INTEGRATED DIVERSIFICATION: PRODUCTION OF HIGH FRUCTOSE SYRUPS AND GLUCOSE-SORBITOL FROM SUGAR

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Key words: High fructose syrup, sucrose, glucose, sorbitol

ABSTRACT

A general description is given of a high fructose content (55%) syrup and a glucose co-product in sugar factories. The quality of the product is such that sorbitol can be produced from it, thus reducing its cost. The integral technical-economic balance permits the recovery, in less than five years, of a low level investment by diversification of the sugar factory production with products having a high additional value.

INTRODUCTION

In the course of the past the years the sugar industry has become increasingly more complex and competitive. The advent of high fructose content or isoglucose syrups, which at present account for almost 50% of the natural sweetening agents in the United States and a large part of the Japanese and European markets, has played an important role in this. These corn based products benefit economically from the distribution of the costs of the raw material between the various by-products (Lodos and Codoves, Vuilloumier). Another important factor has been the increase in world trade of white sugars, which has strengthened the position of certain developed sugar-beet producing countries, especially EEC member countries. The cane sugar industry cannot remain indifferent to this challenge and it is now forced to seek ways of diversifying its production, and obtaining new products of increased value. For this reason, there is a special interest in making an indepth analysis of a system, which could produce a high fructose content syrup (HFS) and glucose from sugar in the sugar factory itself, and then to produce sorbitol from the latter. Sorbitol is used in the cosmetics industry, in dentifrice, and in the foodstuffs industry as a thickening, sweetening and moistening agent. It is also used as a raw material in the pharmaceutical industry for the production of vitamin C and polyurethane (Rapaille). This system would provide more direct competition with corn-based HFS (a new refined product for the home softdrinks market). Importation of sorbitol could be reduced and eventually it might be exported at attractive prices. The financial balance of the sugar factory would be improved accordingly.

EXPERIMENTAL PROCEDURE

Experiments were carried out with white sugar (99.5 pol and 200 ICUMSA colour units). The sugar solution was subjected to an inversion process and subsequently glucose was recovered by chromatographical separation or crystallisation in a 100t capacity pilot plant. Industrial tests, using 20 m³ crystallizers and 15 ton batches of sugar, were done in 1987 and 1988, in the Pablo Noriega sugar mill. Purification of the syrup was carried out in two stages: an initial treatment with quaternary amine, phosphatation and a flocculating agent, and a second treatment with activated carbon and ion exchange resins of one litre capacity. Hydrogenation of the glucose monohydrate was done in a pilot plant using five kg of...
Raney nickel as a catalyst at 120°C and at 50 bar (Fedor et al.). The quality of the product was determined by HPLC. The sugar analyses were done in accordance with the techniques recommended by ICUMSA.²

RESULTS AND DISCUSSIONS

The purpose of the first phase of the work was to obtain glucose monohydrate of sufficiently high quality in order to be able to produce sorbitol of vitamin C or alimentary quality. Two methods were employed:

i) acid inversion with crystallisation or enzymatic inversion (Fig 1)

ii) chromatographical separation.

Figure 1. Glucose production by acid inversion and crystallization

From Fig 2 it can be seen that equilibrium for a 20% yield was attained between the 14th and 18th days. A crystallization capacity of 14 cm³ is required per ton of product. The quality of the glucose obtained did not meet requirements and, consequently, a second crystallization sequence was conducted, which attained equilibrium under the same conditions from day 5 to day 7. Due to its 5% fructose content, the resulting product was suitable for producing alimentary quality sorbitol. The necessary crystallization capacity was 15 m³.

If sorbitol for the production of vitamin C is required, a third crystallization over a period of two to three days, and with a crystallizer unit capacity of 7 m³ is necessary. The yield, in both cases, varies between 15 and 18% in relation to the initial amount of sugar (Table 1).
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Figure 2. First crystallization glucose yield vs time

Table 1 - Composition of the different sugar glucose

<table>
<thead>
<tr>
<th>Composition</th>
<th>1st cryst</th>
<th>2nd cryst</th>
<th>3rd cryst</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glucose</td>
<td>60-65</td>
<td>83-87</td>
<td>90.1</td>
</tr>
<tr>
<td>Fructose</td>
<td>15-20</td>
<td>4-6</td>
<td>0.9</td>
</tr>
<tr>
<td>Water</td>
<td>20-25</td>
<td>9-11</td>
<td>9.0</td>
</tr>
</tbody>
</table>

The initial product is filtered under pressure, whilst the second and third can be centrifuged in existing centrifuges. In this manner, investment and running costs can be reduced and the plant's boiling, crystallization and centrifuging units can be used throughout the year. If vacuum pan capacity can be released due to the production of alcohol and other non-crystal products, then the production of glucose and HFS can be stable throughout the year and lead to notable economic and social benefits.

The HFS produced has a sweetening factor equivalent to that of the sugar employed. It also contains most of the non-sugars contained in the original white sugar and has the additional colouring caused during inversion. Under these conditions, it can be used advantageously for the production of beer. However, for large scale application for soft-drinks, it must be purified. Use was made of a specially designed, laboratory scale system, for the transformation of the white sugar syrup and the HFS (Fig 3).

This process refines the white sugar, which appears in its final form as HFS 55 with glucose as a co-product, at low cost. The colour of the HFS changes from 100 ICUMSA units,
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RAW H.F.S.

FIRST TREATMENT

400 ppm QUATERARY AMIN
300 ppm PHOSPHERIC ACID
LIME
10 ppm FLOCCULANT

PARTIAL DECOLORATION

1 000 ppm C

CATIONIC RESIN

ANIONIC RESIN

MIXED RESINS

CONCENTRATION

REFINED H.F.S.
55 60%
75 BRIX

Figure 3. HFS refination technology

in the raw product, to 250 after the first treatment and then finally to 12. The refined HFS is fully competitive with that obtained from corn. Moreover it is suitable for all foodstuff industry applications.

A study was made also of the process of obtaining glucose by enzymatic inversion and chromatographical separation (Fig 4). In this case, both investment and operating costs were higher. The process operated all the year round and a yield of 45% glucose in comparison with the weight of the initial sugar, could be attained. The fructose syrup contained 90% fructose. Both of these products are of high quality, ie superior to that required for producing alimentary quality sorbitol in as far as the glucose is concerned, and for soft-drinks in as far as HFS is concerned.
Figure 4. Glucose production by enzymatic inversion and chromatographic separation

The two processes are compared in Table 2.

Table 2 - Consumption of chemical products and utilities per ton of HFS

<table>
<thead>
<tr>
<th>Item</th>
<th>Acid inversion and crystallization (crystalline glucose)</th>
<th>Enzymatical inversion chromatographical separation (solution)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Hydrochloric acid 33% (l)</td>
<td>16</td>
<td>35</td>
</tr>
<tr>
<td>Sodium hydroxide (kg)</td>
<td>7</td>
<td>22</td>
</tr>
<tr>
<td>Enzyme (kg)</td>
<td>-</td>
<td>1.2</td>
</tr>
<tr>
<td>Cationic resin (l)</td>
<td>0.015</td>
<td>0.05</td>
</tr>
<tr>
<td>Anionic resin (l)</td>
<td>0.03</td>
<td>0.10</td>
</tr>
<tr>
<td>Activated carbon (kg)</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Phosphoric acid 85% (kg)</td>
<td>0.3</td>
<td>-</td>
</tr>
<tr>
<td>Lime (kg)</td>
<td>0.5</td>
<td>-</td>
</tr>
<tr>
<td>Quaternary amine</td>
<td>0.4</td>
<td>-</td>
</tr>
<tr>
<td>Electricity (kWh)</td>
<td>380</td>
<td>120</td>
</tr>
<tr>
<td>Steam (t)</td>
<td>1.5</td>
<td>2.2</td>
</tr>
<tr>
<td>Water (m³)</td>
<td>14</td>
<td>20</td>
</tr>
</tbody>
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The production of crystalline glucose, from second or third crystallizations, can be integrated into a sugar factory by the addition of two press-filters and tanks. It permits the work-force and the equipment to be used the whole year round. Investment costs are low and the operating costs are comparable to those of an equivalent sugar factory. A 4000 t/day cane sugar factory could produce 4.5 tons of sugar glucoses and 30 tons per day of HFS, i.e. the equivalent of a sugar factory of the same capacity. Investment costs would be US$1,000,000 including the refining of the HFS. Production costs of the sugar glucoses would be less than US$200 per ton, and those for refining the HFS would be less than US$15. Production would be 1300 tons of glucose and 9000 tons of HFS for a sugar consumption of 9000 tons. The production of glucose syrup and HFS by enzymatic and chromatographical separation could be foreseen as an independent industrial unit of any capacity.

To produce 1300 tons of glucose in the form of syrup, it is necessary to invert 9000 tons of sugar and to treat 2600 tons of inverted syrup by chromatographical separation. The mixture of HFS 99 with the remainder of the inverted syrup produces 9000 tons of HFS, as in the preceding case. Investments would be US$3,000,000 and production costs, for the highest quality glucose syrup, would be US$300 per ton. Due to a higher steam consumption, HFS decoloration costs would be US$20 per ton. With this alternative, larger capacity plants could be chosen, thus making the economy relatively more attractive.

The integration of sorbitol production into the sugar glucoses production is straightforward (Fig 5). The results of the pilot plant tests were satisfactory. The glucose of the second crystallization necessitated an initial safety filtering sequence, and a demineralization-decoloration with ion exchange resins. Behaviour during hydrogenation was adequate. The quality of the products obtained is shown in Table 3 and Fig. 6.

Table 3 - Quality of the sorbitol obtained from sugar glucoses

<table>
<thead>
<tr>
<th></th>
<th>With 2nd crystallization glucose</th>
<th>With 3rd crystallization glucose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sorbitol content (min %)</td>
<td>67</td>
<td>69</td>
</tr>
<tr>
<td>Refractive index</td>
<td>1.455 - 1.465</td>
<td>1.455 - 1.458</td>
</tr>
<tr>
<td>Density (min)</td>
<td>1.285</td>
<td>1.295</td>
</tr>
<tr>
<td>Reducing agents (max %)</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Mannitol (%)</td>
<td>3.0 - 3.5</td>
<td>0.6 - 0.8</td>
</tr>
<tr>
<td>Heavy metals (max ppm)</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

The investment for a 1500 ton/year sorbitol plant would be in the region of US$2,000,000. One can assume that various sugar factories would supply the glucose to a 5000 ton/year sorbitol plant. Then the cost, with an improved relative economy, would be US$3,000,000. The production costs of 70% sorbitol would be US$300 ton, which can only be attained by starting with low cost sugar glucoses. In this sense, the overall scheme discussed distributes both the fixed and production costs between the various products of the system, giving a notable profit for a low investment and an increased usage of the plant.

CONCLUSION

It is possible to obtain HFS from sugar factories that is fully competitive with that obtained from corn and high quality sugar. Simultaneously, glucose of a high quality that
BY-PRODUCTS

GLUCOSE

REMELT

FILTRATION

DEMINERALISATION

DECOLORATION

HYDROGENATION

DEMINERALISATION

DECOLORATION

FINAL

TREATMENT

CONCENTRATION

SORBITOL

70%

MIXED RESINS: STRONG ANIONIC AND CATIONIC

RESINS — MIXED RESINS: STRONG CATIONIC AND WEAK ANIONIC

ACTIVATED CARBON

Figure 5. Sorbitol production technology
Figure 6. HPLC of sorbitol 70% from second crystallization sugar glucose

is suitable for the low cost production of sorbitol, it is also produced. The overall balance permits the distribution of the costs between the various production systems and the recovery of the investment in less than five years. The system produces 1300 tons of sorbitol and 9000 tons of HFR for an investment of US$3 000 000.

REFERENCES


UN MOYEN INTÉGRÉ DE DIVERSIFICATION: PRODUCTION DE SIROPS EN HAUTE TENEUR DE FRUCTOSE ET DE GLUCOSE-SORBITOL À PARTIR DU SUCRE.

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EXTRAIT

Il est donné une description générale du produit ayant une teneur élevée en fructose
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(55%) dans le sirop de glucose dans les industries sucrières.
La qualité du produit est telle que le sorbitol peut être produit à partir du même, en
réduisant ainsi son coût.
L'évaluation intégrale technico-économique permet la récupération, en moins de 5 ans,
d'un investissement de bas niveau par la diversification de la production des fabriques
sucrières avec des produits ayant une valeur ajoutée plus élevée.

UN MEDIO INTEGRADO DE DIVERSIFICACION: PRODUCCION DE
JARAPE CON ALTO TENOR DE FRUCTOSE Y DE GLUCOSA -
SORBITOL A PARTIR DEL AZUCAR.

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RESUMEN

É dado una descripción general del producto que tiene un tenor elevado en fructosa
(55%) en el jarape de glucosa en las fábricas azucareras.
La cantidad del producto es tal que el sorbitol puede ser producido a partir del mismo,
reducíndole el costo.
La evaluación integral técnico-económica permite la recuperación, en menos de 5 años
de un investimiento de bajo nivel por la diversificación de la producción en las fábricas
azucareras con productos de valor adicional elevado.