

SUGAR PRODUCTION SYSTEM

This International Patent Cooperation Treaty Patent Application claims the benefit of United States Provisional Patent Application No. 60/457,516, filed March 24, 2003,
5 hereby incorporated by reference herein.

I. TECHNICAL FIELD.

Generally, a system for the production of sugar from sucrose containing liquids
10 obtained from plant material. Specifically, a sugar process liquid conditioner that alters sugar process liquid characteristics, and sugar process steps which utilize sugar process liquid having altered sugar process liquid characteristics, to produce sugar.

II. BACKGROUND

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Sucrose, $C_{12}H_{22}O_{11}$, a disaccharide, is a condensation molecule that links one glucose monosaccharide and one fructose monosaccharide. Sucrose occurs naturally in many fruits and vegetables of the plant kingdom, such as sugarcane, sugar beets, sweet sorghum, sugar palms, or sugar maples. The amount of sucrose produced by plants can be
20 dependent on the genetic strain, soil or fertilization factors, weather conditions during growth, incidence of plant disease, degree of maturity, or the treatment between harvesting and processing, among many factors.

Sucrose may be concentrated in certain portions of the plant such as the sugar beet
25 root or the stalks of the sugarcane plant. The entire plant, or a portion of the plant, in which the sucrose is concentrated can be harvested and the plant material processed to obtain a sugar process liquid containing an amount of sucrose. See for example, "Sugar Technology, Beet and Cane Sugar Manufacture" by P. W. van der Poel et al. (1998); "Beet-Sugar Technology" edited by R.A. McGinnis, Third Edition (1982); or "Cane
30 Sugar Handbook: A Manual for Cane Sugar Manufacturers and Their Chemists" by James C. P. Chen, Chung Chi Chou, 12th Edition (1993); and United States Patent Nos. 6,051,075; 5,928,42; 5,480,490, each hereby incorporated by reference herein.

Now referring to Figure 1, as non-limiting example, sugar beets (1) can be sliced into thin strips called "cosettes" (2). The cosettes (2) can be introduced a cosette mixer (3) through which a flow of sugar process liquid (4) passes. The cosettes (2) traverse the cosette mixer (3) counter current to the flow of the sugar process liquid (4) in the cosette mixer (3). As the cosettes (2) traverse the cosette mixer (3) a portion of the sucrose in the cosettes (2) transfers to the flow of sugar process liquid (3). The cosettes (2) and a portion of the sugar process liquid (4) can be transferred to a cosette slurry inlet (5) at the first end of a diffuser (6) while a diffusion liquid (7) enters at a diffusion liquid inlet (8) at the second end (8) of the diffuser. The cosettes (2) traverse the diffuser (7) counter current to the flow of diffusion liquid (8). Counter current diffusion of sugar beet cosettes (2) can transfer up to about ninety eight percent (98%) of the sucrose along with a variety of other materials from the cosette (2). The cosettes (2) are transferred from the diffuser (6) at the cosette slurry outlet (9) to a pulp press (10) in which liquid is squeezed from the cosettes (2). The liquid squeezed from the cosettes (2) is often referred to as "pulp press water" (11) can have a pH value of about 5 and is returned to the diffuser (6) at a pulp press water inlet (9) at the second end of the diffuser (6) to combine with the diffusion liquid (7). The flow of sugar process liquid (4) from the diffuser (6)(often referred to as "diffusion juice") returns the combined diffusion liquid (7), pulp press liquid (11), and other liquid(s) that may be introduced into the diffuser (6) to the cosette mixer (3). The flow of sugar process liquid (4) from the diffuser (6) may be split into two or more streams and other liquids may be combined into the flow of sugar process liquid (4) as it returns to the cosette mixer (3). The flow of sugar process liquid (4) entering the cosette mixer (3) traverses the cosette mixer (3) counter current to the cosettes (2). The sugar process liquid (4) transferred from the cosette mixer (3) is often referred to as "raw juice".

There are many alternative methods of transferring sucrose containing liquids from plant material. As a second non-limiting example (not shown by the figures), a diffusion process for sugarcane utilizes a moving bed of finely prepared sugarcane pieces passed through a spray of diffusion liquid to transfer sucrose (along with a variety of other materials) from the plant material into the diffusion liquid.

As a third non-limiting example, a milling process for sugar cane passes sugar cane stalks through rollers to squeeze sugar cane juice from the plant material. This

process may be repeated several times down a series of mills to ensure that substantially all the sugar cane juice is removed.

Regardless of the process or method utilized to transfer sucrose from plant material, the resulting sugar process liquid (4) contains sucrose, non-sucrose substances, and water. The non-sucrose substances may include all manner of plant derived substances and non-plant derived substances, including but not limited to: insoluble material, such as, plant fiber, soil particles, metal particles, or other debris; and soluble materials, such as, fertilizer, sucrose, saccharides other than sucrose, organic and inorganic non-sugars, organic acids (such as acetic acid, L-lactic acid, or D-lactic acid), dissolved gases (such as CO₂, SO₂, or O₂), proteins, inorganic acids, phosphates, metal ions (for example, iron, aluminum, or magnesium ions) or pectins; colored materials; saponins; waxes; fats; or gums; as to each their associated or linked moieties, or derivatives thereof.

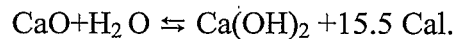
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Now referring to Figure 2, a gradual addition of base (13) to the sugar process liquid (4) raises pH from within a range of between about 5.5 pH to about 6.5pH up to a range of between about 11.5 pH to about 11.8pH. The rise in pH enables certain non-sucrose substances contained in the sugar process liquid (4) to reach their respective isoelectric points. This step is often referred to as "preliming" can be performed in a multiple cell preliher (14). The term "preliming" is not meant to limit the step of adding base to sucrose containing sugar process liquids (4) solely to those process systems that refer to this addition of base as "preliming". Rather, it should be understood that in the various conventional juice process systems it may be desirable to first utilize base to raise pH or sugar process liquid (4) prior to subsequent clarification or purification steps. The subsequent clarification and purification steps can involve a filtration step, as described by United States Patent Nos. 4,432,806, 5,759,283, or the like; an ion exchange step as described in British Patent No. 1,043,102, or United States Patent Nos. 3, 618, 589, 3,785,863, 4,140,541, or 4,331,483, 5,466,294, or the like; a chromatography step as described by United States Patent Nos. 5,466,294, 4,312,678, 2,985,589, 4,182,633, 4,412,866, or 5,102,553, or the like; or an ultrafiltration step as described by United States Patent No. 4,432,806, or the like; phase separation as described by United States Patent No. 6,051,075, or the like; or process systems that add active materials to the final carbonation vessel as described by United States Patent No. 4,045,242, each as an

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alternative to the conventional sugar process steps of "main liming" and "carbonation", each reference hereby incorporated by reference herein.

The term "base" involves the use of any material capable of raising pH of a juice
5 or sugar process liquids (4) including, but not limited to the use of lime or the underflow
from processes that utilize lime, such as calcium carbonate sludge (13) recovered after hot
liming and carbonation. The use of the term "lime" typically involves the specific use of
quick lime or calcium oxides formed by heating calcium (generally in the form of
limestone) in oxygen to form calcium oxide (15). Milk of lime is preferred in many juice
10 process systems, and consists of a suspension of calcium hydroxide ($\text{Ca}(\text{OH})_2$) in water
produced in a slaker (16) in accordance with the following reaction:



15 The term "iso-electric point" involves the pH at which dissolved or colloidal
materials, such as proteins, within the sugar process liquid (4) have zero electrical
potential. When such dissolved or colloidal materials reach their designated iso-electric
points, they may form a plurality of solid particles, flocculate, or flocs in the sugar
process liquid (4).

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Flocculation may be further enhanced by the addition of calcium carbonate
materials to juice, which functionally form a core or substrate with which the solid
particles or flocculates associate. This process increases the size, weight or density of the
particles, thereby facilitating the filtration or settling of such solid particles or materials
25 and their removal from the juice.

A conventional sugar process method further purifies the process liquids (4)
including residual lime, excess calcium carbonate, solid particles, flocculant, or floc, to
stabilize the floc or particles formed in the preliming step. A cold main liming step (not
30 shown in Figure 2) may involve the addition of about another 0.3-0.7% lime by weight of
prelimed sugar process liquids (4)(or more depending on the quality of the prelimed
juice) undertaken at a temperature of between about 30°C to about 40°C.

The cold main limed juice may then be hot main limed (17) to further degrade invert sugar and other components that are not stable to this step. Hot main liming (17) may involve the further addition of lime (18) to cause the pH of the limed juice to increase to a level of between about 12 pH to about 12.5 pH. This results in a portion of the soluble non-sucrose materials that were not affected by preceding addition of base or lime to decompose. In particular, hot main liming (17) of the sugar process liquid (4) may achieve thermostability by partial decomposition of invert sugar, amino acids, amides, and other dissolved non-sucrose materials.

After cold or hot main liming (17), the main limed sugar process liquid (4) can be subjected to a first carbonation step (18) in which carbon dioxide gas (19) can be combined with the main limed sugar process liquid (4). The carbon dioxide gas (19) reacts with residual lime in the main limed juice to produce calcium carbonate precipitate (13) or sludge. Not only may residual lime be removed by this procedure (typically about 95% by weight of the residual lime), but also the surface-active calcium carbonate precipitate (13) may trap substantial amounts of remaining dissolved non-sucrose substances. Furthermore, the calcium carbonate precipitate (13) may function as a filter aid in the physical removal of solid materials from the main limed (17) and carbonated juice (18).

The clarified sugar process liquid (4) obtained from the first carbonation step (18) may then be subjected to additional liming steps, heating steps, a second carbonation step (20), filtering steps, membrane ultrafiltration steps, chromatography separation steps, or ion exchange steps as above described, or combinations, permutations, or derivations thereof, to further clarify or purify the juice obtained from the first carbonation step resulting in a sugar process liquid (4) referred to as "thin juice".

Now referring to Figure 3, which provides a further non-limiting example, "thin juice" may be thickened by evaporation of a portion of the water content to yield a sugar process liquid (4) conventionally referred to as "thick juice". Evaporation of a portion of the water content may be performed in a multi-stage evaporator (21).

Now referring to Figure 4, as a non-limiting example, the thickened sugar process liquid (4) or "thick juice" mixed with other sugar process liquids ("thin juice", centrifugal

wash liquids and syrups) and remelted (22) (23) lower grade sugar crystals generated are transferred to a "white pan" (24). In the "white pan" (24), even more water is boiled off until conditions are right for sucrose or sugar crystals to grow. Because it may be difficult to get the sucrose or sugar crystals to grow well, some seed crystals of sucrose or sugar are added to initiate crystal formation. Once the crystals have grown the resulting mixture of crystals and remaining thickened sugar process liquid (4) can be separated in a "white centrifuge" (25). The thickened sugar process liquid (4) from the "white pan" is transferred to the "high raw pan" (26) for recrystallization. The "high raw sugar crystals" (27) generated in the "high raw pan" (26) are separated from the thickened sugar process liquid (4) by the "high raw centrifuge" (28) and returned to the "high melter" (22) to be combined with incoming "thick juice", while the thickened process liquid (4) from the "white pan" (24) is recrystallized in the "low raw pan" (29). The "low raw pan sugar crystals" (30) are returned to the "low raw melter" (23) to be combined with incoming "thick juice". The remaining thickened sugar process liquid (4) from the "low raw pan" (29) which is not recrystallized is referred to as "molasses".

The sugar crystals from the "white pan" (31) after separation from the thickened sugar process liquid in the "white centrifuge" can be washed ("high wash") (32) to generate the desired color. The "high wash" (32) from the "white centrifuge" contains a substantial amount of sucrose and is returned to the "high melter" (22). The separated sucrose or sugar crystals (33) are then transferred to a sugar dryer (34) to bring the sugar crystals (33) to obtain the desired moisture content.

As can be understood from the above non-limiting examples numerous types of sugar process liquids and sugar process products are generated by purification of sucrose containing liquid from plant material. Solids comprising the remaining plant material; solids separated from sugar process liquid during clarification, purification or refining; sugar or sucrose containing juices; crystallized sugar or sucrose; mother liquors from crystallization of sugar or sucrose; by products of the process system; and various combinations, permutations, or derivatives thereof, each having a level of impurities consistent with the process steps utilized in their production, or consistent with conventional standards for that type or kind of product produced, including, but not limited to: animal feeds containing exhausted plant material, such as, exhausted beet cossettes, pulp, or bagasse or other solids or juices separated from process liquids; solid

fuel which can be burned to generate steam for electrical power production, or to generate low pressure steam that can be returned to the sugar process system, or to generate low grade heat; syrup ranging from pure sucrose solutions such as those sold to industrial users to treated syrups incorporating flavors and colors, or those incorporating some
5 invert sugar to prevent crystallization of sucrose, for example, golden syrup; molasses obtained by removal of all or any part of the crystallizable sucrose or sugar, or products derived from molasses, one example being treacle; alcohol distilled from molasses; blanco directo or plantation sugars generated by sulfitation using sulfur dioxide (SO₂) as a bleaching agent; juggeri or gur generated by boiling sucrose or sugar containing juices
10 until essentially dry; juice sugar from melting refined white sugar or from syrup(s) which may be further decolorized; single-crystallization cane sugars often referred to as "unrefined sugar" in the United Kingdom or other parts of Europe, or referred to as "evaporated cane juice" in the North American natural foods industry to describe a free-flowing, single-crystallization cane sugar that is produced with a minimal degree of
15 processing; milled cane; demerara; muscovado; rapadura; panela; turbina; raw sugar which can be about 94-98 percent sucrose, the balance being molasses, ash, and other trace elements; refined sugars such as extra fine granulated having a quality based upon "bottlers" quality specified by the National Soft Drink Association being water white and at least 99.9 percent sucrose; specialty white sugars, such as, caster sugar, icing sugar,
20 sugar cubes, or preserving sugar; brown sugars that can be manufactured by spraying and blending white refined sugar with molasses which can be light or dark brown sugar depending on the characteristics of the molasses; or powdered sugar made in various degrees of fineness by pulverizing granulated sugar in a powder mill and which may further contain corn starch or other chemicals to prevent caking.

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This list is not meant to be limiting with respect to the products generated from the sucrose containing liquids obtained from plant material or subsequently generated sugar process liquids during purification, but rather, is meant to be illustrative of the numerous and varied products that can be generated by conventional sugar process
30 systems, including, but not limited to, the sugar process systems described above, and other sugar process systems not specifically described but understood inherently from the above description based upon the type of plant material processed or the final product obtained. Sugar process systems encompass numerous permutations and combinations of individual components or process steps which can result in the same or similar or

different sugar process products and by products. It is to be understood that the invention can be useful in each type or kind of sugar process system whether expressly or inherently described herein.

5 There is a competitive global commercial market for the products derived from sugar process systems. Because the market for sugar and by products of sugar process systems are vast, even a slight reduction in the cost of sugar or a by product can yield a substantial and desired monetary savings. While this strong commercial incentive has been coupled to a long history of sugar production of at least 1000 years, and specifically
10 with regard to production of sugar from sugar beets for which commercial process systems have been established 100 years, there remain significant unresolved problems related to the production of sugar.

 A significant problem related to the production of sugar can be the amount of
15 organic acids and inorganic acids in sugar process liquids. When plant cell juice (3) contains sufficient cations, hydroxide ion (OH^-) can act as a anion, which enables carbon dioxide (CO_2) to dissolve into the juice (3) as carbonate ions (CO_3)⁻², or as bicarbonate ions HCO_3^- . The dissociation of HCO_3^- provides a very weak acid. However, when juice (3) contains an insufficient number of cations to allow dissolved CO_2 to form carbonate
20 or bicarbonate ions, an equilibrium results between carbon dioxide and carbonic acid H_2CO_3 . Carbonic acid can act as a strong acid in the pH range at which sugar process liquid (4) are processed.

 Similarly, sulfur dioxide (SO_2) or ammonium bisulfite (NH_4HSO_3) may be
25 introduced into the sugar process liquid (4) to control, reduce, or eliminate microbiologic activity, sucrose hydrolysis, formation of invert sugars, or loss of sucrose, or to adjust pH lower. Again, when sugar process liquid (4) contains sufficient cations, such as calcium, sulphites, such as calcium sulfite can result. However, when juice contains an insufficient number of cations to allow dissolved sulfur dioxide (SO_2) to form sulphites, an
30 equilibrium results between sulfur dioxide (SO_2), sulfurous acid (H_2SO_3), and sulfuric acid (H_2SO_4). Sulfuric acid and sulfurous acid can also act as strong acids.

 Additionally, other inorganic and organic acids can be generated by the plant during normal growth and other acids are generated by microbial activity including, but

not limited to: acetic acid; carbonic acid; propanonic acid; butanoic acid; pentanoic acid; phosphoric acid; hydrochloric acid; sulfuric acid; sulfurous acid; citric acid; oxalic acid; succinic acid; fumaric acid; glycolic acid; pyrrolidone-carboxylic acid; formic acid; butyric acid; maleic acid; 3-methylbutanoic; 5-methylhexanoic; hexanoic acid; or a
5 heptanoic acid, individually or in various combinations and concentrations

Inorganic acids and organic acids contained within the sugar process liquids (4) lower pH of the sugar process liquids and must be neutralized with base. The higher the concentration of organic acids or inorganic acids within the sugar process liquids (4), the
10 greater the amount of base that may be necessary to raise the pH of the juice to a desired value in the preliner (14) or other step prior to subsequent purification steps.

As discussed above, calcium oxide (15) or calcium hydroxide may be added to sugar process liquid (4) to raise the pH allowing certain dissolved materials to come out
15 of solution as solids, flocculent, or flocs. Calcium oxide is typically obtained through calcination of limestone a process in which the limestone is heated in a kiln in the presence of oxygen until carbon dioxide is released resulting in calcium oxide. Calcination can be expensive because it requires the purchase of a kiln, limestone, and fuel, such as gas, oil, coal, coke, or the like, which is combusted to raise the temperature
20 of the kiln sufficiently to release carbon dioxide from the limestone. Ancillary equipment to transport the limestone and the fuel to the kiln and to remove the resulting calcium oxide from the kiln must also be provided along with equipment to scrub certain kiln gases and particles from the kiln air exhausted during calcination of the limestone.

25 Additionally, calcium oxide generated by calcination must be converted to calcium hydroxide for use in conventional sugar process systems. Again this involves the purchase of equipment to reduce the calcium oxide to suitably sized particles and to mix these particles with water to generate calcium hydroxide.

30 Another problem related to the use of base in conventional process systems can be disposal of precipitates, flocs, and calcium carbonate formed in liming and carbonation steps. When the sugar process system uses one or more carbonation steps (18)(20) in clarifying or purifying juice, the amount of calcium carbonate or other salts formed, often referred to as "sludge", "spent lime", or "carbonation lime" (13), will be proportionate to

the amount of lime (15) added to sugar process liquids (4). Simply put, the greater the amount of lime (15) added to the sugar process liquids (4), the greater the amount of "spent lime" (13) formed during the carbonation steps. The "spent lime" (13) may be allowed to settle to the bottom of the carbonation vessel (18)(20) forming what is sometimes referred to as a "lime mud". The "lime mud" or "spent lime" (13) can be separated by a rotary vacuum filter (34) or plate and frame press. The product formed is then called "lime cake"(35). The lime cake (35) or lime mud may largely be calcium carbonate precipitate but may also contain sugars, other organic or inorganic matter, or water. These separated precipitates are almost always handled separately from other process system wastes and may, for example, be slurried with water and pumped to settling ponds or areas surrounded by levees or transported to land fills.

Alternately, the carbonation lime, lime mud, or lime cake can be recalcined. However, the cost of a recalcining kiln and the peripheral equipment to recalcine spent lime (13) can be substantially more expensive than a kiln for calcining limestone. Furthermore, the quality of recalcined "carbonation lime" can be different than calcined limestone. The purity of calcined limestone compared to recalcined carbonation lime may be, as but one example, 92% compared with 77%. As such, the amount of recalcined lime required to neutralize the same amount of hydronium ion in juice may be correspondingly higher. Also, the carbon dioxide content of spent lime can be much higher than limestone. As such, not only can recalcined lime be expensive to generate, it can also require the use of substantially larger gas conduit and equipment to transfer the generated CO₂ from recalcining spent lime, larger conveying equipment to move the recalcined lime, larger carbonation tanks, or the like. Whether spent lime (13)(35) is disposed of in ponds, landfills, or by recycling, the greater the amount of lime (15) utilized in a particular process system, generally the greater the expense of disposing the spent lime.

Another significant problem with conventional sugar process systems may be an incremental decrease in sugar process system throughput corresponding with an incremental increase in the amount of lime (15) used in processing sugar process liquid (4). One aspect of this problem may be that there is a limit to the amount of or rate at which lime (15) can be produced or provided to sugar process steps. As discussed above, lime stone must be calcined to produce calcium oxide (15) prior to its use as a base in

sugar process systems. The amount of lime (15) produced may be limited in by availability of limestone, kiln capacity, fuel availability, or the like. The rate at which lime (15) can be made available to the sugar process system may vary based on the size, kind, or amount of the lime generation equipment, available labor, or the like. Another
5 aspect of this problem can be that the amount of lime (15) used in the sugar process system may proportionately reduce volume available for sugar process liquid (4) in the sugar process system. Increased use of base, such as lime (15), may also require the use of larger containment areas, conduits, or the like to maintain throughput of the same volume of juice.

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Another significant problem with conventional sugar process systems, can be limesalts in sugar process liquid (4) which are not precipitated during the steps of preliming (123), mainliming (17), and carbonation (18)(19), but none-the-less, must be removed from sugar process liquid (4) prior to evaporation of water from "thin juice" to
15 prevent or reduce scale formation in the evaporator. For example, oxalate the calcium salt of oxalic acid often forms the main component of scale remains in sugar process liquids (4) after carbonation. However, "thin" or "thick" sugar process liquids can contain sufficient calcium to force oxalate out of solution as water is evaporated. The process of removing scale from the surfaces of equipment can be expensive, including, but not
20 limited to, costs due to production slowdowns and efficiency losses, or the reduction in the effective life of equipment.

To remove limesalts prior to evaporation steps (21) to affect a reduction of scale deposition in the evaporators (21), sugar process liquids (4) can be passed through an
25 anion exchanger (34) which binds calcium ion to anion exchange resin in exchange for the release of two sodium ions which are transferred to the sugar process liquids (4) (certain conventional process systems do not remove limesalts prior to evaporation). The calcium ion bound to the anion exchange resin is released by periodic washing of the column with a regenerate (35) such as sodium hydroxide solution or sulfuric acid solution
30 depending on the type of exchange resin. The spent regenerant (35) primarily made up of calcium ion and hydroxide ion in solution (when sodium hydroxide in solution is utilized as a regenerate) has a high pH and can be recycled prelimer (14) to supplement to the milk of lime (18). This can be a benefit by reducing the amount of milk of lime (18) needed to increase pH of the sugar process liquid (4) in the prelimer (14) to achieve a pH

in the range of 11.5 to 11.8. However, when limesalts increase the amount of spent regenerant (35) produced also increases and can cause problems in balancing the preliner (14) to operate consistently. Shifts in alkalinity and pH in the preliner (14) can result in poor removal of non-sucrose materials and higher limesalts which in turn requires more frequent regeneration of the anion exchanger. All of which add cost to the production of sugar.

Another significant problem with conventional sugar process systems can be the amount of other organic compounds in the sugar process liquid (4). These organic compounds can without limitation include: acetaldehydes; ethanol; acetone; dimethylsulfide; 2-propenenitrile; methyl acetate; isopropanol; 2-methyl propanal; methacrolein; 2-methyl-2-propanol; propanenitrile; 1-propanol; 2-butanone; 2,3-butanedione; ethyl acetate; 2 butanol; methyl propanoate; 2- butanal; 3-methylbutanal; 3-methyl-2-butanone; isopropyl acetate; 2-methyl butanal; 1-butanol, 2-butenenitrile; 2-pentanone; 2,3-pentanedione; ethyl propanoate; propyl acetate; 3-methyl butanenitrile; methyl isobutyl ketone; 2-methyl-2-butenal; 3 methyl-1-butanol; isopropyl propanoate; isobutyl acetate; 2-methyl-3-pentanol; 2,3-hexanedione; 2-hexanone; ethyl butanoate; butyl acetate; 4-methyl pentanenitrile; 2-hexenal; 3-methyl-1-butanol acetate; 3-heptanone; 2-heptanone; 5-hepten-2-one; heptanal; 3-octene-2-one; 2-heptenal; 3-octanone; butyl butanoate; 2-methoxy-3-isopropyl pyrazine; 2-methoxy-3-(1-methylpropyl)pyrazine; alcohols; aldehydes; ketones; volatile acids; carbon monoxide; carbon dioxide; sulfur dioxide; esters; nitriles; sulfide; pyrazine;.

Certain organic compounds can be highly colored or are the precursors to colored compounds which can be generated as pH and temperature of the sugar process liquids (4) are elevated during prelining (14) and hot main liming (17). A sugar process system as above-described processing about 8,500 tons per day of sliced sugar beets, with thin juice color at about 4,000 reference base units (RBU) produces a final white sugar color of about 43 RBU. To achieve a "standard" white sugar color of at least 40 RBU the "white centrifugal wash" (32) must be adjusted to bring the color of the "white pan" sugar crystals (33) from 43 RBU to 40 RBU. Adjustment of the centrifugal wash (32) to reduce color also reduces the amount of sugar (33) produced by about 0.65 tons/hour.

Another significant problem with conventional sugar processing systems may be low purity of sugar process liquids (4) expressed as a percent ratio of sugar to total dry solids of sugar process liquid (4). Typically, the higher the concentration of total dry solids in sugar process liquid (4), including any of the above-described materials or other materials, relative to the amount of sucrose in the sugar process liquid (4), the less desirable the sugar process liquid (4). Understandably, any decrease in the total dry solids relative to sucrose in the sugar process liquid (4) yields a comparatively better juice for subsequent purification.

Soluble non-sucrose materials in sugar process liquid (4) can interfere with subsequent processing or purification steps or adversely impact the quality or quantity of the resulting sugar or other products produced. It has been estimated that on average each pound of soluble non-sucrose substances reduces the quantity of sugar produced by one and one-half pounds. As such, it may be desirable to have all or a portion of these soluble non-sucrose substances separated from or removed from the sugar process liquids (4). For example, in the sugar process system above described, a thin juice color of about 2,500 RBU with a "thin juice" purity of about 92.00 can produce about 57 tons of white sugar per hour at 30 RBU. If "thin juice" purity can be increased to about 92.40 white sugar yield can be increased by 0.54 tons per hour.

The present invention provides a sugar process system involving both apparatuses and methods that address each of the above-mentioned problems.

III. DISCLOSURE OF INVENTION

Accordingly, a broad object of the invention can be to provide a sugar process system

A first aspect of this broad object can be to provide an entire sugar process system, including both apparatus and methods, to generate products from sucrose containing liquids or sugar process liquids. A second aspect of this broad object can be to provide apparatus and methods of conditioning sugar process liquid compatible with conventional sugar process system methods. As to this second aspect, the invention can provide method steps or apparatus, individually or in combination, that can be further

added to, replace, or modify conventional methods and apparatus used to process sugar process liquids or other sucrose containing liquids.

A second broad object of the invention can to reduce the cost of generating
5 products from sugar process liquids or other sucrose containing liquids. One aspect of this object of the invention can be to increase sugar process liquid throughput that may be, in whole or in part, limited by availability of base, such as a reduced availability of limestone or the a lack of capacity to convert limestone to calcium oxide, or the like. Another aspect of this object of the invention can be to provide a cost savings by reducing
10 the amount of base, such as lime, that has to be used to process sucrose containing liquids or juice into products. A third aspect of this object of the invention can be to reduce the amount of waste generated, such as a reduction in the amount of spent lime.

A third broad object of the invention can be to provide a conditioned sugar
15 process liquid having characteristics which are more desirable with respect to subsequent process or purification steps or which yield a greater amount of sugar per ton of plant material. One aspect of this object of the invention can be to provide a conditioned sugar process liquid having a reduced amount or reduced concentration of non-sucrose materials relative to the concentration of sucrose. The conditioned sugar process liquid
20 can have a reduced concentration of organic or inorganic acids (such as acetic acid, D-lactic acid, L-lactic acid, propionic acid, citric acid, hydrochloric acid, sulfuric acid, or the like), volatile organic compounds (such as alcohol), dissolved gases (such as, CO₂ or SO₂), ammonia, or the like. A second aspect of this object of the invention can be to provide a conditioned sugar process liquid that has a higher pH value after treatment in
25 accordance with the invention (whether or not base was added to the juice prior to treatment). A third aspect of this object of the invention can be to provide a conditioned sugar process liquid that has a higher pH even when an amount of base, such as lime, or the underflow from conventional processing of juice, or the like, has been added prior to treatment in accordance with the invention. A fourth aspect of this object of the invention
30 can be to provide a conditioned sugar process liquid that has a reduced capacity to generate hydronium ion. A sixth aspect of this object of the invention can be to provide a conditioned sugar process liquid that requires less base to raise the pH to a desired value, iso-electric focus dissolved material(s), perform preliming or main liming steps in conventional process systems, degrade invert sugars, or otherwise generate products from

sucrose containing liquids or juices. A seventh aspect of this object of the invention can be to provide a conditioned sugar process liquid with a higher concentration of oxidized material after treatment in accordance with the invention. An eighth aspect of this object of the invention can be to provide a conditioned sugar process liquid which upon addition
5 of lime and subsequent addition of carbon dioxide to yields a sugar process liquid having a lower concentration of dissolved solids relative to the concentration of sucrose as compared to the same juice not treated in accordance with the invention.

A fourth broad object of the invention can be to provide methods and apparatus
10 that reduce the amount or concentration of non-sucrose material in juice obtained from plant material by conventional juice extraction procedures such as pressing, milling, or diffusion. One aspect of this object of the invention can be to provide a method of reducing the amount or concentration of non-sucrose material in sugar process liquid without the addition of base, prior to the addition of base, or after the addition of base. A
15 second aspect of this object of the invention can be to provide a method of conditioning sugar process liquids that can be used prior to, in conjunction with, or after the addition of base to reduce the amount or concentration of non-sucrose material. A third aspect of this object of the invention can be to provide a method that assists in reducing the amount or concentration of non-sucrose material in sucrose containing liquid or juice. A fourth
20 aspect of this object of the invention can be to provide a method of reducing non-sucrose material sugar process liquid or juices compatible with conventional juice clarification or purification methods, including but not limited to, preliming, main liming, ion exchange, or filtering, as above described.

A fifth broad object of the invention can be to provide various apparatuses that
25 inject, introduce, or otherwise mix an amount of gas having desired partial pressures with sugar process liquid obtained from plant material. One aspect of this object of the invention can be to provide an apparatus to introduce a mixture of gases into sugar process liquids to provide a mixed stream of sugar process liquid and gas having a desired
30 partial pressures.

A sixth broad object of the invention can be to provide various apparatuses and methods to increase the interface area of sugar process liquids mixed with a gas having

desired partial pressures, or a desired mixture of gases to effect mass transfer of non-sucrose materials from the sugar process liquid.

5 A seventh broad object of the invention can be to provide various apparatuses and methods to separate or remove mixtures of gases which are in partial or complete equilibrium with the vapor pressures of non-sucrose material, or partial pressures of gases contained by or dissolved in sugar process liquids.

10 An eighth broad object of the invention can be to provide various apparatuses and methods to oxidize non-sucrose materials within juice

Naturally, further objects of the invention are disclosed throughout other areas of the specification and drawings.

15 IV. BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 provides a diagram illustrating a conventional process system for the diffusion and pulp pressing of sugar beet cosettes to obtain a raw juice.

20 Figure 2 provides a diagram illustrating a conventional process system for purification of raw juice obtained from the diffusion and pulp pressing of sugar beet cosettes as illustrated in Figure 1.

25 Figure 3 provides a diagram illustrating a conventional process system for evaporation of water from thin juice produced by the purification system illustrated in Figure 2.

Figure 4 provides a diagram illustrating a conventional process system for crystallization of thick juice produced from the evaporation system illustrated in Figure 3.

30

Figure 5 provides a diagram of a particular embodiment of aeration chamber and vacuum chamber components of the sugar process system invention.

Figure 6 provides a diagram which illustrates a method of purification in accordance with the invention.

Figure 7 provides a diagram which illustrates a method of evaporation in accordance with the invention.

Figure 8 provides a diagram which illustrates a method of crystallization of sucrose in accordance with the invention.

V. MODE(S) FOR CARRYING OUT THE INVENTION

As can be understood from the description of the methods and apparatus relating to the invention below, the invention provides a sugar process system which conditions sugar process liquid to alter various sugar process liquid characteristics which affect the quality and the quantity of sugar produced.

Referring now primarily to Figure 5, a non-limiting embodiment of the invention which can be utilized for the production of sugar from sugar beets (other sugar process liquids obtained from other types of plant material), can include an aeration chamber (36) which receives sugar process liquids (4) from the cossette mixer (3). A sugar process liquid transfer means (40), such as a pump or gravity, allows transfer of sugar process liquids (4) from the cossette mixer (3) to the aeration chamber (36) at a desired volume and pressure (step 1020). The aeration chamber (36) can be configured to provide a containment zone (37) having a boundary limited by the interior configuration of the aeration chamber (36). An amount of sugar process liquid (4) can be passed through the containment zone (37) coincident to passing an amount of at least one gas (38) through the containment zone (37)(step 1130). By passing an amount of at least one gas (38)(a mixture of gases or desired partial pressure of gases) through the containment zone (37) coincident with an amount of sugar process liquid (4), materials transferable from the sugar process liquid (4) move toward equilibrium with the amount of gas (38) (step 1140). The amount of gas (38) passing through the containment zone can be separated from the amount of sugar process liquids (4) passing through the containment zone (37) (step 1150) and can be transferred from the aeration chamber (38) (step 1080).

Transferable non-sucrose materials are distributed between the amount of gas (38) and the sugar process liquid (4)(step 1030). As such, a portion of transferable non-sucrose materials transferred will be transferred to the amount of gas (38) and transferred from the aeration chamber (36)(step 1080) while a certain portion of the non-sucrose materials will remain in the sugar process liquid (4) as shown by step (1040) and step (1050). The process of transferring a portion of the non-sucrose materials from the sugar process liquid (4) results in an amount of heat lost from the sugar process liquid (4)(step 1160).

The term "sugar process liquid" should be understood to broadly encompass any sucrose containing liquid regardless of the manner obtained or the proportion of sucrose to non-sucrose substances or water which can occur in various proportions depending upon the quality or kind of plant material, the materials associated with the plant material, or the methods or steps used to process the plant material. As such, the term "sugar process liquid" may be used as a generic term to identify sucrose containing liquids obtained from a variety of plant materials by milling or pressing steps; sucrose containing liquids obtained from a variety of plant materials by diffusing the plant material with another liquid; sucrose containing liquids obtained or resulting from various sugar production process steps for the clarification or purification of liquids obtained by milling or diffusion; or sucrose containing liquids specifically defined by terms of art utilized in the sugar production industry such as "raw juice", "diffusion juice", "diffusion liquids", "limed juice", "thin juice", "thick juice", "carbonation juice", or the like.

The term "gas" broadly encompasses without limitation a purified gas, such as oxygen, nitrogen, helium, ozone, carbon dioxide, neon, krypton; or a mixture of gases such as air, atmospheric gases, atmosphere, a mixture of gases containing an amount of ozone greater than atmosphere, a mixture of gases containing an amount of oxygen greater than atmosphere, a mixture of gases containing an amount of nitrogen greater than atmosphere, a mixture of gases containing an amount of hydrogen peroxide greater than atmosphere, a mixture of gases containing an amount of carbon dioxide greater than atmosphere, a mixture of gases containing an amount of argon greater than atmosphere, a mixture of gases containing an amount of helium greater than atmosphere, a mixture of gases containing an amount of krypton greater than atmosphere, a mixture of gases containing an amount of ozone less than atmosphere, a mixture of gases containing an amount of oxygen less than contained in atmosphere, a mixture of gases containing an

amount of nitrogen less than atmosphere, a mixture of gases containing an amount of hydrogen peroxide less than atmosphere, a mixture of gases containing an amount of carbon dioxide less than atmosphere, a mixture of gases containing an amount of argon less than atmosphere, a mixture of gases containing an amount of helium less than atmosphere, a mixture of gases containing an amount of krypton less than atmosphere, or the like; or a gas or mixture of gases that have been passed through one or more filters to reduce, or to substantially eliminate, non-biological particulate or biological particles (such as bacteria, viruses, pollen, microscopic flora or fauna, or other pathogens); a gas or a mixture of gases that have been passed through chemical scrubbers or otherwise processed to generate a desired concentration or range of concentrations of partial pressures of gases; or combinations or permutations thereof.

Gas filter(s) (not shown) responsive to a flow of gas can comprise a Hepa filter, or a Ulpa filter, or other type of macro-particulate or micro-particulate filter. For example, an unfiltered gas or mixture of gases can be drawn into a first stage prefilter, then through a second stage pre-filter, if desired, and then through a gas flow generator (7). The prefiltered mixture of gases can then flow through a gas filter (Hepa filter, or Ulpa filter, or other type of filter). The resulting filtered gas or filtered mixture of gases can be up to 99.99% free of particles as small as about 0.3 microns when a Hepa filter is used, and up to 99.99% free of particles as small as about 0.12 microns when a Ulpa filter is used.

Again referring primarily to Figure 5, the amount of gas delivered to the flow of sugar process liquid (4) (step 1130) can be transferred through a gas inlet (39) which terminates in a single or a plurality of aperture elements (not shown in Figure 5). A gas flow generator (40) can be adjusted to generate sufficient gas pressure to deliver the desired amount of at least one gas (38) into the flow of sugar process liquid (4) which passes through the containment zone (37).

The flow of sugar process liquid (4) which passes through the containment zone can be a continuous flow of sugar process liquid, or responsive to a sugar process liquid flow adjustment means, such as a valve, variable flow restrictor, or regulator (mechanical or electronic) coupled to the sugar process liquid transfer means (40) whereby a continuous, intermittent, or pulsed flow of sugar process liquid (4) can be established to

increase or decrease the duration of time the flow of sugar process liquid (4) remains in the containment zone (37).

As to certain embodiments of the aeration chamber, a sugar process liquid distribution element (41) can divide the flow of sugar process liquid (4) to create a plurality of streams which pass through the containment zone (37). As to certain sugar process liquid distribution elements (41) (as a non-limiting example, nozzles manufactured by BEX Incorporated, 37709 Schoolcraft Road, Livonia, Michigan) the plurality of streams of sugar process liquid (4) can be directed to converge which further disperses the streams in the containment zone (37). The flow of sugar process liquid (4) can be further divided to generate a plurality of droplets which pass through the containment zone (37). Understandably, the smaller the droplets (whether individually or on average) generated by the juice distribution element (41) the greater the cumulative surface area of the sugar process liquid (4) presented to the amount of at least one gas (38) delivered into the containment zone (37). Understandably, the amount of gas (38), the amount of sugar process liquid (4), the dispersion pattern of the sugar process liquid (4), the amount of cumulative surface area, and heat loss (step 1160) can be adjusted to establish the rate at which transferable non-sucrose materials move toward equilibrium with the amount of gas (38) (step 1140). The sugar process liquid (4) received at the outlet of the aeration chamber (step 1050) can have various sugar process liquid characteristics altered to obtain certain desired affects in subsequent processing steps as described below.

Again referring primarily to Figure 6, a non-limiting embodiment of the invention which can be utilized for the production of sugar from sugar beets, can include a vacuum chamber (42) independent of or in combination with the aeration chamber (36) to condition sugar process liquids (4). Sugar process liquid (4) introduced into the vacuum chamber (42) can pass through a reduced pressure zone (43) generated by reducing partial pressures of gases in the vacuum chamber (step 1090) with a pressure reduction means (44). The reduction in partial pressures of gases in the vacuum chamber (42) can increase the vapor pressure of non-sucrose materials (certain of which are above-described as organic and inorganic materials)(step 1170). By increasing the vapor pressure of transferable non-sucrose materials an amount of non-sucrose material can be separated from the sugar process liquids (4)(step 1080) and transferred from the vacuum chamber

(step 1110). A portion of the non-sucrose material returns to the sugar process liquid (step 1070) and the conditioned sugar process liquid is transferred from the vacuum chamber (step 1100). The sugar process liquid received at the outlet of the vacuum chamber (step 1100) can have various sugar process liquid characteristics altered to
5 obtain certain desired affects in subsequent processing steps as described below.

In similar fashion to that described for the aeration chamber (36), the flow of sugar process liquid in the vacuum chamber (42) can be dispersed or further divided to increase the surface area of the sugar process liquid (4) on which the reduced partial
10 pressures of gases within the evacuation zone (43) can act. The vacuum chamber (42) whether a single chamber or multiple vacuum chambers in serial or parallel can be used independent of the aeration chamber, or used with the aeration chamber or multiple aeration chambers whether in serial or in parallel to condition a sugar process liquid.

15 A first characteristic of the sugar process liquid (4) that can be altered by conditioning sugar process liquids (4) through the various embodiments of the aeration chamber (36), or the vacuum chamber (42), or both in various combinations or permutations, can be pH. The pH of the sugar process liquid (4) can be increased by about 0.01 pH units, about 0.05 pH units, about 0.1 pH units, about 0.2 pH units, about
20 0.3 pH units, about 0.4 pH units, about 0.5 pH units, about 0.6 pH units, about 0.7 pH units, about 0.8 pH units, about 0.9 pH units, about 1.0 pH units, about 1.1 pH units, about 1.2 pH units, about 1.3 pH units, about 1.4 pH units, about 1.5 pH units, about 1.6 pH units, about 1.7 pH units, about 1.8 pH units, about 1.9 pH units, or about 2.0 pH units.

25

The increase in pH of the sugar process liquids prior to preliming (13) can affect the demand of the sugar process liquid (4) for base, such as lime (15), to achieve a necessary or desired pH, concentration of hydronium ion, or acidity as compared to unconditioned sugar process liquid (4) or conventionally processed sugar process liquid
30 (4). The amount of lime added after conditioning of the sugar process liquid (4) in accordance with the invention can be substantially less to establish a desired pH value, such as, between about 11.0 to about 12.0, or between 11.5 to about 12.5, or the range of pH used to "prelime", "main lime", "intermediate lime, or to establish a pH value corresponding to the iso-electric point of any particular non-sucrose material in the sugar

process liquid (4), or required to adjust the acidity or alkalinity of the juice to a desired concentration. As a non-limiting example, sugar process liquid (4) conditioned as above-described, can exhibit a reduced lime demand of up to 30%. Now referring primarily to Figure 2, if a 30% reduction in lime demand can be achieved a savings of \$708.00 per day (\$141,163.00 over a 200 day campaign) could be achieved.

A second characteristic of the sugar process liquid (4) that can be altered by conditioning sugar process liquids (4) through the various embodiments of the aeration chamber (37), or the vacuum chamber (43), or both in various combinations or permutations, can be color. Importantly, even a minor reduction in "thin juice" color can substantially increase the amount of white sugar (33) produced from a ton of sugar beets or sugar cane, or per unit of process liquid (4).

In certain embodiments of the invention, materials which generate color in sugar process liquids (4) or in sugar (33) can be transferred from the flow of sugar process liquid (4) as it passes through the aeration chamber (36) or the vacuum chamber (42) (steps 1150, 1040, 1060, and 1070). The removal of these color generation materials correspondingly reduces the amount of color generated in the conditioned sugar process liquid (4), introduces a conditioned sugar process liquid (3) with less color in subsequent sugar process steps, and can result in less color in sugar crystals (33)(27)(30). In this regard and referring now to Example 4, Table 4, as a non-limiting example, color generation materials such as 2,3 butanedione and 2-butanone can be removed from the flow of sugar process liquid (4) as it passes through the containment zone (37) of the aeration chamber (36). These materials are known to generate color in juice and removal can reduce juice color and sugar (33) color.

In other embodiments of the invention, the molecular structure of certain materials contained in the sugar process liquids (4) can be oxidized by conditioning the sugar process liquid (4) in accordance with the invention. The corresponding oxidized forms of certain materials may generate less color or generate no color in sugar process liquid (4) or in the resulting sugar (33). As a non-limiting example, primary alcohols can be converted to the corresponding aldehydes or carboxylic acids.

With respect to certain embodiments of the invention the amount of gas (38) or partial pressures of gases can be adjusted to include or increase the amount of an oxidant in the gas (38) delivered to the containment zone (37) of the aeration chamber (36) including, but not limited to, oxygen, ozone, peroxide, air stripped of certain partial pressures of gases, or an amount of oxidant capable of converting primary alcohols to corresponding aldehydes or carboxylic acids. A separate oxidant flow generator (45) can be used to disperse oxidant(s) into the flow of sugar process liquid (4) which passes through the containment zone (37).

Now referring to Figures 2 and 6, a conventional sugar process system can be compared with a sugar process system in accordance with the invention. A conventional sugar process system processing about 335 tons of sugar beet cosettes (2) per hour (see Figure 1) can have a "thin juice" color after the second carbonation (20) of about 3,414 RBU (see Figure 2). A sugar process system which further includes an aeration chamber (37) and a vacuum chamber (42) in accordance with the invention processing the same tonnage of sugar beet cosettes can produce a "thin juice" after the second carbonation (20) of about 2,911 RBU (see Figure 6). Under these conditions the conventional sugar process system achieves a final white sugar color of 37 RBU (see Figure 4) while the sugar process system in accordance with the invention achieves a final white sugar color of 34 RBU. In the conventional sugar process system as described above, "thin juice" having color greater than 3,000 RBU can result in a loss of up to \$12,000.00 per day in sugar loss, sugar recovery and energy with every 500-1000 RBU increase in sugar process liquid color.

As a further example, a conventional sugar process system operating at about 8,500 tons per day of sliced sugar beets, with thin juice color at about 4,000 RBU produces a final white sugar color of about 43 RBU. To achieve a "standard" white sugar color of 40 RBU the centrifugal wash procedure must be adjusted to reduce the recycle of sugar at the sugar end. This results in more sugar to washed out and ultimately into molasses reducing sugar yield by about 0.65 tons/hour.

Additionally, a centrifugal wash (32) or a longer centrifugal wash of sugar crystals (33) in the "white centrifuge" (25) results in less sugar end capacity and reduces

throughput of sugar process liquid (4). Moreover, a reduction in color of sugar process liquids can result in lower color molasses for desugarization with increased extract yield.

5 A third characteristic of the sugar process liquid (4) that can be altered by conditioning sugar process liquid (4) with the aeration chamber (36), or the vacuum chamber (42), or both, in various permutations or combinations, can be concentration of limesalts. Because conditioning of sugar process liquid (4) in accordance with the invention removes certain anions, "raw juice" forms few limesalts to be carried forward into carbonation steps (18)(19). As described above, limesalts may not precipitate during
10 the steps of preliming (14), mainliming (17), or carbonation (18)(19) because the solubility of such salts in sugar process liquid (4).

When limesalts are not removed prior to the evaporators (21), precipitates of limesalts can form on the surface of evaporators (21) as water is removed from sugar
15 process liquid (4). Boiling out evaporators (21) to remove scale can be costly because of the labor and equipment involved to perform the procedure. The removal of scale from evaporators and associated equipment can also result in additional days to the sugar process campaign.

20 Limesalts or sodium salts when limesalts are exchanged carry sucrose to molasses. For example, when limesalts are removed from sugar process liquid (4) by ion exchange and replaced with the corresponding sodium salts during regeneration (sodium salts recycled into liming steps as described above) each pound of sodium salt can carry between about 0.9 pound and about 1.5 pounds of sucrose to molasses. If limesalts are
25 reduced by 25 parts per million, additional sugar (33) produced per day (about 0.56 tons at a 8,000 ton slice rate per day of sugar beets) has a value of about \$246.40 at \$22.00 per hundred weight. At 200 parts per million in the same process system a savings of about \$2000.00 can be achieved per day.

30 Additionally, as the part million limesalts are reduced there is a corresponding reduction in caustic used to regenerate the ion exchange resin. For sugar process liquid (4) generated from a beet slice rate of 8,000 ton per day with a 25 ppm reduction in limesalts achieved in accordance with the invention the corresponding reduction in

caustic saves about \$142.00. If a reduction in limesalts of 200 ppm can be achieved in the same system about \$2,000.00 can be saved.

Moreover, the more frequent regeneration of the anion exchange resin further
5 slows the sugar end of conventional sugar process systems.

A fourth characteristic of the sugar process liquid (4) that can be altered by conditioning sugar process liquid (4) with the aeration chamber (36), or the vacuum chamber (42), or both, in various permutations or combinations, can be purity. Purity as a
10 percent relates the amount of sucrose in sugar process liquids to the amount of soluble non-sucrose materials in sugar process liquid.

As discussed above, there can be a significant reduction in the amount of volatile inorganic materials and organic materials when "raw juice" is conditioned in accordance
15 with the invention. The reduction in these non-sucrose materials by transferring them to atmosphere (steps 1080 and 1100) can increase purity of sugar process liquids (4) from the cossette mixer in the range of about 0.2% and about 0.4% and can increase purity of thin juice in the range of between about 0.15% and about 0.35%. This increase in purity corresponds to an increase in sugar (33) production of between about 1 pound and 3
20 pounds per ton of sugar beets sliced. For a sugar process system in accordance with the invention having a slice rate of 8000 pounds per day a savings of between about \$1,500.00 and about \$5,000.00 a day can be achieved.

Additionally, the same purity of thin juice can be achieved at greater throughput in a sugar process system in accordance with the invention. Colloidal particles, or other
25 particles, in sugar process liquid (4) can be contaminated by electrostatic adsorption of ions to the surface. This primary adsorption layer can give rise to a substantial surface charge (electric potential at the surface). This surface charge can cause a repulsion to exist between two particles when they approach each other and can also attract counter ions into the vicinity of the particle.

30 Thus, the colloidal or other particles can have a charged surface with an associated "ion cloud" which extends into the sugar process liquid (4) some distance away from particles to balance the surface charge. The thickness of this ion cloud around the particle

determines how close two particles can get to each other before they start experiencing repulsive forces. The size of this "ion cloud" depends on the magnitude of the surface charge which depends on the solution concentration of the adsorbing ion, and the concentration of electrolyte in solution.

5 The volume defined by the entire ion cloud surrounding a particle and that defined by the slip plane for a particle are not the same things. The counter-ion layer thickness is the thickness of the solution layer around the particle that is required so as to contain enough counter-ions to "balance" the surface charge, while the slip plane involves the thickness of the solvent/ion film which moves with the particle.

10 Zeta potential (ζ) is the electric potential that exists at the "slip plane" - the interface between the hydrated particle and the bulk solution. It is the measurable potential of a solid surface and also called electrokinetic potential. According to the electrostatic principles zeta potential is calculated by the equation,

$$\zeta = \frac{4\pi s d}{D}$$

15 d : thickness of the electrical double layer
 s : the electrical charge in the Stern layer
 D : dielectrical constant.

20 The relationship between the value of the zeta potential and flocculation or dispersion in the sugar process liquid (4) favors flocculation of colloidal particles or other particles at low zeta potential values and favors dispersion of colloidal particles at high zeta potential values.

25 As to certain embodiments of the invention, the amount of energy imparted to the sugar process liquid (4) by increasing velocity, distribution, and delivery of at least one gas (38) into the flow of sugar process liquid (4) in the containment zone (37) can be adjusted to overcome the zeta potential of the colloidal particles in the sugar process liquid (4) to promote additional particle to particle collisions. As a non-limiting example, sugar process liquid (4) can be flowed through the juice distribution element (41)(without limitation a BEX PSW 3FPS140) at about 200 gallons per minute to about 300 gallons per minute (between about 27 cubic feet per minute and 40 cubic feet per

minute) at a pressure of about 10 psi to about 40 psi. Between about 108 cubic feet and about 160 cubic feet per minute of gas (38) (air or atmosphere) can be delivered into the dispersion of that amount of sugar process liquid (4) as it passes through the containment zone (37). Conditioned sugar process liquid (4) manifests a more rapid production of
5 floc as pH is increased (typically from a range of between about 5.5 pH 6.5 pH to a range of between about 11.5 pH to about 11.8 pH) and increased juice purity with lower sugar color.

Now referring primarily to Figures 2 and 6, a conventional sugar process system can be compared with an embodiment of a sugar process system in accordance with the
10 invention. A conventional sugar process system processing about 335 tons of sugar beet cossettes (2) per hour (see Figure 1) can generate a "thin juice" purity after the second carbonation (20) of about 91.82 percent (see Figure 2). A sugar process system which further includes an aeration chamber (37) and a vacuum chamber (42) in accordance with the invention processing the same tonnage of sugar beet cosettes can generate a "thin
15 juice" purity of about 93.02 percent.

Now referring to Figures 4 and 8, the same conventional sugar process system as described above can generate a sugar process liquid (4) separated from sugar crystals from the "white pan" (24) of about 93.52 percent while the sugar process system which further includes an aeration chamber (37) and a vacuum chamber (42) in accordance with
20 the invention generates a sugar process liquid (4) separated from sugar crystals from the "white pan" of about 94.17 percent.

Again referring to Figures 4 and 8, the conventional sugar process system operated as described above generates about 49.92 tons of sugar per hour having a color
25 of 37 RBU while the sugar process system in accordance with the invention which further includes an aeration chamber (36) and a vacuum chamber (42) can generate a greater amount of sugar (33) about 51.55 tons of sugar per hour having a lower color of 34 RBU. The additional 1.63 tons of sugar (33) per hour equates to about \$5,700.00 of revenue per day.

30

While additional sugar (33) production may vary in a sugar process system operated in accordance with the invention, additional revenue calculated for a 200 day campaign can easily be in excess of \$1,000,000.00.

5 The following further non-limiting examples along with the description above are sufficient for the person of ordinary skill in the art to make and use the numerous and varied embodiments of the invention.

EXAMPLE 1

10 Juice was obtained by conventional tower diffusion of sugar beet cossettes. A control group and an experimental group each consisting of six substantially identical 500 mL aliquots of the diffusion juice were generated. Each aliquot within the control group and the experimental group was analyzed to ascertain the pH value. As to each aliquot of the diffusion juice in the control group the pH value was about 6.3. Each aliquot within
15 the control group without any further treatment was titrated to an 11.2 pH endpoint with a solution of 50% wt./vol. caustic soda. Each aliquot within the experimental group was treated in accordance with the invention after which the pH of each aliquot was ascertained and each experimental aliquot titrated in substantially identical fashion to the control group to an 11.2 pH endpoint with a solution of 50% wt./vol. caustic soda.

20

 The results are set out in Table 1 below. As can be understood from the table each aliquot of juice prior to any treatment had a pH of about 6.3. The experimental group after treatment in accordance with the invention had increased pH values without the addition of any base, and required a reduced amount of caustic soda to achieve the 11.2
25 pH endpoint as compared to the control group.

30

TABLE 1.

Untreated Juice pH	mL Caustic Soda	Treated Juice pH	mL Caustic Soda	% reduction Caustic Soda
6.3	1.8	6.5	1.5	16.6
6.3	1.8	6.6	1.4	22.2
6.3	1.8	6.6	1.4	22.2
6.3	1.9	6.6	1.6	15.8
6.3	1.9	6.5	1.5	21.0
6.3	1.9	6.5	1.6	15.8

The reduction in the amount of caustic soda to reach the 11.2 pH endpoint for the aliquots of juice in the experimental group treated in accordance with the invention as compared to the aliquots of juice in the untreated control group was between about 15.8% and about 22.2%.

EXAMPLE 2.

Juice was obtained by conventional tower diffusion of sugar beet cossettes. A control group and an experimental group each consisting of five substantially identical 500 mL aliquots of the diffusion juice were generated. Each aliquot within the control group and the experimental group was analyzed to ascertain the pH value. As to each aliquot of the diffusion juice in the control group the pH value was about 6.1. Each aliquot within the control group without any further treatment was titrated to an 11.2 pH endpoint with a solution of 30 brixs milk of lime. Each aliquot within the experimental group was treated in accordance with the invention after which the pH of each aliquot was ascertained and each experimental aliquot titrated in substantially identical fashion to the control group to an 11.2 pH endpoint with a solution of 30 brixs milk of lime.

The results are set out in Table 2 below. As can be understood from the table each aliquot of juice prior to any treatment had a pH of about 6.1. The experimental group after treatment in accordance with the invention had increased pH values without the

addition of any base, and required a reduced amount of milk of lime to achieve the 11.2 pH endpoint as compared to the control group.

TABLE 2.

5

10

Untreated Juice pH	mL Milk of Lime	Treated Juice pH	mL Milk of Lime	% reduction Milk of Lime
6.1	4.6	6.5	3.3	28.3
6.1	4.4	6.6	3.2	27.3
6.1	4.7	6.6	3.5	25.5
6.1	4.4	6.6	3.3	25.0
6.1	4.5	6.6	3.3	26.7

15

The reduction in the amount of milk of lime to reach the 11.2 pH endpoint for the aliquots of juice in the experimental group treated in accordance with the invention as compared to the aliquots of juice in the untreated control group was between about 25.0% and about 28.3%.

20

25

Also, the data set out in Table 1 and Table 2 provides a comparison of two different types of diffusion apparatus and diffusion methods. Importantly, the data shows that different diffusers or different diffusion methods can generate diffusion juice having significantly different pH values even though pH values attributed to each type of diffusion technology can be substantially internally consistent. See for example the initial pH value of the untreated diffusion juice in Table 1 which shows a pH value of 6.3 as compared to the untreated diffusion juice in Table 2 which a pH value of 6.1.

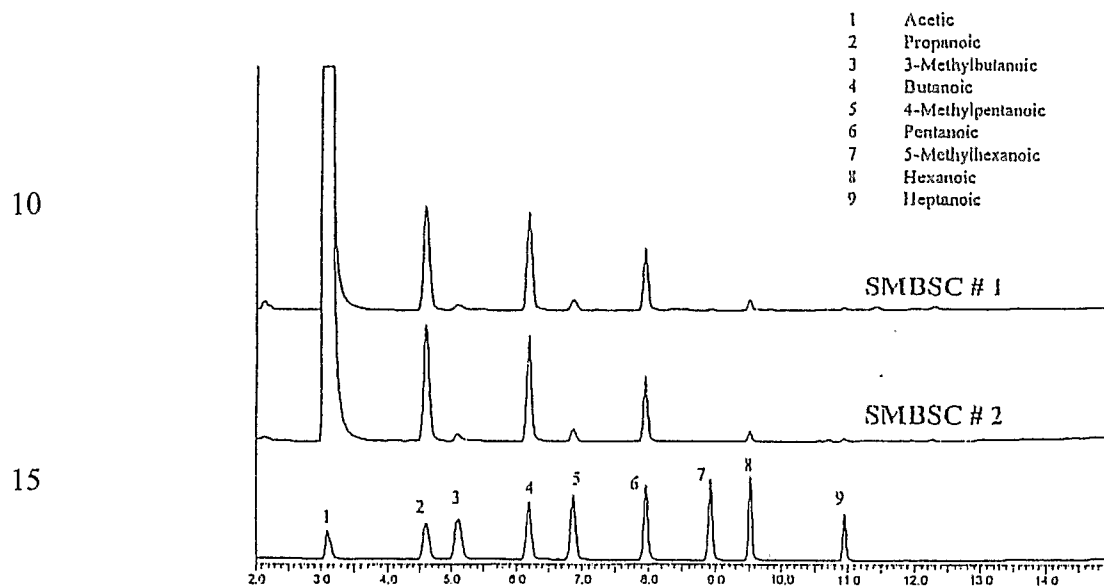
EXAMPLE 3.

30

Diffusion juice was obtained by conventional tower diffusion of sugar beet cossettes and treated in accordance with the invention using the embodiment shown by Figures 12 and 13 having location between the mixer and the pre-limer. Diffusion juice dispersed at a rate of about 100 cubic foot per minute into a flow of atmospheric gases generated at a rate of about 400 cubic foot per minute (counter current path of 72 inches x

72 inches with counter current path height of about 144 inches) generated transfer a variety of substances from the dispersed juice as identified by gas chromatograph/mass spectra analysis shown in Tables 1 and 2 below:

5 TABLE 3.



20 Table 3 shows gas chromatography analysis of samples SMBSC 1 and SMBSC 2 (condensates obtained from gas flow after counter current exchange with juice as described herein) with the chromatographs of those samples compared with a gas chromatograph of a sample of a standard mixture of organic acids listed as 1-9 above. As can be understood, treatment of juice in accordance with the invention removed varying

25 amounts of each organic acid included in the standard mixture.

30

TABLE 4.

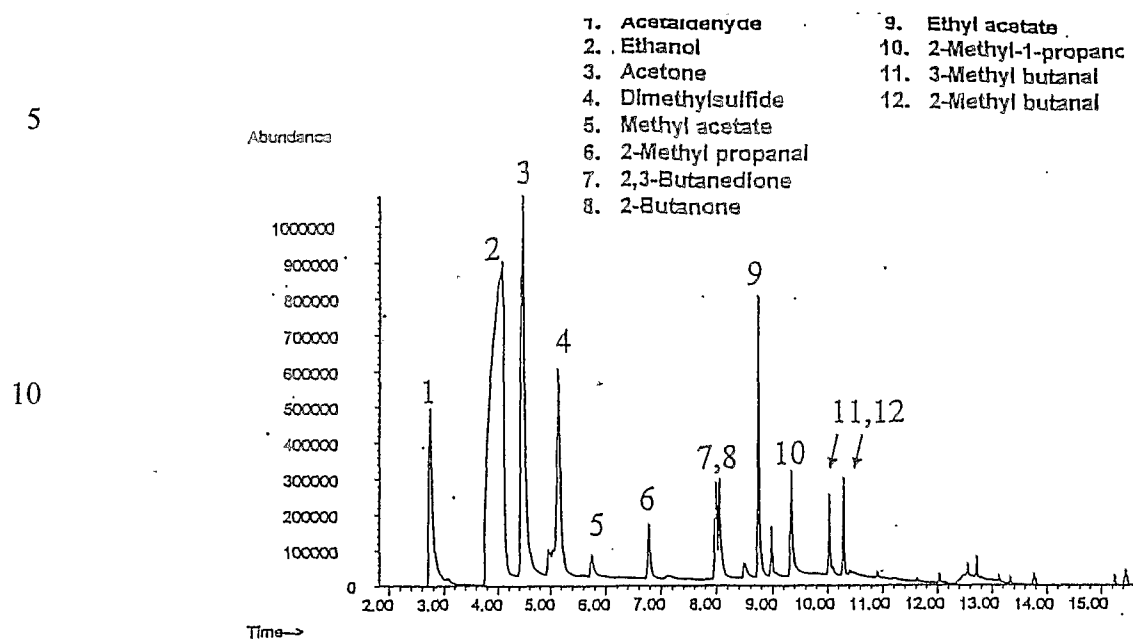


Table 4 shows gas chromatography/ mass spectrometry analysis of sample SMBSC 5 D (condensates obtained from gas flow after counter current exchange with juice as described herein without use of reduced pressure with a juice temperature of between 60°C and 70°C with the chromatograph of this sample showing various volatile compounds rising above a base line having a curvature predominated by a variety of alcohols.

The basic concepts of the invention may be embodied and claimed in a variety of ways. The invention involves a juice conditioner system useful for the production of sugar, methods of making and using embodiments of the invention, and products generated by using the invention.

While specific illustrative examples of the invention are disclosed in the description and drawings, it should be understood that these illustrative examples are not intended to be limiting with respect to the generic nature of the invention which encompasses numerous and varied embodiments; many alternatives are implicit or inherent. Each feature or element of the invention is to be understood to be representative

of a broader function or of a great variety of alternative or equivalent elements. Where the feature or element is described in device-oriented terminology, each element of the device is to be understood to perform a function. Neither the description nor the terminology is intended to limit the scope of the claims herein included solely to an apparatus or to a method.

Particularly, it should be understood that as the disclosure relates to elements of the invention, the words for each element may be expressed by equivalent apparatus terms or method terms -- even if only the function or result is the same. Such equivalent, broader, or even more generic terms should be considered to be encompassed in the description of each element or action. Such terms can be substituted where desired to make explicit the implicitly broad coverage to which this invention is entitled. As but one example, it should be understood that all actions may be expressed as a means for taking that action or as an element which causes that action. Similarly, each physical element disclosed should be understood to encompass a disclosure of the action which that physical element facilitates. Regarding this last aspect, as but one example, the disclosure of a "flow of sugar process liquid" should be understood to encompass disclosure of the act of "flowing sugar process liquid" -- whether explicitly discussed or not -- and, conversely, were there effectively disclosure of the act of "flowing sugar process liquid", such a disclosure should be understood to encompass disclosure of a "flow of sugar process liquid" and even a "means for flowing sugar process liquid". Such changes and alternative terms are to be understood to be explicitly included in the description.

As such, it should be understood that a variety of changes may be made to the invention as described without departing from the essence of the invention. The disclosure encompassing both the explicit embodiment(s) shown, the great variety of implicit alternative embodiments, and the methods or processes are relied upon to support the claims of this application.

Any patents, publications, or other references mentioned in this application for patent are hereby incorporated by reference. In addition, as to each term used it should be understood that unless its utilization is inconsistent with such interpretation, common dictionary definitions should be understood as incorporated by reference for each term

and all definitions, alternative terms, and synonyms such as contained in the Random House Webster's Unabridged Dictionary, second edition.

Thus, the applicant(s) should be understood to claim at least: i) each of the juice
5 conditioner systems as herein disclosed and described, ii) the related methods disclosed
and described, iii) similar, equivalent, and even implicit variations of each of these
devices and methods, iv) those alternative designs which accomplish each of the
functions shown as are disclosed and described, v) those alternative designs and methods
which accomplish each of the functions shown as are implicit to accomplish that which is
10 disclosed and described, vi) each feature, component, and step shown as separate and
independent inventions, vii) the applications enhanced by the various systems or
components disclosed, viii) the resulting products produced by such systems or
components, ix) methods and apparatuses substantially as described hereinbefore and
with reference to any of the accompanying examples, x) the related methods disclosed
15 and described, xi) similar, equivalent, and even implicit variations of each of these
systems and methods, xii) those alternative designs which accomplish each of the
functions shown as are disclosed and described, xiii) those alternative devices and
methods which accomplish each of the functions shown as are implicit to accomplish that
which is disclosed and described, ivx) each feature, component, and step shown as
20 separate and independent inventions, xv) the various combinations and permutations of
each of the above, and xvi) each potentially dependent claim or concept as a dependency
on each and every one of the independent claims or concepts presented.

It should be understood for practical reasons, the applicant may initially present
25 only apparatus or method claims and then only with initial dependencies. The applicant
does not waive any right to present additional independent or dependent claims which are
supported by the description during the prosecution of this application. The applicant
specifically reserves all rights to file continuation, division, continuation-in-part, or other
continuing applications to claim the various inventions described without limitation by
30 any claim made in a prior application to the generic nature of the invention or the breadth
of any claim made in a subsequent application.

Further, the use of the transitional phrase "comprising" is used to maintain "open-
end" claims herein, according to traditional claim interpretation. Thus, unless the context

requires otherwise, it should be understood that the term “comprise” or variations such as “comprises” or “comprising”, are intended to imply the inclusion of a stated element or step or group of elements or steps but not the exclusion of any other element or step or group of elements or steps. Such terms should be interpreted in their most expansive
5 form so as to afford the applicant the broadest coverage legally permissible.

The claims set forth in this specification are hereby incorporated by reference as part of this description of the invention, and the applicant expressly reserves the right to use all of or a portion of such incorporated content of such claims as additional
10 description to support any of or all of the claims or any element or component thereof, and the applicant further expressly reserves the right to move any portion of or all of the incorporated content of such claims or any element or component thereof from the description into the claims or vice-versa as necessary to define the matter for which protection is sought by this application or by any subsequent continuation, division, or
15 continuation-in-part application thereof, or to obtain any benefit of, reduction in fees pursuant to, or to comply with the patent laws, rules, or regulations of any country or treaty, and such content incorporated by reference shall survive during the entire pendency of this application including any subsequent continuation, division, or continuation-in-part application thereof or any reissue or extension thereon.

VI. CLAIMS

I claim:

- 5 1. A sugar production system, comprising:
- a. an aeration chamber, wherein raw juice obtained from plant material flows through said aeration chamber coincident to a flow of gas through said aeration chamber; and
 - b. a conditioned sugar process liquid which flows from said aeration
10 chamber.
2. A sugar production system, comprising:
- a. an vacuum chamber, wherein raw juice obtained from plant material flows through said an evacuation zone having reduced pressure within said vacuum chamber;
15 and
 - b. a conditioned sugar process liquid which flows from said vacuum chamber.
3. A sugar production system, comprising:
- a. an aeration chamber, wherein a sugar process liquid flows through said
20 aeration chamber coincident to a flow of gas through said aeration chamber; and
 - b. a conditioned sugar process liquid which flows from said aeration chamber having an increased pH.
- 25 4. A sugar production system as described in claim 3, further comprising a vacuum chamber, wherein said conditioned sugar process liquid which flows from said aeration chamber flows through an evacuation zone within said vacuum chamber to increase pH.
5. A sugar process system, comprising:
- a. a vacuum chamber, wherein a sugar process liquid flows through an
30 evacuation zone within said vacuum chamber; and
 - b. a conditioned sugar process liquid which flows from said vacuum chamber having an increased pH.

6. A sugar process system as described in claim 5, further comprising an aeration chamber, wherein said conditioned sugar process liquid which flows from said vacuum chamber flows through a containment zone within said aeration chamber to increase pH.
- 5 7. A sugar production system, comprising:
- a. an aeration chamber, wherein a sugar process liquid flows through said aeration chamber coincident to a flow of gas through said aeration chamber;
 - b. an amount of lime added to a conditioned sugar process liquid which flows from said aeration chamber; and
 - 10 c. an amount of carbon dioxide added to said conditioned sugar process liquid to which said amount of lime has been added, whereby said conditioned sugar process liquid has a reduced amount of color compared to said sugar process liquid which does not flow through said aeration chamber.
- 15 8. A sugar production system as described in claim 7, further comprising a vacuum chamber, wherein said conditioned sugar process liquid which flows from said aeration chamber flows through an evacuation zone within said vacuum chamber.
9. A sugar production system, comprising:
- 20 a. an vacuum chamber, wherein a sugar process liquid flows through an evacuation zone within said vacuum chamber;
 - b. an amount of lime added to a conditioned sugar process liquid which flows from said vacuum chamber; and
 - c. an amount of carbon dioxide added to said conditioned sugar process
 - 25 liquid to which said amount of lime has been added, whereby said conditioned sugar process liquid has a reduced amount of color compared to said sugar process liquid which does not flow through said evacuation zone of said vacuum chamber.
10. A sugar production system as described in claim 7, further comprising an aeration
- 30 chamber, wherein said conditioned sugar process liquid which flows from said vacuum chamber flows through a containment zone within said aeration chamber.
11. A sugar production system, comprising:

- a. an aeration chamber, wherein a sugar process liquid flows through said aeration chamber coincident to a flow of gas through said aeration chamber;
- b. an amount of lime added to a conditioned sugar process liquid which flows from said aeration chamber; and
- 5 c. an amount of carbon dioxide added to said conditioned sugar process liquid to which said amount of lime has been added, whereby said conditioned sugar process liquid has a reduced amount of limesalts compared to said sugar process liquid which does not flow through said aeration chamber coincident to said flow of gas through said aeration chamber.
- 10
12. A sugar production system as described in claim 10, further comprising a vacuum chamber, wherein said conditioned sugar process liquid which flows from said aeration chamber flows through an evacuation zone within said vacuum chamber.
- 15 13. A sugar production system, comprising:
- a. an vacuum chamber, wherein a sugar process liquid flows through an evacuation zone within said vacuum chamber;
- b. an amount of lime added to a conditioned sugar process liquid which flows from said vacuum chamber; and
- 20 c. an amount of carbon dioxide added to said conditioned sugar process liquid to which said amount of lime has been added, whereby said conditioned sugar process liquid has a reduced amount of limesalts compared to said sugar process liquid which does not flow through said evacuation zone of said vacuum chamber.
- 25 14. A sugar production system as described in claim 7, further comprising an aeration chamber, wherein said conditioned sugar process liquid which flows from said vacuum chamber flows through a containment zone within said aeration chamber.
15. A sugar production system, comprising:
- 30 a. an aeration chamber, wherein a sugar process liquid flows through said aeration chamber coincident to a flow of gas through said aeration chamber;
- b. an amount of lime added to a conditioned sugar process liquid which flows from said aeration chamber; and

c. an amount of carbon dioxide added to said conditioned sugar process liquid to which said amount of lime has been added, whereby said conditioned sugar process liquid has increased purity compared to said sugar process liquid which does not flow through said aeration chamber coincident to said flow of gas through said aeration chamber.

16. A sugar production system as described in claim 10, further comprising a vacuum chamber, wherein said conditioned sugar process liquid which flows from said aeration chamber flows through an evacuation zone within said vacuum chamber.

10

17. A sugar production system, comprising:

a. an vacuum chamber, wherein a sugar process liquid flows through an evacuation zone within said vacuum chamber;

b. an amount of lime added to a conditioned sugar process liquid which flows from said vacuum chamber; and

c. an amount of carbon dioxide added to said conditioned sugar process liquid to which said amount of lime has been added, whereby said conditioned sugar process liquid has increased purity compared to said sugar process liquid which does not flow through said evacuation zone of said vacuum chamber.

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18. A sugar production system as described in claim 7, further comprising an aeration chamber, wherein said conditioned sugar process liquid which flows from said vacuum chamber flows through a containment zone within said aeration chamber.