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The Success and Sustainability of the Brazilian Sugarcane-Fuel Ethanol Industry

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ABSTRACT

Currently, Brazil has 410 sugar and ethanol plants that crushes about 660 million tons of cane per crop, producing about 28.5 billion liters of ethanol and 38.7 million tons of sugar. New varieties launched in the last two years are less demanding in water, high sugar concentration and are more adaptable to mechanical harvesting. Regarding the sustainability of ethanol production from sugarcane, it is essential to consider the use of the land, reduction of greenhouse gases (GHG), bioelectricity production from bagasse, energy balance of ethanol produced from sugarcane and reduction of vinasse. No other technology available nowadays, has been able to transform the sun's energy and to reduce carbon emissions as efficiently and economically as the production of ethanol from sugarcane and its use as biofuel. This amazing combination of sun energy, fixation of CO_2 by sugarcane and transformation of sugars in a high quality, clean and liquid fuel make the ethanol industry in

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Brazil a success as well as an example of sustainability.

Introduction

The Brazilian sugarcane production dates 400 years. At the begining, sugar was the main product, and later the distillate “cachaça” and then the ethanol fuel in 1920-30. The ethanol production till 1975 was marginal totaling 300 to 600 million liters, used chiefly for industry and neutral alcohol for beverage. In this same year the Brazilian government launched the ethanol program due chiefly to overcome the high international oil prices chief in 1973.

Because of the international oil crises and dependence on petroleum imports, it was necessary to choose alternative energy sources that could replace oil derivatives. At that time, the Alcohol National Program, named “ProÁlcool” was instituted by the Brazilian government in 1975 (Amorim and Leao, 2005). Initially the program was based on anhydrous alcohol production to be mixed to gasoline. However, after the new oil crisis in 1979, beyond the mixture to the gasoline, it was initiated the manufacture of automobiles moved only on ethanol. The success of ethanol cars changed the automotive industry. The concern about pollution comes in the 80s to replace the lead in gasoline to ethanol, chiefly in the São Paulo city. The brain defects caused by lead contamination in the air decreased significantly after substitution of lead to ethanol in gasoline.

At the medium of 80s the production of cars running with hydrated ethanol reached 98% of all vehicles produced in Brazil increasing the consumption of this fuel and reducing oil imports. In the middle of 80s, due to decrease of oil prices, and the lack of subsides to the ethanol, the ethanol plants in Brazil started producing sugar too. To overcome the low prices in the market and its costs of production, without government subsides, the sugar and alcohol industry improved their fermentation processes. New technologies were developed and transferred to industries that allowed them to survive different crisis in the last 20 years (Amorim, 2006).

Today, another step was reached regarding the sustainability of the sugarcane production with the cogeneration program in electricity by sugar and ethanol industries. Production of fuel ethanol from sugarcane in Brazil has many advantages in comparison with other biofuels produced from different raw materials such as corn, beet and sorghum in other countries. Despite of low investments in research it has been essential to keep production costs at low levels and to improve sustainability of ethanol production. In addition, the development of new technologies and diversification of products such as bioelectricity, biodegradable plastics, yeast as feed, and others co-products open new opportunities of expansion.

The use of the land: fuel versus food

Besides the European Union dilemma on fuel versus food, so far Brazil has no problem regarding this matter. The Figures 1 and 2 show an increase of the sugarcane, corn and soybean production at the same time. It is important to emphasize that sugarcane has not occupied or limited the expansion of other important cultures such as corn and soy that uses 36.3 million hectares in 2009, being 13.1 for corn and 23.2 for soy (CONAB, 2009 and CONAB 2010).

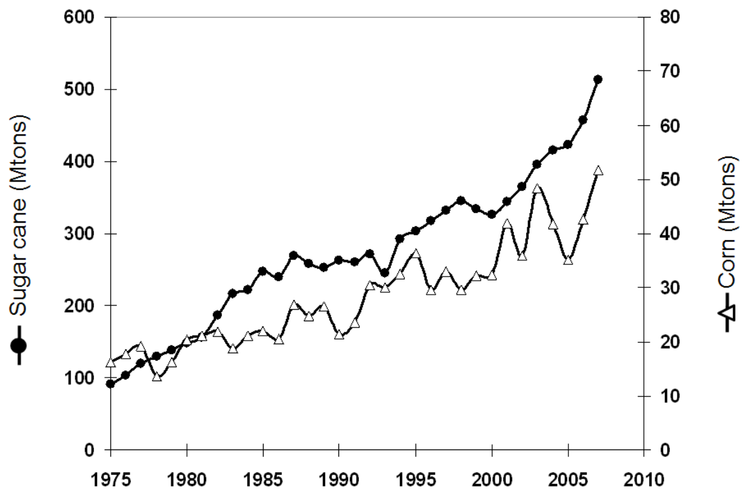

Figure 1. Sugarcane and corn production in Brazil

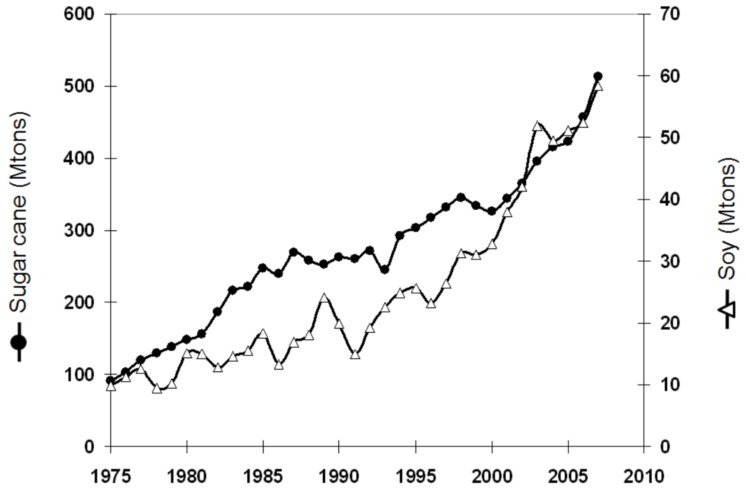

Figure 2. Sugarcane and soy production in Brazil

Regarding the use of land, another important initiative from Brazilian government was to carry out an agroclimatic zoning for sugarcane and several cultures in all territory, to conserve watersheds, forests and aquatic reserves (Manzatto, 2009). Most of the sugarcane expansion areas are degraded pastures that don't support more than one cattle head per hectare. These areas of degraded pastures overpass 100 million hectares and are located very far from the Amazonia wet tropical forest where sugarcane does not grow well (Goldemberg, 2008).

Regarding deforested areas there is no evidence that it have been used for the expansion of sugarcane fields. In all Brazilian states (São Paulo, Minas, Paraná and Goias) where the growth of sugarcane areas was 1.2 million hectares in these state. There was also a simultaneous growth of forested areas (3.6 million hectares). Moreover, some states where sugarcane doesn't have been cultivated have increased their deforested areas. It means that sugarcane expansion in relation to land use has been insignificant to deforested areas as well as to food crops such as corn and soy (Walter et al., 2008). Moreover, it is important to emphasize that 45% of all sugarcane produced in Brazil is destined to sugar production for internal consumers as well as to export to several countries worldwide. The remaining sugarcane (55%) is crushed for fuel ethanol production.

In 2009 just 0.87% of all land in Brazil was used to produce sugarcane. It means that half of this sugarcane areas is destined to ethanol fuel production while corn and soy occupied 4.23% of Brazilian lands (CONAB, 2009). In 2009, each hectare cultivated with corn and soy produced in average 4.2 and 2.9 tons of grains respectively, while the same area produced 81.6 tons of sugarcane, 10.1 tons of sugars, 6,218 liters of ethanol and 9.8 tons of bagasse (CONAB, 2010).

In addition, sugar production processes generate molasses, a by-product very rich in sucrose, glucose and fructose. Molasses has been used by the distilleries for ethanol production where it is mixed to low quality sugarcane juice to be fermented by yeast cells. After the fermentation step the yeast cells are recycled to be used in the next fermentation step while the wine is distillated to produce ethanol and vinasse (Amorim and Lopes, 2005).

Vinasse is a co product rich in minerals, chiefly potassium. Vinasse is used to fertilize the sugar cane fields. Furthermore, minerals from filter cake and ash are incorporated also the soil. Then, just carbon, oxygen and hydrogen are removed from the sugarcane crops through sugar and ethanol production.

Ethanol is a liquid fuel that contains 93% of the energy found in sugar. While the sugar might be poetically called “the crystallized energy from the sun” formed through photosynthesis, water and CO2 by sugarcane, the ethanol represents the sugar energy converted in liquid fuel by a living process carried out by yeast cells. A great biodiversity of yeast strains has been observed in industrial processes and enormous efforts have been done to select new yeast strains with improved fermentative abilities (Basso et al., 2008). Recently, the genome of two Brazilian yeast strains (CAT1 and PE2) selected by Fermentec in the 90s were sequenced and characterized by molecular techniques (Stambuk et al. 2009 and Argueso et al., 2009).

Nowadays, the gasoline sold in Brazil has 25% of anhydrous ethanol. This percentage is controlled by Brazilian government and might vary according with offers and prices of anhydrous ethanol in the market. Besides the addition in gasoline, in the last years there were an expansion of the use of ethanol by a growing fleet of light vehicles running with flex fuel engines (Ministério das Minas e Energia, 2010). In January (2009) ethanol surpassed gasoline as fuel for cars in Brazil. Today more than 95% of all cars sold in the Brazilian market are flex fuel. It means that can run with gasoline, which contains anhydrous ethanol, or any blend with ethanol. Besides of the fleet of light cars moved to ethanol, most of the planes used for crops pulverization also use ethanol as fuel reducing sulfur and carbon monoxide emissions.

Reduction of GHG emissions

Nowadays, sustainability of biofuel production has been one of the main issues focused in current discussions over the world. Because of its prompt availability to displace fossil fuels, ethanol production from different feedstock has gained attention due to the need to mitigate GHG emissions worldwide. Of course other reasons also include oil prices and diversification of energy matrix.

The balance of GHG emissions from Brazilian bioethanol production has been considered the best among all biofuels currently produced (Walter et al., 2008). Considering a full life-cycle analysis of ethanol production and consumption, the reduction of GHG emissions reached 90% compared to gasoline. This result is much better than avoided emissions for ethanol produced from maize (30%) and beet (45%).

According to studies carried out by Macedo et al., (2008) along of all life-cycle of ethanol production from sugarcane production and processing the most significant GHG emissions were attributed to soil emissions, followed by agricultural operations and transport, burning of the sugarcane fields before manual harvesting, use of fertilizers and ethanol distribution.

However, current technologies available to sugar and ethanol industries such as mechanical harvesting and surplus of electricity from bagasse and sugarcane trash have contributed to reduce the emissions of GHG in relation to total energy produced by sugar and alcohol industries.

With the prohibition of burning the cane for harvest, many people have to be trained to cope with the evolution of harvesting and direct planting fully mechanized. In the state of São Paulo, more than 60% of the cane is mechanized and harvested green. On the other hand, re-composition of the forest reserves in crop areas, including riparian forest, is mandatory to sustainability programs, not only for emissions of GHG but also to preserve water reserves, biodiversity, soil conservation and other.

Variation in emission change with the land use, due to massive deforestation, that could be an additional source of GHG emissions. However, the expansion of sugarcane fields in Brazil is not taking place on forests but on degraded pastures that do not involve deforestation. For this reason the impact of GHG emissions due to change of land is very small (Goldemberg, 2008).

On the other hand, the global warming caused mainly by industrialized countries and emerging economies based on use of fossil fuels (petroleum and coal) has change the CO2 concentration in the atmosphere as well as the global climate. These changes in the world climate have also induced the change of crop practices in several countries and the use of lands. It means that while we are focused to discuss the very small impact of bioethanol on GHG emissions due to use of land, the truly and biggest changing has been caused by fossil fuels. Thousand tons of CO2 have changed the climate of several places in the world. These changes have affected small communities, forests, rivers as well as the use of land for agriculture.

According to Macedo et al., 2008, around 90% of CO2 emissions can be avoided by the use of bioethanol produced from sugarcane in substitution to gasoline. Even ethanol produced from sugarbeet and corn has a very significant contribution for reduction of CO2 emission in comparison with gasoline. This reduction reach 45% for sugarbeet and 30% for corn.

For this reason, ethanol also represents an excellent alternative to coal and oil for dependent countries. Emerging economies such as China, India, Australia and Africa may improve the bioethanol production from sugarcane reducing environmental impacts caused by coal, oil and its derivates.

Summarizing the sugarcane industry, Figure 3 shows that from 1 ton of sugarcane 1/3 (145kg) is sugar, 1/3 (280kg) is bagasse with 50% moisture, and 1/3 (140kg) is straw. The sugar can be crystallized and sold as sugar, and the bagasse can be burned to produce steam to run the factory and transformed in electrical energy. Also can be used to make paper and others products. The straw today can be burned to produce steam and / or electricity, can be sold to feed boilers (orange juice concentration factory, soybean extraction oil, etc.). Tomorrow could also produce ethanol.

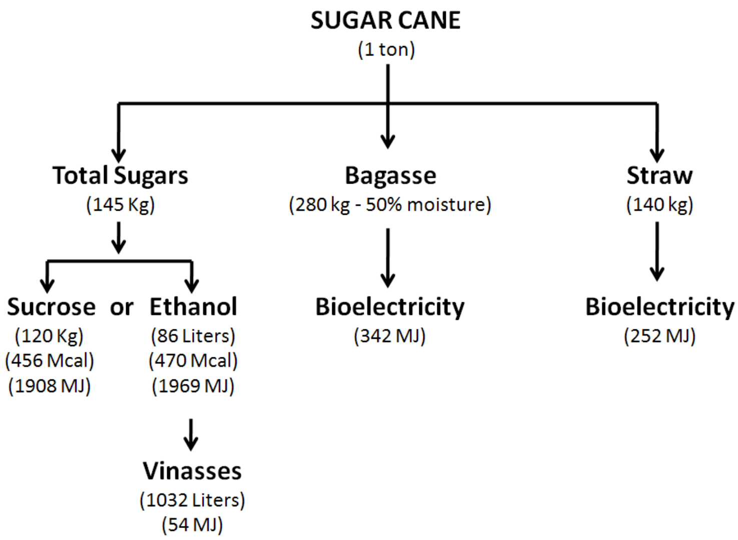

Figure 3. Sugarcane potential to produce energy

From bagasse to bioelectricity

The energy matrix of the World x Brazil is remarkable different. While the world uses 88% nonrenewable energy and 12% renewable, Brazil uses 45% renewable and 55% nonrenewable (Ministério das Minas e Energia, 2009). In the region where sugarcane is planted in the harvest season does not rain, and there is a shortage of electricity due to the low level of water of the hydroelectric power plants. Just at that time, the plants produce electricity from the bagasse, and in the future, from the straw also.

The first Brazilian mill started to produce surplus electricity in the second half of 80s. Considering the sugarcane production in 2009, about 4.6 TWh of surplus electricity could be produced and commercialized. However, for the same amount of sugarcane produced, but using both sugarcane bagasse and trash (e.g., leaves of the sugarcane plant) as fuels, the potential could be 5-7 times higher than what has been produced.

In 2009 the electricity produced from sugarcane bagasse contributed with 3% of the total electricity production in Brazil. The installed capacity at the 289 sugarcane mills is estimated about 3,400 MW, being about 1,800 MW the capacity of surplus electricity production. It has been recognized by the sugar mills in Brazil that diversification of the production as sugar, ethanol, bioelectricity, dry yeast and other is essential to enhance the industry competition as well as to survive from market oscillations and economical crisis. In addition, there are new opportunities to transform mills in biorefineries. However, it is necessary to investment in research, transfer of new technologies and training of technical staff.

The energy balance between corn and sugarcane, today, both are positive, however the output in sugarcane is 7.2 times higher than corn. The energy in cane production and transport shall increase in terms of MJ/ton, because the increase in mechanization, not only in harvesting, but also in planting. The total input should increase from 233.8 to 262.0 MJ/ton. However, the total output renewable will increase from 2,185 to 3,032. The balance, considering the production / energy consumption there are two situations: One situation is if the plant produce bioethanol and bagasse only, in the future, with a higher input due to more mechanization and big areas, the ratio production/consumption will decrease, besides bioethanol and bagasse, the production/energy consumption will increase from 9.3 to 11.6 in 2020 (Macedo et al. 2008).

The highest positive balance for sugarcane can be explained due to use of bagasse as a source of heat and electricity (biomass) in the production of ethanol, including crushing, evaporation and distillation (Dorfler and Amorim, 2007).

Moreover, the development of new technologies and improvement of industrial processes have reduced the consumption of energy becoming the distilleries more efficient. In the industry, to improve efficiency in energy, boilers passed from 21 bar to 86 and 92 bar saving 2.6 times more steam per Kwh (from 12.5 to 4.7 Kg steam/kwh) than older systems. Ethanol produced from Brazilian sugarcane is the biofuel with the best energy balance. It means that a positive ratio between renewable products and the energy input as fossil fuel. For Brazilian sugarcane ethanol this balance is 9.3. In comparison with ethanol from corn (1.3) and wheat from European (2.0) (Goldemberg, 2007).

This energy balance represents the ratio between renewable energy output (ethanol + electricity + bagasse as fuel) to the fossil energy input in different stages of the supply chain. The advantage of sugarcane can be explained due to the fact that bagasse (a fibrous material) can be used as fuel at the mills, producing steam and electricity. One third of all sugarcane produced in 2009 by

Brazilian mills (600 milion tons) was bagasse with 50% moisture. All these crop and industrial characteristics make the ethanol production from sugarcane a success in sustainability. Based on Brazilian experience, other countries where sugarcane grows well may adopt similar programs for bioethanol, bioelectricity and sugar production with low impact on the environment.

Solutions to vinasse

In the ethanol plant, we have a co product, the vinasse, which is rich in potassium and some organic matter. All the plants uses this vinasse mix with water that washes the cane and fertirrigate the cane field, and with this procedure the cane and sugar yield increases significantly. In this way, potassium and other minerals return to cropped soils. Brazil imports more than 85% of the potassium it needs, and this process brings a tremendous economy.

However, for each liter of ethanol produced, it is generated other 12 liters of vinasse. It happens because the alcoholic content in the wine in the end of fermentation reach 8-9% in the Brazilian distilleries. It means that for 26 billion liters of ethanol produced in 2009 another 312 billion liter of vinasse were generated. Nowadays the government keeps track of the levels of potassium, nitrate and others elements in the soil, to avoid table water contamination.

An interesting idea arose six years ago to reduce vinasse volumes with saving in energy and transport costs. Fermentec developed a process which increases the ethanol concentration in the fermented mash up to 16% with yeast recycle, and with this process the vinasse is reduced by half or 6 liters per liter of ethanol (Table I).

Table I. Reduction of vinasses volume with higher ethanol % in the wine

Ethanol % in the wine (v/v)	*Volume of vinasses / liter of ethanol*	*Concentration factor*[a]
5.0	20	1.00
7.5	13	1.53
10	10	2.00
14	7.0	2.86
16	6.0	3.33
18	5.5	3.63

[a] Obtained in relation to vinasses volume produced by fermentations with 5% of ethanol in the wine.

This process will decrease the energy for distillation in 0.56 to 0.80 Kg steam/liter of ethanol, and bring an economy of two dollars per ton of cane crushed for vinasse distribution in the field. In summary, it has been demonstrated that the development and transference of new technologies to mills need to be aligned to economical and sustainability proposals. The success of first and second ethanol generation of biofuels production, depend upon the investiment in research. In this way, we will build the sustainable knowledge for biofuels production.

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