries lose ground to alcohol since flex fuel cars enable consumers to switch easily from alcohol to gasoline and vice-versa. So that price makers have had to think carefully before passing on crude oil price increases to the petroleum products and risking a reduction of their market share.

It is not merely price increases and concern over petroleum reserves depletion that has driven researchers the world over to seek alternatives to petroleum products. Since the discovery of the direct relation between Earth's temperature increases and the gases resulting from fossil fuel burning, which led several developed countries to sign the famous Kyoto Protocol whereby they commit themselves to reduce gas emissions, the scientific community has been searching for alternative vehicular energy sources that can be used without increasing global warming. And, once again, renewable fuels produced from biomass, among which alcohol, are playing an important role.

The expression "renewable fuels" is used to define fuels produced from agricultural products or the fermentation of organic matter. Contrary

to fossil fuels (petroleum and natural gas) that, when finally gone, cannot be obtained again, people can always produce more renewable fuels to meet their needs. They just have to plant or ferment.

There is another particularity that adds significance to the term renewable and has made renewable fuels a saving solution for global warming. It is the fact that the gas CO₂ - emitted when any fuel is burned and the main cause of atmospheric warming - is reabsorbed through photosynthesis by the plants used to produce renewable fuels, so that the burning of such fuels is neutralized. Thus, the CO₂ issued in fuel burning is renewed without harming the environment.

Renewable fuels can be used with the existing vehicular technologies, replace the expensive and increasingly depleted petroleum and help reduce the environmental impact. Accordingly, renewable fuels produced from biomass have increased their share of the market and led some countries to consider their usefulness.

Just as there are countries interested in using renewable fuels, others wish to produce them for export purposes, since their climatic and geographical characteristics are usually translated into strong agricultural sectors and, thus, fuel production from biomass becomes a real economic opportunity.

Consequently, it is easy to imagine the swift emergence of an international renewable fuels market that would provide socio-economic alternatives for many countries and an energy alternative for others, at least until a new, cleaner, affordable and reliable vehicle is developed and produced in large scale to replace the current, internal-combustion engine cars.

And what are the new most promising technologies being developed?

Basically, all on-going studies point to the same solution, which is the use of electric motors. They are efficient, noiseless, potent, non-polluting, and simple. Nevertheless, two

questions remain unanswered: how to generate electric power to move the vehicle in a safe and non-polluting way and how the vehicle would carry aboard a sufficient amount of that energy to ensure a good cruising range.

Generating energy in a safe and non-polluting manner requires an analysis of the risks surrounding nuclear or thermal plants and carrying enough energy aboard means something other than the well known, lead or other heavy-metal batteries.

It is believed, at present, that the most adequate way to generate sufficient electric power would be through an ionic exchange resulting from the passage of hydrogen through a set of electrolytic membranes, the so-called fuel cell, together with a catalytic reformer that can extract the hydrogen from a hydrogen-rich substance such as natural gas (rich in methane) or, preferably, a liquid such as alcohol (methanol or ethanol), because of the ease of supply and transportation. Due to its very low density and explosion potential scientists are trying to avoid the transportation of hydrogen gas cylinders in the vehicle.

As can be noted, Brazil will continue to be a privileged country in the future of vehicular technology, since the use of alcohol to generate hydrogen, which in other countries would be methanol obtained from natural gas (fossil and finite) or wood (exceedingly low yield), would in our case be ethanol, for which we are unsurpassed.

Putting everything together, we still have a rather promising picture.

We are replacing the current vehicles in our fleet with more flexible automobiles that can use either gasoline or alcohol, which enables us to migrate from one fuel to another depending on prices and availability. We are also introducing a vegetable oil/diesel oil mixture, which will reduce our dependence on petroleum as biodiesel production increases and attains a sufficiently large scale. Although they are behind us, other countries are proceeding along similar paths, which will lead to an international

renewable fuel market, increase Brazil's energy security and enable new developments. Because of its sustainability, because it contemplates the economic, social and environmental aspects, and because it reduces the emissions of gases that cause global warming, the renewable fuel market will attract international investors. There is an enormous

application potential for renewable fuels in future vehicular technologies. We have achieved self-sufficiency in petroleum production and we still have natural gas available to include in our energy mix.

Contrary to countries fearing for their future, Brazil is eagerly waiting for the opportunity to better enjoy the possibilities of its energy mix.

Champions of deforestation

Evaristo Eduardo de Miranda¹

Eight thousand years ago Brazil harbored 9.8% of Earth's forests. Today, the country accounts for 28.3%. Out of the 64 million square kilometers (km²) of forest that existed before the populational and technological expansion of human beings, less than 15.5 million km² are left, or approximately 24%. More than 75% of the world's forests have disappeared. With the exception of the Americas, all continents have razed their forests, really razed them, as shown in an Embrapa Satellite Monitoring study on the evolution of world forests².

More than 7% of the forests in the world were in Europe, not counting Russia; only .1% are left. Africa held 11% and now holds only 3.4%. Asia was home to almost one-fourth of the world's forests (23,6%); it now contains 5.5%, and has yet to stop deforestation. Going in the opposite direction, South America, which harbored 18.2% of the forests, now supports 41.4%, most of them in Brazil. And Brazil's share grows year after year.

Far from being a thing of the past, that trend continues. And if world deforestation continues at the present rate, Brazil - being among those who deforest least - will hold almost half the primary forest on Earth in the future. The paradox is that, instead of having its history of forest maintenance acknowledged, the country is being severely criticized by the champions of deforestation and gradually divested of its own memory.

In most European, African and Asian countries, defending nature is a recent phenomenon. Forest preservation in Brazil, however, is a long-standing tradition. Since the 16th century, when the Portuguese began settling Brazil, the Ordenações Manuelinas e Filipinas established rules and limits to land, water and plant exploitation. In 1550 there was already a list of royal trees protected by law, the origin of the Portuguese expression *madeira-de-lei*³. The Regimento do Pau-Brasil, or Brazil Wood Act, of 1600 established the right to use the trees, but not the land where they stood, which was considered the Crown's forest reserve and could not be farmed. That legislation guaranteed the maintenance and sustainable exploitation of Brazil wood forests until 1875, when aniline became available. Contrary to what many people think and even publicize, the rational exploitation of Brazil wood helped maintain a good part of the Atlantic Rainforest until late in the 19th century, rather than being the cause of deforestation, which occurred much later.

The same is true of mangroves. Dom José I King of Portugal issued a royal warrant protecting mangroves in 1760. The Municipal Chambers were notified and called upon to enforce the warrant. In 1797 a series of royal charters consolidated the environmental laws of the time: the forests along the coastline and along rivers flowing immediately into the sea or allowing the passage of wood-carrying craft belonged to the

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² www.cnpem.embrapa.br

³ 'Wood in the Law', literally, a play on words in Portuguese. Hardwood, in English. (Translator's Note)

Crown. Another landmark in forest conservation was the creation of Conservation Judges, in charge of applying the penalties contemplated in the law. The penalties varied from fines, imprisonment and banishment to even death for felonious fires⁴. The Wood Felling Act enacted in the late 19th century established strict rules for tree felling, as well as restrictions to clearing land for farming.

Deforestation from the 17th to the 19th century was limited to some points along the coastline. In June 1808 Dom João VI created the first forest conservation unit, the Rio de Janeiro Botanical Gardens, which extended over more than 2,500 hectares⁵. An Order issued on 9 April 1809 freed slaves who informed against Brazil wood smugglers and a Decree dated 3 August 1817 prohibited felling trees near and around the springs of the Rio Carioca. The total deforested area in Brazil was less than 30,000 square kilometers⁶ in 1830. Today, an equivalent or even bigger area is deforested every two years.

In 1844, after a prolonged draught, Minister Almeida Torres proposed expropriating land and planting trees to save the headsprings of Rio de Janeiro. Minister Couto Ferraz expropriated farms for that purpose in 1854 and 1856. And, in 1861, Dom Pedro II issued Imperial Decree Number 577 ordering the creation (and plantation) of the Tijuca and Paineiras Forests.

Brazilian environmental thinking and opinions today result from continuous records extending back over several centuries: a unique intellectual tradition⁷. The forestry policy of the Portuguese and Brazilian Crowns managed, through diverse mechanisms, to preserve the plant cover until the end of the 19th century. Deforestation in Brazil is a 20th century phenomenon. From 1985 to 1995, almost one million hectares of the Atlantic Rainforest were lost, more than the total area deforested during

the Portuguese Crown rule. In the states of São Paulo, Santa Catarina and Paraná the settlement of the west regions caused much deforestation. The Republic surrendered the araucaria forests to Anglo-American railroad builders, together with the adjacent lands (a 15-30-km wide strip of land on each side of the railway!).

In the Amazon, for four hundred years, the humans lived in riverside cities or extractivist communities in the hinterlands. The region's settlement by migrants during the second half of the 20th century brought along population growth, highways, hydroelectric power plants, and other infrastructure works. For 30 years the deforestation rates in the Amazon have varied from 15,000 to 20,000 square kilometers per year, with deforestation peaks of 29,000 and 26,000 square kilometers in 1995 and 2003, respectively. In the last two years, however, the deforestation rates dropped to 11,000 square kilometers per year, according to National Space Research Institute (INPE, in Portuguese)⁸ estimates.

A Brazilian Agricultural Research Corporation (Embrapa) study indicates that despite the deforestation of the last 30 years Brazil is among the countries with the best records in maintaining its plant cover. Meanwhile, only 7.8% of the original African forest endures. Only 5.6% of Asian forests, 9.7% of Central American forest and .3% of European forest - the worst case in the world - still abide. Although the European reforestation effort for tourism and commercial purposes should be mentioned, it is not possible to ignore that 99.7% of European primary forests have been replaced by cities, farms or commercial agricultural operations.

The continent with the largest percentage of original forests is South America, which holds 54.8% of the world's forest. Having preserved 69.4% of its primeval forests, Brazil has great authority to speak forth on this theme vis-à-vis

⁴ The first law contemplating environmental crimes during the Republic only dates back to 1999.

⁵ Today, the Rio de Janeiro Botanical Gardens have been reduced, in the manner of the Republic, to slightly more than 100 hectares.

⁶ CASTRO, Carlos Ferreira de Abreu. *Gestão Florestal no Brasil Colônia*. UNB, Brasília, 2002.

⁷ PADUA, José Augusto. *Um sopro de destruição, pensamento político e crítica ambiental no Brasil escravista (1786-1888)*. Zahar, Rio de Janeiro, 2002.

⁸ Projeto Prodes - www.obt.inpe.br/prodes/index.html

the criticisms of the world's champions of deforestation. Brazil will also act in a responsible manner to restore through long-lasting policies and practices the effectiveness of the historical management and exploitation

measures that guaranteed the preservation of its primary forests. A good beginning would be to place the commercial cultivated forests under the responsibility of the Ministry of Agriculture, Livestock and Food Supply.

Collaboration



Brazilian Agricultural Research Corporation



**Secretariat of
Agricultural Policy**

**Ministry of
Agriculture, Livestock
and Food Supply**

