TECHNO-ECONOMICAL EVALUATION OF DIVERSIFICATION IN THE SUGARCANE INDUSTRY

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Abstract

As a consequence of the continuous decrease in the sugar price, product diversification in the sugar industry, by the simultaneous production of energy, fuels, animal food and other by-products, is mandatory. In this paper, an optimisation program named ‘Diversification’ is developed and a case study is presented. For this case study, costs and prices were supplied by a medium-sized sugar and alcohol mill from Minas Gerais State in Brazil. The optimisation program determines the optimal quantity of each product and by-product to be produced looking for a maximum specific profit (by tonne of milled cane). The set of products includes sugar, alcohol, molasses, surplus electricity and surplus bagasse. The Monte Carlo method was used for the investment risk evaluation. It is concluded that optimised diversification programs are economically justified and can lead to a considerable increase in the total specific profit of a sugar mill.

Introduction

The sugar industry is undergoing a deep crisis as a consequence of protective policies and commercial blocks applied by some countries, as well as from the dissemination of new artificial sweetener products, factors that are clearly reflected in the continuous fall in the world sugar price. This leads to the necessity to diversify the range of products from sugarcane, through the implementation of systems able to produce energy and fuels, animal food and other by-products.

These by-products can represent commercial and strategic advantages that should be evaluated in different economic contexts. A diversified sugar industry could be defined as a flexible production system, which is able to react according to the trends in market prices of products and by-products, varying the proportion among the manufactured quantities of each product, always aiming at operating under maximum profit conditions.

An important antecedent in diversification studies was the project ‘The diversification in the sugarcane agro-industry in Latin America and in the Caribbean’ (GEPLACEA/PNUD/RLA/86/011). The statement that says that the diversification is: ‘... fundamentally, a strategy of development of the sugarcane sector’ (GEPLACEA, 1991) is still valid. However, many diversification projects in the sugar and alcohol industry have not been very successful, because they demand a technical and economic analysis for each case, depending on the geographical location of the project and on the predominant economic activities in the region. In addition they also need a minimum market price for the products.

This paper intends to show the advantages of the sugar and alcohol industry diversification as a competitive differential at the current conditions. A computational tool was developed to optimise the variety and quantities of products for an assumed scenario of prices and taking into account the constraints of the industrial process. A case study is also shown. The question we try to answer regards the correct combination of products and their quantities so that their production may reach the maximum net profit in a certain scenario of market prices.
Products and by-products in a diversified sugarcane mill

The assortment of products that might be obtained from a diversified sugar mill is shown in Figure 1.

Energy

At the moment, there are two commercial cogeneration technologies: the steam cycle with backpressure turbines, TC, and the steam cycle with condensing/extraction turbines, TEC. The technology with biomass gasification integrated to gas turbines to gas, BIG-GT, is still being developed. Figure 2 shows schemes of these technologies. To shift from TC towards TCE and BIG/GT technologies allows a considerable increase in the availability of electricity. Another important aspect is the convenient reduction in the process steam consumption to maximise the surplus generation when the TCE technology is used. Typical BIG/GT systems need a specific steam consumption lower than 400 kg/te for rational operation (Hobson and Dixon, 1998). This technology is being tested through several demonstrative projects in Europe and in the United States using wood residues as fuel. In Australia and Brazil, the possibility of implementing BIG/GT demonstrative pilot plants using sugarcane bagasse as fuel is under evaluation.

Economic and legal factors, effective commercialisation tariff, and encouraging legislation and contracts must be considered simultaneously with the technological ones (more appropriate cogeneration technology and the reduction of the steam consumption in process) to ensure the success of surplus electricity generation projects at sugar mills.

Animal food

The feeding of cattle with sugarcane, especially during the dry season, when the availability of conventional forage resources is lower, is an old practice. A great experience in cattle feeding with sugarcane and its by-products comes from research carried out in Cuba in the late 1960s (Preston and Willis, 1974).

Institutions like ICIDCA (Cuba), ESALQ (Brazil), CIPAV (Colombia), CETABOL (Bolivia), among others developed studies regarding the use of sugarcane and its by-products for the feeding of cattle. Orama and Penichet (2004) suggest dividing the potential of sugarcane used as animal food into two categories: proteins (yeasts, musts and hydrolytic molasses) and carbohydrates (integral cane, molasses, daily feed molasses-urea-bagacillo, hydrolysed bagasse and straw).

As an exclusive food for ruminants, sugarcane has a low nutrient value, because it is unbalanced in relation to the nutrients the ruminant demands as well as by the microorganisms that live in the rumen. One of the factors that limit the use of sugarcane as animal food is the low content of proteins. Experiments
carried out by researchers of the National Center of Investigations of Cattle for Milk Production that were summarised by Moreira (1983) show that rice and wheat flour are good supplements for diets based on sugarcane and urea.

Fig. 2—Commercial and developmental technologies for electricity generation in sugar mills. 
- a) Steam cycle with backpressure turbines—TC.
- b) Steam cycle with condensing/extraction turbines—TCE
- c) Cycle with biomass gasification integrated with gas turbines—BIG-GT

Sugarcane bagasse has poor digestibility, lower than 35%, and its density is not greater than 150 kg/m³. These two factors make its nutritious value low and limit its use to less than 30% of the daily feed (dry basis). The hydrolysis process with steam is one of the physical-chemical treatments used to change the composition of the bagasse fibrous fraction aiming at increasing its digestibility for ruminant animals up to values of approximately 65% (Gutmanis, 1987). Thus, sugarcane needs protein complements and treatments to be successfully used for the feeding of cattle.

The Diversification sheet

The ‘Diversification’ sheet developed for the evaluation of diversification options is an Excel application that simulates, calculates and optimises real production scenarios, costs and profits in sugar mills that have condensing/extraction turbines—TCE at three different levels of pressure: 4.2, 6.0 and 8.0 MPa (TCE-42, TCE-60 and TCE-80 technologies). Figure 3 show the data input screen of the sheet.

The ‘diversification’ sheet allows:
- a) to explore the variety and optimal quantities of products of a diversified sugar mill aiming for profit maximisation in a given context of production costs and market prices;
- b) to select between two formulae of daily feed for cattle starting from hydrolysed bagasse with the addition of milled corn, cotton seed flour, liquid yeast, molasses, urea and minerals;
c) to do feasibility analysis of the investments in electricity cogeneration using TCE technologies for the three defined pressure levels and d) to evaluate the risk of investing in diversification projects.

The optimisation methods used during the economic-financial analysis were:

a) Linear programming: determination of the objective function (O.F.) and from there the linear combination of the optimal quantities of the different products to be produced.

b) Monte Carlo method: evaluation of the investment risk.

Real sugar mill case data and results

The basic data and economic figures used for the case study were kindly provided by a sugar mill of medium capacity located in the State of Minas Gerais in Brazil. In this case, the production of sugar and alcohol and five by-products was assumed: residual molasses, electric power surplus, hydrolysed bagasse for cattle feeding, beef produced near the mill ('hotel for cattle'), and natural bagasse for sale. The yeast production and the energy use of the biogas obtained by anaerobic digestion of stillage were not included in the study.

In the analysed case, the hydrolysed bagasse was enriched with milled corn, cotton seed flour, liquid yeast, molasses, urea and minerals in order to be offered as high-nutritious quality and low-cost daily feed. This kind of mixture has been used for several years in a 'cattle hotel' annexed to a sugar mill located in the state of Sao Paulo (Brazil) with very good results. The main indexes of sugar and alcohol production used during the calculations are shown in Table 1.

Fig. 3—Data input screen for the 'Diversification' sheet showing a scheme of a diversified sugar mill.

<table>
<thead>
<tr>
<th>Indicator symbol</th>
<th>Symbol</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar production index</td>
<td>IS</td>
<td>0.12</td>
<td>t of sugar / t of cane</td>
</tr>
<tr>
<td>Alcohol production index</td>
<td>IAP</td>
<td>0.07</td>
<td>m³ / t of cane</td>
</tr>
<tr>
<td>Generation of residual molasses index</td>
<td>IRM</td>
<td>0.23</td>
<td>t of molasses / t of sugar</td>
</tr>
</tbody>
</table>
The opportunity costs were not considered and an exchange rate of 2.546 R$/US$ was assumed. It was considered that the funding for the investment in cogeneration and bagasse hydrolysis equipment was obtained from the Brazilian National Bank of Economic and Social Development (BNDES) under the following conditions: a) 15 years financing period; b) 2 years of grace period; and c) amortisation system with constant benefits.

The estimated price for the surplus electricity sold to the utility was assumed to be US$33/MWh, considering that the generation cost in the first year of financing of the electricity generation equipment (boiler and condensing/extraction turbine TCE-60) is about US$26/MWh.

Figure 4 introduces the screen with the information about production costs, market prices and produced quantities based on conventional planning and on the optimised one using the ‘Diversification’ sheet. Based on this information, the net profits by tonne of milled sugarcane [US$/tc], for each product during the first year of financing were calculated. Figures 5, 6 and 7 show some results graphically.
Investment risks

By using the Monte Carlo method, the investment risks can be calculated for electricity generation and for the production of daily feed for cattle based on hydrolysed bagasse in diversified mills with TCE-60 technology (Figure 8). With this objective, the net present value was calculated for 200 investment alternatives.

Fig. 5—Annual net profits per tonne of sugarcane for each product during the first year of financing (sugar mill with TCE-60 technology).

Fig. 6—Production program as planned by the user in a sugar mill with TCE-60 technology.

Fig. 7—Production program defined by 'Diversification' sheet in a sugar mill with TCE-60 technology.
TCE-60 technology presents a probability of about 98% of being successful, using the products arrangement defined by using the 'Diversification' sheet and 74% for a planned production attending the user’s criteria. This difference demonstrates the advantages of using the 'Diversification' sheet for the optimisation of the annual production plan of each product to maximise the mill’s profit at minimum risk. Bearing in mind that risk is a subjective parameter whose perception varies from one person to another, it is usually considered low risk when its value lies below to 5%.

**Conclusions**

Diversification is economically justified and could lead to considerable increase in the specific net profits of a conventional sugar mill. For the full materialisation of this objective, new technological paradigms must be reached related to the commercial maturity of the BIG/GT technologies. At the moment, electricity generation with 60 MPa condensing/extraction turbine technologies is the most attractive due to the smallest risks and biggest profits.

The use of the sugarcane alone (pure, 'in nature' bagasse or hydrolysed bagasse) as animal food in the dry period is not shown as viable due to the low daily increase in animal weight and the low digestibility achieved in several experiences carried out around the world. However, it can become an attractive alternative if hydrolysed bagasse and other ingredients are used for daily feed elaboration, especially for cattle confined in final phase (from 300 kg of live weight).

The use of sugarcane bagasse for electricity generation has enormous potential in Brazil. As an important aspect, we should consider that the period of harvest of the sugarcane coincides with the dry season in the main basins of the Brazilian hydroelectric system.

The production of alcohol appears to be very promising due to the rise in oil prices in the international market and the consequent rise in gasoline prices.

In perspective, it would be important to carry out economic analyses including the profits that could be obtained from the reduction in carbon emission as a consequence of electricity cogeneration using biomass. This income could represent an additional incentive for diversification in the sugar and alcohol industry.

**REFERENCES**


EVALUACIÓN TÉCNICO-ECONÓMICA DE LA DIVERSIFICACIÓN
DANS L’INDUSTRIE SUCRIÈRE

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MOTS-CLÉS: Diversification, Sucre, Alcool, Canne à Sucre.

Résumé
Avec la chute continue du prix du sucre, l’industrie sucrière se voit contrainte à diversifier en produisant simultanément l’énergie, les combustibles, la nourriture d’animaux et autres sous-produits. Cette communication présente le développement d’un programme d’optimisation, nommé ‘Diversification’, ainsi qu’une application pratique de ce programme. Toutes les informations utilisées dans cette étude concernant les coûts et les prix proviennent d’une sucrerie de taille moyenne de l’état de Minas Gerais du Brésil. Le programme détermine la quantité optimale de chaque produit et sous-produit qui permettra de réaliser un profit spécifique maximum (par tonne de cannes broyées). La gamme de produits comprend : le sucre l’alcool, la mélasse et le surplus d’électricité et de bagasse. La méthode Monte Carlo a été utilisée pour évaluer le risque à l’investissement. La conclusion est que le programme se justifie économiquement et peut mener à une augmentation considérable du profit spécifique total d’une sucrerie.

EVALUACIÓN TÉCNICO-ECONÓMICA DE LA INDUSTRIA DE LA CAÑA DE AZÚCAR

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PALABRAS CLAVES: Diversificación, Azúcar, Alcohol, Caña de Azúcar.

Resumen
Como una consecuencia del continuo descenso del precio del azúcar, resulta mandatoria la diversificación de la Industria Azucarera, mediante la producción simultánea de energía, combustibles, alimento animal y otros derivados. En este artículo se desarrolla un programa de optimización denominado ‘Diversificación’ y se presenta un ‘estudio de caso’. Los costos y precios para este ‘estudio de caso’ se suministraron por una fábrica de azúcar y alcohol de tamaño medio del Estado de Minas Gerais en Brasil. El programa de optimización determina la cantidad óptima de cada producto y subproducto a ser producido con el propósito de alcanzar una ganancia máxima especifica (por tonelada de caña molid a). El grupo de productos incluye azúcar, alcohol, mieles, electricidad y bagazo sobrante. Para la evaluación del riesgo de inversión se empleó el Método Monte Carlo. Se concluye que los programas de diversificación optimizados se justifican económicamente y pueden conducir a un considerable incremento en la ganancia total específica de una fábrica de azúcar.