ION EXCHANGE RESINS IN THE SUGAR INDUSTRY

Origin

The sugar origin comes from the ancient world, about 8,000 years ago when it was introduced in the Indian culture as a garden plant for chewing purposes. The plant name was Śarkarā. Later in history, the Chinese, Greek, Roman, and Persian cultures had cultivated and used the plant for centuries. However, the first evidence of the use of crystallized sugar comes from ancient Persia, circa 500 A.D., and due to the Arabic control of North Africa, the Europeans, rediscover the sugar in the middle ages, especially in Spain, where the Arabs were ruling for approximated 711 years. The Arabic name for crystallized sugar was Assúkkar, from there the Spanish name, Azúcar, the English name, Sugar, and the German name of Zucker.

Chemically, sugar by definition is a disaccharide called sucrose, it has no color in its pure state, 99.999%, its molecular formula is $C12H22O11$, and is composed of two monosaccharides, Glucose ($C6H12O6$) and Fructose ($C6H12O6$). Sugar is synthesized, naturally by plants through photosynthesis. The higher sugar content fruits in nature are bananas (18-22%), sugar cane (8 – 16%), and sugar beet (10-18%).

Sugar production

The sugar industrial production and manufacturing is a complex process that has evolved throughout the last 1,500 years. From the simple ancient process of crushing the sugar cane and cook the obtained juice until evaporation to get raw sugar crystals, with very low productivity, less than 1 kg per metric ton to the actual average of 106 – 120 kg per metric ton.

The sugar industrial process starts with the milling where the sugar cane is crushed producing a juice, called "Thin Juice", which due to the high content of sugar and pollutant agents is required to add chemical biocides to delay sucrose content decay. After this process, sugar juice is neutralized (pH 6 – 7), with lime to flocculate and precipitate sediments and fibers (alkaline pH is linked with color formation).

The clarified and neutralized thin juice, with initially 8°Bx (Unit of sugar content) is evaporated to concentrate it to 60-65° Bx. Later on, in the raw sugar cooking process, it will be seeded with sugar crystals to promote raw sugar crystallization. The crystallized sugar is centrifuged to separate its water content, obtaining in this way raw sugar with a 96 – 98% purity and color content between 600 to 4,000 ICUMSA (Sugar color measurement unit).

Raw sugar has limited industrial applications, therefore it requires to be refined to bring it to the required industrial standards, 99.96% purity and color < 25 ICUMSA.

To refine the raw sugar and increase its purity it is necessary to remelt it, clarify it, filtrate, and traditionally adding decolorating agents such as powder bone char, polymers, hydrogen peroxide, and/or sulfites.

Ion Exchange Technology in the Sugar Industry

The use of ion exchange technology in the sugar industry started about 70 years ago and has been evolving very fast.

Starting with the raw sugar thin juice, a light to dark green fluid, with a sugar content between 8 - 12° Bx and other substances, among them calcium, magnesium salts (phosphates and silicates among them), iron, and other

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INNOVATIONS IN ION EXCHANGE

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organic substances, that are required to be removed from it to isolate the sucrose molecule.

The hardness (as $CaCO_3$) and iron (as Fe+2) generate problems in the sugar production process. The thin juice hardness (from 1 to 10 Eq/m3) precipitates in the evaporation bodies used to concentrate it, creating particularly hard built-up scales (due to the carbonates, phosphates, and silicates). Therefore, the first application for ion exchangers is softening. For this application, we have our ion exchanger, the CG-10-S to soften the thin juice and remove iron from it. Iron is also associated with the color formation in the sugar juice and corrosion in the pipelines.

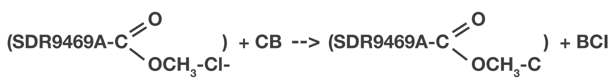
The chemical mechanism for thin juice softening is with the ResinTech CG10-S is:

$$2(CG10S - SO_3)^{-\ Na+} + Ca(HCO_3)_2 \dashrightarrow (CG10S\text{-}SO_3)_2\text{-}^{Ca2}+ + NaHCO_3$$

Having softened the thin juice the operational capacity in the sugar manufacturing facilities will be increased because the evaporation vessels will have substantially less calcium and magnesium built-up scale formation, therefore longer operational cycles, along with less corrosion in pipelines and slightly higher purity level in the thin juice, because the iron, calcium, and magnesium removal.

The sugar refining process requires redissolving the raw sugar, with a color content of between 600 and 4,000 ICUMSA. Once dissolved the raw sugar, in what is called now, refining syrup is clarified again by the addition of several chemicals. Once clarified, the refining syrup is filtrated using precoated filters to remove organic coloring substances, to obtain afterward low color refining syrup of 300 – 500 ICUMSA. This low-colored refining syrup will crystallize as 30 – 50 ICUMSA sugar crystals, by batch production. Further and expensive processing is required to bring down the sugar color from 30 – 50 ICUMSA to the industrial required standard for color (<25 ICUMSA).

ResinTech has developed a new line of ion exchange and adsorbent resins, specifically designed, for adsorption of color-forming molecules in refining syrup. The color adsorbing resins, also remove ash contents, increasing crystallized sugar purity as well. Resintech's resin line for sugar decoloration and processing is based provide stability and continuity to the sugar refining process by keeping the sugar color average production below 25 ICUMSA. The chemical color adsorption mechanism is as follow:



CB: Color forming chemical molecules
C: Trapped color molecule
BCl: Color molecule's chemical tail solubilized by turned into chloride form

The SDR9469-A is a strong base acrylic large-sized macroporous ion exchanger chemically modified to have functionalized adsorption porous that allows the resin to trap organic and inorganic color-forming compounds when the resin is in its chloride form, and when exhausted by simple regeneration with sodium chloride brine, the SDR9469-A releases all the adsorbed color molecules, returning to its original state, being ready for adsorbing color molecules again.

The SDR9469-A has been designed to work in highly colored sugar syrups, from 350 ICUMSA in forth, providing an average decoloration of 75 - 85% during the operational cycle. For low colored sugar syrups, <300 ICUMSA, it is recommended the use of the ResinTech SDR12465-S, a strong base styrenic medium-sized macroporous ion exchanger, as the SDR9469-A, chemically modified to have functionalized medium to small adsorption porous to trap organic and inorganic color-forming compounds, by the same SDR9469-A's mechanism, as follows:

$$(SDR12465S\ \text{-}CH_2N+(CH_3)\ )+Cl\ + CB\text{-} \dashrightarrow (SDR12465S\text{-}CH_2N+(CH_3))+ C + BCl$$

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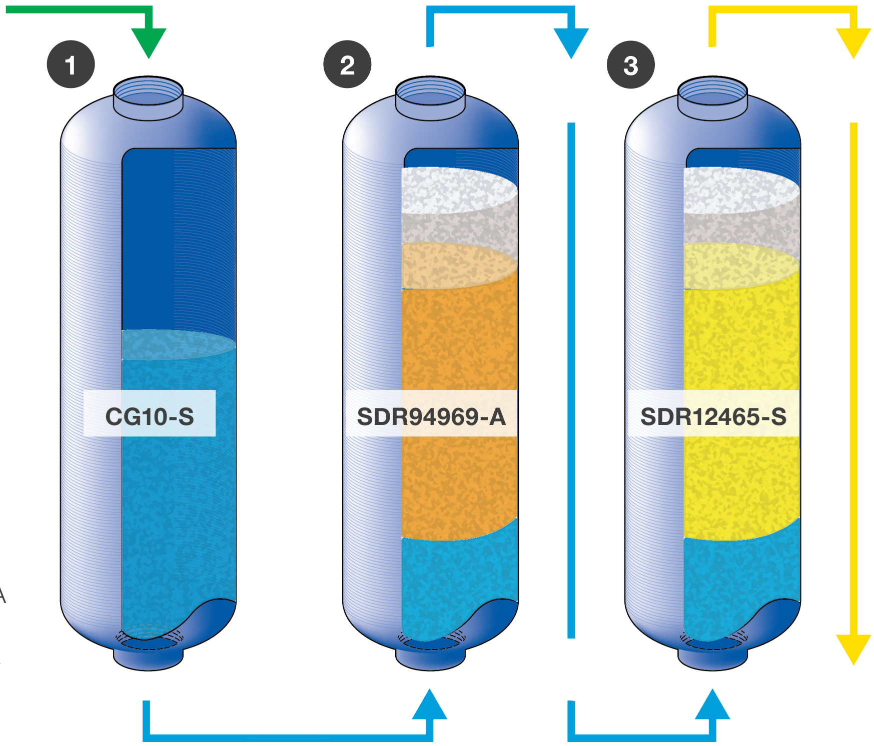
The typical sugar syrup decoloration system recommended arrangement for highly colored sugar refining syrup with a high-quality demand to reach crystallized sugar with a color content of <25 ICUMSA is schematized below.



1. REFINING SYRUP COLOR > 400 ICUMSA AND 2 Eq/m3 TOTAL HARDNESS

2. DECOLORED SYRUPCOLOR 150 ICUMSA

3. DECOLORED SYRUP COLOR 50 ICUMSA

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