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Ethanol as a major coproduct

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Abstract The volatility of the international sugar market and the approaching end of the EU Sugar Regime have increased the interest of sugar-producing countries in diversifying their mills production to reduce the production of sugar and create alternatives to lower their business risk. Several potential coproducts are under evaluation with respect to market size and technical/economic feasibility in a mill environment. However, at a large scale, only two coproducts have become reality in many countries such as Colombia, India, Mauritius, Brazil, Guatemala, Thailand, Réunion, Bolivia, Peru, Argentina and others – ethanol and electricity. In this work, the Brazilian experience is discussed in terms of lessons learned and driving forces that created the present production model with integrated production of sugar and ethanol. The resulting flexibility in production and in demand, also due to the introduction of Flexible Fuel Vehicles (FFVs) and variable ethanol blending mandate (from 18 to 27% ethanol in gasoline), has created an interlinkage between the prices of sugar, ethanol and gasoline that help to attenuate the external price volatility. Finally, we look at the future for ethanol as a commodity of growing importance under the different low carbon scenarios for the transport sector.

Key words Diversification, ethanol, production flexibility, biofuels future

INTRODUCTION

The volatility of the international sugar market and the approaching end of the EU Sugar Regime have increased the interest of sugar-producing countries in diversifying their sugar mills to reduce the production of sugar and create alternatives to lower their business risk. The situation of small industries that export the main part of their production, such as in ACP (Africa, Caribbean, Pacific) countries, is even more critical (Lionnet 2015). With the expiration of the European sugar regime in 2017, these regions will soon be competing directly with larger and more efficient producers without the support of quotas or minimum prices. However, the alternatives are many, varying from large volume/low prices commodities to low volume/high prices specialty products (nutraceuticals, cosmetics, etc.). The balance towards either direction requires a careful analysis before its implementation. Potential markets and competitors, transport distances and infrastructure, technology level and investments are some of the many topics to be considered. South Africa has developed a system to evaluate coproduct alternatives (Davis *et al.* 2015) that organizes the process of coproducts screening.

In the case of smaller mills with a modest technology level it is important to think seriously about the alternatives already in use by sugarcane mills in other regions, such as ethanol (Brazil, Colombia, Thailand, Guatemala, Argentina, Peru, Malawi, Paraguay, India, Australia, Mauritius) and electricity (Mauritius, Brazil, Guatemala, Colombia, Australia, Réunion, India). Another large-volume market alternative, not yet explored by the sugarcane sector, is the production of pellets from bagasse surpluses (Walter *et al.* 2014), which could compete in the international market of wood chips and pellets with a global production of 24 Mt/year in 2014 (REN21 2015).

In this work, we discuss the Brazilian experience with ethanol in terms of lessons learned and driving forces that designed the current production model based on the integrated production of sugar and ethanol and the impacts of this flexibility in production and demand. The future of ethanol as a renewable transportation fuel is briefly discussed.

INTRODUCTION OF ETHANOL IN BRAZIL

From the beginning of the 20th Century, the Brazilian sugar industry has been plagued with surpluses of sugar and sugarcane due to the low competitiveness in the international market. In the 1920s, some mills started to experiment with ethanol as a light-duty vehicle fuel. The government supported this initiative, as it held potential to solve two problems at the same time - surpluses of sugar and the high expense of gasoline imports, promoting research in the end use of ethanol, specially blended with gasoline. By overcoming initial problems with ethanol quality, the government felt confident to issue a mandate in 1931 to blend 5% ethanol in all imported gasoline. The mills were able to provide for the required ethanol production, and during World War II this production helped to reduce the problem with gasoline imports due to security issues caused by the war. After the war, low oil prices caused the program to stagnate, but ethanol blending in gasoline continued at around 5%. The oil crisis in 1973 stimulated the government to launch officially the national alcohol program (Proálcool) in 1975 with a goal of replacing 20% of the gasoline with ethanol. The first phase of the ethanol expansion was achieved essentially by annexing distilleries to the existing sugar mills, maintaining the sugar production (essentially directed to the internal market) and quickly increasing sugarcane production. At this stage, ethanol still continued to be used only blended with gasoline. In 1979, with the second oil shock, the government decided to speed up gasoline substitution by favouring the installation of autonomous distilleries (producing only ethanol from cane juice) and pressured the automakers to market neat ethanol cars (E100) - this happened in 1979. At this time, there were two types of ethanol: anhydrous (99.6% minimum ethanol) for blending mandates with gasoline and hydrous (95.1% minimum ethanol) for the neat ethanol cars. In 1985, oil prices dropped to the pre-crisis levels and the government started to lose interest in ethanol, resulting in a new stagnation phase, maintaining production around 11 GL/year until 2001 when oil prices started to escalate again. In this period, sugar factories were annexed to the existing autonomous distilleries, consolidating the prevailing production model in Brazil where the two products are produced in an integrated way.

In 1989, driven by the new Constitution that promoted a reduction in government action in the country's economy and the maturity of the sugar/ethanol sector, the deregulation phase started with refined sugar and finished in 1999 with hydrous ethanol. Free market conditions currently prevail in both sectors, with government intervention limited to define the ethanol blending rate in the gasoline (initially between 20-24% that evolved to 18-27% today) based on the analysis of the supply/demand scenario.

In 2003, motivated by the increase in demand for neat ethanol cars, due to increasing oil prices, the automakers decided to introduce the Flexible Fuel Vehicles (FFVs), creating flexibility in the demand side. A fluctuating demand emerged as hydrous ethanol (E100) started to compete with the gasoline in the free market. Table 1 presents the resulting Brazilian production profile in which more than two-thirds of the cane in Brazil is milled in mills that produce both sugar and ethanol. Furthermore, dedicated-sugar mills have almost disappeared.

Table 1. Profile of the Brazilian sugarcane sector (2011).

Mill type	Number of mills	Milled cane (Mt/year)	% milled cane
Sugar/ethanol	257	378.4	67.4
Ethanol distillery	127	161.2	28.7
Sugar mill	18	21.4	3.8
Total	402	561.0	100

Source: CONAB (2013)

IMPACTS OF THE FLEXIBLE PRODUCTION MODEL

The links between international sugar prices (NYBOT #11) and ethanol in the Brazilian market are clear (Forber 2013), as well as the links between ethanol and gasoline prices (BNDES/CGEE 2008), considering ethanol parity prices in both cases. This is illustrated in Figure 1, which shows a clear linkage in the price changes of gasoline and sugar in the international market and ethanol in the internal market, as the international oil price is the main driver in the three price changes. Figure 2 shows the behaviour of the sugar, hydrous and anhydrous ethanol prices in the internal market during 2004-2015 all converted to the Total Recoverable Sugars sugar prices corresponding to these three products. It can be observed that the best economic option varies over time and there is a tendency of them to vary somewhat in association.

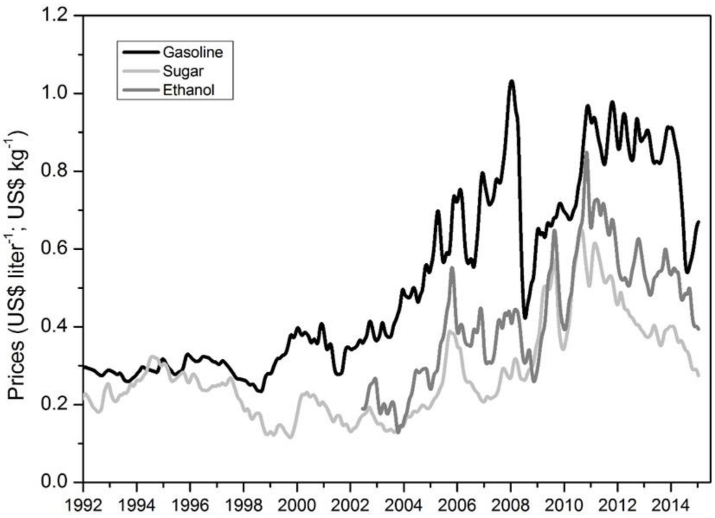

Fig. 1. International sugar[1] and gasoline prices[2], and ethanol prices in Brazil[3]. Note: [1]International sugar prices (World Bank, 2015). [2]Gulf Coast regular conventional retail gasoline prices (EIA, 2015). [3]Hydrous ethanol prices in Brazil (95.1%; CEPEA 2016).

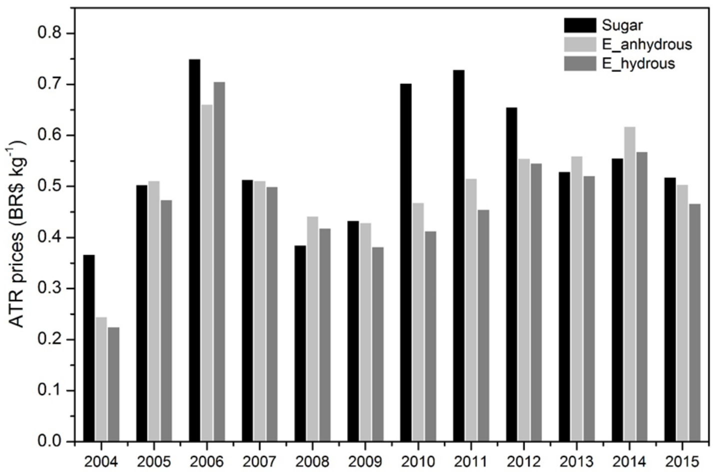

Fig. 2. Total Recoverable Sugar (ATR) prices for sugar, ethanol anhydrous (E_anhydrous) and ethanol hydrous (E_hydrous) in Brazil (updated to 2015 BR$). Source: Consecana (2016).

The explanation for these linkages is that the size of the participation of Brazil in the international sugar market (almost 50%) is enough to influence significantly the prices in these markets. Since ethanol represents around 50% of the total cane milled and mills have the flexibility to change the sugar/ethanol production ratio somewhat, the producers will adjust this ratio based on the market prices of the two products. Long-term sugar contracts limit this flexibility in the short term, but in the medium to long term the production of the best commercial product is favoured, resulting in this interrelation. The direct competition between hydrous ethanol and gasoline at the filling stations creates another link between ethanol and gasoline prices.

The main lessons that can be learned from the Brazilian experience with sugarcane ethanol are:

- Oil price is a strong driver to produce and use ethanol fuel from the consumer and government perspective and sugar surplus or low prices are the main driver from the producer perspective.
- Annexing distilleries to existing sugar mills is a fast and economic alternative to produce significant amounts of ethanol. After reaching the limit from the use of molasses, ethanol production can continue to increase by using B molasses or juice blended with molasses, at the expense of sugar production.

- Blending ethanol with gasoline is the fastest way to increase ethanol use, but after reaching the blending limit of 10% (blend wall) it will be very difficult to maintain growth.
- Overcoming the 10% ethanol limit requires the introduction of neat ethanol (E100) or flexible fuel vehicles (FFVs) and a separate distribution and dispensing system; this can be costly and takes a long time.
- Adequate policies to promote the ethanol production and use are very important for the success, but they should have a defined life or be kept at an essential minimum level (such as blending mandates).
- Technology development was essential to reach competitiveness both in sugar and ethanol.
- There are several synergies in the associated production of sugar and ethanol in terms of scale, sugar quality and energy efficiency; also, the flexibility to change the ratio sugar/ethanol helps to reduce the business risks.

FUTURE OF BIOFUELS

In the present situation of low oil prices, it is reasonable to ask if ethanol and biofuels in general still make sense. The Brazilian experience tells us that the driving forces pushing ethanol vary over time, but the international oil price always plays an important role. Energy security, jobs, local pollution in the cities and, finally, concerns with climate change also made some difference. In a global scene, the International Energy Agency (IEA 2015) considers that to achieve the greenhouse gas (GHG) emission targets to restrain temperature rise within 2°C, as agreed in the Conference of the Parties in Paris (COP 21), biofuels are necessary along with other alternatives to reduce the GHG emissions. In fact, in this scenario the share of biofuels in road transport will increase from 3% in 2013 to 16% in 2040, or in absolute values from 65 Mt of oil equivalent (Mtoe) in 2013 to 98 Mtoe in 2020 to 285 Mtoe in 2030 and 446 Mtoe in 2040. Therefore, considering that ethanol will represent almost three-quarters, as estimated by IEA (2013) (73%), of those amounts it will be equivalent to around 140 GL in 2020, 410 GL in 2030 and 650 GL in 2040, a considerable increase over today's production (94 GL, REN21 2015). In another report (IEA 2011), IEA presents an outlook of biofuels through 2050, and the only first-generation (1G) biofuel to survive in the long term is sugarcane ethanol. Its production costs will remain below the second-generation (2G) alternatives in the period to 2050.

The costs of installation of a distillery annexed to an existing sugar mill and processing only molasses is very low compared to that of a new distillery. In addition, initially it will not reduce sugar production nor require more cane to be produced and milled. For example, a sugar mill processing 1 Mt of sugarcane per year and producing around 126,000 t sugar and 38,000 t molasses per year could produce around 10 ML of ethanol per year in the annexed distillery with an estimated investment cost of only USD3 million (assuming that the boilers have some spare capacity of 10%). If the ethanol production is increased by using 50% of the juice plus molasses, the ethanol production would increase to 42 ML, with the same amount of cane being milled, but with reduced sugar production. In this case, the investment in the distillery would be about USD15 million, also assuming that boiler retrofit is not required (a reasonable assumption since the energy requirements of an ethanol distillery is less than a sugar factory with the same cane-processing capacity).

FINAL COMMENTS

For sugar-producing countries, sugarcane ethanol is the easiest and, most likely, the cheapest biofuel alternative. Installing an annexed distillery to an existing sugar mill using final molasses as feedstock is a simple task and it can start producing anhydrous ethanol from molasses without disturbing the sugar production. When it becomes convenient, the ethanol production can be increased by deviating the sugars from the factory to the distillery and increasing the distillery capacity. The 50/50 sugar/ethanol production profile is an interesting option to increase the product flexibility to take advantage of situation of both markets. Ethanol can be used internally to reduce to country's oil or gasoline imports by blending up to 10% ethanol without any modification in the existing light-duty vehicle fleet and fuel distribution and dispensing infrastructure.

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Éthanol: un coproduit majeur

Résumé. La volatilité du marché international du sucre et la fin du régime sucre de l'Union Européenne ont augmentés l'intérêt de la diversification, afin de réduire la production de sucre et de créer des alternatives pour réduire le risque des entreprises. Plusieurs coproduits potentiels sont en études pour évaluer le marché et la faisabilité technique et économique. Toutefois, à grande échelle, seulement deux coproduits sont réalisés dans de nombreux pays comme la Colombie, l'Inde, Maurice, Brésil, Guatemala, Thaïlande, Réunion, Bolivie, Pérou, Argentine et d'autres – l'éthanol et l'électricité. Ici on discute l'expérience brésilienne, les leçons apprises et les facteurs qui ont créé le modèle actuel de la production intégrée de sucre et d'éthanol. La souplesse en production et demande qui en résulte, également en raison de l'introduction de Véhicules à Carburant Flexible (FFV) et la possibilité du mélange éthanol/essence (de 18 à 27% d'éthanol dans l'essence), ont créé un lien entre les prix du sucre, d'éthanol et d'essence qui aident à atténuer la volatilité des prix externes. Nous considérons aussi l'avenir pour l'éthanol, une denrée d'importance croissante dans les scénarios de faible teneur en carbone pour le secteur des transports.

Mots-clés: Diversification, éthanol, souplesse de production, biocarburants futurs

El etanol como el más destacado coproducto

Resumen. La volatilidad del mercado internacional del azúcar y el próximo final del Acuerdo Régimen Azucarero UE, se ha incrementado el interés , en los países productores de azúcar en diversificar la producción de sus ingenios para reducir la producción de azúcar y crear alternativas para reducir los riesgos financieros. Están en evaluación varios potenciales coproductos con relación al tamaño de su mercado y la factibilidad técnico-económica en el entorno de los ingenios azucareros. Sin embargo, a gran escala, solamente dos coproductos son realidad en muchos países tal como Colombia, India, Mauricio, Brasil, Guatemala, Tailandia, Reunión, Bolivia, Perú, Argentina y otros- etanol y electricidad. En este trabajo se discute la experiencia brasileña en término de una lección aprendida y fuerzas motoras que han creado el actual modelo productivo, con una producción integrada de azúcar y etanol. La flexibilidad resultante en producción y en demanda, resultante también de la introducción de vehículos de combustible Flexible (Flexible Fuel Vehicle (FFVs) y ordenamientos variable de mezclas (de 18 a 27 % de etanol en gasolina), han creado una inter- vinculación entre los precios del azúcar, el etanol y la gasolina, que ayudan a atenuar la volatilidad de los preciso externos. Finalmente, miramos al futuro del etanol como una mercancía de creciente importancia en los diferentes escenarios de bajo carbono para el sector del transporte.

Palabras clave: Diversificación, etanol, flexibilidad productiva, futuro de biocombustibles