DIVERSIFYING SUGAR CANE: CELLULOSE FROM BAGASSE

By

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Abstract

CANE SUGAR industries are going through severe economical crises. To increase profitability, they must use every product or by-product of cane. As an example of diversifying potential, ethanol and cellulose, both obtained from bagasse, are compared. In Mexico, bio-ethanol is worth around US$0.45 per litre, and about 200 litres can be obtained per tonne of dry bagasse. Non-treated dry bagasse contains 51.67% cellulose, 24.42% hemicelluloses, 10.23% soluble and 13.68% lignin. Thus, theoretically, 516.7 kg of cellulose can be obtained per tonne of bagasse. Whitened cellulose in México is MX$4.50 to MX$5.00 (US$0.30 to US$0.33) per kg. Comparing bio-ethanol and cellulose revenue: ethanol is MX$1200 (US$80.00) vs. cellulose MX$2583.50 (US$172.20) per tonne of dry bagasse. Possible cellulose production from Mexican sugarcane (2007–2008): milled cane 46 518 988 t; dry bagasse 6 977 848 t; yielding 3 605 454 t cellulose. Presently Mexico imports 80% of required cellulose. Not all cellulose fibres from bagasse can be efficiently used as fuel. With the new technology developed and tested by us, all long fibres can be converted into cellulose, and 94% of pith can be burnt. However, auxiliary fuel (3.9 litres of heavy bunker C per milled tonne of cane is also required. It is important to establish laboratory methods to determine the real content of fibre convertible to cellulose and how biotechnology can help improve the quantity and quality of cellulose. These tests are to be performed at industrial laboratories and in accordance with official procedures.

Introduction

World sugar consumption is continuously increasing (Figure 1). However, a more detailed study of per capita consumption reveals cane and beet sugar consumption have decreased since 1980, when the corn sweetener (a composite of fructose, glucose and dextrose obtained from corn) replaced sucrose to some extent, Figure 2 (Jensen, 2005).

The sugar market is also affected by the instability of world market prices for sweeteners.

These facts resulted in severe economical crises for cane sugar industries, forcing them to look for new and alternative technologies and products to compensate for market price instability and per capita consumption decrease.

Fig. 1—World sugar consumption (1960–2008).

A typical flow diagram of a cane sugar factory is shown in Figure 3. There are various by-products in the process but only one commercial product, which is sugar; also, in some cases, alcohol. In order to improve the profitability of the sugar industry, by-products can become commercially feasible by applying new technologies or even by converting them to new products.

Diversifying options will be selected by each sugar mill. Local market and exporting opportunities are the factors to be considered.

The following 3 scenarios show and compare different uses of by-products: actual situation, conversion of all bagasse to ethanol, and cellulose production from bagasse.

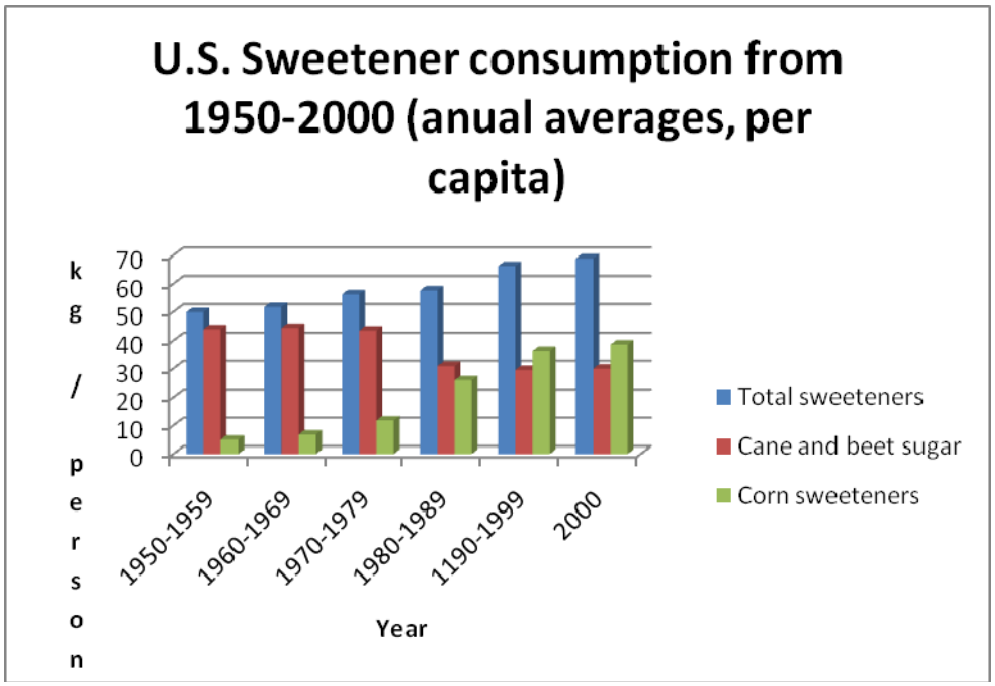

Fig. 2—USA Sweetener Consumption (1950–2000).

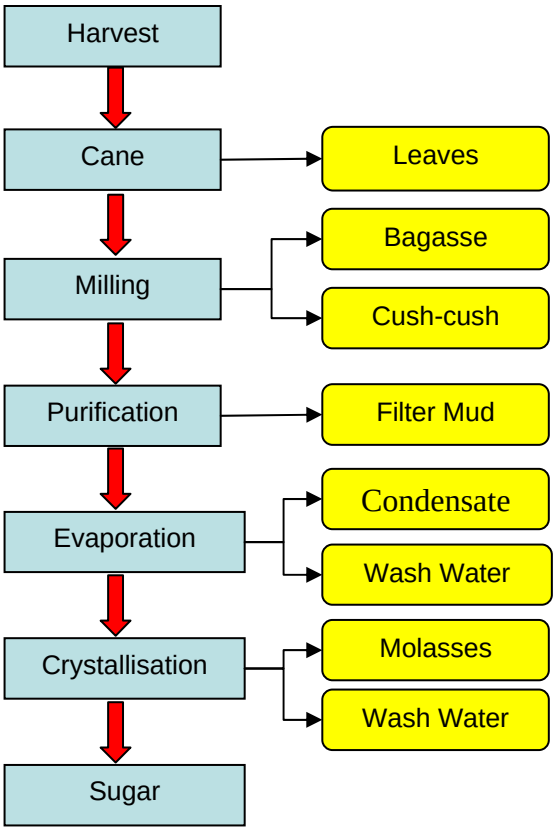

Fig. 3—Typical flow diagram of cane sugar process and its by-products.

Diversification options

There are various options for commercial utilisation of almost all the by-products in the sugarcane process. Some of them are still in a research and development stage, others need new technologies to be competitive, while others are used only in some countries.

Bagasse

Bagasse is the residue from sugarcane milling after the juice has been expressed from the crushed cane stalk. Average composition: 50% cellulose, 30% hemicelluloses and 20% lignin. Actual applications are:

1. Fuel in the sugar process. 91% of energy required in Mexican sugar mills is obtained from bagasse combustion, super heated steam generates electricity, and exhaust steam is used in the sugar process.
2. Cattle feed. Some communities are incorporating bagasse into the diet of different livestock, like cattle and chickens; reports and studies conclude no negative effect in the growth of the animals.
3. Paper and fibre board manufacturing. The old process used in industry to obtain cellulose from cane bagasse requires the chemical delignification and bleaching of the resulting paper pulp, being dangerous for health and environment; uses NaOH and chlorine (Hurter, 2001). A new biotechnology process is being developed by Mexican researchers, so that cellulose can be obtained from bagasse using some filamentous fungi species which are able to produce enzymes that can destroy the lignin and convert it to cellulose.
4. Biodegradable tableware. In China, some disposable tableware from bagasse is produced, replacing plastic or virgin paper. Tableware so produced has no plastic or wax lining applied and can be used for both hot and cold items.

5. As dye removal. Bagasse can be used for the removal of azo dyes by adsorption (Liew *et al.*, 2005).
6. Dietary fibre. There is an industry in the United States selling milled and treated bagasse for use as an additive for human food, for thickening soups, for increasing the fibre content, and to improve the consistency of some precooked meals.

Leaves

In some countries, the leaves are still burnt in the field after harvesting, without any energy recovery. It is possible to burn leaves in the sugar mills' boilers.

Filter cake

Used as fertiliser in the cane fields; for improving its effectiveness, some biochemical treatment and earthworms can be applied.

Molasses

Molasses contains sugar that can be used as a carbon source substrate for different biotechnology processes: citric acid (Garg and Sharma, 1991), acetic acid, ethanol, etc.; development of these technologies is in process around the world.

Cases studies

Comparing three different alternatives using bagasse, results are shown in Table 1:

1) Burning 100% bagasse in boilers (present situation)
2) Convert all obtained bagasse to ethanol, burning diesel and/or bunker C as fuel and
3) Convert all obtained bagasse to cellulose, burning diesel and/or bunker C as fuel.

Considered yields: 1.18 kilograms of dry bagasse per kg of sugar; 200 litres of EtOH per tonne of dry bagasse, 0.4 kg of cellulose per kg of dry bagasse; cellulose recovery efficiency considered to be 80%.

Table 1—Results for 3 different scenarios using bagasse.

Scenario	1	2	3
By-product	None	Ethanol	Cellulose
% burned bagasse	100 %	0 %	0 %
Fuel need, litre/kg sugar	4.8	36.6	36.6
Fuel cost, USD/litre	0.395	0.395	0.395
Specific fuel cost, USD/kg sugar	0.017	0.126	0.126
Dry bagasse, kg/kg sugar	1.277	1.277	1.277
EtOH obtainable, litre/kg sugar		0.255	
EtOH price, USD/litre		0.45	
EtOH obtainable, USD/kg sugar		0.115	
Cellulose obtainable, kg/kg sugar			0.511
Bleached cellulose price, USD/kg			0.33
Cellulose obtainable, USD/kg sugar			0.169
Profit (loss) USD/kg sugar	(0.017)	(0.012)	0.042

Conclusions

Commercial by-product utilisation is a very interesting alternative; much care should be taken to diminish risks when investing.

New technologies are a good opportunity, as by-products can achieve very high values, allowing the mills to increase sales and revenues. As a major labour generator, all alternatives are to be taken after a thorough analysis.

Even with high ethanol prices, cellulose applications are far more profitable.

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DIVERSIFICATION DE LA CANNE A SUCRE: PRODUCTION DE CELLULOSE A PARTIR DE LA BAGASSE

Par

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MOTS-CLÉS: Canne à Sucre, Bagasse, Cellulose, Diversification.

Résumé

LES INDUSTRIES cannières font face à des crises financières aiguës. Pour augmenter leur profitabilité, elles doivent utiliser chacun des produits ou sous-produits de la canne. Comme un exemple du potentiel de diversification, une comparasion est faite entre l'éthanol et la cellulose. Au Mexique, le bioéthanol est evalué à 45 centimes americains le litre et quelques 200 litres sont obtenus d'une tonne de bagasse sechée. La bagasse sèche non traitée contient 51.67% de cellulose, 24.42% de hémicelluloses, 10.23% de produits solubles et 13.68% de lignine. Ainsi, théoriquement 516.7 kg de cellulose peuvent être produits d'une tonne de bagasse. La cellulose purifiée vaut au Mexique 4.50 à 5.00 dollars mexicains ou 30 a 33 centimes americains le kilo. En comparant les revenus de la cellulose et l'éthanol, on s'apercoit que l'éthanol rapporte 1200 dollars mexicains ou 80.00 dollars americains par tonne de bagasse sechée contre 2583.50 dollars mexicains ou 172.20 de dollars americains pour la cellulose. La production potentielle de cellulose en 2007/08 au Mexique, était de 3 605 454 tonnes à partir de 46 518 998 tonnes de canne et 6 977 848 tonnes de bagasse. Actuellement le Mexique importe 80% de ses besoins en cellulose. Pas toutes les fibres de cellulose de la bagasse peuvent être utilisées comme combustible. En ayant recours à la nouvelle technologie développée et évaluée par nos soins, toutes les longues fibres peuvent être converties en cellulose et 94% de la moelle peuvent être brulées. Toutefois un apport exterieur de fioul de l'ordre de 3.9 litres d'huile lourde est nécessaire par tonne de canne usinée. Il est important de mettre au point des procédés de laboratoire capables de determiner la teneur réelle de fibre susceptible d'être convertie en cellulose et comment la biotechnologie pourrait aider à améliorer la quantité et qualité de cette cellulose. Ces procédés doivent être conduits dans des laboratoires industriels et selon les méthodes officiellement acceptées.

DIVERSIFICANDO LA CAÑA DE AZÚCAR: CELULOSA DEL BAGAZO

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PALABRAS CLAVE: Caña de Azúcar,
Bagazo, Celulosa, Diversificación.

Resumen

LA INDUSTRIA de la caña de azúcar atraviesa una severa crisis económica. Para incrementar su viabilidad económica debe utilizar cada producto ó sub producto de la caña. Como un ejemplo del potencial diversificador se comparan el etanol y la celulosa, ambos obtenidos del bagazo. En México el bioetanol cuesta acreedor de US$ 0.45 por litro y cerca de 200litros pueden obtenerse por tonelada de bagazo seco. El bagazo seco no tratado contiene 51.67% de celulosa, 24.42% de hemicelulosa, 10.23% de solubles y 13.68% de lignina. Por tanto, teóricamente, 516.7 kg de celulosa pueden obtenerse por tonelada de bagazo. La celulosa blanqueada cuesta Mx 4.50 a Mx 5.00 (US$ 0.30 a US$ 0.33) por kg. Comparando los ingresos del bioetanol y la celulosa, el etanol vale Mx 1200 (US$ 80.00) vs. la celulosa a Mx 2583 (US$172.20) por tonelada de bagazo seco. La producción posible de celulosa de la caña de azúcar mexicana (2007–2008) es: caña molida 46 518 988 t, bagazo seco 6 977 848 t, rindiendo3 605 454 t de celulosa. En la actualidad México importa el 80% de la celulosa que requiere. No toda la fibra celulósica del bagazo puede ser utilizada eficientemente como combustible. Con la nueva tecnología desarrollada y comprobada por nosotros, toda la fibra larga puede ser convertida en celulosa y el 945 del bagacillo puede quemarse. Sin embargo, se requiere combustible adicional (3.9 litros de Bunker C pesado por t de caña molida).