Manufacturing — Processing

PRODUCTION OF AMORPHOUS REFINED SUGAR IN BRAZIL

Francisco M. D. Leão.
Cia. União dos Refinadores, São Paulo, Brazil.

ABSTRACT

Amorphous sugar is produced by the rapid evaporation of fine liquor in open pans, followed by crystallisation in beaters. All solids present in the fine liquor therefore appear in the amorphous sugar product. Over one million metric tons of amorphous refined sugar is consumed annually in South-Centre Brazil. Modern technological developments, applied to this old technique of sugar refining, reveal amorphous sugar as an economic alternative to vacuum pan granulated sugar for both direct consumption and industrial grades of refined sugar.

INTRODUCTION

According to the Brazilian Institute of Sugar and Alcohol (IAA), Brazil plans to produce 6.9 million metric tons of sugar for the season ending in May, 1974. Of this a little over 2 million tons will be for export and over 4 million tons will be for the domestic market.

With a potential sugar production vastly in excess of this, Brazil is becoming established as one of the world's leading sugar suppliers. It is therefore of interest to examine an unusual feature of production for the domestic market. This concerns the manufacture of refined amorphous sugar, which, unlike the conventional granulated sugar, is produced without the use of vacuum pans or centrifugals. Although the process is not new, the technology involved has been the subject of considerable development. Since the process is seldom referred to in modern technical literature, it is possible that the process is often overlooked by technologists. It is the purpose of this paper to describe the increasingly important part taken by amorphous sugar in the Brazilian refined sugar market and to present some technical details of the manufacturing process.

SUGAR PRODUCTION AND CONSUMPTION PATTERN IN BRAZIL

Because of the vast geographical area of Brazil it is not possible to present a generalised picture of its sugar industry. Instead, it is necessary to describe individual areas, any one of which might be completely different from its immediate neighbour. The sugar market varies from remote farms, where cane juice is used to sweeten coffee, to the great urban areas where the sugar consumption is one of the highest in the world.

As a simplification the Brazilian Sugar Industry may be divided into 2 large areas: the North-North East area where sugar consumption is nearly all in the form of plantation whites, and the South-Centre area, where although plantation whites still form the bulk of consumption, demand for amorphous refined sugar is steadily increasing. In the N-NE the production of this type of refined sugar is as yet very small, and there are only 2 amorphous sugar refineries presently operating.
The N-NE area was, until World War II, the largest sugar producing region of Brazil and the plantation whites, manufactured directly by the sugar mills, probably established the market pattern retained to the present day. Although it would be logical to anticipate the replacement of plantation white raws, manufactured in vacuum pans, by refined granulated sugar which is also manufactured using vacuum pans, it seems likely that the market for amorphous refined sugar will grow quickly in the coastal cities. Consumption habits are strange and it could well be that local population will imitate the habits of the larger cities of the South as a status seeking reaction.

In the South-Centre area the high density urban population, with its increasingly sophisticated habits, demands refined sugar. But it is amorphous not granulated refined sugar which is demanded, and the production of granulated refined sugars is as yet very small. It should be mentioned that a higher grade of raw white crystal is also being marketed in large quantities.

In comparison with the N-NE area the South-Centre produces twice as much sugar, and the domestic market is three times as large (see Appendix I). São Paulo State is the leading producer, with 48% of the total national production.

In view of the fact that the growth of the sugar industry in the South-Centre has taken place largely since the end of World War II, it is perhaps surprising that the growth in the domestic market has been based on a form of crystallisation quite different to the conventional vacuum pan product, all the technology for which was available in the existing raw factories.

With reference to amorphous sugar production in Brazil today, the list below gives the independent refineries (not “white-ends” attached to raw sugar factories) in operation at the moment.

In the N-NE
Pernambuco 2

In the South-Centre
Espírito Santo 1
Guanabara 3
Rio de Janeiro 2
Minas Gerais 1
São Paulo 8
Paraná 2

Total 19*

* This list shows clearly the disappearance of refineries in the N-NE and in Minas, and the merging of refineries in Rio.

The amorphous sugar production of the South-Centre area may be estimated from official quotas of standard quality white raw crystal, which will be referred to later, demanded from the mills for the refineries by the IAA internal market policy. (See Appendix II.) According to IAA sources, these quotas are as follows:

<table>
<thead>
<tr>
<th>State</th>
<th>Quota</th>
</tr>
</thead>
<tbody>
<tr>
<td>São Paulo</td>
<td>654 048 metric tons</td>
</tr>
<tr>
<td>Guanabara and Rio de Janeiro</td>
<td>302 400 metric tons</td>
</tr>
<tr>
<td>Paraná</td>
<td>102 600 metric tons</td>
</tr>
<tr>
<td>Minas Gerais</td>
<td>18 720 metric tons</td>
</tr>
<tr>
<td></td>
<td>1 077 768 metric tons per year</td>
</tr>
</tbody>
</table>
This represents:
16% of the total national production
25% of the total internal consumption
23% of the total regional production
33% of the regional internal consumption.

AMORPHOUS SUGAR PRODUCTION TODAY

Regardless of the doubts concerning the true origins of the amorphous sugar process, the technology of industrial-scale amorphous production, as it stands today, has received a large contribution from Brazil. Unfortunately, other countries have abandoned manufacturing this type of sugar, thus ending sources of further improvements. The author had the privilege of participating in the dramatic increase in production and expansion of the industry in South-Centre Brazil, especially from 1960 onwards. This section is therefore mostly based on the author’s personal experience at CUR, which, with 5 plants in operation, is the largest amorphous sugar producer in Brazil.

Amorphous sugar may be defined as follows: It is a highly agglomerated, finely powdered sugar, produced by the instant crystallisation of refined liquors, at high temperatures, in open pans, without the use of centrifugals.

Regarding its analysis, it ranges from 99,1 to 99,3 pol, and from 0,10 to 0,15% invert; its colour range is from 20 to 40 m.a.u., and its sieve analysis shows the main fraction to lie in the 40 to 80 mesh range.

Although lower in pol than fine granulated sugar, it dissolves more rapidly, leading to the notion that it sweetens more! It has a pleasant texture to look at.

This is the sugar normally produced, but variations of this quality are found among the several amorphous sugars marketed, and quality may be directly affected by the raws processed. (See Appendix III.)

In attempting to describe the amorphous sugar refinery it may be of interest to note that in CUR, it is normal practice to discuss the installation and operations in terms of crystallisation units — the open pans. The refineries were originally built for a production rate of 6 tons per hour per pan but this volume is small by current standards since production rates today are nearing the level of 12 tons per hour per pan. For the purposes of this paper it is convenient to divide the process into 2 main sections, the liquid phase and the solid phase. Operational data and other information are presented separately in Appendix IV.

The liquid phase is produced by normal refining operations, known to all technicians. However there are 1 or 2 differences, compared with fine granulated production, and these will be illustrated in the general description. The process starts with continuous melting of raw sugar, using sweet waters from all the other processes, operated in the range of 68-70° Brix at 70-80 C. There is no affination because refining for amorphous sugar in Brazil starts with a different raw material. This is called standard refiners white raw sugar, and it has a minimum pol of 99,3, and 0,05% average invert content. This type of sugar makes up the bulk of the raw sugar mills production apart from their quotas of normal dark raws, for export.

One may suspect that city refiners, in the past, did not have a market for affination molasses, and the need for white raws has remained to the present day. White raws vary widely in quality and specifications are still very loose
For a long time it was thought that this raw material was much better than affined dark raws. Under present conditions, however, the Brazilian sugar refiner is inclined to think that the quality of the raw material is, at best, equivalent to normal affined sugar. In fact on some occasions CUR has without difficulty processed raw sugars which have been washed up at the mills.

This liquor, made without affination, is pressure filtered through diatomaceous filter aid. Some refiners have used known clarification systems, such as Jacobs, Williamson, or variations of them. Some have used activated vegetable carbon, prior to pressure filtration, and before the last World War the use of activated carbon was common. Now it is rather uneconomical. When white raws were much better in quality, it was thought that no clarification was necessary, and normally good quality liquors could be obtained without it. Furthermore, the excessive heat used in defecation processes created the serious problem of excessive inversion, which must always be avoided in amorphous sugar production.

This point of view has changed entirely and clarification is viewed today as one of the most important single steps in refining, even with the existing white raws. For this reason phosphoric acid and lime clarification systems, which use the new powerful flocculants and surfactants, are being installed in all CUR plants, and indeed most Brazilian refineries, prior to pressure filtration. It is believed that this will start a chain reaction throughout the processes, leading to their simplification in both design and operation.

The filtered liquor is run twice through bone char cisterns, Brazilian material being somewhat coarser in grist than that normally used elsewhere. Char house operations used to be the end of the liquid phase treatment and, for many years, starting with the normal quality white raw, the refinery ended up with liquors capable of yielding refined sugars of colour 0.8 Stammer, equivalent to 54 m.a.u. The Stammer scale of colour is mentioned here as a homage to the past controls used. Plant operations today are discussed in terms of colorimetric readings, for the figure is read directly from instruments, without reverting to tables, which is done only when reporting officially operational results. As production increased at the pans, the char houses became all too small, and the results of yesterday were no longer possible.

To produce the solid phase amorphous sugar, the refined liquor is batched to open pans, where concentration by rapid evaporation is generally effected in 7 to 9 minutes per strike of 700-800 kilos of sugar. There are several pan sizes in use. Steam coils heat the charge to 120-122 C, forming a highly concentrated magma of around 93° brix.

To offset colour formation, a small dose of bleaching agent is added to the pans.

The magma is run into the beaters where instant crystallisation takes place on cooling. Beating time varies from 4 to 7 minutes, depending on the pan temperature, invert content and the grain size desired. Attention and control is needed, for amorphous sugar varies widely in bulking factor, depending on grain size distribution, moisture content etc.

Sugar leaves the beaters with about 2% moisture and at over 90 C temperature. It is then fed to dryers, which at the same time cool the sugar down
to 55-60°C, this cooling being mostly effected by evaporation of the moisture
down to 0.18% to 0.23%. The product is then screened for small lumps and
maximum size grading on 20 mesh screens, and then automatically packaged.

At CUR continued examination of operating procedures and equipment
design had led to the development of several important modifications. The
operating liquor brix has been raised from 64-65° brix to the range of 68-70°
brix. Studies at the pan station have led to several redesigns and steam coil
modifications, and have resulted in the complete automation of the pan/beaters
sequence, although still maintaining the batch method of operation. The strikes
are now performed in 4.0-4.5 minutes. Fuel oil is the second most important
production cost item, and efforts to reduce its consumption are ever present.

This substantial increase in the rate of crystallisation, coupled with the
lowering of white raw quality, has created a bottleneck in the supply of refined
liquor. In a major effort to solve this problem, CUR introduced ion exchange
processing, which, for this company has been one of the major steps in im-
proving quality, apart from the dramatic increase in productivity which it
allowed. A better quality liquor allowed an increase in pan rates, and additions
to the original ion exchange installation had to be made.

At CUR standby columns of acrylic resins were installed, in such a
fashion as to be utilised in between passes of bone char or before ion exchange
decolourisation, as boosters, or in parallel with the existing installations.

In the last 20 years of production of amorphous sugar at CUR, continuous
modifications were being carried out to the refineries.

**PROSPECTS FOR THE FUTURE**

Changes are occurring more rapidly than ever now but some predictions
could be advanced for the future.

The continuous melting stations may be changed to handle dark raws.
Some refineries have planned for this and all melting houses are able to accom-
modate the affination equipment.

The liquid sugar market is developing rapidly and inverted industrial
grades of molasses are a good market prospect, making the change to conven-
tional raw sugar supply for Brazilian refineries a strong possibility. In fact,
some refineries are already melting dark raws in limited quantities.

Invert content will remain the one real problem for amorphous sugar
quality. Inversion creates colour in the pans and the invert content of the
amorphous sugar product is directly related to its moisture adsorption prop-
ties. Normal processing doubles the original invert content which is generally
between 0.05% and 0.1%. However, it must be stressed that whereas the granulated sugar refiner may consider this as a loss, in amorphous production
it is classed as a lowering of quality. An amorphous sugar with 0.1% invert
may have from 0.18 to 0.22% moisture at normal relative humidities up to
80%. This however does not necessarily mean that the sugar will harden.
This occurs only when the product is exposed to a much higher and subse-
quently to a lower relative humidity.

Rapid plate evaporators are already dealing with sweet waters, reducing
the inversion caused by recirculation within the process, and the introduction
of affination is a distinct possibility for the future, as a means of reducing the
invert introduced into process. Also for the future, ion exclusion is a process
which must be considered seriously and is already on CUR's list of projects for economic evaluation. With the introduction of such new technology and a drastic decrease in liquor processing time, amorphous sugar can be placed in competing status with granulated refined sugars.

Phosphatation with the aid of powerful modern chemical additives will perfect pressure filtration and permit the use of tighter grades of filter aid, possibly up to the range of bacterial removal, thereby protecting the processes further down the line.

The opinion may be expressed that the time has come to lay to rest that old work horse called bone char. It has quite a performance record, but it has become an increasingly expensive material, with many problems related to bone char house operation. It appears that it will be overtaken by the various ion exchange resin combinations, which impart a higher standard of both installation and operation besides providing great power to perform the same function.

In this respect, CUR envisages having a train of gross decolourisers, as it has now in bone char, followed by a polishing final decolourisation, coupled with almost complete demineralisation. This will also tend to reduce the large amount of heated liquor in process in the massive bone char houses. It has been found that under Brazilian conditions ion exchange has a small operating cost. However, sodium chloride from the ion exchange columns passes directly into the amorphous sugar and is objected to by some industrial customers. Demineralisation would be introduced to overcome this objection.

To present an indication of the importance of ion exchange in CUR operations, it may suffice to mention that the decolourising plant in the São Paulo Refinery has been in operation since January 1968, and has processed over 900,000 tons of sugar with its original charge of resin, giving a fine liquor colour from 40 to 80 m.a.u. These resins, which are of the macro-reticular type, still have a long way to go before replacements are considered. This is quite a performance and, with the massive research effort being made by the resin manufacturers, the continued development of new and improved resins must be expected.

One might question why a high quality fine liquor is necessary. Bearing in mind the necessity to achieve an economically satisfactory level of operation, it must be stressed that in amorphous sugar production one does not have centrifugals at the final stage of processing, and the sugar will contain all the solid matter present in the refined liquor.

With regard to the future development of the crystallisation process, rapid concentration devices are putting the continuous crystallisation process beyond the pilot plant scale. However at the present time the potential of the transformation process with regard to steam savings and quality of product, are not yet entirely evaluated.

CONCLUDING REMARKS

With its improved quality and its high solubility, amorphous sugar must certainly be considered an alternative to granulated sugar not only for direct consumption but also for industrial use. This alternative is particularly attractive from the point of view of the capital investment required since expensive vacuum pan, granulation and centrifugal equipment is not necessary.
With a sales growth rate of 15-18% per year in the South-Centre area of Brazil, amorphous sugar has established a market position which, based as it is on historical consumer demand habits, will be very difficult to challenge.

REFERENCES


APPENDIX I

SUMMARY OF BRAZILIAN SUGAR PRODUCTION FOR THE 1973/74 SEASON

Source: Official Brazilian Sugar and Alcohol Institute Season Plan, (2). All figures are quoted in metric tons.

<table>
<thead>
<tr>
<th>N-NE States</th>
<th>Total</th>
<th>Int Market</th>
<th>Export</th>
<th>Export</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maranhão</td>
<td>6,000</td>
<td>6,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Piauí</td>
<td>6,000</td>
<td>6,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceará</td>
<td>18,000</td>
<td>18,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R Gr Norte</td>
<td>36,000</td>
<td>36,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paraíba</td>
<td>108,000</td>
<td>108,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pernambuco</td>
<td>1,230,000</td>
<td>360,000</td>
<td>120,000</td>
<td>750,000</td>
</tr>
<tr>
<td>Alagoas</td>
<td>780,000</td>
<td>312,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sergipe</td>
<td>63,000</td>
<td>63,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bahia</td>
<td>63,000</td>
<td>63,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td>2,310,000</td>
<td>972,000</td>
<td>120,000</td>
<td>1,218,000</td>
</tr>
</tbody>
</table>

**South-Centre States**

| Minas Gerais | 360,000 | 360,000 |
| Espírito Santo| 33,000  | 33,000  |
| Rio de Janeiro| 630,000| 570,000 |
| S Paulo     | 3,300,000| 2,028,000| 180,000| 1,092,000|
| Paraná      | 180,000 | 180,000  |
| Sta Catarina| 54,000  | 54,000   |
| R Gr Sul    | 12,000  | 12,000   |
| Mato Grosso | 3,000   | 3,000    |
| Goiás       | 18,000  | 18,000   |
| **Totals**  | 4,590,000| 3,258,000| 240,000| 1,092,000|

**Grand Totals**

| 6,900,000 | 4,230,000 | 360,000 | 2,310,000 |

APPENDIX II

AMORPHOUS Refined SUGAR CONSUMPTION IN SOUTH-CENTRE BRAZIL

Source: Official IAA monthly quotas for refiners.

<table>
<thead>
<tr>
<th>States</th>
<th>60 kg bags/month</th>
<th>metric tons</th>
<th>No. of refineries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guanabara and Rio de Janeiro</td>
<td>420,000</td>
<td>25,200</td>
<td>5</td>
</tr>
<tr>
<td>S. Paulo</td>
<td>908,400</td>
<td>54,304</td>
<td>8</td>
</tr>
<tr>
<td>Paraná</td>
<td>142,500</td>
<td>8,550</td>
<td>2</td>
</tr>
<tr>
<td>Minas Gerais</td>
<td>25,000</td>
<td>1,560</td>
<td>1</td>
</tr>
<tr>
<td>E. Santo</td>
<td>undisclosed</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1,496,900</td>
<td>89,814</td>
<td></td>
</tr>
</tbody>
</table>

**Total annual consumption**

17,962,800 | 1,077,768 metric tons
APPENDIX III

OFFICIAL BRAZILIAN SUGAR AND ALCOHOL INSTITUTE CLASSIFICATION OF SUGARS

<table>
<thead>
<tr>
<th>White Raw Crystal Sugar</th>
<th>Max Moist %</th>
<th>Min Pol °S at 20 °C</th>
<th>Max Colour 560 μm ICUMSA</th>
<th>ash H% max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard refiners</td>
<td>0,15</td>
<td>99,5</td>
<td>200</td>
<td>0,15</td>
</tr>
<tr>
<td>Superior</td>
<td>0,10</td>
<td>99,5</td>
<td>120</td>
<td>0,10</td>
</tr>
<tr>
<td>Special</td>
<td>0,10</td>
<td>99,7</td>
<td>60</td>
<td>0,05</td>
</tr>
</tbody>
</table>

Refined Sugars

<table>
<thead>
<tr>
<th></th>
<th>Total Sugars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amorphous 1st grade</td>
<td>99,4</td>
</tr>
<tr>
<td>Amorphous 2nd grade</td>
<td>99,3</td>
</tr>
<tr>
<td>Granulated</td>
<td>99,4</td>
</tr>
</tbody>
</table>

APPENDIX IV

GENERAL OPERATIONAL INFORMATION FROM A TYPICAL AMORPHOUS REFINERY

1. Average Brix — 68/70°Bx.
2. Average Process pH —
   - melters: 6,8/6,9
   - pressure filtration: 7,0/7,1
   - bone char: 7,4/7,8
   - ion exchange: 7,2/7,4
   - final refined sugar: 6,8/7,1
3. Colorimetric readings, in terms of % transmittance, with 37 mm colorimeter cell, pH 7,0, operating Brix, and 420 μm filter.
   - pressure filtration: average colour 5
   - first bone char: 20/30
   - booster ion exchange plus 2nd char 63/70
   - final ion exchange 82/90
   - amorphous sugar, at 64° Brix 78/90
4. Calcium in terms of CaCO₃, mg/l
   - melters: 600/700
   - pressure filtration 500/650
   - first bone char 420/520
   - second bone char 200/300
   - ion exchange 20/150
5. Average process temperature: 70 C
6. Typical Sieve analysis of Amorphous Sugar, American Standard Sieves:
   - retained at n° 20 1 — 2%
   - 40 25 — 35%
   - 60 30 — 35%
   - 100 20 — 35%
   - passing 01 5 — 12%
7. Steam at the pans: 135 - 150 psig saturated steam.
8. Strike Temperature: 120 - 124 C
9. Pressure Filtration
   - Average filter cake production: 70 - 90 tons
   - Average filter aid consumption: 0,8 - 1,0 kg/ton sugar
10. Bone char House data, for a typical 600 metric tons / day production
    - Bone char house charge in use: 750 tons
    - Monthly make up char rate: 20 - 25%
    - Monthly old char removal rate: Average 15%
    - Sugar processed per ton char in use: 20,4 tons / month
    - Sugar processed per ton washed char: 9 - 10 tons
11. Ion Exchange
    - Sodium Chloride regenerant consumption average: 5 kg / ton sugar
12. Fuel Consumption

Crude fuel oil for steam generation: 55 - 58 kg / ton sugar
Shantship oil at kilns: 4.5 - 5.0 kg / ton sugar processed at bone char house

13. Over all labour figure, directly related to production only, from warehouse to refined sugar stock, prior to distribution: 360 / 420 kg per man / hour worked.

14. Pan Station

average charge: medium size pans: 720 - 900 kg sugar
large size pans: 960 - 1,080 kg sugar
average production rate: 10.2 - 11.2 tons / hour
strike pulsation time: 3.8 / 4.5 minutes
beating time: 4 - 7 minutes
temperature: 120 C - 124 C
Final Brix: 92 - 94 Bx

PRODUCCIÓN DE AZÚCAR REFINADO AMORFO EN EL BRASIL

Francisco M. D. Leão.

RESUMEN

Se consumen más de un millón de toneladas métricas del llamado azúcar refinado amorfo en el Centro-Meridional del Brasil. Los desarrollos tecnológicos modernos aplicados a esta antigua técnica para refinar azúcar, revelan que la producción de azúcar amorfo puede ser una alternativa económicamente viable para azúcar directo tanto como para tipos industriales de azúcar refinada.