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A Study of Sugarcane Sucrose Synthesis and Utilization

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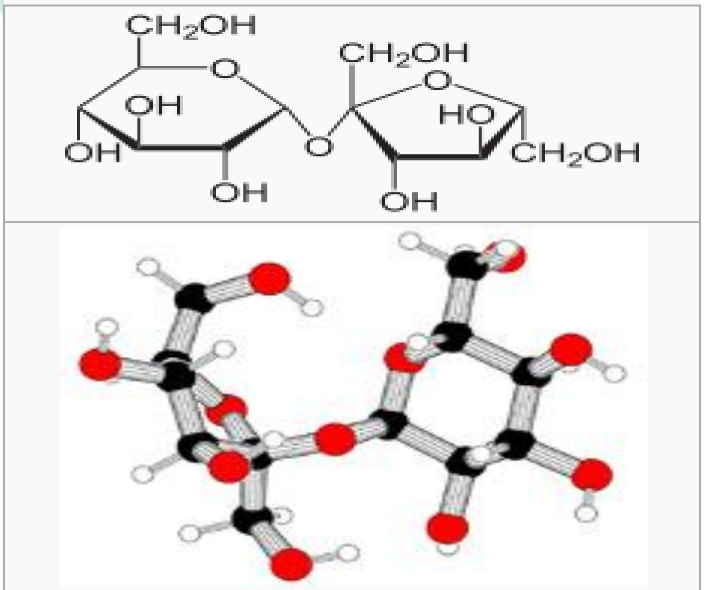
Introduction:

Sucrose is a common, naturally occurring carbohydrate found in many plants and plant parts. Saccharose is an obsolete name for sugars in general, especially sucrose. The molecule is a disaccharide combination of the monosaccharides glucose and fructose with the formula C12H22O11.

Sucrose is often extracted and refined from either cane or beet sugar for human consumption. Modern industrial sugar refinement processes often involve bleaching and crystallization also, producing a white, odorless, crystalline powder with a sweet taste of pure sucrose, devoid of vitamins and minerals. This refined form of sucrose is commonly referred to as table sugar or just sugar. It plays a central role as an additive in food production and food consumption all over the world. About 175 million metric tons of sucrose sugar were produced worldwide in 2013.

Sucrose



The word "sucrose" was coined in 1857 by the English chemist William Miller from the French sucre ("sugar") and the generic chemical suffix for sugars -ose.

Sucrose in sugarcane plant:

- Sucrose is a transport form of sugar in plants. It is a major product of photosynthesis.
- Sucrose is sweet and soluble and also called cane sugar, table sugar plays role in growth and development.
- Sucrose is a major human macronutrient, widely used as a sweetening agent.
- The disaccharide having α-D-Glucose and β-D-fructose linked through 1→2 linkage O-α-D-glucopyranosyl-(1→2)-β-D-fructofuranoside
- The presence of 1→2 linkage indicates sucrose is a non-reducing sugar.

Structural O-α-D-glucopyranosyl-(1→2)-β-D-fructofuranoside :

In sucrose, the components glucose and fructose are linked via an ether bond between C1 on the glucosyl subunit and C2 on the fructose unit. The bond is called a glycosidic linkage. Glucose exists predominantly as two isomeric "pyranoses" (α and β), but only one of these forms links to fructose. Fructose itself exists as a mixture of "furanoses", each of which has α and β isomers, but only one particular isomer links to the glucosyl unit. What is notable about sucrose is that, unlike most disaccharides, the glycosidic bond is formed between the reducing ends of both glucose and fructose, and not between the reducing end of one and the non-reducing end of the other. This linkage inhibits further bonding to other saccharide units. Since it contains no anomeric hydroxyl groups, it is classified as a non-reducing sugar.

Sucrose crystallizes in the monoclinic space group $P2_1$ with room-temperature lattice parameters a = 1.08631 nm, b = 0.87044 nm, c= 0.77624 nm, β = 102.938°.

The purity of sucrose is measured by polarimetry, through the rotation of plane-polarized light by a solution of sugar. The specific rotation at 20 °C using yellow "sodium-D" light (589 nm) is +66.47°. Commercial samples of sugar are assayed using this parameter. Sucrose does not deteriorate under ambient condition.

Thermal and oxidative degradation:

The formula for sucrose decomposition can be represented as a 2 step reaction: the first is dehydration to pure carbon and water, then carbon oxidizes to CO_2 with O_2 from the air.

$$C_{12}H_{22}O_{11} + \text{heat} \rightarrow 12C + 11H_2O$$

$$12C + 12O_2 \rightarrow 12CO_2$$

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Sucrose does not melt at high temperatures. Instead, it decomposes—at 186 °C (367 °F)—to form caramel. Like other carbohydrates, it combusts to carbon dioxide and water.

Biosynthesis of sucrose:

During photosynthesis, phosphoglyceric acid (PGA) is the first stable compound formed in the majority of crop plants. The PGA is converted into phosphoglyceraldehyde and then to glucose phosphate through a series of chemical reactions. The glucose and fructose phosphates are condensed in the presence of an enzyme sucrose phosphate synthetase to form sucrose phosphate which on hydrolysis yield sucrose and phosphoric acid. Sucrose thus formed is not utilized by the plants at once but H_3PO_4 is re-utilized.

Pathway of sucrose synthesis

COOH | CHOH | $CH_2OH_2PO_3$ ⇨ CHO | CHOH | $CH_2OH_2PO_3$ ⇨ CH_2OH | C=O | $CH_2OH_2PO_3$

Phosphoglyceric acid (PGA) **Phosphoglyceraldehyde**

Dihydroxyacetone phosphate

↓

Fructose – 1, 6 - Diphosphate

↓ *Fructose 1,6-Bisphosphatase*

Fructose – 6 - phosphate

↓

Glucose – 6- phosphate

↓ *Phosphoglucomutase*

Glucose – 1 - phosphate

↓ *Hexose phosphate isomerase*

Sucrose – phosphate

↓ *Sucrose phosphate synthetase*

Sucrose + H_3PO_4 (Phosphoric acid)

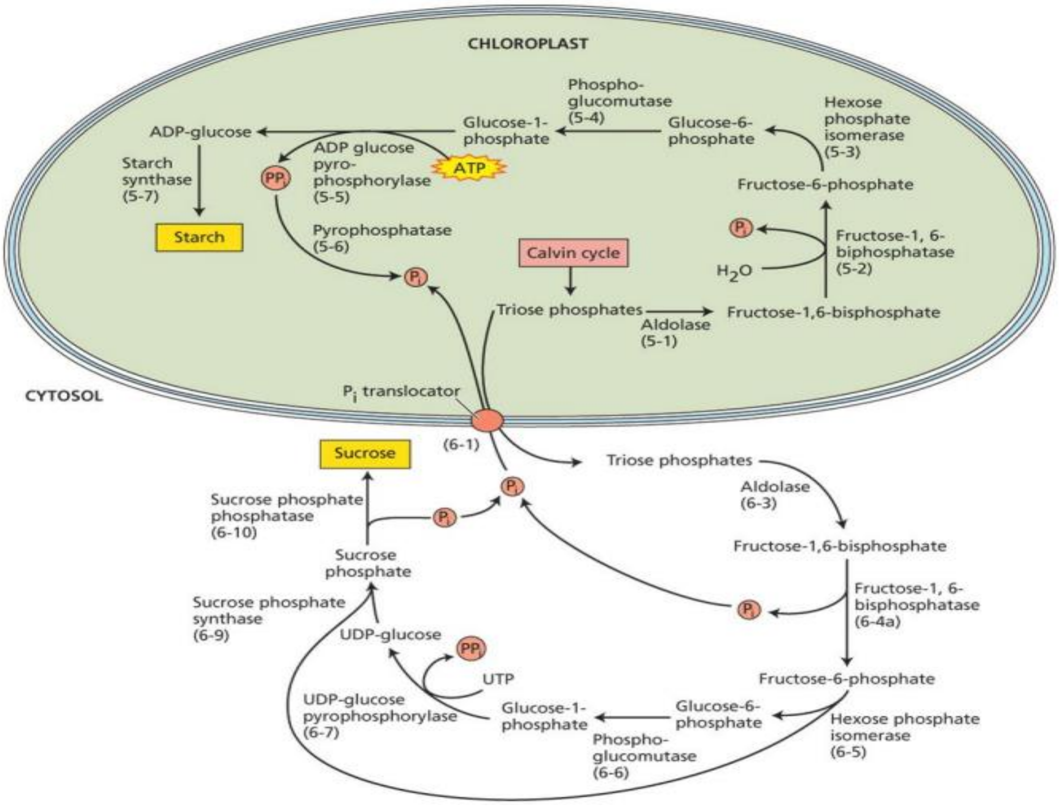
Steps involved Synthesis of sucrose:

- Triose phosphate formed in by Calvin cycle comes into the cytosol through the Pi translocator and is converted into Fru 1,6-BisP which then converted into Fru 6-P

- Fru 6-P is converted to Glc 6-P and then converted to Glc 1-P
- Glc 1-P combines with UTP to form UDT-Glc which combines with Frc 6-P to form Sucrose 6-phosphate.
- The phosphate group is cleaved to release sucrose catalyzed by sucrose phosphate phosphorylase

Different enzymes involved are:

- Aldolase
- Fructose 1,6-Bisphosphatase
- Hexose phosphate isomerase
- Phosphoglucomutase
- UDP-glucose pyrophosphorylase
- Sucrose phosphate synthase



Different theories on Sucrose Synthesis:

I. UDPG (Uridine Diphospho Glucose) Theory

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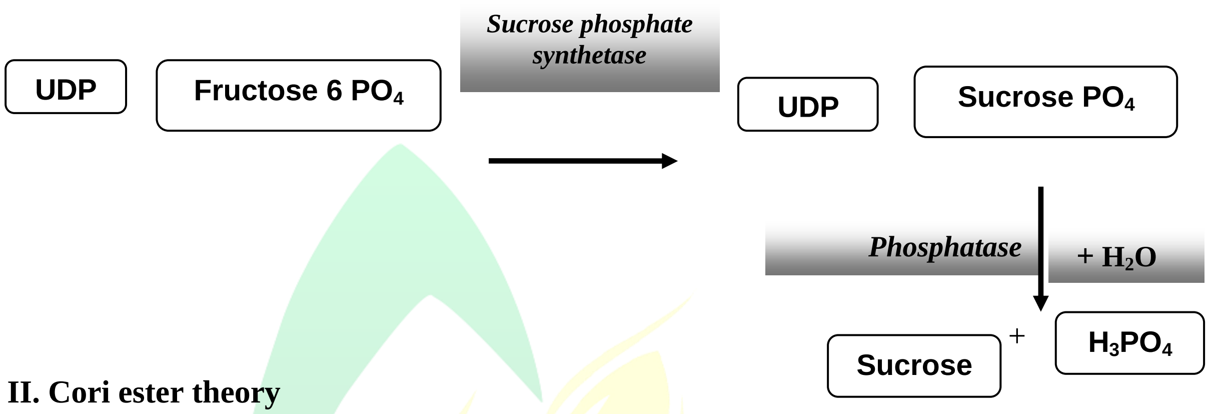
Fructose 6 PO_4 and UDPG are the precursors in sucrose synthesis. They combine under the influence of the enzyme sucrose phosphate synthetase to form sucrose phosphate and UDP. Sucrose phosphate on hydrolysis yields sucrose and H_3PO_4.



II. Cori ester theory

Cori ester (Phosphoric ester of glucose – Glucose 1 phosphate) aids in sucrose formation.

Glucose –1 PO_4 + Fructose 6 PO_4

↓ *Sucrose phosphorylase*

Sucrose + H_3PO_4

III. Involvement of Invertase enzyme

Invertase functions as a Transferase rather than acting as a hydrolase

Fructose + Glucose

↓ *Invertase (transferase)*

Sucrose

. Utilization of sucrose:

Sugars thus formed are utilized in respiration and bodybuilding. Excess sugar is stored in the form of sucrose. Sugar translocation takes place during the day and night while sucrose synthesis takes place only during the daytime. During the daytime, the rate of synthesis exceeds the translocation capacity of phloem vessels and the excess sugar is converted to starch and other insoluble polysaccharides.

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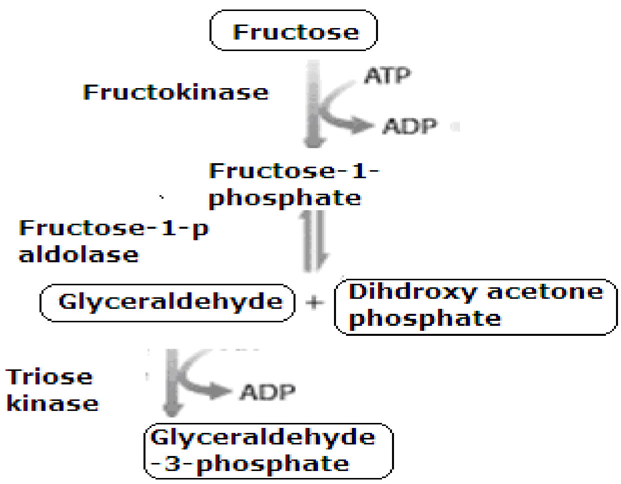
Sucrose content is more or less uniform along the stalk except for the top and below-ground butt which might be due to the immature internode in the top and high fiber content in the lower butt. The maximum content of glucose is present in the topmost internode and decreases as they grow older. Sucrose accumulation is much affected by the water content of tissues.

Sucrose is utilized for two things:

- To provide energy (ATP) through glycolysis
  - Hydrolysis in plants by fructo furanosidase (invertase) provides D-Glc & D-Fructose.
  - In animals, gastrointestinal sucrase (invertase) cleaves sucrose to release D-glucose and D-fructose.
- To Provide precursors for different types of carbohydrate synthesis
  - Sucrose acts as a primer for the synthesis of oligo and polysaccharides based on a sucrose core.
  - Some sucrose cores containing oligosaccharides are raffinose, stachyose, verbascose, melezitose, etc.



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