New technology for invert sugar and high fructose syrups from sugarcane

J K Gehlawat
Raha Gehlawat Sugar Academy, 248, R K Vihar, I P Extension, Delhi 110092, India
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The invert sugar is an equimolar mixture of glucose and fructose. It may be obtained on hydrolysis of sucrose under milder conditions using strong cationic resins. The fructose content may be increased to about 60 per cent level by a partial removal of glucose from invert sugar using the technique of column chromatography. The resultant product is called high fructose syrups (HFS) which is traditionally produced from starch. HFS may be produced from sucrose with economic advantage by this novel process. The production of invert sugar and high fructose syrups from sucrose (cane juice) is cost effective. It has been commercialized in India. This paper discusses the salient features of this novel technology, which results in an effective 25 per cent increase in the sweeter output from the same quantity of sugarcane as molasses as a waste product is avoided.

Invert Sugar

Invert sugar finds applications for biscuits, confectionery, beverages, bakery, several other food and pharmaceutical formulations. Traditionally, invert sugar is produced from sucrose using minerals acids like H₂SO₄ and HCl. This conventional method suffers from low conversion efficiency (65-70 per cent), high ash content and undesirable products (7-8 per cent). Moreover, the invert syrup thus obtained is dark in colour. In view of these drawbacks of the traditional process, attempts have been made to develop alternate methods to produce invert sugar under relatively milder process conditions. Enzymatic hydrolysis of sucrose with invertase has been recommended in the literature. Recently, the use of an immobilized invertase as a catalyst in a fixed-bed reactor is claimed to produce invert sugar syrups of high purity.

Inversion of sucrose may be carried out using cationic resins. Strong cationic resins behave as catalysts in liquid media. They possess catalytic properties comparable to strong acids. Thus, by choosing a cation resin of proper acidity and porosity, any degree of sucrose inversion could be achieved without the introduction of any electrolyte into the syrup. The inversion of sucrose using strong cation resins is a cheaper process for invert sugars and high fructose syrups.

High Fructose Syrups

During the past three decades, high fructose syrups (HFS) have emerged as cheaper alternative sweeteners. They are manufactured by isomerization of high purity (+98 DE) starch hydrolysates using immobilized glucose isomerase as the catalyst. The equilibrium mixture thus obtained contains about 42 per cent fructose and 58 per cent glucose. Commercially acceptable syrups must possess minimum 55 per cent fructose content. This is achieved by enrichment of fructose content in the mixture through column chromatography. Gehlawat has been a strong supporter of production of HFS on large scale in India to supplement the supply of cane sugar. The production of high fructose syrups from sucrose through its cationic inversion has been suggested.

Cane juice is the principal source of sucrose. The raw cane juice may be clarified by membrane techniques like ultrafiltration to eliminate organic impurities and by electrodialysis to remove inorganic salts. The sucrose solution (clarified cane juice) thus obtained may be inverted in a fixed bed reactor of strong cation resins as discussed by Seema and Gehlawat and Sinha and Gehlawat. Nearly equal amounts of glucose and fructose are formed with cation resins in H⁺ form. Interestingly, the Ca⁺⁺ form of the same resin is found to separate glucose from fructose in column chromatography.

Inversion of sucrose present in refined cane juice is the most economical method of obtaining equimolar mixtures of glucose and fructose which on enrichment through the column chromatographic technique produces the cheapest and superior grades of high fructose syrups. Thus, in India, HFS from cane juice may compete favourably with the syrups obtained from corn in countries like USA.
alternate schemes for the production of fructose and high fructose syrups.

This paper describes recent developments for the production of invert sugar and high fructose syrups. Table 1 gives data on relative sweetness of common sugars and Table 2 provides typical composition of commercial grades of high fructose syrups.

**New Technology for Invert Sugar**
India has taken a lead in developing new processes for invert sugar. The National Research and Development Corporation (NRDC) is marketing the enzyme process developed by Bhabha Atomic Research Centre (BARC). A few plants have been set up based on this technology. Indian Institute of Technology, Kanpur, has developed a novel process based on resin technology. Fig. 2 shows the kinetics of hydrolysis of sucrose using strong cationic resins. It is a reasonably fast reaction and complete inversion occurs within about 30 min under optimum conditions. This technology has been commercialized with excellent results. The details of the process have been reported elsewhere. Invert sugar is obtained on hydrolysis of sucrose. The final syrup contains about 75-80 per cent dry solids (mixture of glucose and fructose). It has a relative sweetness of 120 as compared to sucrose as 100 (Table 1). Fig. 3 shows the process flow sheet. Scheme A is for the production of syrup from refined cane juice during the season. Scheme - B is with crystal sugar as the raw material that may be used during the off season.

**Cheaper Syrups from Cane Juice**
Traditionally high fructose syrups are produced from the hydrolysates of starch. The extraction of starch from corn (maize) is a complex process.
Moreover, the subsequent processes such as enzymatic hydrolysis of starch to glucose and its partial isomerization to fructose are far more complex reactions. On the other hand, the extraction of sucrose either from sugarcane or sugar beet and its inversion to obtain equimolar mixtures of glucose and fructose are relatively simple operations. Fig. 4 shows a schematic flow diagram for a commercial process.

It may be noted that realizable starch content in maize is about 60 per cent. At its current price of Rs.5,500 per metric tonne, the material cost of starch works out to about Rs.9,000 per metric tonne. Similarly, the practical range of sucrose content in mature cane is 13-15 per cent. About 2 per cent sucrose is lost with bagasse during juice extraction. Hence, the realizable sucrose content in refined juice may be 12 per cent on an average. At the current sugarcane price of Rs.800 per metric tonne, the raw material cost in terms of sucrose amounts to Rs. 6,500 per metric tonne. In the southern zone, where the sugar content in cane is much higher, the effective raw material cost will be lower at Rs.6,000 per metric tonne.

This analysis shows that as compared to starch, sugarcane is cheaper by about Rs.2,500 per metric tonne for the production of high fructose syrups. Further in view of the complexity of the process from starch the investment in plant and equipment as well as the manufacturing cost for the traditional process for HFS is much higher than from sugarcane as an alternative route for the given capacity. Hence, under Indian conditions, sugarcane is a cost-effective raw material for the production of HFS.

### Table 1 — Relative sweetness of sugars; 15°C, 15% solution

<table>
<thead>
<tr>
<th>Sugar</th>
<th>Relative sweetness</th>
</tr>
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<tbody>
<tr>
<td>Cane sugar (sucrose)</td>
<td>100</td>
</tr>
<tr>
<td>Fructose (crystalline: 100%)</td>
<td>178</td>
</tr>
<tr>
<td>D-glucose (crystalline: 100%)</td>
<td>70</td>
</tr>
<tr>
<td>Invert sugar (100%)</td>
<td>123</td>
</tr>
<tr>
<td>Medium invert (50%)</td>
<td>110</td>
</tr>
<tr>
<td>HFS (90 wt %)</td>
<td>125-130</td>
</tr>
<tr>
<td>HFS (55 wt %)</td>
<td>105-110</td>
</tr>
<tr>
<td>HFS (42 wt %)</td>
<td>95-100</td>
</tr>
<tr>
<td>42 DE Glucose syrup</td>
<td>45</td>
</tr>
<tr>
<td>Maltose</td>
<td>35</td>
</tr>
<tr>
<td>Lactose</td>
<td>15</td>
</tr>
</tbody>
</table>

### Table 2 — Typical compositions of commercial grades of HFS

<table>
<thead>
<tr>
<th>% solids</th>
<th>% ash (sulphated), DS</th>
<th>% Fructose, DS</th>
<th>% D-glucose, DS</th>
<th>% other saccharides, DS</th>
</tr>
</thead>
<tbody>
<tr>
<td>55 to 60%</td>
<td>77.00</td>
<td>0.03</td>
<td>55-60</td>
<td>4.00</td>
</tr>
<tr>
<td>90% HFS</td>
<td>80.00</td>
<td>0.03</td>
<td>90.00</td>
<td>3.00</td>
</tr>
</tbody>
</table>

As regards the economics of invert sugar from refined cane juice, it may be mentioned that there is no loss of sucrose, like it takes place to the extent of about 2 per cent in molasses in the case of crystal sugar. Consequently the yield is higher by about 2 per cent. Moreover, invert syrup contains about 20 per cent water and possesses higher sweetness. Hence, invert sugar from cane juice is much cheaper than crystal sugar.

### Huge Market Potential for Invert Sugar and HFS

As sweeteners, invert sugar and high fructose syrups can replace sucrose in almost all its applications. Functionally, they possess more desirable properties than sucrose and are much sweeter. In fact, chemically, invert sugar is same as honey and replaces honey in herbal cosmetics and similar other applications. Its humectant property increases shelf life of processed fruits, bread, cake and pastry. It is used by bakers and biscuit manufacturers as carameliser and it lends texture to the product. In bread, it hastens yeast activation. It does not crystallize even at high concentrations and low temperatures. Hence, it is ideal for cough syrups, condensed milk, squashes and icecreams. Being much sweeter than sugar, it helps in masking the bitterness of tonics and pharmaceutical preparations. It is good for soft drinks and fruit juices. It releases instant energy as it is readily assimilated by the human body. Hence, it is good for the kids and the sports persons.

It emerges from the above that invert sugar and HFS are ideally suited for the non-domestic market.
like the food processing industry, soft drinks and pharmaceuticals. It is estimated that the industrial sector consumes about 30 per cent of current sugar consumption that is about 13.0 million tonnes. Thus, the potential market for invert sugar is of the order of 4.0 million tonnes, which is indeed a huge market.

**Effective Sweetener Output could be up by 25 per cent**

It emerges from the above analysis that invert syrups can substitute crystal sugar in the industrial sector with advantage. Presently the non-domestic sector consumes about 4.0 million tonnes of crystal sugar. 25 per cent extra quantity, that is about 1.0 million tonnes additional invert syrup can be produced from the same quantity of sugarcane since the loss of sugar in molasses is eliminated. This additional 1.0 million tonne equivalent of sugar produced annually is worth about Rs.1,500 crores. The surplus sugar thus produced will improve the profitability of sugar industry.

**Conclusion**

The sugar industry need to increase product range to improve its profitability. The production of invert
sugar and high fructose syrups by this new technology, particularly for the non-domestic sector, is in the national interest. The corresponding sugar output will increase by about 25 per cent. The integration of cane splitting technique for juice extraction as discussed elsewhere\textsuperscript{6} in details, makes this process ideally suited for the mini-sugar plants. The development and implementation of such cost-effective technologies should be promoted in the larger national interests.

References