PRODUCTION OF LIQUID SUGARS

FROM FINE LIQUOR IN THE REFINERY

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ABSTRACT

The authors describe the advantages of the production of liquid sugars directly from the fine liquor of the refinery.

Using ion-exchange refining, it is possible to produce high quality liquid sugars, without crystallization, suitable for the food industry markets: liquid sucrose, medium or total invert liquid sugar ...

The advantages for the refinery are obvious:
- The decolorized (fine) liquor is a perfect raw material, filtered and decolorized.

- Using the fine liquor for the production of liquid sugars instead of refined sugar frees extra capacity of crystallization for the production of refined sugar.

- The processing costs of liquid sugar are lower: less energy requirement, better yield of extraction.
INTRODUCTION

The production of liquid sugars in central units is for the sugar industry an opportunity to better serve the various end-users of the food industry: soft drink manufacturers, confectionaries, bakeries, dairy products manufacturers….

Indeed, liquid sugar is sold as a syrup of suitable quality, ready for use.

The product can be delivered in cistern trucks of 20 – 25 m³ capacity and stored in stainless steel tanks from which it is pumped directly to the process, without the need of any further treatment.

*Truck delivery of liquid sugar*

This concept was initially proposed by the Cane Sugar Refiners (1) who are traditionally very close to the needs of their customers of the food industry.

In the United States before the mid-seventies, large refiners like Amstar, Revere, Refined Sugars Yonkers, etc…. were all equipped with liquid sugars producing facilities, already using ion-exchange technology for the purification of liquid sucrose and invert sugars.
These units were very profitable, because the customers were prepared to pay a premium for these products over the price of crystalline sugar, due to the advantages of “tailor made for recipes” and “readiness to use”.

When it became technically possible thanks to the enzymatic conversion from glucose to fructose to produce “High Fructose Corn Syrups” or “HFCS”, the interest of the market of liquid sugars did not escape to the U.S. Corn Refiners who invested heavily in the construction of large HFCS factories using also ion-exchange technology for the refining of liquid sugar.

Within a decade, from the mid seventies to the mid eighties, the Corn Refiners were able to take over the larger part of the liquid sugar market in the USA.

However, the loss of the liquid sugar market by the US cane sugar refiners should by mostly attributed to the high price of raw sugar imposed to them by Government Policies (the US “Farm bills”) which did not allow them to compete efficiently against the very cheap starch price of the US Corn Refining Industry.

While these conditions are still prevailing in the United States, it is far from being the case in the rest of the world : the price of sugar, due to the high production of cane sugar at low cost in countries like Brazil, Thailand, South Africa, Australia will remain low for the foreseeable future :

In this situation, there are clearly good opportunities for the cane sugar refiners who want to fulfil the needs of their customers for liquid sugars :

Using ion-exchange modern technology coupled with the proper membrane filtration, it is now possible to produce high quality liquid sugars at a very competitive price. One of the best raw materials for this being the decolorized (fine) liquor of the cane sugar refinery.
I. PRODUCTION OF LIQUID SUGARS FROM VARIOUS TYPES OF CRYSTAL SUGAR

As the needs of the end users are growing, the construction of central units as “stand alone operations” independent of the sugar refinery process has occurred, often under the control of sugar producers, or sometimes created for the needs of the market by new Entrepreneurial groups. (2), (3), (4).

In these cases, the raw materials used for the manufacturing of liquid sugars are the various types of crystalline sugars available on the market. The size of these plants vary from 30 000 tons of liquid sugar produced per year to more than 100 000 tons (expressed as Dry Substance). Typically these units supply all the potential end-users of a local sugar consumption area, and avoid to the end-users the otherwise necessary investment in small melting stations tailored to their own needs, with the necessary purification equipment.

The following table 1 indicates various ways to produce high quality liquid sucrose or inverted liquid sugar from different types of crystal sugar available on the market:
Table 1: Liquid sugars from crystal sugar

<table>
<thead>
<tr>
<th>Crystal sugar type</th>
<th>Direct consumption sugar</th>
<th>High Pol</th>
<th>Raw sugar</th>
<th>Refined sugar</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Blanco directo</td>
<td>Plantation white</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pol</td>
<td>99,8</td>
<td>99,6</td>
<td>98,5</td>
<td>97,5</td>
</tr>
<tr>
<td>Color (Icumsa)</td>
<td>150</td>
<td>500</td>
<td>900-1200</td>
<td>3000</td>
</tr>
<tr>
<td>Turbidity (Icumsa)</td>
<td>50 / 150</td>
<td>500</td>
<td>900-1200</td>
<td>≥ 2000</td>
</tr>
<tr>
<td>Ash (%)</td>
<td>0,05</td>
<td>0,1</td>
<td>0,20</td>
<td>≥ 0,4</td>
</tr>
<tr>
<td>Invert (%)</td>
<td>0,02</td>
<td>0,1</td>
<td>0,25</td>
<td>0,5</td>
</tr>
</tbody>
</table>

Total turbidity removal
Acid beverage floc elimination

Deminerlization-Decolorization stage with cationic, anionic and adsorbent resin exchange columns and mixed beds

for possible hydrolysis of the product between 33 and 95 % inverted sugar

Complete removal of the abnormal residual taste and smell

Perfect microbiological characteristics of the final product

Adjustment of the Brix between 67 (liquid sucrose) and 77 (inverted liquid sugar)

Target
As can be seen, the lower the quality, the heavier the process of refining.

1.1. **FROM RAW SUGAR**

Starting from raw sugar at 97.5 polarization and high color, ash and turbidity, it is necessary to proceed, after the melting operation, to an microfiltration of the syrup to remove the turbidity, followed by three successive steps of demineralization/decolorization using resins, to bring down the ash level from 0.3 – 0.4 % to less than 0.01 % on DS and the color from 3 000 Icumsa to less than 35 Icumsa units.

*Microfiltration of a raw sugar remelt*

A final treatment with activated carbon, pasteurization and sterile filtration will remove all residual taste and smell impurities and ensure the perfect microbiological characteristics of the final product.

Between the ion-exchange demineralization/decolorization and the final polishing with activated carbon, it is possible to insert a special column of catalytic resins for the inversion of sucrose into liquid inverted sugars.

The final product is concentrated to 67 Brix if liquid sucrose is produced or to 73 – 76 Brix if liquid invert sugar is produced.
1.2. – FROM “BLANCO DIRECTO” SUGAR

Starting from “blanco directo”, a direct consumption sugar of higher quality at low color (150 Icumsa), low ash (0.05 %) and low turbidity (150 Icumsa), it is possible to reduce the refining treatment after remelt to a conventional pressure leave filtration with filter aid to remove the turbidity, followed directly by a mixed bed demineralization/decolorization to lower the ash/color to the proper level prior to polishing with activated carbon treatment.

Liquid sugar plant – France
100 t DS/day from EEC n° 1 beet sugars
Ion-exchange and hydrolysis system
1.3. **FROM REFINED SUGAR**

Many refiners are using the “fastest” route to produce liquid sugars for satisfying the demand of their industrial customers:

They simply remelt refined sugar and, after a safety filtration, pasteurization and sterile filtration, the liquid sugar is ready for use. If invert sugar is required, it is produced from the remelt by direct inversion with HCl followed by neutralization. While this production is of course satisfying the demand of the market, it is not using the best potential of the cane sugar refinery, because the starting material for the process is refined crystal sugar, the highest value product of the refinery.
II. PRODUCTION OF LIQUID SUGARS FROM DECOLORIZED (FINE) LIQUOR IN THE CANE SUGAR REFINERY

As indicated above, the cane sugar refiners were the first to develop the concept of liquid sugar, because they are traditionally close to the industrial end users in the sugar consumption areas. Within the process of refining sugar, there is an ideal intermediate product which can be used as raw material for the production of liquid sugars: it is the decolorized (fine) liquor.

Indeed, this liquor is:

→ in the liquid form
→ perfectly filtered
→ already decolorized for the needs of the production of white sugar
Table 2: Simplified diagram of a cane sugar refinery producing liquid sugars from fine liquor

- **RAW SUGAR**
  - AFFINATION
  - MELT
  - CARBONATION or PHOSPHATATION
  - FILTRATION
  - DECOLORIZATION
  - DECOLORIZED (FINE) LIQUOR
    - CRYSTALLIZATION (HIGH GRADE BOILING)
      - REFINED CRYSTAL SUGAR
    - ION-EXCHANGE REFINING
      - FINAL CONCENTRATION
        - LIQUID SUGARS
  - LOW GRADE BOILING
    - REFINERY MOLASSES
→ Using fine liquor to produce liquid sugars instead of crystalline refined sugar allows to save energy for the refinery, since it is not necessary to first crystallize the sugar and then remelt it for the liquid sugar production.

→ Also, for a refinery which is producing liquid sugars from crystal refined sugar, converting this production of liquid sugars for using fine liquor as a raw material will make available more capacity for the crystallization of dry products, a way to increase the overall capacity.

→ Finally, the refining by ion-exchange of fine liquor for the production of liquid sugars will remove from the load to be processed in the sugar recovery house the non-sugar attached to the fine liquor, and thus increase the sugar recovery since the molasses produced will decrease proportionally.

<table>
<thead>
<tr>
<th>Table 3 : Typical composition of decolorized (fine) liquor</th>
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<tbody>
<tr>
<td>Brix</td>
</tr>
<tr>
<td>Ash</td>
</tr>
<tr>
<td>Color</td>
</tr>
<tr>
<td>Turbidity</td>
</tr>
<tr>
<td>Pol.</td>
</tr>
</tbody>
</table>

As can be seen from the typical composition of the decolorized fine liquor, the necessary steps to produce liquid sugars from this material will be principally decolorization and deashing, since the turbidity and the largest part of the color have already been removed in the general process of the refinery.
Table 4: The various steps for the production of liquid sugars from fine liquor

<table>
<thead>
<tr>
<th>EFFECT</th>
<th>STEPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>DECOLORIZATION</td>
<td>ION-EXCHANGE ADSORPTION WITH NANOFILTRATION OF THE REGENERANT</td>
</tr>
<tr>
<td>DEMINERALIZATION/DECOLORIZATION</td>
<td>MIXED BED ION-EXCHANGE</td>
</tr>
<tr>
<td>(PRODUCTION OF INVERT SUGAR)</td>
<td>(RESIN HYDROLYSIS OPTIONAL)</td>
</tr>
<tr>
<td>ORGANOLEPTIC POLISHING</td>
<td>POWDER ACTIVATED CARBON FILTRATION</td>
</tr>
<tr>
<td>MICROBIOLOGICAL POLISHING</td>
<td>PASTEURIZATION STERILE FILTRATION</td>
</tr>
<tr>
<td>ADJUSTMENT TO FINAL CONCENTRATION</td>
<td>EVAPORATION</td>
</tr>
<tr>
<td></td>
<td>LIQUID SUGAR</td>
</tr>
</tbody>
</table>
The operations of decolorization and deashing are constituting the main steps of the liquid sugar production unit from fine liquor.

- The decolorization is similar to the main decolorization (or primary decolorization) of the refinery. (5)
  Strong anionic resins are installed in a secondary decolorization system, which decreases the color from 150-200 Icumsa units down to 60-70 Icumsa.
  The regeneration of the resin is made with alkaline brine which can be recycled using nanofiltration technology.

* Typical resin decolorization system in a cane sugar refinery *
Nanofiltration unit for the recovery of caustic brine used for regenerating the resin decolorizer

- The demineralization is then performed by passing the low color liquor through an ion-exchange “mixed bed” unit, where the ash content is removed. The mixed bed includes a mixture of cationic resins (ReH) in the hydrogen form and anionic resins (RaOH) in the hydroxide form, where the following reaction occurs:

\[
\text{Sugar} + \text{NaCl} + \text{ReH} + \text{RaOH} \rightarrow \text{sugar} + \text{H}_2\text{O} + \text{ReNa} + \text{RaCl}
\]

liquor with ash  regenerated mixed bed  liquid sugar  exhausted mixed bed
Thanks to the mixed bed technology, the ash level can be lowered to less than 0.01 %, which is the required level for the liquid sugar. The mixed bed unit is typically regenerated with hydrochloric acid (for the cationic resin) and caustic soda (for the anionic resin) after separating the two types of resin with a brine solution.
CONCLUSION

- The food industry is constantly looking for a supply of liquid sugars (sucrose or invert) of high quality that can be delivered as products “ready to use”. (6)

- In the foreseeable future, the price of raw cane sugar and VHP sugar will remain low, which is the reason why there are many projects of sugar refineries in countries where the sugar demand is higher than the domestic production.

- Using ion-exchange modern technologies, it is possible for the cane sugar refiner to fulfil the needs of the food industry by diverting part of the fine liquor of the refinery to the production of high quality liquid sugars, at a better cost than a stand alone operation starting from crystal sugar.
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