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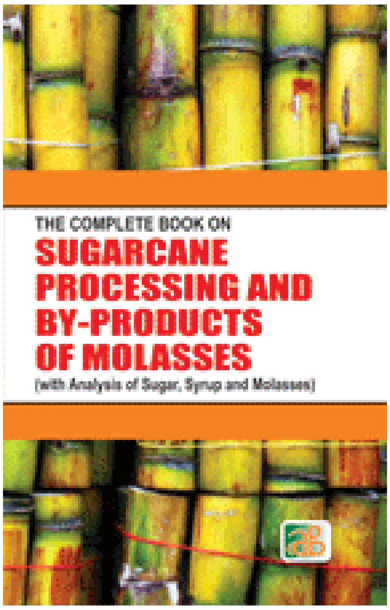
The Complete Book on Sugarcane Processing and By-Products of Molasses (with Analysis of Sugar, Syrup and Molasses)



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Sugarcane grows in all tropical and subtropical countries. Sucrose as a commercial product is produced in many forms worldwide. Sugar was first manufactured from sugarcane in India, and its manufacture has spread from there throughout the world. The manufacture of sugar for human consumption has been characterized from time immemorial by the transformation of the collected juice of sugar bearing plants, after some kind of purification of the juice, to a concentrated solid or semi solid product that could be packed, kept in containers and which had a high degree of keep ability. The efficiency with which juice can be extracted from the cane is limited by the technology used. Sugarcane processing is focused on the production of cane sugar (sucrose) from sugarcane. The yield of sugar & Jaggery from sugar cane depends mostly on the quality of the cane and the efficiency of the extraction of juice. Other products of the processing include bagasse, molasses, and filter cake. Sugarcane is known to be a heavy consumer of synthetic fertilizers, irrigation water, micronutrients and organic carbon. Molasses is produced in two forms: inedible for humans (blackstrap) or as edible syrup. Blackstrap molasses is used primarily as an animal feed additive but also is used to produce ethanol, compressed yeast, citric acid, and rum. Edible molasses syrups are often blended with maple syrup, invert sugars, or corn syrup. Cleanliness is vital to the whole process of sugar manufacturing. The biological software is an important biotechnical input in sugarcane cultivation. The use of these products will encourage organic farming and sustainable agriculture.

The book comprehensively deals with the manufacture of sugar from sugarcane and its by-products (Ethyl Alcohol, Ethyl Acetate, Acetic Anhydride, By Product of Alcohol, Press mud and Sugar Alcohols), together with the description of machinery, analysis of sugar syrup, molasses and many more. Some of the fundamentals of the book are improvement of sugar cane cultivation, manufacture of Gur (Jaggery), cane sugar refining: decolourization with absorbent, crystallization of juice, exhaustibility of molasses, colour of sugar cane juice, analysis of the syrup, massecuites and molasses bagasse and its uses, microprocessor based electronic instrumentation and control system for modernisation of the sugar industry, etc.

Research scholars, professional students, scientists, new entrepreneurs, sugar technologists and present manufacturers will find valuable educational material and wider knowledge of the subject in this book. Comprehensive in scope, the book provides solutions that are directly applicable to the manufacturing technology of sugar from sugarcane plant.

Content:

Sample Chapter:

Manufacture of Gur (Jaggery)

The raw material Gur is manufactured in India from sugarcane juice and sweet juices of palmyra and date-palm trees. The major proportion of Gur produced is from sugarcane juice.

The sugarcane (Saccharum officinarum) is a well-known perennial plant of the grass family and its cultivation is confined to the warmer regions of the earth. The sugarcane looks like a thin bamboo and is made up of root, root stock, the stalk, the leaves and the inflorescence. The stalk is the portion crushed for the extraction of juice. It is a cylinder, the walls of which are formed by a hard outer tissue called the rind and the interior being filled with a soft cellular structure, the pith consisting of cells (parenchyma) which serve to store the juice. The cylinder is subdivided into a number of smaller cylinders by transverse partitions, namely the nodes. The material, of which the rind is made, is of a hard woody nature and contains an impurer juice which may be termed as rind-juice. The pith is of a softer nature and contains a purer juice which may be called pith-juice. Broadly therefore the sugarcane is divided into juice and fibre, the latter term including everything which is not water or which is insoluble in water. The fibre, therefore, is made up of rind-tissue and pith-tissue and the juice is composed of rind-juice and pith-juice. The composition of cane Varies with locality, climatic and soil condition in which it is grown and with variety and degree of maturity. The average composition in India may be taken to be as follows:-

Cane = 100

Juice 85% cane — Fibre 15% cane

Soluble solids 14%	Water 71%	Fibre in pith 3.6%	Fibre in bundles 4.8%	Fibre in rind 6.6%

Sugar 13% — Non-Sugar 1.0%

Maturity of Sugarcane. The cane is harvested when it is fully ripe. The period which the sugarcane takes to attain ripeness or maturity depends upon the climate and rainfall of the region in which it is grown, on the variety of sugarcane and on whether it is a plant crop or ratoox crop. It is generally 10 to 12 months* for sali cane and 16 to 18 months** for Adsali cane in India. When the cane is fully ripe the reducing sugar content is minimum or even zero and the purity of juice is the highest. Arrowing and flowering of sugarcane marks the end of the vegetative period of growth. After the cane has arrowed no further formation of sugar takes place in the plant but an elaboration of that already formed obtains with an increase in the sugar content and purity. The time to which cane can be left standing after arrowing is variable and is dependent upon variety and climate, but arrowing should be regarded as an unfavourable sign since vegatative growth having ceased the cane is more liable to die off than if it had not arrowed. Ratoon crop (peri) ripens earlier than the plant crop (Naulaf) but its yield is less than that of the plant cane.

A simple though rough method of ascertaining the maturity of cane is to test the brix (specific gravity) of juice tapped from top half and botton half of the cane by means of a Hand Refractomer. Where the ratio of top and bottom brixes is very near unity the cane may be regarded as having attained maturity.

The practice with cultivators in Northern India is to start harvesting operations soon after Deothan Ekadashi i.e. sometime in the middle of November when the cane is believed to have ripened.

Harvesting of Cane. This process consists of cutting off the cane from the ground, stripping off the Leaves and removing the tops. The cane should be cut as close to the ground as possible as the bottom most portion is the richest in sugar. The topping should be done just above the highest coloured joint. For the manufacture of Gur it would be better to remove the top two or three joints below the top most joint as these joints are of lower sucrose and higher glucose content than the rest of the stalk.

Harvesting is done in India almost entirely by manual labour and no mechanical means are employed. The

tool used for the purpose is a broad-bladed knife, a pick axe spade or a sickle. The green tops are read for feeding the cattle or if the topped portion have a few nodes it may be used as seed.
The dry leaves are left in the field to be collected and tied into bundles and carried to the boiling shed to be used as fuel or to thatch huts or to spread as litter in cattlesheds.

Transport

When the stock of canes cut is sufficient to feed the crushers for a day, they are tied in bundles and carried to the crusher either in head-loads or in carts or in trucks.

Deterioration of cane after cutting

After cutting the cane begins to lose weight through evaporation and simultaneously a loss of sugar takes place due to inversion. The rate of loss of weight and sugar will depend upon the prevailing temperature and humidity. For this reason it is essential to crush the cane for *Gur* manufacture as soon after cutting as possible. It should preferably be crushed within twenty-four hours of harvesting.

Manufacturing Operations

Three main operations are involved in the manufacture of *Gur*, *viz.* (1) Extraction of juice from sugarcane (2) Purification of juice and (3) Concentration of juice into Gur.
The equipment used for the purpose consists of a crusher or a number of crushers for the extraction of juice from sugarcane and a pan or set of pans heated over a furnace. The combined equipment consisting of a furnace with pans fixed on it is termed in Hindi as *BEL*. The process of clarification of juice and its concentration is carried out in the *Bel*.

(1) Extraction of juice

From very remote times crushing has been the mode generally practised for the extraction of juice from sugarcane. The earlier method of crushing cane in India for the manufacture of *Gur* consisted in bruising or grinding bits of cane in a mortar by means of a wooden pestle moved by bullocks or camels. Mills used to be made by cutting down standing trees about two feet above the ground level and utilising the two feet stump as the mortar and cut-out trunk as the pestle. Such trees were however not available at all times and places and so later on the mortar was made of stone. A stone will with a wooden pestle.
Crushing of cane in a pestle and mortar being a very crude and inefficient device it was followed by the crushing cane between two wooden or iron rollers fitted close to one another vertically or horizontally. The two-roller mills were later on substituted by three-roller mills and these are now in general use in India by those who make Gur. Three-roller vertical crushers driven by bullock power are employed by cultivators for small-scale crushing and the three-roller (horizontal) power-driven crushers are employed by big farm owners who have to deal with larger quantities of cane.

(a) Bullock-driven crushers

The sketch shows a vertical three-roller bullock-driven crusher and its component parts.
Description of the various parts of the crushers

1. Frame
2. Cover
3. Roller A
4. Roller B
5. Roller C
6. Guide
7. Bottom plate
8. Top plate
9. Frame crescent
10. Cover crescent
11. Two Blocks

15. Pivot plate
16. Socket
17. Spout
18. 1^2 bolts and nuts
19. $5/8^2$ “ “ “
20. $1/2^2$ “ “ “
21. $1/4^2$ “ “ “
22. Spout stud
23. Bolts for iron standards
24. 1/2” Guide bolt
25. Washers

12. Wood Bushings
13. Oil Box
14. Pivot ring
26. Small spanner
27. Large spanner
28. Tightening Pin.

The sizes of these crushers vary from make to make and generally range between 7^2 to 10^2 in diameter or height for major rolls and somewhat smaller diamensions for the minor rolls. The capacities vary depending upon the size of crusher and quality of cane and range between 2 mds & 4.5 mds. of cane per hour. Juice extraction varies from 50 to 70 per cent. cane.

(b) Power crushers

Three-roller horizontal mills are generally in use though vertical three-roller crushers (Kolhus) driven by mechanical power are also met with a three-roller horizontal power crusher and Photo No.4 a three-roller vertical power-driven Kolhu.

The capacities of power crushers (horizontal type) vary from 15 to 55 mds. cane per hour according to their size and juice extraction from 64 to 72 per cent. cane. The power requirement varies from 5 to 25 B.H.P. according to size.

Extraction

The quantity of juice expressed out from cane depends upon the quality of cane, design features of the crusher and the feeding of cane into the crusher and the pull applied by the bullocks. A fresh cane having lower percentage of fibre will naturally give more juice than a dried cane having higher percentage of fibre. The design features, such as roller settings (distance apart of rollers), and the type and size of groovings of rollers as also the quality of roller material and rigidity of construction have a profound influence on extraction. From the Gur manufacturer’s point of view the cane should be of low fibre, soft and light-coloured and rich in sucrose content.

Composition of cane juice

The cane juice is an opaque liquid varying in colour from grey to dark green according to the colour of cane from which it is expressed. It contains in solution all the soluble constituents of cane, viz, sucrose, reducing sugar, salts, organic acids etc., and besides air it carries in suspension gums, fine bagasse fibre, wax and clay and colouring matter and albumin. The proportion of the different constituents varies depending upon variety and age of cane, nature of soil, manures applied and climate in which cane is grown. In the cane, main figures for sucrose and reducing sugars show the greatest differences while the other elements do not vary much in sound and ripe canes. The proportion is somewhat as follows:-

	Per cent. Cane
1. Water	70 to 72
2. Fibre	12.5 to 17.5
3. Sugars	11 to 14
4. Ash	0.5
5. Nitrogenous substances	0.4
6. Fat and wax	
7. Pectin (gums)	0.6
8. Organic acids	

Purification or clarification of juice

The turbid viscous juice from the mills is not fit to be worked up into an edible material without clarification. The course suspended particles of fibre may therefore first be removed by straining and the viscous and gummy constituents and fine particles of fibre by coagulation. As sucrose is very liable to inversion and fermentation due to the action of micro-organisms it is very necessary to boil the juice immediately after it is expressed from cane whereby the albuminoids are also coagulated and development of micro-orgamisms is checked. The aim of clarification is to prevent non-sugars being formed again in the juice and next to remove as far as possible al objectionable matter which may be present. A further requirement is to prevent charring or overheating during the concentration of juice. The aim therefore is to make juice clear as well as to make it light in colour. The first object is achieved by coagulating the colloidal impurities whereby the insoluble matter held in suspension by the colloidal constituents is also thrown down or rises to the surface leaving the juice clear.

Amongst the means that may be adopted for the flocculation of colloids the following may be mentioned (i) addition of an electrolyte, (ii) action of electric current, (iii) change in the reaction of solution, (iv) elevation of temperature, (v) addition of vegetable albumins which coagulate on heating and entangle suspended impurities and (vi) adsorption by surface-attraction using flocculent materials.

In the process of manufacture of *Gur* from cane juice the fourth method alone or a combination of the fourth and the fifth methods is generally employed. These Methods are further combined with the third or the sixth mehtod or with both when a very good quality of *Gur* is desired. The actual procedure is as follows:-

When the furnace has been sufficiently heated juice is filtered into the pan of the *Bel* and heated up slowly to the boiling temperature. Care is taken not to boil it over. In the course of this process the scum appears on the surface of the juice and accumulates to the sides of the pan. This is removed by means of a perforated ladle. When vegetable mucilages are used as clarificants of flocculants they are added when the temperature of juice has risen to the boiling point and the cracking of the scum layer on the top has well advanced and not before. With fall in temperature, which follows, any separable particles still contained in the juice are set over and ascend to the top, whence they are easily removed with the thick layer of the scum.

If it is found that the waves of impurities do not continually travel from the south to the north side of the pan it should be concluded that the fault lies in the construction of the furnace. The *Nikhar* or the clarifying pan should receive the heat at the southern end and the boiling must not be allowed to originate except in that part of the pan. Too much emphasis cannot be laid on the necessity of faithfully observing this important rule as neglect to do so would result in bad clarification and defective quality of *Gur*.

When a fairly clear liquor has been obtained *Sajji* water may be added taking care not to exceed the dose. If this is done firing should be checked for a while otherwise violent ebullition would take place and the juice may boil over.

In the above case no chemical change takes place. The clarification of juice can however be affected by effecting a change in the reaction of the juice. Cane juice being acidic initially (acidity varying according to the maturity, freshness or staleness of cane) the chemical change or the change in the reaction of the juice can be brought about by the addition of heat and alkalies such as *Sajji* and lime water. This change in reaction would also effect flocculation and result in the production of coagulated scums rising to the surface whence they may be ladled out.

The scums which are ladled out are transferred into a strainer which is usually made of a coarse cloth spread into a basket kept over an earthen pot into which the juice entrained with scum will filter through.

The clarification process may be considered complete when no more scums are formed and the juice is clear and the foams formed are white.

Clarificants

The clarificants used may be divided into two classes, viz. (i) vegetable clarificants and (ii) chemical clarificants.

(i) *The vegetable clarificants*. The principal vegetable clarifying agents used in the manufacture of *Gur* from cane juice are *Deola* (Hibiscus Ficulneus),*Bhindi* (Hibiscus Esculentus), bark of *Semal* tree (Bombax Malabaricum), bark of *Phalsa* tree (Grewia Asiatica), and *Sukhlai* (Kydia Calycina). The method of preparing and using them is described below:-

Deola. The freshly cut green lower portions of the stem and a part of roots of the *Deola* plant are well pounded in water and rubbed between the hands with the addition of more water.

A mucilaginous colourless liquid having a thick consistency is produced. This extract is added to the juice in the clarifying pan at the time when the juice is about to boil. The exact point is judged in the following way:- At first green scums begin to come up to the surface and a hissing sound is heard from the heated juice in the clarifying pan. This sound gradually becomes less and less audible as the temperature of juice goes higher up. Before the sound stops the requisite quantity of extract is poured in the juice. The extract contains vegetable albumins, which coagulate on heating, entangle the suspended and colloidal impurities and bring them up to the surface, where they are skimmed off. In order to reduce vigorous boiling, while skimming cold water is occasionally sprinkled on the juice. The scums at first are dark green in colour and are known as *Dhandoi* or *Maili.* But towards the completion of clarification these are like white froth and are called *Chandoi*. If the scums appear to be still dirty at this stage it means that the juice requires a further dose of clarificant which is added, though sparingly till the froth rising to the surface is perfectly white.

Bhindi (Hibiscus Esculentus). It is used just in the same way as Deola (Hibiscus Ficulneus) above.

Bark of several Tree (Bombax MalaBaricuns):- The green barks of the tree are pounded in water, rubbed between the hands and the mucilaginous liquid extracted. The extract is used for the clarification of juice in the same way as that of *Deola*.

Bark Of Phalsa (Grewia Asiatica). The green bark of the tree is used in the same way as that of the *Semal* tree.

Sukhlai (Kydia Calycina). The dry barks of Kydia Calycina are soaked in water for some time before the mucilaginous liquid is extracted in the same way as that of other clarificants and the manner of using it is also similar.

(ii) *The chemical clarificants*. The chemical clarificants used in the manufacture of *Gur* are:-

1. Lime water
2. Sodium carbonate
3. Sodium bicarbonate
4. Sajji
5. Superphosphate
6. Alum.

Some of these chemicals such as sodium carbonate, sodium bicarbonate, *Sajji* and lime water can be used with advantage in the manufacture of *Gur* from inferior canes such as lodged cane, diseased cane or canes of over-luxuriant growth. They help in solidification of *Gur*, but impart dark colour to the finished product.

1. *Lime water*. Saturated lime water, which is quite clear, is added to the juice after clarification with Deola. Lime water is of special advantage whilst treating the juice from inferior canes. This treatment helps in solidification of the resulting *Gur* very perceptibly. It should be used in moderate quantity which is judged by experience. If lime water is employed in an excessive quantity the colour of the *Gur* becomes dark though the crystals will be stronger. If the juice is limed to the point of neutrality of there about the *Gur* produced is dark.

2. *Sodium carbonate.* This chemical is also used after clarification of juice with *Deola.* This minimises the effect of aoids during boiling and improves the keeping quality of *Gur.* Sodium carbonate should be used only when *Gur* is to be made from inferior quality canes. It should also be used in moderate quantity.

3. *Sodium bicarbonate*. It is added in the *Chak* before churning the cooled concentrated mass. It improves the colour of the *Gur* but the effect is temporary. The *Gur* acquires its real colour after some days. So there is no advantage in adding sodium bicarbonate. Rather it has a disadvantage that it increases the cost of manufacture.

4. *Sajji*. It is commonly used in manufacture of *Rab* but it is also used in manufacture of *Gur* when *Gur* is made from unripe cane or canes of the inferior type. *Sajji* contains about 50 per cent of sodium carbonate,

6.4 per cent of sodium sulphate and 4.5 of sodium chloride and being cheaper than sodium carbonate it is used in place of sodium carbonate to partially neutralise the acidity of the juice.

A solution of *Sajji* in water is prepared and is boiled before use. The *Sajji* solution is added to the boiling juice after clarification with *Deola*. A copious evolution of carbon dioxide takes place, and the heavy froth which forms, consists chiefly of gummy impurities of the juice which are skimmed off. A strong smell of sulphur dioxide is also noticed, due probably to the breaking up and reduction of sulphates. The sulphur dioxide exercises a bleaching action on the juice. But *Sajji* spoils the taste of the finished product even if it is used in small quantity.

5. *Super-phosphate.* Superphosphate added to the juice clarified in the usual way with the extract of *Deola* or *Bhindi* gives to the *Gur* a golden colour but the crystalline structure for which the *Gur* is valued is lacking, more so with increased amount of superphosphate. The drop in purity of the *Gur* from that of the juice increases with addition of superphosphate. This is due to the increase of the natural acidity of juice. When that juice is heated inversion occurs with rise in temperature and the quality of *Gur* suffers.

6. *Alum.* Alum is used as a clarificant in some parts of Bengal. Alum used along with the extract of *Deola* effects very good clarification, but the juice has to be subsequently neutralised with soda or lime water. Where *Gur* is made in lump form, no useful purpose is served by using this chemical. If the juice treated with alum is neutralised with soda or lime water, colour of the finished product is affected and if neutralisation is not done after alum clarification the crystalline structure of the *Gur* is affected. It should be used only in those parts of the country where *Gur* is made in semi-liquid form as in Bengal. In that case neutralisation of juice after *Deola* and alum clarification is not necessary.

Manufacture of Cream Jaggery

The colour of *Gur* usually ranges from yellowish to dark brown. The lighter the colour of *Gur* the better is its quality. In order to improve the colour special treatment has to be given utilising the principle of surface-attraction. A process has been evolved for making *Gur* directly from juice yielding a creamy white product. This *Gur* has been termed *cream jaggery*.

Details of the process of manufacture of cream jaggery are given below:-

(1) Cream Jaggery

The process of manufacture of cream jaggery was evolved by the Indian council or Agricultural Research, New Delhi. The *Gur* produced by this process is of good quality and has cream colour. It is superior to ordinary *Gur.* Due to its fancy colour there is great demand for it. Manufacture of this type of *Gur* was started first in the western part of U.P. But now it is gaining popularity in other parts of the country as well.

Process of manufacture

Raw juice from the cane mill is strained through a coarse *Garaha* cloth or a wire netting of five mesh before filling it in the pan of a *Bel*. The juice is then heated to boiling point and clarified with *Deola* in the usual way. When clarification is complete it is treated with activated carbon to remove colouring matters from it. Treatment of juice with activated carbon is done in two ways - one is called the filtration process and the other the settling process.

(i) The filtration process. In this process juice after clarification with deola is passes through a layer of activated carbon in a percolator. Percolator is a conical bucket with perforated bottom. It is made of 1/16^2 G.I. Sheet and is placed on an angle iron stand. Design of a percolator of 16^2 top dia. x 10^2 bottom dia. x 30^2 high is given in the Drawing No. 1. The size and number of percolators depend upon the quantity of juice to be treated daily.

Carbon is filled in the percolator after placing a thin pad of cotton-wool on the perforated bottom. A small wooden disc is placed on the layer of carbon so that it may not be disturbed when the juice is poured over it. Before passing clear juice the carbon is washed with hot water.

The quantity of carbon required for complete decolourisation of juice depends upon the quality of the

carbon and the juice to be treated with a fairly good quality of carbon - it is 2.5% on juice.
When the percolator is ready a clean bucket is placed under it to receive the decolourised juice. The clear juice from the *Bel* is then filled in the percolator slowly. In the beginning, juice coming out from the percolator brings with it fine particles of carbon. Such juice is again passed through the percolator. The juice is examined from time to time by means of a test tube and when brilliant juice, free from carbon particles, starts coming out it is received in the bucket and transferred into the concentrating pan of the *Bel*. When sufficient quantity of decolourised juice has been colected in the pan it is concentrated and converted into *Gur* in the usual way.
This process of decolourisation of juice is suitable for small scale work. It works efficiently only with coarser carbons and cannot be easily adopted in the case of more efficient but finer carbons available in the market.
(ii) The settling process. This process is suitable for both small scale as well as large scale work. It was evolved at the Sugar Research & Testing Station, Rilari. In this process activated carbon is added directly to the juice in the boiling pan. The raw juice after straining is heated and clarified with *Deola* in the usual way. Requisite quantity of activated carbon (2.5% on juice in normal cases) is added to the boiling juice in the pan and thoroughly mixed by stirring with a wooden *Ghota* for about ten minutes for complete action. Paddy husk carbon, which is of a coarser variety is to be powdered fine before use. Milk (whole or skimmed) diluted about four times with water is added to the juice. After a couple of minutes a spongy mass of carbon particles rises to the surface and is removed with a ladle (*Pauna)*. The process of adding diluted milk followed by skimming is repeated a few times until the treated juice when taken in a glass test tube settles down quickly leaving a transparent layer of juice. In this way a large portion of light carbon is eliminated from the juice. The juice is then at once transferred to a rectangular settling tank made of G.I. Sheet. After allowing the juice to settle for 20 to 30 minutes the upper cock is opened and the clear juice is allowed to discharge into the next pan of the *Bel*. When juice stops coming out from the upper cock the lower cock is opened. The small quantity of juice with carbon left over at the bottom of the settling tank and the scums are Filtered and washed in bag filters. The filtrate is mixed and boiled with clear decolourised juice received from settling tanks.
The settled juice still contains some suspended particles of fine carbon which are easily removed by further sprinkling diluted milk and skimming. The juice now possesses a colourless sparkling appearance and is free from carbon particles. Afte this stage, all further contamination of the juice with carbon is to be carefully avoided. The transparent juice is concentrated in the usual manner for making *Gur*.
Cost of manufacture
The cost of manufacture of cream jaggery and that of ordinary *Gur* is given in the Table No. 12 as supplied by the Agricultural Research Station Anakapalli. It will be observed from the table that the cost of manufacture of one 1b. of cream jaggery is 10.16 Pies as against 4.19 Pies of ordinary *Gur*. Thus for producing cream jaggery an additional expenditure Per of only 5.97 pies per 1b. is incurred. This additional expenditure maund of *Gur* comes to Rs. 2-9-0.
(2) Manufacture of Neutral Gur
Neutral Gur is prepared for refining purposes. It cannot be consumed directly due to its unpleasant taste. But it contains higher percentage of sugar in it and would fetch better price than ordinary *Gur* in the refineries.
In the manufacture of ordinary *Gur* there is much destruction of sugar during boiling of juice. The finished product is therefore of poor quality. The two most important causes responsible for the poor quality of *Gur* are (i) inversion due to acidity and high temperature and (ii) caramelisation due to concentration at high temperature. In order to avoid the loss of sugar due to inversion caused by boiling an acidic juice at high temperature for a long time the juice is neturalised before boiling, The *Gur* produced from the juice

thus neutralised is called Neutral *Gur*.

The process or manufacture of neutral *Gur* differs slightly from the process of making ordinary *Gur* and is given below.

Process of manufacture

Neutral *Gur* can be prepared in any *Bel*. But a three pan furnace is more suitable for this work. In such a *Bel* one pan is utillised for storing and heating of raw juice, the second for clarification and neutralisation of juice and the third for concentration. For small scale work Bilari *Bel* No. 1 is the most suitable *Bel* for this Purpose and for large scale work the meerut *Bel* can be used.

Lime sucrate is used for the neutralisation of juice. It is prepared in the following way:-

Quick lime is first slaked in a small quantity of water and when it is completely slaked more water is added so that the total quantity of water added in two stages is about 5 times the quantity of lime by weight. If the quantity of lime is good the milk of lime will be approximately 20° Be. The milk of lime thus prepared is strained through a wire gauge of about 20 mesh and through a course *Garaha* cloth and is then mixed with cold raw juice to prepare lime sucrate. To 100 parts of raw juice 18 parts (depending upon the quality of lime and juice) of milk of lime are added and after stirring vigorously the mixture is allowed to settle. The clear supernatant liquid is decanted and is ready for use.

Neutralisation of juice and boiling

The juice from cane mill after proper straining is filled in the pan or pans of the *Bel* and the furnace is fired. When the juice temperature reaches to cracking point *Deola* mucilage is added and the juice is clarified in the usual way. After the clarification of juice is complete freshly prepared sucrate of lime is added in requisite quantity til the pH of juice comes to 6.8 to 7.0. The Ph of juice is Frequently tested by means of Bronco Thymol *Blue Paper*. When this (BTB) paper gives a faint blue tint the pH of 6.8 to 7.0 is indicated. In the begining some difficulty is felt in detecting the exact shade. The best course is to moisten one end of a strip of BTB paper with normal saliva and to match the shade obtained with that obtained by dipping the BTB paper in neutralised juice. The juice is then boiled vigorously. The scums formed at the surface of the juice are removed by means of a ladle from time to time. If a multiple pan furnace is employed for making neutral *Gur*, clarification and neutralisation is carried out in the second pan as the juice comes to the *Nikhar* stage. The further process of boiling and concentration of the neutralised juice to *Gur* is similar to that of preparing ordinary *Gur.*

Due to neutralisation of juice the quality of *Gur* is much improved. Comparative results obtained by the ordinary process and the neutralisation method using the same quality of juice in the two processes are shown in Table 13. It will be seen from these results that the nett rendement of neutral *Gur* is 8.15 units higher than that of ordinary *Gur*.

Cost of production

The cost of manufacture of neutral *Gur* is only about 8 pies more per mol. of *Gur* as compared to the cost of ordinary *Gur.* This is due to the use of lime for the preparation of lime sucrate. Otherwise all other items of cost are the same as in the manufacture of ordinary *Gur*. The higher purity of neutral *Gur*possessing better keeping quality however more than counter balances the increased cost.

Advantages of manufacturing neutral Gur

The refineries purchase *Gur* on nett rendement basis according to a sliding scale. Generally a flat rate is paid for *Gur* having nett rendement between 40 and 45. If the value is below 40 the *Gur* is rejected and for each degree rise in the nett rendement value above 45 the supplier gets more price. In pre-war times, it used to be generally one anna more for each degree rise. The supplier of *Gur* would thus receive from the refineries eight annas more per maund of neutral*Gur* than for the ordinary *Gur*. Deducting the extra expenditure of a pies, he would get annas seven and four pies more per md. of *Gur.*

The refineries, on the other hand, get much better raw material which in addition to increasing the recovery would lower the cost of production of sugar. The extra payment made by the refinery would represent only a fraction of the increased return accruing from a better raw material.

Manufacture of Molassine Gur

In the Khandsari system of sugar making two straight boilings are generally practised. The cane juice is boiled to first *Rab* and the molasses from first *Rab* is boiled for obtaining second sugar and exhaust molasses. During normal times a major portion of this molasses for want of adequate utilisation is not easily saleable at a fair price so as to give a good return to the *Khandsari*. Under such circumstances the molasses is converted into *Gur*. As the sugar per cent in exhaust molasses is very low *Gur* prepared from it does not solidify. To make solid *Gur* from molasses it is prepared from molasses obtained after curing first*Rab*.In this case manufacture of 2nd sugar and exhaust molasses is eliminated and the *Khandsari* is saved from the problem of disposing of its exhaust molasses.

Process of manufacture of molassine Gur

When the first *Rab* is fully matured it is purged in centrifugal machines. The first light and heavy molasses obtained from it are mixed together and diluted with a little water to dissolve the false grains of sugar present in it. The diluted molasses is then boiled without any treatment to 122°C. When it reaches the desired consistency it is transferred to a *Chak* where it is cooled and solidified in the usual way.

The molassine *Gur* prepared in this way is of ordinary quality and does not fetch good price in the market. Better type of molassine *Gur* may be prepared from:-

(i) Molasses obtained from partially crystallized first *Rab*.
(ii) Exhaust molasses by mixing clarified juice.
(iii) First molasses using *Khandsari* sugar.

(ii) Manufacture of molassine Gur from exhaust molasses by mixing clarified juice.

A weighed amount of cane juice is taken in a flat bottomed pan furnace and clarified with *Deola* Mucilage in the usual way. Skimmed exhaust molasses equal to one third the weight of cane juice is then mixed with the clarified juice. The mixture is boiled to *Gur* in the ordinary way. The molassine *Gur* thus prepared is semi-crystalline, hard and good in taste. It can be distinguished with difficulty from the average quality *Gur* sold in the market. It will be seen from the data given in the table below that the purity of the *Gur* prepared from exhaust *Khandsari* molasses alone is 55.73 while that of *Gur* prepared from clarified cane juice and exhaust molasses, mixed with proportion or 3 : 1, is 64.95 i.e. over 9 units higher. Leaving aside the chemical composition of this *Gur,* it compares favourable with the ordinary *Gur* available in the market. But owing to the increase in the impurities due to the addition of molasses its keeping quality during rainy season is comparatively poor.

(iii) Manufacture of molassine Gur from first molasses using Khandsari sugar

The first molasses is diluted with an equal quantity of water and then the diluted molasses is boiled in the same way as the cane juice is boiled for making*Gur*. During the course of boiling, a solution of sodium bicarbonate is sprinkled, two or three times, on the boiling mass. When the *Gur* is ready, the pan is removed from the furnace for cooling for about ten minutes. When the temperature of the mass comes down to about 110°C a small quantity of powdered*Khandsari* Sugar is sprinkled over it and the whole mass is thoroughly mixed. The process is repeated three times till the temperature of the mass goes down to about 75°C. The semi-liquid mass is transferred to *Gur* moulds or frames. About three *Chattaks* of powdered *Khandsari* sugar is required for making one maund of molassine *Gur*. This process, which has been developed at the Patna Agricultural farm, (a) ensures a crystalline structure to the *Gur*, (b) reduces considerably the stickiness of the product, (c) helps rapid solidification of *Gur* and (d) improves the keeping quality of *Gur*. The yield of molassine *Gur* on cane is 4 to 5 per cent., while on molasses it is 58 to 64 per cent.

Manufacture of molassine Gur in Bombay

In the Bombay Presidency the purity of cane juice is usually much higher and hence the manufacture of molassine Gur From First Molasses alone is always possible. This Gur is of fairly good quality and fetches about 75 to 80% of the price realised for the first quality of *Gur*. The process of manufacturing molassine*Gur* as worked out by the Agricultural Department of the Bombay Govt. is described below:-

In order to dissolve the false grain of sugar it is necessary to add water to the first molasses. In the beginning of the season when the brix of cane juice is only about 16, addition of fresh juice in the proportion of 1 : 5 (one part of juice and five parts of molasses) is necessary. Later on as the brix of juice increases to 18° it is not necessary to add any fresh juice to molasses. In the latter case the proportion of water to molasses is one part of molasses and two parts of fresh clear water. By the addition of water the dilution is brought to 65° to 70° and is necessary to bring about clarification. The impurities of the diluted molasses get a better chance to come up to the surface and are then easily removed. During the boiling of the molasses, a solution of sodium bicarbonate in water is added after the removal of scum. This helps the impurities still remaining to come up frothing in the form of white scums which are removed with the ladle. The boiling temperature of the molasses is to be kept to 122° C to 125° C, to get the proper strike. The pan containing the concentrated mass is then removed from the furnace and the contents are poured into the cooling pan. Further operations are the same as followed for making *Gur* in the usual way. This Molassine Gur is only a little inferior to Gur made from fresh juice and its yield is much higher than that obtained in Northern India.

***Gur* By Bugloss (Gaozaban) Clarification**

1 seer of *Gaozaban* and 1/4 seer of black *Sajji* are steeped in 6 seers of water in a bucket for 24 hours. The mass after being well rubbed between the hands is strained through fine muslin cloth. The strained mass is again put in 3 seers of water well rubbed and restrained. To the strained liquids 1 drum of alum is added and this is boiled till the bulk is reduced to 1/4th. 3 ozs. of this liquid is added to a charge 2.5 mds. of juice in the pan after the scums have been removed. On its addition the scums that rise to the surface are again removed. The clarified juice is then boiled to *Gur* in the usual way.

In order to study the quality of *Gur* that is produced by this process comparatively, *Gur* was also made from the same quality of juice by the usual *Deola*clarification. In appearance, the colour of *Gur* produced by *Deola* clarification was lighter than that of *Gaozaban.*

Andarki Gur

Andarki Gur is manufactured in the districts of Saharanpur and Dehradun. The process of manufacture for this form of *Gur* is the same as that for *Chaku Minjha Gur* except that in this case only a single layer of cooled mass is spread over the hessian cloth in the *Adda*. When the mass has cooled it is cut with knives into oblong bits and collected in baskets. Some times the *Andarki Gur* is spiced with powdered ginger roots, cloves, cardamoms and shredded *Copra*. These are added to the boiling juice after clarification.

Shark

It is a kind of raw sugar directly consumed or used by *Halwais* for the manufacture of inferior kinds of sweets. The process of clarification and boiling is similar to that of *Gur* except the boiling is continued a little longer than in case of *Bheli Gur*. When the boiling mass attains the proper consistency which is at a temperature of 120° C, the contents are emptied in earthen *Chaks* and allowed to cool. When the mass has cooled down somewhat soda dissolved in a little water is sprinkled over it and the mass well kneaded with *Khurpies* until it has required a pale yellow colour. The mass is then made into a conical lump and removed to next *Chak* to cool down further. After 15–20 minutes the mass is rubbed violently between the hands till the powdered *Gur* (*Shakkar*) is ready. The quantity of soda is about 30 gms. per 24 seers of the boiled mass. In order to decolorise the *Shakkar* and give it a good appearance Blankit (Sodium Hydrosulphite) is also used. The blankit is added in two stages. It is first added with a little soda when the juice is boiling in the pan after clarification. In the 2nd stage it is added dissolved along with soda to the

cooled mass in the earthen *Chak*. The quantity of blankit added is about half that of the soda.
The *Shakkar* so produced is pale yellow in appearance, and its taste is somewhat different.

Bagasse and its Uses

23.1 By product of Milling

The by-product of residue of milling cane is bagasse (in British Commonwealth areas megass), the woody fiber of the cane with the residual juice and the moisture remaining from the imbibition water. In practice, about one-half is fiber, the other half water and soluble solids, with variations resulting from the milling procedures and the variety and quality of the cane.

The great majority of the bagasse produced, amounting to one-fourth of all the cane ground in the world, supplies the fuel for the generation of steam in the raw factories. Because of electrification and other means of fuel economy most modern factories have an excess of bagasse during the regular grinding season.

The handling of this excess presents a problem because of the bulk of the material. Baling is resorted to in many areas so that less storage volume is needed. Rehandling for locomotive fuel domestic usage, and the like is facilitated by briquetting, sometimes with molasses.

From figures by Tromp and others, Hugot takes the average bulk weight of bagasse as 12.5 lb. per cu. ft. when stacked, 7.5 lb. When loose.

23.2 Fuel Value of Bagasse

The fuel value of dry bagasse shows surprising uniformity throughout the world. Numerous calorimeter combustion tests in Cuba, Louisiana, Hawaii, Puerto Rico, Natal, and Australia give Btu. values between 8200 and 8400 (4550 to 4660 cal.) Investigations of the fuel values of the newer variety canes in several of these countries corroborate these figures. The average of 8350 Btu. per lb. of *ash -free dry bagasse* (4640 cal. per kg.) falls within the limits of error of sampling and analysis, but bagasse is not ash-free so the average figure chosen is not too important. The actual fuel value of bagasse burned upon the grates depends on the moisture present, which requires heat units to evaporate it. Other variables are the stack temperature and the excess air drawn through the grates the must be heated. The hydrogen present in the fuel forms water that also absorbs part of the heat value.

Pure bagasse fibre has been analyzed by various investigators with average figures of carbon 47.0, hydrogen 6.5, oxygen 44.0h, ash and undetermined 2.5 per cent. Hugot tabulates the results of ten such analyses that indicate the variations.

These figures represent the actual number of Btu's available at the burners with conditions of excess air, stack temperature, and moisture as indicated.

The amount of excess air actually used may be arrived at by determining the CO_2 in the flue gases (now generally determined automatically). The curve given in Fig. 23.1 shows the relationship between CO_2 by volume and percentage of excess air as well as the volume of gases produced. One hundred per cent excess air was formerly taken as good average practice. However, with modern installations this has been reduced, so that 50 per cent is closer to the average for good furnaces, and 25 per cent is the reported average for spreader stokers. The heat lost in stack gases is a function of the excess air and the temperature of the stack gases

23.3 Bagasse Feed to Boilers

The bagasse is carried directly from the mills to the boilers by carriers of the drag type and is fed to the boilers mechanically. The simplest mechanical device consists of a hopper fitted with a counterbalanced trap door. Rotary feeders are mechanically driven drums that seal the opening at all times while revolving and delivering the bagasse to the furnaces.

Automatic devices regulating the quantity of bagasse fed to the boilers have become quite common in recent installations. Variable-speed drives operating in conjunction with automatic combustion-control equipment maintain uniform feed rate, proper air-fuel ratio, and improved boiler efficiency.

23.6 Drying Bagasse

Partial drying of the bagasse by the waste heat in chimney gases to increase the net Fuel value has been advocated by many and is actually practiced in a few small plants in some European colonies. It offers many mechanical difficulties, together with considerable danger of fire in the driers.

23.7 Preheating Air

Preheating the air admitted to the furnace for combustion purposes will effect as great a saving as drying the bagasse and requires much simpler equipment. The simplest of the air preheaters are of the tubular type in which the flue gases pass

Fig. 23.3. Detrick-Dennis Multicell Bagasse Furnace.

through tubes and the air to be heated circulates around the tubes. (A preheater of this type is shown in Fig. 23.7) Practically all modern installations include preheaters.

Fig. 23.4. Step-Grate Bagasse Furnace.

23.8 Bagasse Furnaces

The earliest furnaces for burning green bagasse were introduced almost simultaneously in 1886, first in Louisiana, then in Cuba, by Samuel Fiske and Frederick Cook. Fiske's furnace had horizontal grate bars on which the bagasse burned. Cook's furnace was of the hearth type. Both used forced draft. The step-grate furnace, consisting of horizontal grate bars, resembles a stepladder down which the bagasse falls as it burns, the ash being collected on a small flat grate at the bottom. Air passes between the grate bars and through the burning bagasse blanket. The grate or hearth types have been generally favored in the West Indies, and the stepgrate in Hawaii, the Philippines, and Australia; but Hugot says that the stepgrate is giving way in most areas to hearth-type furnaces.

Recent tendencies are toward much larger furnace volumes to ensure high furnace temperatures. With modern furnace design temperatures of 2300° F. are the rule , as contrasted with 1700° F. in older installations.

Many furnaces have suspended flat tops (so-called flat arches) which, besides having many advantages of construction, distribute the hot gases to the boiler more evenly than the circular brick arch formerly used. Another important detail is the mixing wall, above the bridge wall, which directs the gases at the top of the furnace downward to promote mixing and prevents stratification of the gases, thereby aiding in securing complete combustion. The use of forced draft also aids in mixing the gases and avoiding stratification. The downward slope of the roof reflects the heat back on the fuel bed, promoting the drying of the incoming bagasse.

23.9 Modern Furnace Designs

Two improvements in furnace design that have received wide acceptance are the Ward single-pass furnace and the Detrick-Dennis cell construction. The Ward single-pass furnace in connection with a sterling-type boiler, consists of a cast-iron hearth with a bottle-shaped furnace, from which the name has been derived. Air is admitted at the lower rim of the hearth, and secondary air is induced from tuyeres at the bottleneck. Because of the contraction and expansion of the combustion gases a torch effect results. No combustion chamber is required, and the multiple hearths need to be cleaned only once a day, according to local conditions. Recent installations include hydraulic devices for dumping the ashes.

The Detrick-Dennis Multi-Cell furnace usually consists of four high round cells each with a restricted throat on top, set beneath the boiler radiant surfaces. The cells are equipped with tuyeres in their lower side walls for the introduction of primary air. Tangential air introduced at several points higher up produces a cyclonic action which provides an intimate mixture of air and fuel. This whirling mixture sorts out the fine particles From the incoming bagasse fed into the cells From above the throat restriction. These fines are carried into the upper furnace chamber and burned in suspension. The resultant coarse bagasse relieved of the blinding effect of the fines, dries and burns at an accelerated rate.

The larger boiler furnace chamber above the cells acts as an expansion chamber to provide low vertical velocity for burning carbon particles, resulting in little carry-over of unburned carbon particles. Cell cleanouts are required as often as in any other method of cell burning of an equivalent hearth area, but by cycling the individual cell cleanouts at least 30 minutes apart, full steam ratings on the other three cells may be maintained. Some installations have cylinder operated dumping hearths above the boiler room floor under each cell.

10. Spreader Stokers. The most marked advance in bagasse burning in the past 15 years has been the growing use of spreader stokers, particularly in connection with boilers of large capacity. The method of feeding the bagasse constitutes the original features of the spreader stoker. The bagasse discharges through a chute at the bottom of which a blast of air throws the bagasse particles from a distributor plate into the furnace. The finer particles dry and burn as they fall through the air and the coarser bagasse burns on the grate. Spreader-stoker installations generally employ manual-dumping grates for boilers of less than 40,000 lb. Steam per hr., whereas units above 70,000 lb. Steam per hr. have continuous mechanical discharge of ashes. Boilers from 40,000 to 70,000 lb steam capacity per hr. may use ash-removal methods of either style. The spreader stoker with automatic feed regulation and automatic combustion controls permits bagasse burning, or the burning of any waste fuel, at higher combustion rates and improved boiler efficiencies not possible with older-type furnaces. The ease of ash removal and the economical brick work made possible by the lack of arches and separate furnaces are other advantages cited by Hugot. Spreader-stoker improvements have been introduced primarily for other waste fuels, such as bark and wood waste, and have later been adapted to bagasse burning, in contrast to earlier furnaces especially designed for bagasse.

COMMERCIAL UTILIZATION OF BAGASSE

23.11 Bibliography

An annotated bibliography on the commercial utilization of bagasse compiled for Sugar Research Foundation includes all references to July 1951. The interest in bagasse as a raw material for commercial products is evident from the 541 items in this compilation. Additional references will be found in “A Century of Utilization and Fundamental Work of Sugar Cane Bagasse” by Srinivasan and Pathak.

23.12 Paper

Studies on the manufacture of paper from bagasse extend back nearly 100 years but full commercial success was achieved only during the past 25 years by the W.R. Grace Company in Peru. In the interval, this paper factory in connection with Paramonga Sugar Factory has supplied the greater part of the paper products required by the Peruvian market. Almost every grade of paper from corrugated medium to white bond is manufactured, according to representatives of the Grace Company with annual production approaching 45,000 metric tons. Similar paper mills have been established in Puerto Rico and Colombia, using the PEADCO process as in Peru.

A second successful process, utilizing soda, developed by Valentine Sugar Company in Louisiana, started in 1953 on a commercial scale. The annual out put has now reached 25,000 tons of fine writing and bond papers. Bagasse paper mills are in operation in the Argentine, the Philippines, India, and Spain besides the ones mentioned in Peru, Puerto Rico, Colombia and Louisiana.

23.13 Wallboard and Insulating Board

Bagasse for the manufacture of building and insulating board, inaugurated by the Celotex Company in Louisiana in 1922, has superseded its use as fuel in about one-fourth of Louisiana mills. Bagasse from the mills is baled and stored in large piles under roofing paper. The process includes shredding and cooking, which removes the resins, waxes, and pectocelluloses and renders the fibers tough and flexible. From the cooker and washer the bagasse goes through paper-mill refiners to separate the fiber bundles, after which waterproofing and termiteproofing chemicals are added. The board forms by the process known in pulp handling as “felting,” the strength of the board being due solely to the interweaving and entangling of the fiber. As the wet board comes from the forming machine it is fed into a continuous hot-air drier, from which it emerges finished in a continuous sheet 12 ft. wide, cut by saws into convenient sizes. The board is made in several forms and thickness, and a special tile about 1 in. thick and 12 in. square is drilled with 441 holes as a sound absorbent or sound deadener.

Similar processes are in operation in Hawaii and Australia with some modifications. The Australian factories, because of the rising cost of coal in wartime, found it advisable to use an admixture of pulp made from low grade eucalyptus trees, rather than all bagasse. Their building material production more than doubled between 1940 and 1555. A projected factory to produce hard board (as contrasted with the soft-style board presently made) in Louisiana will employ resins to cement the fibre together, the first operation of this type using bagasse as a base.

23.14 Alpha-Cellulose

Attempts to utilize the finer portions of bagasse for the production of alpha-cellulose, to be used as a basis for rayon, high explosives, etc., have not met with the commercial success that the production of paper and wallboard has. De la Rosa described the production of a white alpha-cellulose of 97 per cent purity at Central Tuinucu, Cuba, but his later articles indicate that the commercial venture was discontinued. The process involved digestion with SO2 at 110° C. and then with 10 per cent caustic soda at 140° C., followed by bleaching with hypochlorite. Laboratory studies in Hawaii, using nitric acid digestion, gave high-grade alpha-cellulose pulp D.F.J. Lynch and others made a detailed study of pulping bagasse and other fibrous materials with nitric acid, including a complete bibliography.

23.15 Pith

Mechanical separation of the pith by gravity separators of the type used for bone char has been practiced. Lathrop says that in the manufactures of Celotex a certain amount of the pith is washed out of the fibre, which is collected, washed, and dried. The annual yield is several thousand tons of an extremely light, porous product sold to the explosives industry.

23.16 Agricultural Mulch and Cattle Bedding

Another Louisiana operation involves separation of the bagasse into various fractions according to particle size. The bagasse from the mill loses about 40 per cent moisture in passing through gas-fired Heil driers at 1400° F. The dehydrated bagasse goes to Roten screens and divides into three fractions. The coarsest fraction serves as a horticultural mulch; the middle fraction (also Fibrous) is used for chicken litter and cattle bedding. The finest fraction, the pith, is further separated by the gravity separator mentioned above, yielding two fractions: a fairly high-test alpha-cellulose for explosives manufacture, and a coarser fraction used as roughage in a feed mix with molasses.

23.17 Plastic from Bagasse

A successful venture in bagasse utilization credited to the Valentine Sugar company of Louisiana is the production of various plastics from the lignin in bagasse. First worked out as pilot-plant operations in government laboratories, the process was commercially perfected at Valentine about 1950. The products, sold under the general trade name Valite, are thermoplastic and thermosetting wheel suited for the manufacture of phonograph records. Several articles by T.R. Mc Elhinney and colleagues cited in the annotated bibliography describe the various uses to which the bagasse resins may be put, such as varnishes, laminates and low-cost molding material.

23.18 Other Products from Bagasse

A prolific subject for patents is activated carbons from bagasse, but none of the present-day carbons uses bagasse as the base material. The production of furfural from bagasse, by approximately the same methods as those using corn cobs as a base, has also been the subject of several patents and has resulted in commercial production in Dominican Republic under American sponsorship.

Surcose and Reducing Sugars

Crystalline form

Sucrose crystals are hard and anhydrous and belong to the mono-clinic system, characterised by three axes of unequal length. Their density is equal to 1.606 g/cm3. Impurities have a remarkable influence on the formation of the crystals.

Solubility

Sucrose is very soluble in water and in dilute ordinary alcohol. It is insoluble in chloroform, in cold absolute alcohol, ether and glycerine.

The solubility of pure sucrose in water increases with the rise in temperature of the solution as indicated below.

In pure sucrose solutions the boiling point elevation can be used as an index of the concentration of the sucrose solution at a given absolute pressure.

When pure sucrose is dissolved in water, sucrose hydrate is formed. 1 molecule of sucrose in diluted solution is hydrated by not less than 4 molecules of water. Other consider that the formation of hydrates in the range of 60-120°C is not so much influenced by temperature as by concentration. With increasing concentration, the degree of hydration falls between 60 and 75 per cent and increases between 80 and 60 per cent.

Sucrose-salt addition compounds

The solubility of sucrose in water is modified by the presence of other substances. In general salts in lower concentration at up to about 40°C have the effect of lowering the solubility of the sucrose (salting-out M effect), while in higher concentrations of salt (except in the case of calcium salts) the solubility increases. Solubility of sucrose in impure solution is influenced by temperature, composition of the non-sucrose, and its concentration. It is supposed that the increase of solubility of the sucrose is due to the development of addition compounds of salt and sucrose, and this is one of the several hypotheses put forward for the formation of molasses. The higher solubility of calcium oxide in a solution of sucrose compared with the solubility in pure water is due to the formation of soluble compounds of sucrose and calcium oxide : at 12°C only 0.137 g of calcium oxide are dissolved in 100 g of solution without sucrose, while in a solution containing 29.2 g of sucrose 8.5 g of calcium oxide are dissolved, that is to say 62 times more. Soluble and insoluble compounds of sucrose and lime can be destroyed even by weak acids.

Specific gravity

The specific gravity varies from 1.033 to 1.106 according to concentration. The density of the sugar solution is determined in practice by Brix and Beaume spindles or Balling saccharimeter.

Refractive index of sugar solutions

A ray of light bends (refracts) if passed through sucrose solution. The refractive index, as it is called, is measured with a refractometer and varies with concentration of the solution under examination, the length of the column of liquid, the nature of light and the temperature. By having a fixed length of column of liquid, standard temperature and class of light, the rotation then becomes *afunction* of the concentration of the sugar in solution.

Action of dilute acids on sucrose solution

The inversion of sucrose is much more rapid when the solution is made slightly acidic. The acid acts as a catalyst and remains unchanged. The rate of inversion gets accelerated with increase in temperature.

The rate of inversion has been studied by Ostwald who established the following laws. The rate of inversion depends upon:

(i) The strength, nature of acid and the temperature of reaction.

(ii) Time during which the acid acts.

(iii) Proportional to the active mass of sucrose (k) if temperature and concentration of acid remain

unchanged.
A 20% sugar solution inverts twice as fast as a 10% solution. This can be represented mathematically as under.
Rate of inversion = k (a –x),
By integration between 0 and *x* limits,
log = kt
or log = k
Where ‘k’ is a specific reaction rate constant and is different for different acids; ‘a’ denotes original amount of sugar present and ‘x’ denotes quantity of sugar inverted in time ‘t’ after the commencement of the inversion.
Example:
Initial reading = 40°
Reading after complete inversion = 12°
Total change = 40– (–12) = 52°
Reading after 60 minutes = 30°
Proportionate amount of sugar inverted = X = (40–30) = 10
Then, constant k = 1/60 log = 0.001546
The inversion of sucrose is combined with a reversal of the optical activity. If pure sucrose is treated with dilute acid under certain conditions, then the optical rotation recedes from + 100° S to – 33°C, so that the decrease in the rotation value amounts to 133°S (inversion).
(iv) Invert sugar itself has no inverting power.
Action of concentrated acids
Concentrated acids effect a more complete decomposition of sucrose in solution, especially when heat is applied. The concentrated sulphuric acid removes elements of water from solid sucrose molecules, leaving a black mass of carbon.
Inversion of cane juice: It has been found that free acids alone even in traces rapidly invert pure sucrose solution, but this is not so in the case of sugar in cane juice as expressed from mills.
The reason for this is the inhibitory effect of the neutral salts of weak acids present in cane juice. The hydrolysing action of mineral acids is replaced by weaker organic acids and so very weak acid juices can be worked for sometime and heated under vacuum upto a temperature of 90 to 95°C without much fear of ‘inversion’. The allowable acidity (due to weak acids) will depend upon the quantity of neutral salts present in the juice.
Action of organic acids on sugar solutions
Organic acids posses weak inverting power because of their small dissociation constant.
Ostwald states that if the ‘inverting power’ of hydrochloric acid is taken as 100, that of formic acid is only 1.5, of lactic acid 1; and of acetic acid only 0.5.
Action of dilute alkalies (lime) and alkaline earths
Dilute alkalies such as calcium, potassium and sodium hydroxides do not decompose sucrose (cane sugar) even on boiling and require for their neutralization just as much acid as corresponds to the amount of the base present in the compound.
Concentrate alkalies decompose sucrose into lactic, formic, acetic and humic acids which combine with the base present to form salts. Barium and strontium (alkaline earth elements) likewise form saccharates, with varying quantities of the base.
The moderately concentrated alkalies unite with sucrose, even in cold, readily forming soluble compounds having an alkaline reaction called ‘saccharates’.
Lime forms three well-known compounds called ‘saccharates’ with varying quantities of the base, viz.

Calcium monosaccharate : $C_{12}H_{22}O_{11}.CaO$

Calcium disaccharate : $C_{12}H_{22}O_{11}.2CaO$

Calcium trisaccharate : $C_{12}H_{22}O_{11}.3CaO$

Of these the first two are soluble in water but the third is practically insoluble. On boiling, the mono and the disacchartaes change into insoluble trisaccharate and free sucrose.

Clear solution of mono and dicalcium saccharates on being heated consequently become gradually turbid. The following reaction takes place:

$3C_{12}H_{22}O_{11}.CaO = C_{12}H_{22}O_{11}.3CaO + 2C_{12}H_{22}O_{11}$

(monosaccharate) (trisaccharate) (free sucrose)

When carbon dioxide is introduced into a heavily limed solution of sucrose (a mixture of mono-, di- and trisaccharates), the gas is at first almost completely absorbed, but soon the mass becomes gelatinous and viscous, so that the carbon dioxide is only partly absorbed, the remainder escaping free. The gelatinous and viscous compound formed is called 'calcium hydro-sucrocarbonate' presumably of the following formula :

$C_{12}H_{22}O_{11}.2Ca(OH)_2.3CaCO_3$

On further gassing of carbon dioxide, the viscous liquid will gradually become more fluid, in which case the hydro-sucrocarbonate of calcium breaks up into insoluble calcium carbonate which precipitates and the carbon dioxide gets completely absorbed until the point of neutrality is reached. Finally, a stage is arrived when all the three sacharates without distinction decompose on treatment with carbon dioxide into free sucrose and calcium carbonate. Upon this reaction the principle of carbonation is chiefly based.

Action of oxidising agents

Sucrose is not readily oxidised and is, therefore, not affected by free oxygen or ozone. Nitric acid oxidises sucrose first to saccharic acid and afterwards to tartaric, oxalic and uric acids. Sucrose does not reduce Fehling's solution and differs from reducing sugars in this respect.

Action of yeast

Yeast contains different enzymes which have specific action. The sucrose is first decomposed into reducing sugars and then into alcohol and carbon dioxide and finally into glycerine and non-volatile organic acids.

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