CHAPTER 6

SUGAR

CHAPTER 6 OBJECTIVES

- INTRODUCTION
- THE CHEMISTRY OF SACCHARIDES
- PROPERTIES OF SUCROSE
- CANE SUGAR
- BEET SUGAR
- OTHER SUGARS
- BY-PRODUCTS OF SUGAR INDUSTRY
- OTHER SWEETENERS
- SUGAR ANALYSIS

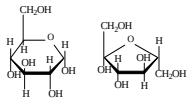
INTRODCUTION

- Carbohydrates, sugars and starches are the most widely distributed and abundant “organic chemicals” on earth.
- They serve as a basic food and they act as sweetening agents, gel-or paste-forming and thickening agents.
- They are also stabilizers and precursors for aroma and coloring substances generated within the food by a series of reactions and during handling and processing.
- Carbohydrates are considered as polyhydroxy aldehydes, polyhydroxy ketones, or substances that yield such compounds on acid hydrolysis.

THE CHEMISTRY OF SACHARIDES

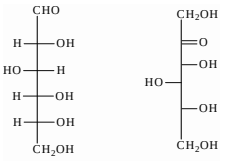
- The simplest sugars belong to the carbohydrate class, monosaccharide; they include fructose and glucose.
- Glucose and fructose are structural isomers. The molecular formula is as follows: $C_6H_{12}O_6$
- The structural formula of glucose contains a ring having six atoms (C_5O, *pyranose form*) and an aldehyde group (*aldoses*).
- The structural formula of fructose contains a ring containing five atoms (C_4O, *furanose form*) and a ketone group *(ketoses*):

THE CHEMISTRY OF SACHARIDES



α-Glucose Fructose

- The formulas of D-glucose and D-fructose using simplified Fischer projections may also be represented as follows:



D-Glucose

D-Fructose

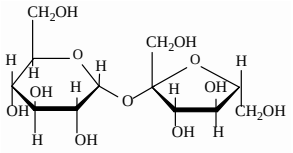
THE CHEMISTRY OF SACHARIDES

- The disaccharides are formed by the union of two monosaccharides with the loss of one molecule of water.
- Disaccharides include lactose, cellobiose, maltose and sucrose. The molecular formula for sucrose is as follows:

$$C_{12}H_{22}O_{11}$$

THE CHEMISTRY OF SACHARIDES

- The structural formula of sucrose contains two units of monosaccharide (glucose and fructose) joined together by an atom of oxygen, a glycoside link, from carbon 1 of one unit (glucose) to an OH of the other unit (fructose).



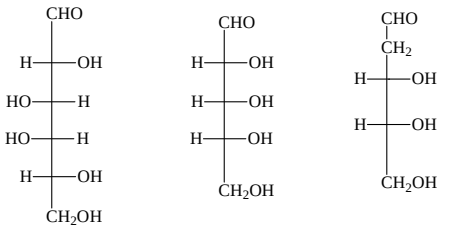
Sucrose

(glucose (α1-➤2) fructose)

7

THE CHEMISTRY OF SACHARIDES
MONOSACCHARIDES

- **D-Glucose, D-Fructose, D-Galactose, D-Ribose and 2-deoxy-D-Ribose**



D-Glactose D-Ribose 2-deoxy-D-Ribose

THE CHEMISTRY OF SACHARIDES
DISACCHARIDES

- Maltose, Cellobiose, Lactose, and Sucrose

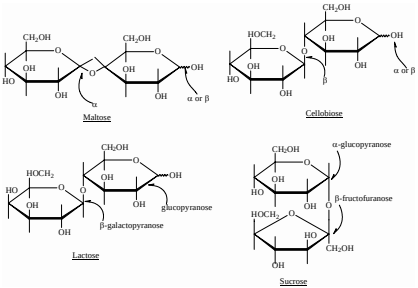


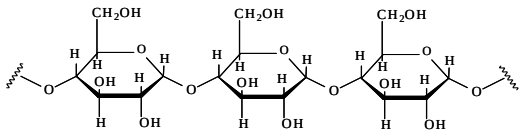
Figure 6.1 illustrates the structures of some important mono- and disaccharides.

9

THE CHEMISTRY OF SACHARIDES
DISACCHARIDES

- The carbohydrate class, polysaccharide represents compounds in which the molecules contain many units of monosaccharides joined together by glycoside links.
- Upon complete hydrolysis, a polysaccharide yields monosaccharides.
- Starch is the most valuable polysaccharide. The starch molecules (amylose and anylopectin) are tree-like, containing 250 to 1000 or more glucose units per molecule joined together through alpha linkages:

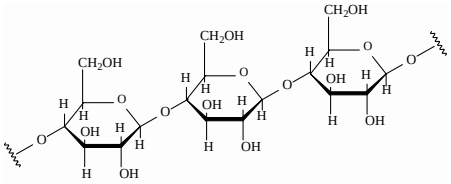
THE CHEMISTRY OF SACHARIDES
DISACCHARIDES



Amylose
poly (1,4'-O-α-D-glucopyranoside)

THE CHEMISTRY OF SACHARIDES
DISACCHARIDES

- Cellulose is the most abundant type of polysaccharides. It is the fibrous component of plant cell wall (e.g. cotton). Cellulose molecules are chains of molecules of up to 14,000 units of d-glucose linked together by beta linkages:



Cellulose
poly(1,4'-O-β-D-gluycopyranoside)

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PROPERTIES OF SUCROSE

- Sucrose is a disaccharide sugar that occurs naturally in every fruit and vegetable.
- Sugar occurs in greatest quantities in sugarcane and sugar beets from which it is separated for commercial use.
- Fully refined sugar, whether made from cane or beet, is pure sucrose and the consumer cannot tell from which of the two plants it derives.
- The melting point of sucrose, ca. 188ºC, is rather indefinite, since it appears to depend upon the solvent used for its crystallization.
- The density of sucrose is 1.5879 g/cm^3.

PROPERTIES OF SUCROSE

- Characteristic infrared (IR) absorption bands occur at 1010, 990, 940, 920, 870, 850 cm^{-1} (sharp) and at 680, 580 cm^{-1} (broad).
- The specific heat of crystalline sucrose is 415.98 J/mol at 20ºC. The dipole moment is 2.8x10-29 cm (8.3 D).
- Sucrose is readily soluble in water, the solubility increasing with rise in temperature. It is little soluble in alcohol but moderately soluble in such organic solvents as dimethyl-formamide, pyridine and dimethyl sulfoxide.

PROPERTIES OF SUCROSE

- An important property of sucrose in solution is its polarization.
- It is well known that sucrose in solution rotates a polarized light to the right in equal proportion to the quantity of sucrose present.
- The great utility of this property is in the use of the instrument, saccharimeter, which reads directly the percentage of sucrose.

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CANE SUGAR

Raw Sugar Manufacture

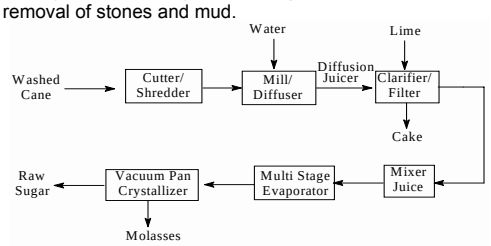
- White sugar is essentially pure sucrose derived from sugarcane. The mature sugarcane stalk (stem) may vary from 4 to 12 feet or more in height, and in commercial varieties are from 0.75 to 2 inches in diameter.
- 12 to 20 months are required for crops to mature from new plantings. The high-sugar-containing juice is in this center. More than one crop is harvested from a single planting.
- The bulk of all sugarcane harvested in the world today is still cut by hand with a cane knife or machete.

CANE SUGAR
Raw Sugar Manufacture

- However, harvesting of cane in Hawaii and Louisiana is highly mechanized. Machines top the canes at a uniform height, cut them off at ground level, and deposit them in rows.
- A second system is to burn the leaves from the standing cane, after which it is cut and taken directly to the mill.
- The mechanically harvested cane picks up field mud, sand, trash, and fine dirt during transportation into the factory. All of this creates problems in grinding cane and clarification of juices.

CANE SUGAR
Raw Sugar Manufacture

- To avoid these problem cane first goes through a washer. Washing systems vary from a simple spraying with warm water on a table to a very elaborate system consisting of conveyors with water jets, stripping rolls, and baths for removal of stones and mud.



CANE SUGAR
Extraction of Juice

- The juice is extracted from the cane either by *milling,* in which case the cane is pressed between heavy rolls, or by *diffusion*, in which case the sugar is leached out with water.
- In either case, the cane is chopped into short segments (8-12 in. long) and these segments are passed through two sets of rotating knives.
- In case of diffusion, the cane is put through an even finer shredder called a buster. No juice is extracted in the shredders.

CANE SUGAR
Milling

- The prime objective in sugarcane milling is to extract the greatest possible amount of sucrose from the sugarcane in juice form, and to make the final bagasse (fibrous residue from the cane) as dry as possible so that it will burn readily in the boilers.
- The cut pieces from the shredder then pass through a series of mills called a tandem or milling train.
- After passing through the mill, the bagasse is carried to the next mill by bagasse carriers and is directed from the first squeeze in a mill to the second by a turn plate.

CANE SUGAR
Milling

- In order to achieve good extraction, a process called “compound imbibition” is used to reduce the sucrose in the fiber by repeated dilution and milling.
- The juice is collected from the first mill and is mixed with the juice from crusher.
- The mixed juice is then passed through perforated metal screens with openings about 1 mm in diameter for clarification.

CANE SUGAR
Diffusion

- Diffusers are universally used for the extraction of sucrose from sugar beets but their installation for sugarcane factories has been relatively recent.
- The process in cane diffusion is mostly lixiviation (washing) with only a little true diffusion (osmosis).
- There are two main systems in cane diffusion–diffusion of cane or diffusion of bagasse.
- In the first, the prepared whole cane passes through the diffusion unit.

CANE SUGAR
Purification of Juice

- The raw juice leaving the mill is slightly acid (pH., 5.5-6.5), turbid and colored. It carries in suspension cane fiber, field soil, protein, fats, waxes, gums, coloring matter and soluble salts.
- Under slightly acidic conditions, the sucrose in the juice is gradually inverted (hydrolyzing to glucose and fructose) under the influence of native inverters enzyme.
- The process designed to stop inversion and remove impurities is called ***clarification or defecation***.

CANE SUGAR
Purification of Juice

- The inversion reaction is stopped by adding milk of lime to the cold juice in amounts sufficient to raise the pH to the range of 7.5 to 8.5.
- The limed juice is then gradually heated to nearly 100ºC to inactivate the enzyme and stop microbiological action.
- A large fraction of the suspended material is removed by settling. Clarification by heat and lime, a process called defecation, is the oldest and in many ways the most effective means of purifying the juice.
- Phosphate is added to juice deficient in phosphate to increase the amount of calcium phosphate precipitate.

CANE SUGAR
Purification of Juice

- The precipitated mud is removed in a settling device known as a clarifier.
- The clarification process divides the whole juice into two portions: (1) the clarified juice, and (2) the precipitated settlings, which are the scum or mud waters.
- The clarified juice is usually darker (dark brown) than the combined raw juice from crusher, mills and subsequent diffusers because of heating (100ºC) during lime treatment.

CANE SUGAR
Purification of Juice

- The raw sugar produced from this juice is brown in color and contains about 98% sucrose. In order to produce plantation white sugar, or at least very light brown raw sugar, SO_2 or CO_2 in conjunction with lime are used by some sugar producers.
- The use of sulfur dioxide in addition to lime makes a better clarification. In this method (sulfitation process), lime is added as usual, but then sulfur dioxide from a sulfur burner is bubbled through the juice.
- The bleaching effect of sulfur makes a lighter-colored-sugar.

CANE SUGAR
Evaporation and Heating

- Clarified juice contains about 85% water and requires evaporation of water from the sugar solution to yield a final crystalline product.
- The evaporation is done in two stages: first, the solution is concentrated in an evaporator system, and, second, the sugar is crystallized in a vacuum pan.
- The evaporation is carried on to a final 65-68 percent sugar concentrate (syrup). The syrup thus obtained is very dark brown and turbid.
- The concentration of sugar solution (juice) is measured on the Brix scale which is a density scale for sugar (sucrose) solutions.
- The degrees on the scale Brix are numerically equal to the percentage of sucrose in the solution (e.g. 65 to 68 degrees Brix is 65-68% sucrose in solution).

CANE SUGAR
Crystallization (Sugar Boiling)

- The clarified juice (syrup) from the multiple-effect evaporator is transferred to a vacuum pan - a vessel in which syrup is boiled under vacuum to form a heavy mixture of crystals and the mother liquor, called MASSECUITE.
- The function of the vacuum pan is to produce and develop satisfactory sugar crystals from the syrup or molasses fed to it.
- Any of the different methods of crystallization of sugar in a vacuum pan is known as SUGAR BOILING.
- Each batch of finished massecuite in a batch-sugar boiling process is a STRIKE.

CANE SUGAR
Centrifuging

- The crystals in the massecuite are separated from the surrounding molasses or syrup by centrifugal force in batch-type centrifuges.
- The continuous centrifuges are used to save a greater amount of energy and time.
- The massecuite is fed into the spinning conical basket as in the batch process. The centrifugal force moves the massecuite up the wall of the cone over a perforated stainless steel screen.
- As the massecuite is moving up the cone, the sugar crystals and the molasses are being separated and the sugar is washed with steam, water, or both.

CANE SUGAR
Refining of Raw Sugar

- Raw sugar is light to dark brown in color, slightly sticky and contains about 1-2% of ash, starch and coloring matter.
- The purpose of refining raw sugar is to remove these impurities and produce refined sugar of nearly 100% purity.
- There are several stages in the refining procedure, and in each a certain amount of impurities and color is removed.

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CANE SUGAR
Affination

- ***Affiniation*** is washing process to remove the adhering film of molasses from the crystals of raw sugar.
- This process is done by mixing the raw sugar with hot raw syrup.
- The raw syrup, which has dissolved some of the adherent molasses film from the crystal faces, is spun off and the residual sugar is washed with a jet of hot water to remove residual syrup.
- The affination process yields a pale-colored sugar, which is discharged by ploughs into continuous melter tanks.

CANE SUGAR
Melting

- The washed sugar is melted in hot water in the melter tank where it meets a stream of hot sweet waters from the process.
- The dark brown sugar liquor coming from the melter is adjusted to a *density of about 65 degrees Brix*.
- The melter liquor is strained through a plain screen to remove insoluble debris.

CANE SUGAR
Clarification

- The raw washed sugar liquor from the melter contains particulate matter coming from all sources, e.g., field soil and fiber, yeast, molds, gums, colloids and foreign contaminants.
- The object of clarification is the complete removal of these undesirables.
- The raw liquor is also acidic. One of three processes is then used: *carbonation, phosphatation, or filtration.*

CANE SUGAR
Clarification

- Carbonation and phosphatation are chemical treatment processes, which form a precipitate in the liquor; filtration uses inert filter aids that permit filtration under pressure.
- The carbonation process involves two stages.
  - In the first stage, the high density liquor is heated to 60 to 80ºC in a saturated tank and is limed to about pH 10. The carbon dioxide gas from the flue is bubbled through the limed liquor until the pH drops to between 8.4 and 9.0.
  - In the second stage, the precipitate formed in the first stage is conditioned in order to improve its filter-ability. The precipitate carries down with it most of the coloring matter present and is removed by filtration.

CANE SUGAR
Clarification

- In phosphatation, the high-density liquor is heated to 60 to 70ºC and treated with small amounts of phosphoric acid and sufficient milk of lime to bring the pH to 7.2-7.8.
- After the addition of lime, the temperature of the liquor is raised to 90ºC and time is allowed for floc formation.
- The precipitate then floats to the surface as a scum and is scrapped off without any filtration.
- The phosphate clarifiers have many sizes and shapes.

CANE SUGAR
Clarification

- Filtration is the most straightforward, probably the oldest form of sugar liquor clarification process.
- Filtration is effected with plate and frame pressure-filters or some type of leaf pressure-filter such as Sweetland filters with stationary suspended circular leaves covered on both sides with filter cloth.
- A filter aid of some sort (diatomaceous earth, paper pulp or kieselghur) is essential to the operation.

CANE SUGAR
Clarification

- The precipitated calcium carbonate serves as a filter aid in the carbonation process.
- The liquor is mixed with the filter aid and forced under pump pressure through the fabric, which retains the cake and allows the clear liquor to flow through.
- The retained sugar in the cake can be washed out with hot water. Filtration is no longer used as the sole means of clarification.
- The process is used for further clarification of the liquor from a carbonation or phosphatation process.

CANE SUGAR
Decolorization

- The clarified liquor, although clear of contaminates, is very dark brown in color.
- Colorants may originate:
  - from plant pigments, which have remained in the sugar solution;
  - may have resulted from the reaction of amino acids as reducing sugars (melanoidins);
  - or from caramels resulting from the thermal decomposition of sucrose or reducing sugars.

CANE SUGAR
Decolorization

- Decolorization is an important step because the presence of any colorant in the sucrose is highly objectionable for use of the product in food manufacturing.
- The color has an aesthetic appeal for the consumers and is the main property that distinguishes refined sugar from raw sugar.
- Carbon adsorbents have traditionally been used for removal of coloration in the clarified effluent liquor.

CANE SUGAR
Decolorization

- The general carbon adsorbents, which may be bone char, granular carbon or powdered carbon products, are used in either a fixed-bed operation or a moving-bed process.
- These carbons are regenerated at intervals in order to maintain their effectiveness.
- The use of ion-exchangers for decolorization is also more widely applied these days in sugar refining.
- The chloride form of a strong anionic resin decolorizes the liquor, and the sodium form of a strong cationic resin softens the liquor.

CANE SUGAR
Crystallization and Finishing

- The decolorized liquors going into the crystallization and finishing processes ranges from water that is white to pale yellow with solid contents of 55 to 65 degree brix (55-65%).
- In many cases this liquor is preevaporated to bring the brix to ≥ 68 (68%).
- The evaporated liquor is then drawn into the vacuum pan in which the massecuite is boiled.
- The controlled crystallization of sugar to produce various sizes of crystals is a complex process depending largely on the boiling rate throughout and proper seeding.

CANE SUGAR
Crystallization and Finishing

- The seed is finely pulverized sugar dispersed in isopropyl alcohol or sugar liquor.
- Addition of the seed induces an immediate formation of crystal nuclei throughout the supersaturated syrup (massecuite) once the nuclei are grown to a significant grain size, rapid crystallization known as a “strike” takes place.
- The crystallized sugar is transferred to centrifuges for removal of free liquor.
- The sugar from centrifuges contain about 1% moisture.
- They are conveyed to holding bins located above dryers.

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BEET SUGAR

- The basic steps in the manufacture of beet sugar consist of (1) washing, (2) slicing, (3) diffusion, (4) juice purification, (5) evaporation, and (6) crystallization.
- ***Washing and Slicing***
  - The sugar beets are transferred from factory storage to the processing area in water flumes.
  - These flumes are equipped with rock and stone removers, vegetation and trash catchers, and beet washers. The beets are rewashed, weighed, and sliced into long narrow strips called *cossettes.*

BEET SUGAR

- ***Diffusion:***
  - The cossettes are fed into the diffuser by means of a continuous weigher.
  - Countercurrent hot water is introduced at the upper end of the diffuser.
  - The extracted sugar leaves from the lower end of the diffuser as a grayish-black 10-15% sucrose solution called diffusion or raw juice.
  - The extracted pulp are discharged at the top. The pulp contains residual sugar of approx. 0.2% of the beet dry weight. The pulp is pressed, dried and enriched by the addition of 2-3% molasses. It serves as cattle feed.

BEET SUGAR

- ***Juice Purification:***
  - **In the carbonation process**, the juice is first screened to remove small particles and then heated to 80-90°C. A small amount of lime is added under controlled conditions up to a pH 10.8-11.9.
  - The carbon dioxide is bubbled through the mixture in a carbonator. A number of organic acids and phosphate are precipitated as calcium salts and colloid flocculate.
  - The other non-sucrose products are removed through coagulation by calcium or hydroxyl ions. The substances coagulated are proteins, saponius, and various vegetable coloring matters.

BEET SUGAR

- ***Juice Purification:***
  - In addition, small amounts of iron, aluminum, and magnesium are precipitated as hydroxides.
  - **The carbonation process** can be either continuous or batch processes and is performed in two steps.
  - In the first step, the sludge is separated. In the second step, further addition of carbon dioxide removes the excess lime, which is left in solution. The resulting solution is called “thin juice”.

BEET SUGAR

- ***Juice Purification:***
  - In subsequent sulfitation, a small amount of sulfur dioxide is frequently added to the thin syrup to lighten and stabilize the color during the evaporation process.
  - After sulfitation, the thin juice is again clarified by filtration and is sent to the evaporators.

BEET SUGAR

- ***Juice Purification:***
  - The use of ion exchangers is also becoming very important in juice purification.
  - In cation exchange, the substitution of Ca2+ and Mg2+ for the alkali ions (Na+, K+) softens the thin syrup and prevents the formation of hardness scale on the evaporator coil.
  - The larger pore ion exchangers also help in bleaching of the thin juice due to the binding of pigments mainly by adsorption in the ion exchangers.

BEET SUGAR

- ***Evaporation:***
  - The thin juice is heated and pumped from the filter presses to the multiple-effect evaporators.
  - The dissolved solids concentration is raised from an initial concentration of about 15% to 50-65%.
  - The concentrated juice is now known as “thick juice”.
  - A decolorizing adsorbent (granular carbon) is added counter-currently in towers to purify and decolorize the thick juice, followed by a tight filtration process.

BEET SUGAR

- ***Crystallization:***
  - The filtered thick juice is now sent to the vacuum-pan for boiling. It is essential to use low temperatures (65-80°C) in this process to avoid sucrose inversion and caramalization.
  - Pan boiling and crystallization practices are very similar to the same unit process in the sugarcane refinery described earlier for cane sugar.
  - Crystallization is continued until the crystals have reached the required size.

BEET SUGAR

- ***Crystallization:***
  - This mixture of crystals and mother liquor, known as massecuite, is discharged into a mixer tank and from there it is sent to centrifugal separators.
  - The syrup is reboiled to yield a further crop of massecuite from which the sugar and second syrup are again separated by centrifuges.
  - The syrup remaining after the several crystallizations, called beet molasses, is still quite high in sugar (up to 60% dry basis). It is sold for cattle feed directly or desugared commercially by the following process.

BEET SUGAR

- ***Sugar Recovery from Molasses:***
  - A typical analysis of final molasses from sugar beets includes sucrose (34.1%) reducing sugars (16.5%), ash (11.3%) water (21.8%), and various sugar, gums and acids (16.3%).
  - The ash includes calcium, magnesium, potassium, silicon, iron, phosphorus and other elements in the form of inorganic salts.
  - The process using dry lime as the precipitant is known as the Steffen Process. About 95% of the sucrose is recovered from the beet molasses. The diluted molasses is cooled to about 6°C and dry lime is added.

BEET SUGAR

- ***Sugar Recovery from Molasses:***
  - The precipitated calcium saccharate is carbonated to reduce the lime content, filtered, and concentrated. About 90% of the sucrose can be recovered by the Steffen Process.
  - The calcium carbonate precipitated can be roasted and reconverted to quick lime.
  - Chromatographic methods using ion exchange resins have been developed for separation of sucrose, invert sugars and non-sugars from both beet and cane molasses.
  - The separation of sucrose, invert sugars and non-sugars is accomplished in special columns filled with a special cation exchanger, which acts as an adsorbent for the fractions.

BEET SUGAR

- ***Starch Sugars (Syrup):***
  - Starch and cellulose could be used as a source of saccharides, but only starch hydrolysis is currently of economic importance.
  - The starch (mainly corn) can undergo various hydrolytic processes to yield mixtures of various saccharides in the form of syrups or crystalline products.
  - Such saccharification is achieved by either acidic or enzymatic hydrolysis.
  - The extent of starch conversion into sugars is generally expressed as dextrose equivalents (DE value), i.e., the amount of reducing sugars produced, calculated as glucose (DE value: glucose = 100, starch = 0).

BEET SUGAR

- ***Starch Sugars (Syrup):***
  - Starch Acid hydrolysis of starch is conducted with hydrochloric acid or sulfuric acid, mainly in a continuous process, yielding syrups with 20 to 68 DE.
  - The process consists of the acidification of starch slurry with hydrochloric acid to about a pH of 1.8 to 1.9.
  - Converted liquids are neutralized with sodium carbonate to a pH of 5 to 7. Proteins, lipids and colloidal matter are separated as sludge. Pigments are eliminated with activated carbon and minerals with ion exchangers.
  - The raw juice, thus obtained, is evaporated under a vacuum (falling-film evaporator) up to a solids content of 70-85 percent.

BEET SUGAR

- ***Starch Sugars (Syrup):***
  - Starch During acid hydrolysis, 5-6% of glucose undergoes side reactions to produce reversion products. These are predominantly isomaltose and gentiobiose, and, in addition, other di- and tri-saccharides.
  - In enzymatic processes, α-amylases, β-amylases, glucoamylases, and pullulanases as enzymes are used. First, starch is liquefied and hydrolyzed with acid, with a-amylase, or with a combination acid/enzyme process.
  - The enzyme most commonly used is α-amylase. Optimal pH and temperature are 6.5 and 70-90°C, respectively.

BEET SUGAR

- ***Starch Sugars (Syrup):***
  - Hydrolysis can be carried out to obtain a product consisting mostly of maltose with small amounts of glucose or vice versa.
  - The wide range of starch syrups starts with those with a low DE value of 10-20 (maltotriose) and ends with a high DE vale of 96 (dextrose).

BEET SUGAR

Table 6.2: Average Composition of Starch Hydrolysates[a]

DE-Value	Glucose (Dextrose)	Maltose	Maltotroise	Higher Oligo-saccharides
Acid hydrolysis				
30	10	9	9	72
40	17	13	11	59
60	36	20	13	31
Enzymatic hydrolysis				
20	1	5	6	88
45	5	50	20	25
65	39	35	11	15
97	96	2	--	2

[a] All values expressed as % of starch hydrolysate (dry weight) basis.

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- CANE SUGAR
- BEET SUGAR
- OTHER SUGARS
- BY-PRODUCTS OF SUGAR INDUSTRY
- OTHER SWEETENERS
- SUGAR ANALYSIS

OTHER SWEETENERS

- High fructose syrups, prepared from starch, are commonly used instead of sugar.
- They are generally known as “High Fructose Corn Syrup” (HFCS) containing 30 percent fructose, 35 percent glucose, and 6 percent higher saccharides.
- They are only 74 percent as sweet as sucrose, therefore more has to be used to achieve the same sweetness.
- Sugar alcohols, such as sorbitol, mannitol, and xylitol are also used as sweeteners.
- They are derivatives of sugars that occur naturally in some fruits, and are manufactured by chemical reduction of the parent sugars.

OTHER SWEETENERS

- Sugar alcohols have a lower calorie yield than the sugars from which they are derived, and are commonly used in the preparation of jams and sweets used by diabetics.
- They are considered safe and can be used in foods in any required amount; however, an intake greater than about 20-50 g per day may cause gastrointestinal discomfort and have a laxative effect.
- Fructose, prepared from hydrolysis of sucrose and isomerization of glucose are used in the manufacture of candy, soft drinks, and other processed foods.

OTHER SWEETENERS

- Since fructose is 124 percent as sweet as sucrose, substitution of fructose for sucrose in foods permits a reduction in the calorie content of a food.
- Sugar substitutes (sometimes called artificial sweeteners or intense sweeteners) are synthetic compounds that are many times sweeter than sucrose.
- They are commonly used instead of sugar (sucrose) in the manufacture of low-calorie soft drinks and other foods.
- Unlike sucrose, which is metabolized by the human body and ultimately changed into fat, the intense sweeteners are nonnutritive and low calorie.

OTHER SWEETENERS

- The first artificial sweetener was saccharin.
- Cyclamate was another major artificial sweetener, marketed from 1950 to 1969 in the US. Mixtures of cyclamate and saccharin were especially well accepted from taste consideration, and met stability and compatibility requirements.
- The increasing market demand for sweeteners resulted in the development of a number of chemicals.
- The major artificial sweeteners in the present market include Acesulfame K, Alitame, Aspartame, Cyclamate, Saccharin and Sucralose.

OTHER SWEETENERS

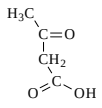
Sweeteners intensity factors of several sweeteners compared with sucrose are given below:

Sweetener	Sweetness Intensity
Sucrose	1
Fructose	1.73
Glucose	0.74
Invert Sugar	1.30
Maltose	0.32
Lactose	0.16
Sodium Cyclamate	35
Acesulfame K	200
Alitame	2500
Aspartame	200
Saccharin	550
Sucralose	600-800
Thaumatin	3500

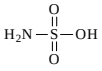
OTHER SWEETENERS

Acesulfame-K:

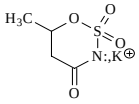
- Acesulfame-K is based on its following relationships to acetocetic acid and sulfanic acid, and to its potassium salt nature:



Acetoacetic Acid



Sulfamic Acid



Acesulfame K

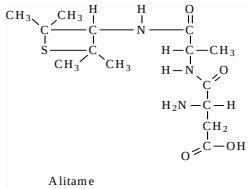
OTHER SWEETENERS

- Acesulfame-K is 200 times as sweat as sugar and is not metabolized and is thus noncaloric.
- It is exceptionally stable at elevated temperatures encountered in baking, and it is also stable in acidic products, such as carbonated soft drinks.
- It has a synergistic effect when mixed with other low calorie sweetner, such as aspartame.
- Common application of acesulfame-K are table uses, chewing gums, beverages, foods, bakery products, confectionary, oral hygiene products and pharmaceuticals.

OTHER SWEETENERS

Alitame:

- Alitame is a sweetener based on an amino acid.
- It is a very intense sweetener, possessing a sweetening power of about 2000 times that of sucrose.
- It also exhibits a clean sweet taste similar to sucrose. Alitame is prepared from the amino acids, L-aspartic acid and D-alamine and a novel amine:

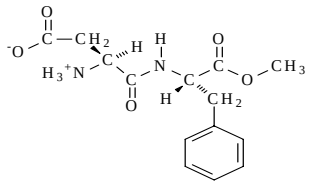


Alitame

OTHER SWEETENERS

Aspartame:

- The chemical name for aspartame is L-aspartyl-L-phenylalamine methyl ester:



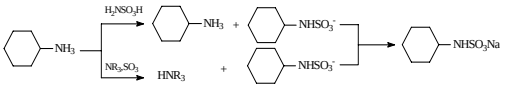
OTHER SWEETENERS

- It is a white crystalline powder and is about 200 times as sweet as sucrose.
- It is noted for a clean, sweet taste that is similar to that of sucrose.
- Aspartame is the most widely used artificial sweetener in the world.
- The shelf life of the aspartame-sweetened products with high water content is limited to about 6 months, after which it breaks down into its constituent components and looses its sweetness abilities.

OTHER SWEETENERS

Cyclamate:

- Cyclamate is produced by reacting cyclohexylamine with sulfonating agents, followed by reactions with sodium or calcium hydroxides to produce cyclamates and free cyclohexylamine as follows:



OTHER SWEETENERS

Cyclamate:

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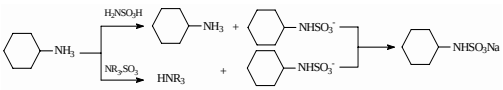
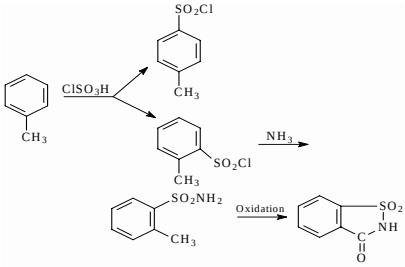
- The main application of cyclamates is in blends with saccharin in a 10:1 ratio by weight.
- The mixture is more than twice as sweet as either component alone, making them an important sweetener in countries approving the use of both sweeteners.



OTHER SWEETENERS

Saccharin:

- Commercially, saccharin is usually produced according to the following reactions:



76

OTHER SWEETENERS

- The calcium and sodium salts of saccharin are used as table-top sweeteners, soft drinks, and deserts.
- Saccharine is blended with other sweeteners for improving taste and sweetness, and sometimes combined with sucrose to reduce sugar level in the preparation of diet deserts.
- In oral hygiene products, e.g., toothpastes and mouthwashes, and other pharmaceutical products, saccharine is used to mask undesirable tastes of other ingredients.

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SUGAR ANALYSIS

- The laboratory control of factory operations, from milling to final product, basically depends on the following three operations:
  1. Sampling
  2. Weighing and measuring
  3. Pol and Brix determination
- The system of sampling must be uniform, representative and agreed upon between the operations and laboratory departments.

SUGAR ANALYSIS

- All the scales for weighing and measuring must be properly calibrated and checked periodically.
- Pol and Brix test methods are used by a greater number of sugar factories in the world.
- “Pol” is the value determined by direct or single polarization of the normal weight solution in the saccharimeter.
- Brix is the percentage by weight of the solids in a pure sucrose solution.

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