

METHOD FOR PURIFICATION OF HIGH PURITY SUCROSE MATERIAL

PRIORITY CLAIM

This application claims the benefit of U.S. Provisional Application 60/487,706,
5 filed July 16, 2003.

TECHNICAL FIELD

This invention pertains to the removal of impurities from a high purity sucrose
material, including raw sugar as typically produced by the cane sugar industry.
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BACKGROUND

The standard method used to refine, for example, raw sugar to levels acceptable
for marketing as white sugar and/or use in food products is through crystallization
methods. Less practiced methods include ion exchange, chemical precipitation or
15 carbon absorption. Raw sugar usually includes sugar in crystalline form produced from
sugar cane, and may be in a moist or in a liquid form where taken from a refining
process prior to crystallization or in liquid form by dissolving raw sugar in crystalline
form in water.

As an example only, a source of sugar is sugar cane. Harvested sugar cane
20 typically is sent to a raw sugar mill. The sugar cane is processed in a shredder to break
apart the cane and rupture juice cells. Rollers extract sugar juice from the fibrous
material, typically called bagasse. The bagasse may be recycled as a fuel for the mill
boiler furnaces, or can be used as a raw materials source for the production of chemicals
such as furfural and ethanol. It is also used in the production of fibrous materials such
25 as wood products and paper, and as animal feedstuffs.

Sugar juice is purified before concentration by boiling in an evaporator. The
concentrated juice or syrup is concentrated further and seeded with small sugar crystals
in a crystallization process. Sugar crystals are grown to a required size by adding syrup
during boiling. A syrup is separated from these raw sugar crystals in centrifugals, and a
30 molasses is typically left over from the final centrifuging. This raw sugar from the
centrifugals typically is dried and transferred for storage.

A current practice of certain industrial scale food and/or beverage producers that utilize sugar is, for economic reasons, to purchase a high purity sugar product on the market from time to time that is in a form not yet suitable for use in food production, because such sugar product, e.g., contains impurities such as color and ash components.

5 Such producers, while saving cost in purchasing such sugar for food and/or beverage production, usually also desire a whiter appearing sugar for their use in food and/or beverage production. Raw sugar, for example, while substantially pure in sucrose, typically is not considered fit for direct use as food or a food ingredient due to the impurities it ordinarily contains. As stated, high purity sucrose material such as raw

10 sugar currently has been purified by non-chromatographic processes such as a process utilizing affination in which raw sugar is mixed with hot concentrated syrup to soften outer coating crystals, which are then separated from syrup by centrifugation. Crystals are discharged from the centrifuge and dissolved in hot water to form a sugar liquor.

The melted sugar liquor is purified with either a carbonation or phosphatation

15 process which traps suspended impurities in larger particles that are easier to separate from the sugar liquor. Carbonation adds carbon dioxide and lime to melted sugar to form a precipitate of calcium carbonate. Carbonation precipitate is removed, for instance, by pressure filtering sugar liquor through cloth in a pressure leaf filter, leaving a straw-colored, crystal clear liquid. Phosphatation adds phosphoric acid to melted

20 sugar and removes precipitate as a layer from a flotation clarifier. Phosphatated liquor is generally filtered through sand in a deep bed filter to remove residual precipitate left after clarification. This liquid then passes through decolorizing columns which adsorb the colorant molecules. A clear liquid is concentrated by boiling in a vacuum pan, and then seeded with fine sugar crystals and grown to a desired size by adding liquor. When

25 crystals are a desired size, crystals and syrup are discharged from the pan. The mixture of crystals and syrup is processed in centrifuges where crystals are separated from syrup. Separated syrup is boiled again and more sugar crystals are extracted from it, and repeated. Refined sugar crystals are dried by tumbling them through a stream of air, then graded and packaged. Other purification methods include sulfitation processes and

30 processes known as Talofoc and Talodura processes which use phosphotation and cationic surfactants or polyacrylamides for color removal.

Industrial applications of chromatographic separations are typically applied to a feedstock in order to separate constituents present in significant quantities. For example, a commonly practiced application of chromatography in the sugar industry is to recover sugar from molasses. Sugar in molasses, which makes up approximately
5 60% of the dissolved solids, is separated from non-sugars that make up the remaining 40% of the dissolved solids.

U.S. Patent No. 4,412,866 describes an example of the operation of chromatographic simulated moving bed (or sometimes called "SMB") method to separate the components of a feed stock. A resin bed is divided into a series of discrete
10 vessels, each of which functions as a zone within a circulation loop. A manifold system connects the vessels and directs, in appropriate sequence to (or from) each vessel, each of the four media accommodated by the process. Those media are generally referred to as feed stock, eluent, extract and raffinate, respectively. As applied to a sugar factory, a typical feed stock is a lower purity sucrose solution, the eluent is water, the extract is an
15 aqueous solution of sucrose and the raffinate is an aqueous solution containing nonsucrose, such as salts and high molecular weight compounds. The simulated moving bed disclosed by the '866 patent is of the type sometimes referred to as a "continuous SMB."

An example of a batch chromatographic method is described in the disclosure of
20 U.S. Patent No. 4,359,430, which utilizes sucrose feedstocks derived from sugar beets at purities of approximately 7% to 60% sucrose. See also, e.g., U.S. Patent No. 5,466,294, which utilizes a "soft raw syrup" as a feedstock to a chromatographic method which is not in a high purity form at a less than 89% purity sucrose on a dry solids basis, i.e., approximately 11% non-sucrose impurities.

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DISCLOSURE OF INVENTION

The use of chromatography to purify already high purity sucrose material, however, has not been known to have been considered by those in the art because the impurities in raw sugar, for instance, are present at a very low level quantities and/or
30 percentages on a dry solids basis. We have unexpectedly discovered that a chromatography process or processes can be cost effectively used to separate the

relatively small quantities of non-sucrose impurities such as ash components and color present in a high purity sucrose material, such as raw sugar. A major cost prohibitive aspect of using chromatography for the application, the common step of concentration of water from the product streams of chromatography, is typically eliminated by
5 producing a sugar product stream which is sufficiently high in solids concentration such that it requires little or no subsequent concentration and a waste stream which is sufficiently low in solids that it can be sent directly to water disposal facilities with little or no concentration required.

The sugar in raw sugar, for example, typically makes up 98% to 99% of the total
10 dissolved solids or could be lower, such as 96%. Given this purity level, the use of chromatography to remove a 1% or 2% contaminant of other constituents or even higher would be considered economically unfeasible to those of ordinary skill in the art. High purity sucrose material is at a sufficient high concentration level which to those of ordinary skill would be considered as necessitating non-chromatographic methods to
15 achieve further refinement of the sucrose material to obtain, e.g., color or ash component removal. As used herein, the term "high purity sucrose material" will be used to refer to a concentration of sucrose in a material, such as raw sugar dervice syrup, that is at least about 60% and preferably about 90%.

In one embodiment, a process for purifying a high purity sucrose material
20 comprises feeding a stream of a high purity sucrose material to a chromatographic process in a system comprising one or more chromatographic columns or beds. The process further includes producing at least a first product stream and a second product stream from the chromatographic process, wherein the first product stream comprises a higher concentration of the sucrose on a dry solids basis than the stream comprising the
25 high purity sucrose material and a higher concentration of the sucrose on a dry solids basis than the second product stream, and wherein the second product stream comprises a higher concentration of one or more non-sucrose components than the first product stream.

As for product quality, we have found that utilizing a chromatography method,
30 the quality of the sugar stream is improved such that substantial amounts of essentially all of the ash components are removed along with approximately 70% or more of the

color. It also may be desirable to adjust the level of color removal by the method to satisfy the desired color level of consumers or food producers. This method may also be applicable to any number of high purity sucrose materials that have been already partially refined by non-chromatographic methods (or, e.g., intentionally colorized purified sugar) and still containing impurities, e.g., color, including for example
5 turbinado, demerara, muscovada, or brown sugars.

Our method of utilizing chromatography for purification offers a selection of several unique economic advantages over conventional processes. For instance, no chemicals for processes such as carbonation, sulfitation, or phosphotation are used and
10 water is used for diluting and as an eluent in the separation process. The purified sugar product stream is relatively high in dissolved solids. Therefore, evaporation requirements for this stream may be relatively small or not necessary. The non-sugar stream contains most of the water and low amounts of dissolved solids and may be sent on to water treatment or water disposal facilities with little or no prior treatment,
15 eliminating the need to expend substantial energy for evaporation.

In applications such as soft drink bottling, the final product, in the liquid stage, can be used directly, by-passing the need for crystallization. Thus, in another embodiment, the final product may be mixed with a food product such as, for example, soda pop.

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BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is an illustration of the configuration of a simulated moving bed utilized for the chromatography in the Example.

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BEST MODE(S) FOR CARRYING OUT THE INVENTION

There are a number of embodiments of our invention which can be used to further purify high purity sucrose material utilizing chromatography. One embodiment includes a process whereby a high purity sucrose material, e.g., raw sugar, is conveyed to a melter tank and mixed with an eluent such as, for example, water that is
30 approximately 60 degrees centigrade. If the resulting solution has an acidic pH, addition of a base, such as, for example, sodium hydroxide, may be used to raise the pH

of the resulting solution from about 7.0 to 8.0. The higher pH will slow the conversion of sucrose to fructose and glucose if the solution is later held at higher temperatures for extended periods of time.

A 60% to 70% dissolved solids solution is, thus, produced. The raw sugar
5 derived syrup is separated from any insoluble material using a filter or centrifuge. With regard to filtration, systems such as pressure leaf, vacuum drum or plate and frame are acceptable. Membrane filters which can be used in a membrane treatment include micro-filtration, ultra-filtration and nano-filtration. In another embodiment, the membrane treatment may include reverse osmosis. The resulting raw syrup is passed
10 through check filtration if residual suspended solids are present, and degassed if oxygen is present. Optionally, the resulting raw syrup may be subjected to ion exchange before feeding to the SMB chromatography system. This may be useful, for example, for removing the divalent cations from the syrup over time which could result in a slow deterioration of the chromatographic separation. In this case, weak or strong cation
15 exchange softening is appropriate.

The feed syrup may also be subjected to ion exchange prior to entering the separator. Ion exchange is commonly used prior to chromatography and is well known as a chromatography pre-treatment by those of ordinary skill in the art. For example, divalent cations may be exchanged for monovalent cations in cases for which a
20 monovalent form chromatography resin is used.

In other embodiments, the composition comprising the eluent and the high purity sucrose material may be melted before filtration. In yet an additional embodiment, the composition including the eluent and the high purity sucrose material may be subjected to a process to reduce the content of matter that may plug a resin used
25 in a subsequent chromatography process. The process may include pressure filtration, rotary drum filtration, membrane filtration, centrifugation or combinations of any thereof.

A filtered and/or degassed raw syrup is fed to a chromatographic separator to remove part of the ash and color from the solution. The chromatographic separator may
30 include a batch type operation or the generally more efficient simulated moving bed operation, and operated using continuous internal recirculation. Examples of simulated

moving bed processes are disclosed, for instance, in U.S. Patent No. 6,379,554 (method of displacement chromatography); U.S. Patent No. 5,102,553 (time variable simulated moving bed process), U.S. Patent No. 6,093,326 (single train, sequential simulated moving bed process); and U.S. Patent No. 6,187,204 (same).

5 The number of columns or beds is 1 to 8. A column may comprise one or several beds containing chromatographic media. Those feed tanks, filters, piping connecting flow between columns and/or beds where so connected, pumps, valving, pressure regulators, metering equipment, flow control and microprocessor equipment utilized in one embodiment are well known in construction and function to those of
10 ordinary skill in the art. The chromatographic media may be a cation ion exchange resin, such as a DIAION UBK-530 (Na), available from Mitsubishi chemicals, which is a strong acid cation resin. Other non-limiting examples of chromatographic separation resins include Rohm and Haas 1310 and 1320 resins, Purolite PCR resins and DOWEX monosphere chromatographic resins.

15 In one embodiment, the steps of an 8 column system are as shown in FIG. 1. These steps are managed by a microprocessor which controls the appropriate valve opening/closing, flow rates, and pressures. Those of ordinary skill in the art will appreciate multiple alternative arrangements of such steps to optimize the disclosed process for particular needs and feedstock materials after reading this disclosure.

20 Water is used as the chromatographic eluent for a chromatographic process. Other eluents that perform functions the same as or similar to water known to those of ordinary skill in the art are also contemplated herein. Depending on the configuration of the chromatographic separator, any number of product streams may be obtained. Usually, however, two streams are taken from the separator. These are an extract which
25 is high quality sugar product, and raffinate which is non-sugar product.

 Depending on the original quality of the high purity sucrose material, the extract stream from the chromatography step may require further purification, clean-up or polishing, usually to remove residual color. Addition of final polishing represents separate embodiments of our invention. If desired, we recommend that the optional
30 polishing step include one or more of the following known color removal methods: ion exchange, absorption, chemical treatment, carbon treatment or membrane treatment.

Chemical treatment can include the addition of oxidizing agents, such as hydrogen peroxide wherein 0.1% to 0.15% on weight is our recommended dosage. An example of membrane treatment is the employment of nano-filtration membranes which can remove small remaining colored compounds.

5 Evaporation of, or water removal from raffinate, will be unnecessary where low in dissolved solids and desired to, e.g., send to water treatment or water disposal facilities; although one of ordinary skill in the art may desire, e.g., to evaporate such stream for commercial reasons to concentrate remaining solids.

10 Further purification methods may include filtration, evaporation, distillation, drying, gas absorption, solvent extraction, press extraction, adsorption, crystallization, and centrifugation. Other purification methods may include further chromatography according to this invention utilizing batch, simulated moving bed (including continuous, semi-continuous, or sequential), such simulated moving bed utilizing more than one loop, utilizing more than one profile, less than one profile, or combinations of any of the
15 forgoing as will be appreciated for application with this invention by those of ordinary skill in the art after reading this disclosure. In addition, further purification can include combinations of any of the forgoing, such as for example, combinations of different methods of chromatography, combinations of chromatography with filtration, or combinations of membrane treatment with drying.

20 The following example is given to illustrate the present invention. This Example is given for illustrative purposes, and the invention embodied therein should not be limited thereto.

Example I – as applied to raw sugar.

25 A raw sugar derived from cane sugar processing was treated by this invention. In other embodiments, the raw sugar may originate from other sources including, but not limited to, beet sugar. The purpose was to remove color from the raw sugar. A pilot scale simulated moving bed was used for the chromatography and it was configured as illustrated in FIG. 1. The SMB system was operated using continuous
30 internal recirculation. The SMB columns were filled with Mitsubishi UBK-530 which is a strong cation resin. The system was loaded at 2672.2 kg. dissolved solids per cubic

meter resin/day. Total resin volume for the test was 0.013 cubic meter distributed equally among the 8 columns. Other parameters are listed in Table 1.

Table 1 -- Operating Parameters

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Step time	4 minutes
Eluent	Water at a ratio of 3.0 water to 1.0 feed on a volume to volume basis
Operating temperature	60° Centigrade
Product ratio	1.0 ratio of extract product collected to raffinate collected on a volume to volume basis

Prior to chromatography, the dissolved raw sugar was filtered using a plate and frame filter. The system was operated until equilibrium conditions were reached. The purpose of the operation was to remove significant color from the raw sugar. The results are reported in Table 2 and Table 3.

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Table 2 -- Color, Dry Solids, Turbidity

Stream	Color (ICUMSA -- International Commission for Uniform Methods of Sugar Analysis)	Dry Solids %	Turbidity (absorbance at 720 nm and based on dissolved solids)
Feed	480	66.5	52
Extract	160	35.6	1
Raffinate	6600	2.1	634
% Color elimination by material balance (includes weights of materials) = 69.3%			

Table 3 – Apparent Purity

Stream	Apparent purity
Feed	99.2%
Extract	99.6%
Raffinate	97.1%

5 The raffinate stream was relatively low in dissolved solids and, if desired, may be sent for processing in, e.g., water treatment or water disposal facilities. The extract stream was relatively high in dissolved solids and relatively low in color.

10 While the above invention has been described with reference to certain embodiments, the scope of the present invention is not limited to these embodiments. One of ordinary skill in the art may find variations of these embodiments which may, nevertheless, fall within the scope of the present invention, whose scope is defined by the claims set forth below.

CLAIMS

What is claimed is:

- 5 1. A method for purifying a high purity sucrose material, the method comprising:
 degassing a stream comprising a high purity sucrose material;
 feeding said stream to a chromatographic process in a system comprising one or more
 chromatographic columns or beds; and
10 producing at least a first product stream and a second product stream from said
 chromatographic process, wherein said first product stream comprises a higher
 concentration of said sucrose on a dry solids basis than said stream comprising
 said high purity sucrose material and a higher concentration of said sucrose on a
 dry solids basis than said second product stream, and wherein said second
15 product stream comprises a higher concentration of one or more non-sucrose
 components than said first product stream.
2. The method according to claim 1, wherein said chromatography process
 is selected from the group consisting of batch chromatography, simulated moving bed,
20 continuous simulated moving bed, semi-continuous simulated moving bed, time
 variable simulated moving bed, sequential simulated moving bed, and combinations of
 any thereof.
3. The method according to claim 1, further comprising dissolving said
25 high purity sucrose material in an eluent prior to feeding said stream comprising the
 high purity sucrose material to said chromatographic process.
4. The method according to claim 3, wherein said chromatographic process
 utilizes a water solution as the eluent.

5. The method according to claim 1, further comprising:
dissolving said high purity sucrose material in an eluent;
melting said high purity sucrose material; and
5 filtering said high purity sucrose material prior to feeding said stream to said chromatographic process.
6. The method according to claim 3, wherein the eluent is approximately 60°C.
- 10 7. The method according to claim 1, further comprising subjecting said high purity sucrose material to a process to reduce the content of matter in said stream fed to said chromatographic process, wherein said matter may result in plugging a resin used in said chromatographic process.
- 15 8. The method according to claim 7, wherein said process to reduce the content of said matter is selected from the group consisting of: pressure filtration, rotary drum filtration, membrane filtration, centrifugation and combinations of any thereof.
- 20 9. The method according to claim 1, further comprising subjecting said stream fed to said chromatographic process to ion exchange prior to feeding said stream to said chromatographic process.
- 25 10. The method according to claim 1, wherein at least one of said product streams is subjected to a subsequent polishing step selected from the group consisting of: ion exchange, absorption, chemical treatment, carbon treatment, membrane treatment and combinations of any thereof.
- 30 11. The method according to claim 10, wherein the chemical treatment comprises adding hydrogen peroxide.

12. The method according to claim 10, wherein the membrane treatment is selected from the group consisting of: micro-filtration, nano-filtration, ultra-filtration, reverse osmosis and combinations of any thereof.

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13. The method according to claim 1, wherein said high purity sucrose material is raw sugar produced from cane sugar processing.

14. The method according to claim 1, further comprising partially refining
10 said high purity sucrose material by non-chromatographic methods prior to feeding said stream to said chromatographic process.

15. The method according to claim 1, further comprising subjecting at least one of said product streams to further processing in a separate system by one or more
15 methods selected from the group consisting of: chromatography, filtration, membrane treatment, evaporation, distillation, drying, gas absorption, solvent extraction, press extraction, adsorption, crystallization, centrifugation and combinations of any thereof.

16. The method according to claim 15, wherein the eluent is approximately
20 60°C.

17. The method according to claim 1, wherein at least one of said product streams has a color rating of less than 200 on a United States ICUMSA scale.

18. The method according to claim 1, wherein a percentage of sucrose in
25 said high purity sucrose material comprises at least 90% of the total dissolved solids.

19. The method according to claim 1, further comprising mixing the first product stream with a food product.

20. A method for purifying a high purity sucrose material, the method comprising:

feeding a stream comprising a high purity sucrose material to a chromatographic
5 process in a system comprising one or more chromatographic columns or beds;
and producing at least a first product stream and a second product stream from said
chromatographic process,

wherein said first product stream comprises a higher concentration of said sucrose on a
dry solids basis than said stream comprising said high purity sucrose material
10 and a higher concentration of said sucrose on a dry solids basis than said second
product stream, and

wherein said second product stream comprises a higher concentration of one or more
non-sucrose components than said first product stream wherein said high purity
sucrose material is selected from the group consisting of: turbinado sugar,
15 demerara sugar, muscovada sugar, brown sugar, and combinations of any
thereof.

21. The method according to claim 20, further comprising degassing said
stream fed to said chromatographic process.

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22. The method according to claim 20, wherein said chromatography process
is selected from the group consisting of batch chromatography, simulated moving bed,
continuous simulated moving bed, semi-continuous simulated moving bed, time
variable simulated moving bed, sequential simulated moving bed, and combinations of
25 any thereof.

23. The method according to claim 20, further comprising dissolving said
high purity sucrose material in an eluent prior to feeding said stream comprising the
high purity sucrose material to said chromatographic process.

24. The method according to claim 20, further comprising:
dissolving said high purity sucrose material in an eluent;
melting said high purity sucrose material; and
5 filtering said high purity sucrose material prior to feeding said stream to said chromatographic process.

25. The method according to claim 23, wherein said chromatographic process utilizes a water solution as the eluent.
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26. The method according to claim 20, further comprising subjecting said high purity sucrose material to a process to reduce the content of matter in said stream fed to said chromatographic process, wherein said matter may result in plugging a resin used in said chromatographic process.
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27. The method according to claim 26, wherein said process to reduce the content of said matter is selected from the group consisting of: pressure filtration, rotary drum filtration, membrane filtration, centrifugation and combinations of any thereof.

28. The method according to claim 20, further comprising subjecting said stream fed to said chromatographic process to ion exchange prior to feeding said stream to said chromatographic process.
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29. The method according to claim 20, wherein at least one of said product
25 streams is subjected to a subsequent polishing step selected from the group consisting of: ion exchange, absorption, chemical treatment, carbon treatment, membrane treatment and combinations of any thereof.

30. The method according to claim 29, wherein the chemical treatment
30 comprises adding hydrogen peroxide.

31. The method according to claim 29, wherein the membrane treatment is selected from the group consisting of: micro-filtration, nano-filtration, ultra-filtration, reverse osmosis and combinations of any thereof.

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32. The method according to claim 20, wherein said high purity sucrose material is raw sugar produced from cane sugar processing.

33. The method according to claim 20, further comprising partially refining
10 said high purity sucrose material by non-chromatographic methods prior to feeding said stream to said chromatographic process.

34. The method according to claim 20, further comprising subjecting at least
15 one of said product streams to further processing in a separate system by one or more methods selected from the group consisting of: chromatography, filtration, membrane treatment, evaporation, distillation, drying, gas absorption, solvent extraction, press extraction, adsorption, crystallization, centrifugation and combinations of any thereof.

35. The method according to claim 20, wherein at least one of said product
20 streams has a color rating of less than 200 on a United States ICUMSA scale.

36. The method according to claim 20, wherein a percentage of sucrose in said high purity sucrose material comprises at least 90% of the total dissolved solids.

25 37. The method according to claim 20, further comprising mixing the first product stream with a food product.